APGA Submission

Victorian Gas Substitution Roadmap Consultation Paper

6 August 2021

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Executive Summary

Renewable gases delivered through gas infrastructure represent the lowest cost, most reliable pathway to decarbonise gas demand for Victorian citizens, households and businesses. The Australian Pipelines and Gas Association (APGA) emphasizes the importance of the VGSR focusing on the needs of Victorian citizens, households and businesses as decarbonisation is not simple. Victorian's must be put first when charting the path to Victorian gas use decarbonisation.

APGA welcomes the opportunity to contribute to the Victorian Gas Substitution Roadmap (**VGSR**) via this submission to the VGSR Consultation Paper (the **Consultation Paper**) and commends the Victorian Government on the robust process undertaken to date.

APGA represents the owners, operators, designers, constructors and service providers of Australia's pipeline infrastructure, with a focus on high-pressure gas transmission. APGA's members build, own and operate the gas transmission infrastructure connecting the disparate gas supply basins and demand centres of Australia, offering a wide range of services to gas producers, retailers and users.

As proponents of Gas Vision 2050 (attached), APGA sees renewable gases such as hydrogen and biogas playing a critical role in decarbonising energy in homes, buildings, industry, transport and electricity generation in the future energy mix. APGA has sought to support this future as the largest industry contributor to the $30M, 80+ research project strong Future Fuels CRC, as well as the facilitation of industry-based research and analysis of the decarbonisation of gas demand.

Across the past half-decade of targeted decarbonisation research, nine key understandings have risen to the surface. While the specific details vary slightly from jurisdiction to jurisdiction, these nine key understandings are most prominent in understanding Victoria's gas decarbonisation pathways.

The best possible outcome for Victorian households and businesses is the lowest cost most reliable energy system that delivers net zero emissions by 2050 (Section 2.1)

The technical and societal changes required for Victoria's equitable transition to a net-zero emissions future will be extensive and challenging. The potential impacts on people and their livelihoods means the energy transition must be about more than just a battle between different energy providers. The energy trilemma in part holds the key to achieving this end.

Gaseous energy is high-quality, affordable energy (Section 2.2)

Gaseous energy has innate qualities that make gaseous energy a highly usable, transportable and storable form of energy, which in turn lead to gaseous energy being highly affordable for a wide range of energy customers.

These innate qualities are not unique to natural gas, with renewable gases having all of these innate qualities without the carbon emissions of natural gas.

Renewable gas is viable and being developed around the globe (Section 2.3)

Key renewable gas technologies across both the hydrogen and biogas pathways are technologically mature and are currently undergoing commercial scale uplift at a faster pace than solar PV. The Viability renewable gas is supported by the IEA who forecast renewable gases as contributing 13% of total global energy consumption in their net-zero 2050 scenario, as well as being their backup plan if Carbon Capture and Storage (CCS) fails.

A decarbonised gas system is a huge opportunity for Victoria (Section 2.4)

Victorian gas infrastructure delivers more energy at lower cost, lower emissions intensity and greater reliability today than Victoria's electricity infrastructure. Victoria's existing gas infrastructure represents a greater opportunity than existing electricity infrastructure to deliver lower cost renewable energy to Victorian households and businesses. The Australian gas industry sees its contribution to energy affordability and reliability in a net zero Victoria as key to delivering the lowest cost, most reliable decarbonisation outcome for Victorian households and businesses.

Table E1: Scale and Context of Victorian Gas Decarbonisation Opportunity

Victorian Energy System	Percent of Total Victorian Energy Use	Percent of Total Victorian Emissions	Emissions Intensity (tCO2e/MWh)	Average Energy Price Wholesale (W) and Retail (R)
Electricity	17%	45.5%[2018]	0.98	W: $57/MWh or $16/GJ R: 27c/kWh or 7.6c/MJ
Gas	27%	15.8%	0.186	W: $21/MWh or $6/GJ R: 9.2c/kWh or 2.6c/MJ

Gas infrastructure provides cost-effective energy delivery (Section 2.5)

New gas infrastructure cost less to transport and store energy than electricity infrastructure. This is why existing Victorian gas infrastructure can deliver energy six times more cost effectively than Victorian electricity infrastructure and can support peak demand ten times more cost effectively than Victorian electricity infrastructure. Every dollar spent on new gas infrastructure today will continue to deliver energy cheaper than new electricity infrastructure.

Table E2: Costs and deliveries of Victoria's energy infrastructure (2019)

Transmission and Distribution Infrastructure	Regulated Asset Base ($m)	Actual Annual Revenues ($m)	Actual Energy Delivered (GWh)	Max Demand Capacity (MW)
Electricity	17,329	2,825	41,480	8,684
Gas	5,631	774	64,722	23,250

Decarbonised gas is a lower-cost option to achieve net-zero in 2050 (Section 2.6)

Combining the innate qualities of gaseous energy with the viability of renewable gases and the cost effectiveness of gas infrastructure, the opportunity to decarbonise gas via the renewable gas pathway stands out as a lower cost option to achieve net zero emissions by 2050 in Victoria. This stands out in research undertaken by Frontier Economics which demonstrates that a 100% green hydrogen pathway will cost Australians less in 2050 than the 100% electrification pathway.

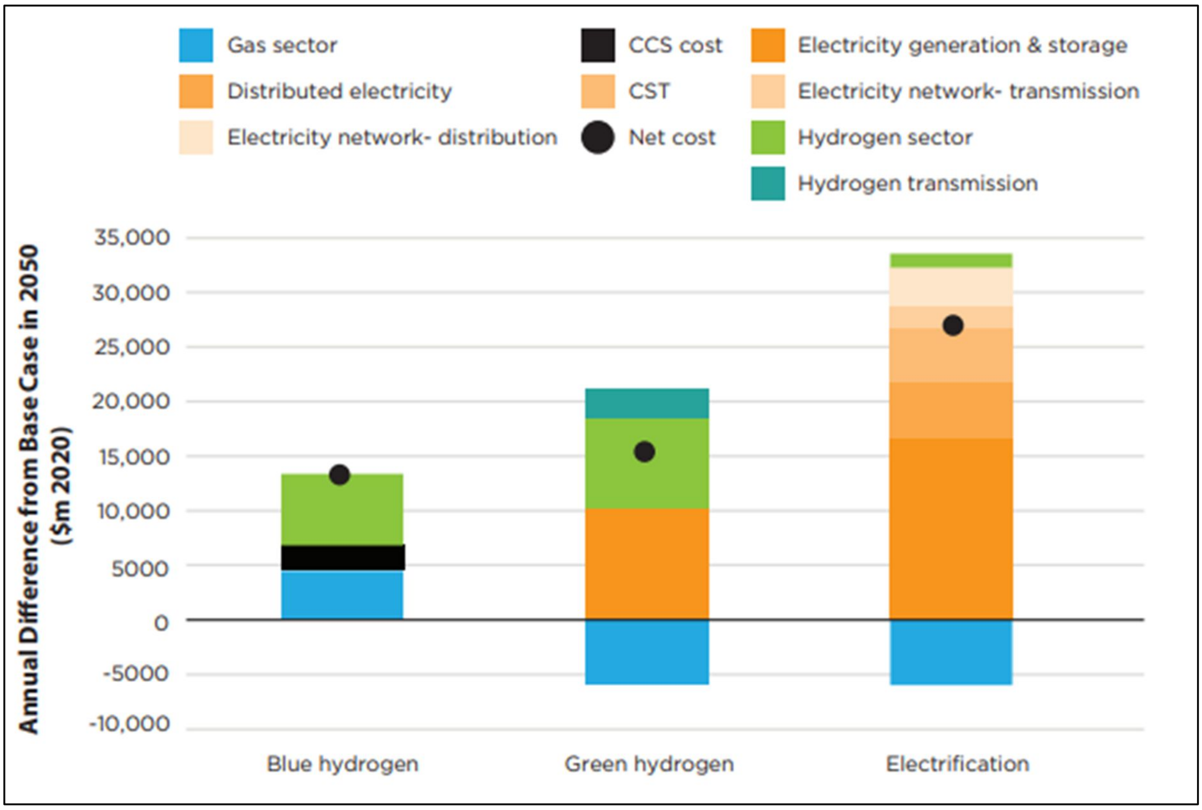

Figure E1: Cost Benefit Analysis Summary by Components ($2020)

The renewable gas pathway offers more reliable renewable energy (Section 2.7)

Both acting alone and in concert with renewable electricity, the renewable gas pathway will result in a more secure and reliable renewable energy system for Victorian citizens and businesses. Parallel and complimentary renewable gas and renewable systems operating in tandem can minimise the impact of outages in either system on Victorian households and businesses. Sector coupling opportunities such as gas power generation and electrolysis can even lead cross network support in managing minimum and maximum demand.

The gas system offers superior emission outcomes in the short-term (Section 2.8)

Future Fuel CRC research has demonstrated that switching natural gas demand to electricity in 2021 will increase Victoria's emissions, and indicates that appliance switching from gas to electricity will not deliver emissions reduction in Victoria before 2035 through forecasts emission intensity of Victoria's electricity supply. Gaseous energy is not only the lowest cost pathway to net zero emissions in 2050, it is also the lowest emission pathway to 2030.

Gas is a key contributor to a net-zero electricity sector (Section 2.9)

In addition to the direct role gas plays in Victorian energy supply, gas power generation has a key role to play in supporting the electricity sector achieve net-zero affordably and reliably.

The Gratton Institute identifies that *gas also plays a critical backstop function in electricity generation as its ability to quickly ramp production up and down can balance variations in supply from other sources. This 'firming', or stabilising, role is likely to become more important as the proportion of electricity supplied from renewable energy sources grows*.

Ensuring that Victoria's electricity system can decarbonise in the lowest cost, most reliable manner is also dependant on a gaseous energy supply for gas power generation.

Through an understanding of these nine points, APGA is confident that the Victorian Gas Substitution Roadmap will propose technology neutral recommendations that enable the lowest cost, most reliable decarbonisation pathway for Victorian citizens, households and businesses.. In desiring an accelerated outcome by 2030, it is hoped that the Victorian Government learns from the policies which successfully enabled the renewable electricity revolution, repurposing these to enable a renewable gas revolution in the decade to come.

To discuss any of the details within this submission further, please contact APGA's National Policy Manager, Jordan McCollum, on +61 422 057 856 or jmccollum@apga.org.au.

Yours Sincerely

STEVE DAVIES
Chief Executive Officer
Australian Pipelines and Gas Association

1 Introduction

Gaseous energy provides more energy than electricity to Victoria. Today, this energy comes in the form of natural gas, which proves more energy at a lower cost and lower emissions intensity than Victorian electricity. Tomorrow, in a net zero emission future, Victoria has the opportunity to continue to receive affordable renewable energy in the form of renewable gaseous energy.

APGA and the gas infrastructure industry are committed to delivering the best-case net zero emission energy outcome for Victorian households and businesses.

It is no accident that gaseous energy plays such a valued role in the Victorian energy mix. Gaseous energy is innately versatile, energy dense and compressible [Section 2.2]. These innate qualities make gaseous energy a highly usable, transportable and storable form of energy, which all lead to gaseous energy being affordable for a wide range of energy customers.

Table 1: Scale and Context of Victorian Gas Decarbonisation Opportunity[1,2,3,4,5]

Victorian Energy System	Percent of Total Victorian Energy Use	Percent of Total Victorian Emissions	Emissions Intensity (tCO2e/MWh)	Average Energy Price Wholesale (W) and Retail (R)
Electricity	17%	45.5%[2018]	0.98	W: $57/MWh or $16/GJ R: 27c/kWh or 7.6c/MJ
Gas	27%	15.8%	0.186	W: $21/MWh or $6/GJ R: 9.2c/kWh or 2.6c/MJ

The opportunity for Victoria to reach net-zero emissions by decarbonising gas and utilising its gas infrastructure is huge.

The Consultation Paper identifies six pathways for the substitution of gas demand in Victoria. In APGA's view, the issue at the core of the Consultation Paper is the competition between pathways that decarbonise gas and the pathways that electrify gas demand. Three pathways, improving energy efficiency, Emerging technologies and Fugitive emission can, and should, be pursued without impacting the competition between the other three pathways.

[1] Australian Energy Update 2020, Australian Government Department of Industry, Science, Energy and Resources 2020
https://www.energy.gov.au/publications/australian-energy-update-2020

[2] National Greenhouse Accounts Factors, Australian Government Department of Industry, Science, Energy and Resources 2020
https://www.industry.gov.au/sites/default/files/2020-10/national-greenhouse-accounts-factors-2020.pdf

[3] National Greenhouse and Energy Reporting (Measurement) Determination 2008, Australian Government 2008
https://www.legislation.gov.au/Details/F2020C00600

[4] Australian Energy Market Operator Website 2021
https://aemo.com.au

[5] State of the energy market 2021 – Retail Energy Markets, Australian Energy Regulator 2021
https://www.aer.gov.au/system/files/State%20of%20the%20energy%20market%202021%20-%20Chapter%206%20-%20Retail%20energy%20markets.pdf

Improved energy efficiency is a clearly desirable outcome and all efforts to reduce energy demand should be encouraged across the energy system. Similarly, all emerging technologies that can assist with achieving net-zero emissions are desirable and should be supported. APGA considers that all technologies should be enabled to deliver the best outcome and it is critical that Government policy allows this to happen. The gas industry's skills, experience and expertise are especially relevant to carbon capture and storage and significant efforts are underway around the globe and in Australia to deploy the technology at a large scale.

Fugitive emissions are a key pathway to reducing emissions from gas in the short-term and initiatives in this space are already being pursued by industry. Importantly, these initiatives will reduce emissions at no cost to consumers.

The remaining three pathways are:

- Electrification
- Substituting natural gas with hydrogen
- Substituting natural gas with biogas

It is likely some combination of these three will be used to achieve net-zero emissions [Section 2.3]. APGA contends that the last two options, striving to decarbonise gas rather than replace it, are effectively a single pathway of renewable gas and offer a superior solution to the full electrification of gas demand.

In its May 2021 report, Net Zero by 2050 A Roadmap for the Global Energy Sector, the International Energy Agency (IEA) forecasts that renewables gases will account for 13% of global energy demand in 2050. APGA notes that the IEA also forecasts natural gas will provide 6.5% of global energy demand in 2050. This is an expanded collective contribution for gaseous energy above the 14% of global energy demand that natural gas provides today[6].

The IEA forecasts the role of renewable gas will be even greater if widescale deployment of carbon capture and storage technology is not achieved.

APGA notes that AEMO's 2021 Inputs, Assumptions and Scenarios Report puts forward that net-zero emissions will be achieved earliest, and with the greatest economic growth, in its Hydrogen Superpower scenario. This is a further excellent indication of the potential of renewable gas.

While these and other key authorities recognise the potential of renewable gases, as a relatively new set of technologies there is room to improve understanding and awareness of the capabilities and viability of each. APGA considers this VGSR process can make an important contribution to this improved understanding and awareness.

All options to decarbonise gas have costs associated with them. These costs have been actively explored by APGA and co-signatories to Gas Vision 2050 leading us to the conclusion that the costs to consumers of switching to more sustainable gaseous fuels are lower than other options. APGA encourages DELWP to draw on existing findings and

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[6]These figures do not include the contribution of gas power generation to electricity supply in 2050.

conduct its own work to verify the conclusion that decarbonisation of gas is the lowest cost option available to the energy system.

Importantly, through emission reduction from operations and the commencement of renewable gas blending, there is great potential to reduce emissions from gas use in the period to 2030 with little-to-no cost to consumers. In contrast, electrification results in additional cost to customer and the system and, with the current emissions intensity of grid electricity, results in increased emissions in Victoria [Section 2.5 - 2.8].

There is clear evidence showing that the current emissions intensity of the Victorian electricity supply would lead to an increase in emissions if electrification was to occur today [Section 2.8]. APGA encourages DELWP to investigate in full detail the energy use of appliances, time-of-use of energy and the emission intensity and emission reduction profile of electricity and gas supply in Victoria to reach an independent assessment of the merit of each choice.

Achieving net-zero emissions is not simply a matter of affordability, issues of safety, security, reliability and equity are equally important.

One of the least discussed benefits of renewable gas is the benefit of having two parallel renewable energy infrastructure systems. Victoria already greatly benefits from having two parallel energy systems today, with the flexibility and stability of Victoria's gas system taking up the overwhelming heating load during winter, providing consistent heat year-round to the state's households, heavy industry, manufacturers and businesses, while firming electricity supply when required [Section 2.4, Section 2.9]. From an energy system resilience perspective, the ability to achieve all of this in a carbon neutral manner through two systems rather than reducing to a single, harder to stabilise system is a superior option [Section 2.7].

It is critical the final Victorian Gas Substitution Roadmap recognises the competitive forces at play between these options and does not produce policy recommendations that distort that competition in the short, medium and long-term.

To do so, it is vital that the consultation paper investigates each option objectively. APGA appreciates that the information it presents in this submission will be viewed by some as biased and self-serving. In recognition of this, APGA endeavours to be conservative when working with economic modellers to produce reports and findings and welcomes further discussion and investigation by DELWP of all information presented in this submission.

2 APGA Key Points

APGA wish to draw attention to nine key points which APGA has based its answers to the Consultation Papers questions upon. Elaborated upon further in the appendices, APGA recommend the VGSR consider the following key points when developing recommendations for the decarbonisation of gaseous energy use in Victoria.

1. The best possible outcome for Victorian households and businesses is the lowest cost most reliable energy system that delivers net zero emissions by 2050
2. Gaseous energy is high-quality, affordable energy
3. Renewable gas is viable and being developed around the globe
4. A decarbonised gas system is a huge opportunity for Victoria
5. Gas infrastructure provides cost-effective energy delivery
6. Decarbonised gas is a lower-cost option to achieve net-zero in 2050
7. The renewable gas pathway offers more reliable renewable energy
8. The gas system offers superior emission outcomes in the short-term
9. Gas is a key contributor to a net-zero electricity sector

It is upon these nine key points that APGA recommends the VGSR enable all decarbonisation options as a minimum. By either enabling all decarbonisation options, or supporting the development of renewable gases, Victoria has the greatest opportunity to secure the lowest cost most reliable energy system that delivers net zero emissions by 2050.

2.1 The best possible outcome for Victorian households and businesses is the lowest cost most reliable energy system that delivers net zero emissions by 2050

The technical and societal changes required for Victoria's equitable transition to a net-zero emissions future will be extensive and challenging. The potential impacts on people and their livelihoods means the energy transition must be about more than just a battle between different energy providers. Policy makers must consider each of the three pillars of the energy trilemma, and the interactions between the pillars, in devising such a transition[7]:

- <u>Energy Affordability</u>
  Keeping energy prices down, making energy more affordable for households
- <u>Energy Reliability</u>
  Ensuring stable supply of energy at all times, preventing blackouts
- <u>Energy Sustainability</u>
  Increasing use of clean renewable energy, reducing carbon emissions

APGA is confident that enabling complimentary renewable gas and renewable electricity systems to deliver energy to Victorian households and businesses as one combined renewable energy system will result in the best possible energy decarbonisation outcome for Victorian households and businesses.

[7] The energy trilemma – what matters the most to consumers?, CSIRO 2019
https://www.csiro.au/-/media/EF/Files/Energise-insights/Insight-40-Energy-Trilemma.pdf

Both the gas and electricity system offer advantages to energy users. It should go without saying that delivering critical energy through two parallel and complimentary energy systems, as opposed to restricting the State to only one system, delivers greater reliability and flexibility to the combined energy system as a whole. This is the situation that Victorian finds itself in today, with complimentary electricity and gas systems securing energy reliability and affordability to the State.

It is apparent to APGA, as will be shown throughout this submission, that decarbonising both the gas and electricity systems is a more affordable, more reliable option than decarbonising only one (electricity) and expanding it to replace the other (gas).

The Victorian Government has a target to reduce emissions by 45% to 50% by 2030. APGA recommends that a wholistic review of all emissions in Victoria is conducted to identify the lowest cost emission reduction opportunities across the entire State economy in that timeframe. It is important that the Victorian Government establish an achievable emission reduction trajectory to 2030 and 2050 to ensure that all emission reduction pathways are appropriately evaluated for their ability to deliver the lowest cost net-zero outcome.

2.2 Gaseous energy is high-quality, affordable energy

Gaseous energy has innate qualities that make it a highly valuable form of energy. These innate qualities make gaseous energy a highly usable, transportable and storable form of energy, which in turn lead to gaseous energy being highly affordable for a wide range of energy customers. This is the reason that gas use is higher than electricity use in Victoria today.

Gaseous energy is innately versatile, being able to be used either as thermal energy or motive force through combustion, or as chemical energy or a feedstock through chemical reactions. Gaseous energy is innately energy dense, which in part enables its versatility, making it easily storable with small quantities having a big impact. Gaseous energy is also innately compressible, leading to simple, flexible energy storage, movement and handling.

Coincidentally, these innate values are what is needed in addressing the challenges faced in achieving net zero electricity. Wind and solar generation are predominantly variable in supply and must be used immediately by either a customer or by conversion into another form of energy for storage (which is generally relatively expensive). Versatile, energy dense, compressible gaseous energy can help address these challenges, as is seen in Victorian gas heating and gas power generation coverage of evening peak energy demand.

In today’s energy industry, gas is synonymous with natural gas. These innate qualities however are not unique to natural gas. Renewable gases including hydrogen and biogas have all of the advantages of gaseous energy without the carbon emissions of natural gas, making them perfectly suited to both decarbonising gaseous energy demand and supporting the renewable electricity sector in achieving whole of energy sector decarbonisation.

This key point is explored further in Appendix 1.

2.3 Renewable gas is viable and being developed around the globe

The VGSR consultation paper correctly identifies the two key renewable gas pathways available to decarbonise gas use in Victoria, namely hydrogen and biogas. It is important to note that these and other renewable gas technologies are being actively developed across the global at a massive scale, and in the case of electrolysis, at a more rapid pace than the uptake of solar PV [Appendix 3].

Key renewable gas technologies across both the hydrogen and biogas pathways are technologically mature. These technologies are currently undergoing commercial readiness uplift, being either in or in development to be in commercial scale trial both nationally and around the globe. Wholesale Biomethane prices are modelled to be around the $15 to $18 per gigajoule mark in Australia today, with hydrogen prices the subject of massive international focus in order to achieve reductions to around $17.60 per GJ by 2030[8,9].

The viability of renewable gas technologies is heavily supported by the International Energy Agency. The IEA's Net Zero by 2050 report forecasts renewable gases as contributing 13% of total global energy consumption in their net-zero 2050 scenario[10].This forecast demonstrates the massive globally potential of this newly forming industry.

In the same report that IEA forecasts that renewable and natural gases will collectively provide 19.5% of total global energy consumption, up from the 14% provided by natural gas in 2020. This is a strong endorsement of the value and advantages of gaseous energy, even in a net zero emissions future.

In an Australian context, AEMO's 2021 Inputs, Assumptions and Scenarios Report anticipates that Australian net-zero emissions will be achieved earliest, and with the greatest economic growth, in its Hydrogen Superpower scenario. This is an excellent indication of the viability of renewable gases and their predicted impact on Australian society as the nation progresses towards a net zero emission future.

Australia's gas industry is well-advanced in the development of renewable gases, having been researching future fuels for over a decade. APGA's decades long track record in collaborative industry research first turned its focus towards future fuels through the Energy Pipelines Co-operative Research Centre from 2009, and continued through the development of the Future Fuels Co-operative Research Centre from 2018.

The Future Fuels CRC is entirely focussed on decarbonising gas infrastructure across Australia. APGA is the largest industry partner in the Future Fuels CRC, with members further contributing as expert advisors to the $30 million, 80+ project strong research

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[8] National Hydrogen Roadmap, CSIRO 2018
https://www.csiro.au/-/media/Do-Business/Files/Futures/18-00314_EN_NationalHydrogenRoadmap_WEB_180823.pdf

[9] Australian biogas and biomethane wholesale prices predicted by the Future Fuels CRC in an anticipated report scheduled for release in in Q3 2021

[10] Net Zero by 2050 A Roadmap for the Global Energy Sector, IEA 2021
https://iea.blob.core.windows.net/assets/20959e2e-7ab8-4f2a-b1c6-4e63387f03a1/NetZeroby2050ARoadmapfortheGlobalEnergySector_CORR.pdf

program. Running across three research programs, the Future Fuels CRC conducts research into the following categories:

- Future fuel technologies, systems and markets;
- Social acceptance, public safety and security of supply; and
- Network lifecycle management

To further enhance research outcomes, APGA and the Future Fuels CRC actively engage with international research organisations to coordinate research programs and share research outcomes. APGA and the Future Fuels CRC are key signatories to a memorandum of understanding with the following international research bodies:

- The Pipeline Research Council International;
- The European Pipeline Research Group; and
- The European Gas Research Group.

Our equal participation in this MOU with much larger international organisations is a clear indicator of excellence and progress of Australian research into renewable gases.

This key point is explored further in Appendix 2.

2.4 A decarbonised gas system is a huge opportunity for Victoria

Victorian gas infrastructure delivers more energy at lower cost, lower emissions intensity and greater reliability than Victoria's electricity infrastructure. It represents a greater opportunity than existing electricity infrastructure to deliver lower cost renewable energy to Victorian households and businesses. The Australian gas industry sees its contribution to energy affordability and reliability in a net zero Victoria as key to delivering the lowest cost, most reliable decarbonisation outcome for Victorian households and businesses. The Australian gas industry sees its contribution to energy affordability and reliability in a net zero Victoria as key to delivering the lowest cost, most reliable decarbonisation outcome for Victorian households and businesses.

Table 1: Scale and Context of Victorian Gas Decarbonisation Opportunity[1 - 5]

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Gas	27%	15.8%	0.186	W: $21/MWh or $6/GJ R: 9.2c/kWh or 2.6c/MJ

It is a myth that the Australian gas industry sees decarbonisation as a threat to its investments. Rather, the Australian gas industry sees its current contribution to energy affordability and reliability in Victoria, across Australia, and to our export partners as an opportunity to support affordable and reliable energy decarbonisation. By doing so the gas industry genuinely considers it is part of delivering the lowest cost, most reliable decarbonisation outcome for households and businesses in Victoria, across Australia, and around the world. This is why the gas industry is actively working to ensure renewable gases reach commercial-scale deployment as soon as possible.

This key point is explored further in Appendix 3.

2.5 Gas infrastructure provides cost-effective energy delivery

As seen in Table 1, gas is cheaper than electricity on both a wholesale and retail basis. This is in no small part due to the deliverability of gas. Put simply, gas is easier to transport and store than electricity. This translates to lower-cost infrastructure delivering more energy to consumers. This is evidenced by the data published in the AER's 2019 operational reports for electricity and gas and AEMO's various energy demand reports.

Table 2: Costs and deliveries of Victoria's energy infrastructure (2019) [11,12,13,14,15,16,17]

Transmission and Distribution Infrastructure	Regulated Asset Base ($m)	Actual Annual Revenues ($m)	Actual Energy Delivered (GWh)	Max Demand Capacity (MW)
Electricity	17,329	2,825	41,480	8,684
Gas	5,631	774	64,722	23,250

[11] Electricity DNSP - Operational performance data - 2006-2019, The Australian Energy Regulator 2020
https://www.aer.gov.au/system/files/Electricity%20DNSP%20-%20Operational%20performance%20data%20-%202006-2019.xlsm

[12] Victorian Gas Planning Report Update, AEMO 2020
https://aemo.com.au/-/media/files/gas/national_planning_and_forecasting/vgpr/2020/2020-vgpr-update.pdf?la=en

[13] AER Annual Reporting – APA GasNet Australia (Operations) Pty Ltd, Australian Energy Regulator 2021
https://www.aer.gov.au/system/files/VTS%20%28APA%20GasNet%29%202020%20-%20Annual%20-%20RIN%20Response%20-%20Consolidated%20-%2030%20April%202021%20-%20PUBLIC%20%2312%2C211%2C975.xlsx

[14] APA Victorian Transmission System pipeline information - RIN responses, Australian Energy Regulator 2021
https://www.aer.gov.au/networks-pipelines/performance-reporting/apa-victorian-transmission-system-pipeline-information-rin-responses

[15] Multinet Gas pipeline information - RIN responses, Australian Energy Regulator 2021
https://www.aer.gov.au/networks-pipelines/performance-reporting/multinet-gas-pipeline-information-rin-responses

[16] AusNet Services Gas pipeline information - RIN responses, Australian Energy Regulator 2021
https://www.aer.gov.au/networks-pipelines/performance-reporting/ausnet-services-gas-pipeline-information-rin-responses

[17] Australian Gas Networks (Victoria/Albury) Gas pipeline information - RIN responses, Australian Energy Regulator 2021
https://www.aer.gov.au/networks-pipelines/performance-reporting/australian-gas-networks-victoria-albury-gas-pipeline-information-rin-responses

Victoria's existing energy infrastructure costs six times more to deliver each MWh of electricity as it does to deliver the same amount of energy via gas infrastructure. Victorian electricity infrastructure costs 10 times more to meet each MW of maximum electricity demand as it does to meet each MW of maximum gas demand. These figures are despite gas infrastructure being more capable than electricity infrastructure, delivering 56% more energy than electricity infrastructure does annually and supplying a peak energy demand of 268% that supplied by electricity infrastructure.

Suggestions that electrical energy efficiency or the difference between summer and winter peak electricity demand are enough to allow the Victorian NEM to absorb the electrification of current gas demand are incorrect. The scale of energy delivered by the gas system is much greater than these. As shown in data explored in Appendix 3 and Appendix 4.

The development of new gas infrastructure also represents a lower cost mode of transport for gaseous energy in Victoria into the future. As identified by the European Hydrogen Backbone, delivering hydrogen via new hydrogen transmission infrastructure is less costly than delivering electricity for electrolysis via new electricity transmission infrastructure[18]. This is in part to the fact that doubling pipeline diameter will double the cost but quadruple the pipeline's throughput capacity.

Considering this European data, APGA has commissioned a report to investigate the relative cost effectiveness of energy transport via pipelines and powerlines in an Australian context, expecting report completion in Q3 2021. Transporting hydrogen by pipeline also allows for electrolysis to access cheaper behind-the-meter utility scale renewable electricity rather than more costly NEM electricity.

Decarbonising gas provides a huge opportunity to Victoria in retaining the significant cost advantages of its existing network of gas infrastructure. From an energy delivery capability perspective, the opportunity to deliver decarbonised energy at a lower cost through Victoria's existing gas infrastructure is greater than through its more expensive electricity infrastructure.

This key point is explored further in Appendix 3.

2.6 Decarbonised gas is a lower-cost option to achieve net-zero in 2050

All decarbonisation pathways have costs associated with them. The two primary pathways to decarbonising gas demand are renewable gases and electrification. Combining the innate qualities of gaseous energy with the viability of renewable gases and the cost effectiveness of gas infrastructure, the opportunity to decarbonise gas via the renewable gas pathway stands out as a lower cost option to achieve net zero emissions by 2050 in Victoria.

The costs of both options have been explored by Frontier Economics it its report, The Benefits of Gas Infrastructure to Decarbonise Australia[19]. Having seen the low cost of renewable gas in comparison to renewable electricity alongside the low cost of gas

[18] Analysing future demand, supply, and transport of hydrogen, European Hydrogen Backbone 2021 https://gasforclimate2050.eu/?smd_process_download=1&download_id=718
[19] The Benefit of Gas Infrastructure to Decarbonise Australia, Frontier Economics 2020 https://www.apga.org.au/sites/default/files/uploaded-content/field_f_content_file/frontier-2020-decarbonise-australia.pdf

infrastructure in comparison to electricity infrastructure in sections above, these results should be unsurprising.

APGA acknowledges that this report was prepared for the Australian gas industry and welcomes detailed examination of its findings, which are consistent with both the views expressed in the National Hydrogen Strategy and by the International Energy Agency on the advantages of renewable gas.

Modelling by Frontier Economics demonstrates that decarbonising gas is likely to be cost much less than electrifying gas demand. Modelling indicates that the national annual cost in 2050 of a decarbonised gas system will be between $13 and 20 billion less than that of the expanded electricity system required to electrify gas demand. Based on the difference today in cost to Victoria of the gas and electricity infrastructure system, APGA is confident these 2050 forecasts are realistic and achievable.

This key point is explored further in Appendix 3.

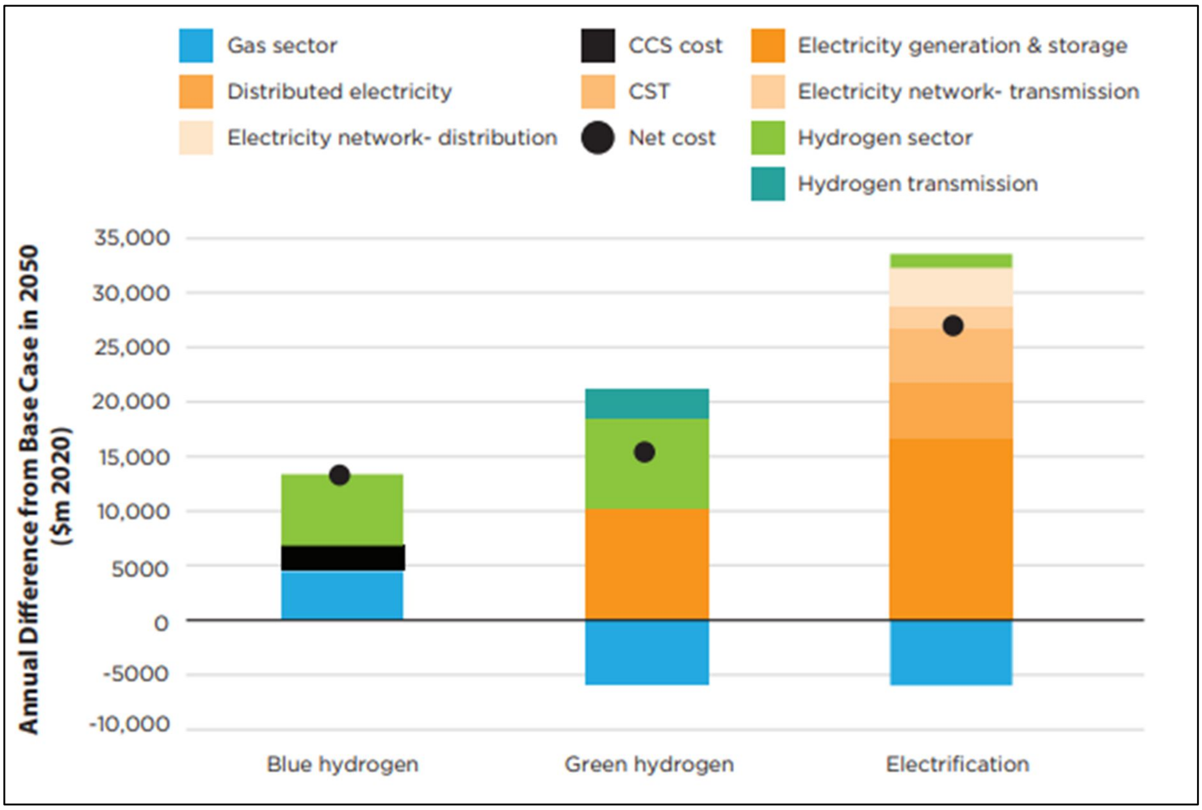

Figure 1: Cost Benefit Analysis Summary by Components ($2020) [19]

2.7 The Renewable Gas Pathway offers more reliable renewable energy

Alongside being a more affordable pathway to net zero emissions energy, the renewable gas pathway also addresses the third branch of the energy trilemma – energy reliability. Both acting alone and in concert with renewable electricity, the renewable gas pathway will result in a more secure and reliable renewable energy system overall.

While there are few like for like measures of reliability between Victoria's electricity and gas systems, APGA are confident that the VGSR Reliability consultation will identify that gas supply is more reliable than electricity supply in Victoria. APGA also notes the relative price spike frequency in Victoria's gas and electricity markets as evidence of the relative reliability of gas supply.

Further than being a reliable system itself, enabling a renewable gas system to exist alongside a renewable electricity system will deliver greater whole energy system reliability results. Two systems, each delivering a major portion of total energy, offers increased reliability and security over a single system supplying all energy. If one system fails, the other will continue to deliver energy. Sector coupling opportunities such as gas power generation and electrolysis can even lead cross network support in managing minimum and maximum demand.

This has been demonstrated in recent major energy system incidents. Gas infrastructure is largely buried, providing protection from extreme events such as storms or fires. In the 2016 South Australian blackout, caused primarily by storm damage to electricity infrastructure, the gas network of South Australia continued to deliver critical energy to homes, business and industry[20]. Gas power generation was then critical to restarting the South Australian NEM. Similarly, gas infrastructure continued to deliver energy throughout the terrible bushfires of the summer of 2019/20, in some instances pipelines where delivering gas while fires burned directly above them.

Gas and electricity systems are highly complementary, delivering different types of energy to different seasonal and daily time patterns, smoothing out the peaks and troughs of each. This is a focus of investigations by the Energy Security Board who are investigating ways of valuing energy security to ensure firming generation such as gas power generation is not lost over coming years[21]. This allows both systems to work together to provide the most reliable system at the lowest cost and can be done so without the carbon footprint thanks to renewable gases.

This key point is explored further in Appendix 3.

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[20] Black System South Australia 28 September 2016, Australian Energy Market Operator 2017 https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf

[21] Energy Security Board Website, Australian Energy Market Commission 2021 https://esb-post2025-market-design.aemc.gov.au/

2.8 The gas system offers superior emission outcomes in the short-term

The renewable gas pathway clearly represents the best-case pathway to achieve net zero gas emissions by 2050. In the leadup to 2030 and through to at least 2035, natural gas will continue to be a lower-emission source of energy than electricity in Victoria.

The facts set out in Table 1 are clear. Natural gas provides 27% of Victoria's energy and accounts for 15.8% of Victoria's emissions while electricity provides 17% of Victoria's energy and accounts for 45.5% of Victoria's emissions. Natural gas emission intensity is 0.186 tCO2e per MWh while Victorian electricity emission intensity is 0.980 tCO2e per MWh.

Detailed analysis by the Future Fuels CRC in its research project RP 1.1-02 Integrated Electricity and Gas System Studies, Electrification of Heating, demonstrate that switching natural gas demand to electricity in 2021 will increase Victoria's emissions[22]. This research took into account the emission intensity of electricity and gas supply alongside appliance efficiency and energy time of use among other factors.

Further work by the Future Fuels CRC looking at the forecast emission intensity of Victoria's electricity supply to 2035 indicates that appliance switching from gas to electricity will not deliver emissions reduction in Victoria before 2035[23].

In contrast, there are actions which are able to successfully reduce the emission intensity of gas demand over the coming decade. These include gas appliance energy efficiency improvements, fugitive emission reductions, and the uptake of renewable gases. An immediate opportunity exists for Victoria to expand existing incentive programs which facilitate the installation of higher efficiency electric appliances to facilitate the installation of all types of higher efficiency appliances, including higher efficiency gas appliances.

The gas industry is very focussed on reducing emissions from operations in the short term, including fugitive emissions, with many companies have made net-zero by 2050 commitments. In support of this action, APGA and Energy Networks Australia have formed a Gas Infrastructure Emissions Working Group to enable collaboration across the industry on critical emissions reduction issues. This will ensuring learnings from the successes and failures of each company are shared across industry to reduce costs and increase effectiveness of future initiatives, as guided by the Methane Guiding Principles[24].

This key point is explored further in Appendix 4.

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[22] This report is only available to Future Fuels CRC participants. As the Victorian Government is a participant, the report is available through the Future Fuels CRC website.
[23] Integrated Electricity and Gas System Studies: Electrification of Heating, Future Fuels CRC 2020 https://www.futurefuelscrc.com/project/regional-case-studies-on-gas-and-electricity-system-integration-rp1-1-02/
[24] Methane Guiding Principles Website, Methane Guiding Principles 2021 https://methaneguidingprinciples.org/

2.9 Gas is a key contributor to a net-zero electricity sector

In addition to the direct role gas plays in Victorian energy supply, gas power generation has a key role to play in supporting the electricity sector achieve net-zero affordably and reliably. As identified within the Infrastructure Victoria Towards 2050: Gas infrastructure in a zero emissions economy – Interim report[25]:

"Gas also plays a critical backstop function in electricity generation as its ability to quickly ramp production up and down can balance variations in supply from other sources. This 'firming', or stabilising, role is likely to become more important as the proportion of electricity supplied from renewable energy sources grows"

The Gratton Institute took this understanding one step further in their 2021 Go for Net Zero report[26]. Through this report, Gratton proposes that Australia target 'net-zero emissions', not 'zero emissions' or '100 per cent renewables', and that Governments should target net-zero emissions for the NEM for the 2040s. Importantly, Gratton's proposed 90% Renewable scenario included a slightly larger role than today for gas in balancing renewable output, with gas power generation (GPG) the only non-renewable generation contributing in 2040. Gratton concluded that the costs of offsetting the emissions from GPG would be significantly lower than costs of pushing the electricity system to 100% renewable generation and storage.

This conclusion is closely aligned with a Frontier Economics report commissioned by APGA to investigate the role of gas power generation in a cost optimised, variable renewable generation maximised NEM[27]. Where Gratton found a 90% renewable generation NEM to be the most cost effective, Frontier Economics found a 93% renewable generation NEM, supported by 7% gas power generation, to result in optimised energy system cost.

Whether 7% or 10%, gas power generation is a key component to achieving a least cost, net-zero electricity supply.

Further, the above reports only consider the benefits of GPG of natural gas, leaving the possibility of an even greater electricity decarbonisation outcome through running GPG on renewable gases. There are already signs that GPG operators are looking for renewable gas options, with Energy Australia seeking to contact 200,000kg of green hydrogen per year from 2025 for its Tallawarra B power station[28].

This key point is explored further in Appendix 5.

[25] Towards 2050: Gas infrastructure in a zero emissions economy – Interim report, Infrastructure Victoria 2021
https://www.infrastructurevictoria.com.au/wp-content/uploads/2021/07/Gas-Infrastructure-Advice-Interim-Report-FINAL-4.pdf
[26] Go for Net Zero, Gratton Institute 2021
https://grattan.edu.au/wp-content/uploads/2021/04/Go-for-net-zero-Grattan-Report.pdf
[27] Potential for Gas-Powered Generation to support renewables, Frontier Economics 2021
https://www.apga.org.au/sites/default/files/uploaded-content/field_f_content_file/210219_potential_for_gpg_to_support_renewables_-_final_report.pdf
[28] Energy Australia gives green light to Australia's first net zero emissions, hydrogen/gas power plant, Energy Australia 2021
https://www.energyaustralia.com.au/about-us/media/news/energyaustralia-gives-green-light-australias-first-net-zero-emissions

3 Consultation Paper Key Questions

In answering key questions, APGA will start with general comments and then address the six pathways either independently or under the following grouped headings:

- Overarching gas decarbonisation strategy
- Energy Efficiency
- Comparison between Electrification, Hydrogen and Biogas
- Emerging Technologies
- Fugitive Emissions

While APGA addresses hydrogen and biogas pathways separately as framed within the VGSR Consultation Paper, APGA recognise the combination of hydrogen, biogas, biomethane, renewable synthetic methane, and all other possible renewable gases as a single combined pathway through which net zero emission gas can be achieved in Victoria.

3.1 What are the key benefits, risks, and potential impacts on various end-users, on energy affordability, safety, security, reliability and equity?

Overall, APGA considers there is sufficient evidence demonstrating that the decarbonisation of gas, through the identified pathways, will deliver greater benefits than electrification. on end-users on energy affordability, safety, security, reliability and equity

The availability of all gas demand decarbonisation pathways leads to one of the least discussed benefits of renewable gaseous energy – the benefit of having two parallel renewable energy infrastructure systems. Victoria greatly benefits from having two parallel energy systems today, with the flexibility and stability of Victoria's gas system taking up the overwhelming heating load in winter and firming electricity supply when required.

From an energy system resilience perspective, the ability to achieve all of this in a carbon neutral manner through two systems rather than reducing to a single, harder to stabilise system, is a superior option[21].

The greatest benefit to Victorian households and businesses comes from having access to all technically viable, affordable opportunities to decarbonise. This allows market forces to determine the best decarbonisation option for each household and business. This benefit is put at risk by recommendations or initiatives which impede access to all decarbonisation options.

Discriminatory recommendations or initiatives could potentially lead to the removal of one or more decarbonisation pathways. This could lead to the following consequences for Victorian households and businesses:

- Reduced energy affordability by preventing the least cost decarbonisation option from emerging via market forces;
- Reduced energy security and reliability by both reducing the number of complimentary energy pathways supplying Victorian households and businesses,

and shifting this load onto the more easily destabilised, hence less secure and reliable, electricity system;

- Reductions in energy safety and/or energy affordability as flow on effects from reduced energy security and reliability as security or reliability issues risk loss of supply and/or greater expense in duplicating electricity supply infrastructure to secure supply
- Reductions in energy equity due to reduced energy affordability, both in the cost of energy and the ability for renters to have equitable access to decarbonisation options.

3.1.1 Energy efficiency

The benefits of energy efficiency uplift apply to all energy appliances and pathways. The only downside to improving energy efficiency is where improving energy efficiency outweighs the financial benefits of doing so, or otherwise reduces safety, security, reliability. A side effect of such reduced affordability is the potential for unequitable availability, leading to decarbonisation being a privilege of the affluent.

Where appliances have dynamic energy efficiency, the safety implications of dynamic energy efficiency must be considered to ensure public safety. Heat pump efficiency can vary significantly depending on ambient and hot-side temperatures. Appliances which struggle to perform at their stated efficiency when temperatures are their lowest could risk exposing vulnerable Victorians to low temperature conditions.

A focus on energy efficiency expands beyond appliances to the energy system as a whole. Noting that energy transport by pipeline is both more energy efficient and more capitally efficient than energy transport by powerline, a transition away from using pipelines to transport energy represents a reduction in energy efficiency of the whole energy system.

It is worth noting that energy efficiency does not necessarily equal lower emissions or energy costs. Appliance and energy system energy efficiency interacts with, energy system emissions intensity, as well as the capital efficiency of both the appliance and the energy system. It is possible, when switching energy systems, to become increase emissions intensity or energy cost despite increasing relative appliance energy efficiency.

3.1.2 Comparing electrification, hydrogen and biogas

While APGA addresses hydrogen and biogas pathways separately as framed within the VGSR Consultation Paper, APGA recognise the combination of hydrogen, biogas, biomethane, renewable synthetic methane, and all other possible renewable gases as a single combined pathway through which net zero emission gas can be achieved in Victoria. From here, the electrification and renewable gas pathways are equal on two points:

1. Current gas and electricity supplies are emissions intensive; and
2. All three offer a technically viable solution to the challenge of decarbonising gas demand.

These two points aside, the key benefits, risks, and potential impacts on various end-users, on energy affordability, safety, security, reliability and equity differ across each pathway.

Table 3: Cost and difficulty of transition for customer, energy infrastructure and energy production

	Customer	Energy infrastructure	Energy production
Electrification of Gas Demand (coupled with net zero emission NEM electricity)	In order to electrify gas demand, customers are expected to incur the capital appliance and integration cost of electrification – a greater capital appliance and integration cost than required for renewable sources of hydrogen. This transition option is expected to be the most difficult for customers due to requiring 100% appliance replacement. Non like for like replacement potentially requires property modification, and additional electrical demand potentially requires an upgrade to electricity supply capacity.	The cost of upgrading the Victorian NEM for gas demand electrification is huge [Appendix 3]. Rural Victorians are often left in the dark by unsatisfactory electricity supply. 34% of rural electricity supply delivered via SWER lines which suffer from stability problems with the voltage as the load increases, restricted load capacity, and inability to provide a three-phase supply[29,30]. Consequently, electrification of rural bottled gas demand will likely struggle to support decarbonisation of rural energy demand without burdening rural Victorians with the need to invest in their own sufficiently reliable renewable electricity infrastructure – a conclusion already reached by the Victorian Govt[31].	The massive uplift in electricity supply required to support gas demand electrification needs to occur in the context of achieving the best-case decarbonisation outcome for electricity supply as well. The Gratton Institute recommend Australia target a net zero NEM as the lowest cost electricity decarbonisation outcome for Australia, identifying this as cheaper than a 100% renewable NEM[26]. To do so however requires gas power generation to provide low cost firming support[26]. By not taking a whole of energy system view on the gas decarbonisation challenge, the best possible outcome for Victorian households and businesses is put in jeopardy.

[29] SWER Workshop - Appendix C, Victorian Department of Environment, Land Water and Planning 2010
https://www.energy.vic.gov.au/safety-and-emergencies/powerline-bushfire-safety-program/Reports-and-regulations/swer-workshop-appendix-c
[30] SWER still going strong, Energy Source & Distribution 2014
https://esdnews.com.au/swer-still-going-strong/
[31] GEA Response to the Regulation Impact Statement 'Residential Tenancies Regulation 2020', Gas Energy Australia 2019
https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/1516/1060/1053/Rental_housing_regulations_-_Gas_Energy_Australia.PDF

	Customer	Energy infrastructure	Energy production
Renewable sources of hydrogen	Hydrogen, including blends with methane with between 10% - 100% hydrogen, will require either like for like appliance change out or existing appliance modification. Customers are expected to incur moderate upfront capital cost, but notably less than the expected cost of electrification. This transition option is expected to be more difficult than decarbonisation through renewable sources of methane, but less difficult than decarbonisation through electrification. Cost of renewable hydrogen is expected to be between the cost of natural gas and electricity by 2030.	Hydrogen, including blends with methane with between 10% - 100% hydrogen will result in a need to modify and bolster existing gas infrastructure. This is expected to incur substantial cost, but as these costs would be building upon the sunk cost of established gas infrastructure, the cost and difficulty of this transition is expected to be less than that required to electrify gas demand. It is also expected to be possible to repurpose existing low-cost gas storage infrastructure[32]. For rural customers dependant on bottled gas, existing energy supply chains could be modified to provide bottle hydrogen. Please refer to GEA submission for more on this topic.	Renewable sources of hydrogen currently cost around $6 per kg, with predictions of reaching $2.50 per kg by 2030[8]. This equates to a production cost price range of $42.25 per GJ today to $17.60 per GJ in 2030. As hydrogen can utilise cheaper behind the meter renewable electricity and cheaper pipeline transport, the production constraint is similar to that of renewable electricity, but without the need for more costly electricity infrastructure where electrolysers are developed near renewable electricity sources.

[32] Future Fuels CRC Website, Future Fuels CRC 2021 https://www.futurefuelscrc.com

	Customer	Energy infrastructure	Energy production
Renewable sources of methane (produced from biogas or hydrogen feedstocks)	Renewable sources of methane require no physical change to customer appliances. Customers are expected to incur no upfront capital cost to transition[33]. This transition option represents the least difficult transition for customers. Cost of renewable methane is expected to be between the cost of natural gas and electricity. For the most part, this applies to blends of renewable methane with up to 10% hydrogen as well.	Renewable sources of methane including blends with up to 10% hydrogen will result in gas infrastructure incurring some engineering costs in updating asset safety cases, but otherwise require little to no physical modification or increases in operational costs. This makes this the lowest cost, lowest difficulty infrastructure option for gas use decarbonisation, and includes access to existing low-cost gas energy storage infrastructure resulting in the lowest cost of decarbonisation to customers. For rural customers dependant on bottled gas, existing energy supply chains can be utilised with little modification.	Renewable sources of methane can take advantage of immediately lower cost biomethane production, identified by the Future Fuel CRC as costing around $15 - $18 per GJ[34]. The difficulty of this supply option comes from a limited quantity of existing biogenic feedstock for biomethane production. It is expected that advancements in the field of Renewable Synthetic Methane would be required to cover 100% of Victorian gas demand alone. Importantly, no single source needs to solve gas decarbonisation alone, and the decision to methanate or not to methanate will come down to relative infrastructure and customer cost of alternatives.

[33] APGA refers to the VGSR submission from GAMAA for higher resolution analysis on customer appliance cost and impact comparisons, and to the VGSR submission from Gas Energy Australia for higher resolution analysis on bottled gas decarbonisation options.
[34] Australian biogas and biomethane wholesale prices predicted by the Future Fuels CRC in an anticipated report scheduled for release in in Q3 2021

3.1.3 Emerging Technologies

Market forces lead to the best technology neutral decarbonisation outcomes. Identifying the benefits, risks and potential impacts of emerging technologies as they evolve towards technology readiness will enable market forces to identify which emerging technologies best support the best possible outcome for Victorian households and businesses.

Each emerging technology has the potential to represent a better outcome for Victorian households and businesses. With so many unknowns involved in emerging technologies, ensuring that the VGSR recommends robust, non-discriminatory policy, regulation and initiatives will be key in maintaining all emerging technology options for the future.

3.1.4 Fugitive Emissions

APGA sees only benefits in reducing fugitive emissions from the gas industry.

In the short-term, fugitive emissions from the gas industry currently account for about 3% of the 15.8% of emissions attributable to Victorian gas use. This is 19% of total emissions from the gas industry. APGA considers this represents a huge opportunity to reduce emissions from the gas industry at minimal, if any, cost to consumers.

In recognition of this opportunity, and the overarching importance of acting immediately to reduce fugitive and other emissions from existing operations. Together with Energy Networks Australia, APGA has formed a Gas Infrastructure Emissions Working Group to facilitate industry collaboration and information sharing on this critical topic.

3.2 What are the scale of opportunities and potential to accelerate uptake?

As identified by the consultation paper, the scale of the opportunity to deliver renewable energy by repurposing the existing gas value chain to deliver renewable gases to Victorians is greater than the current Victorian section of the NEM.

Table 1: Scale and Context of Victorian Gas Decarbonisation Opportunity[1 - 5]

Victorian Energy System	Percent of Total Victorian Energy Use	Percent of Total Victorian Emissions	Emissions Intensity (tCO_2e/MWh)	Average Energy Price Wholesale (W) and Retail (R)
Electricity	17%	45.5%[2018]	0.98	W: \$57/MWh or \$16/GJ R: 27c/kWh or 7.6c/MJ
Gas	27%	15.8%	0.186	W: \$21/MWh or \$6/GJ R: 9.2c/kWh or 2.6c/MJ

Victorian gas infrastructure delivers 150% of the energy delivered by Victorian electricity infrastructure. The gas it delivers is lower emission energy, around one fifth as emission intensive as Victorian NEM electricity on both a whole of system and per MWh emissions intensity basis.

It is clear there is major opportunity to decarbonise Victoria's least emissions intensive and higher capacity energy system, the gas system, at lower cost than electrifying gas demand. Work undertaken through Gas Vision 2050 suggest the total energy system cost in 2050 will be between $13 and 20 billion per year lower if the gas demand is decarbonised through renewable gas rather than electrified.

There is an additional consideration, simultaneous decarbonisation of the electricity and gas systems is likely to achieve faster and cheaper emission outcomes that decommissioning one while doubling the size of the other.

3.2.1 Energy efficiency

The opportunity to deploy more efficient gas appliances is significant. With minimum household appliance efficiencies currently 70% compared to the potential for 90%+ efficiency in gas appliances, reductions in gaseous energy demand of around 30% could be achieved through energy efficiency initiatives alone.

As with the electrification pathway, any pathway which requires the change out of appliances is inherently slow due to the multi-decadal lifespan of major gas appliances. Expecting Victorian households and businesses to bare the expense of changing out appliances ahead of their end of economic life is recognised as untenable, as is expecting renters to be able to change appliances which they have no control over.

Programs to accelerate energy efficiency upgrades already exist in Victoria, however these programs typically are discriminatory against gas appliances, only applying to electricity appliances. This impedes the opportunity for more efficient use of gaseous energy, as well as the uptake of renewable gases. This is particularly perverse where electric heat pumps can be more emissions intensive than gas heaters through cold Victorian winter nights and mornings.

3.2.2 Comparing electrification, hydrogen and biogas

Both electrification and hydrogen pathways have the theoretical ability to scale up to the renewable electricity generation potential of Victoria, which is assumed to be significantly greater than potential Victorian energy demand. Biogas has a more limited potential, seen to be capped around 27% of total gas demand, or greater still if interstate supply potential is accessed.

Producing less than 100% of Victorian gaseous energy demand is not a reason to discount the biogas option. Considering the broader concept of renewable methane, including renewable synthetic methane, results in a similar scalability as the renewable hydrogen pathway. While less commercially advanced, this multi-source pathway could reduce the renewable electricity burden of electrification or hydrogen pathways while simultaneously reducing the cost and difficulty of transition for households, businesses and infrastructure.

So far, acceleration initiatives have solely focused on the electrification pathway. Worse than this, acceleration initiatives to date have actively sought to impede gaseous energy use, slowing down the potential uplift of renewable gases. Bringing neutrality to emissions reduction initiatives is an important first step to accelerating all gaseous energy decarbonisation options equally.

As the renewable hydrogen and biogas industries are in their infancy, three key activities could be undertaken by governments to accelerate uptake as identified in the DNV-GL report National Gas Decarbonisation Plan: Decarbonising Australia's Gas Pipelines and Networks[35]:

- Enabling Market Access
  Ensuring that customers can purchase what producers are selling. This includes Guarantee of Origin or other certification schemes.
- Early Asset Finance Support
  Ensuring first assets within a system are able to be commercially developed with less customer certainty than typically required of a commercial energy asset.
- Market Incentives
  Providing incentivisation for greater acceleration of market uptake in the event that the market does not accelerate at the pace desired by the Victorian government, such as a potential Renewable Gas Target.

3.2.3 Emerging Technologies

The potential scope for emerging technologies is only bounded by the brilliant minds of our nations research institutions. Acceleration of emerging technologies can be best achieved through consistent, technology agnostic emissions reduction frameworks which are easy for any technology to work and be recognised within. This is one of the reasons why APGA advocates for VGSR delivery of robust, non-discriminatory outputs and initiatives.

Additionally, ensuring new energy technology funding is being distributed on a technology agnostic basis of merit will be key to ensuring ideology does not lead to Australia missing out on its next big renewable energy technology opportunity.

3.2.4 Fugitive Emissions

The scope of fugitive emissions has been identified within the consultation paper as 3% of total Victorian emissions. The first step to acceleration of fugitive emission reduction is to gain an accurate view of fugitive emissions in recognition of NGERS inaccuracies. This activity could potentially be accelerated by surveillance uplift funding. This is particularly important in ensuring that regulated assets can include such initiatives within their regulated allowed expenditure.

3.3 What are the key technical, regulatory and economic barriers?

While there are individual technical barriers to each individual pathway, key barriers impeding the Victorian gas decarbonisation strategy overall are predominantly in the form of regulatory and economic barriers.

Regulations and initiatives which discriminate against energy sources rather than target emissions reduction create a false market where more costly decarbonisation options are

[35] National Gas Decarbonisation Plan: Decarbonising Australia's Gas Pipelines and Networks by DNV-GL is due for release in Q3 2021.

favoured, and less costly decarbonisation options are prevented from entering the market. This exacerbates economic barriers in the expectation that households and businesses will not only replace gas appliances with more costly electric appliances but replace gas appliances before the end of their economic life[36].

3.3.1 Energy efficiency

The greatest barrier to energy efficient appliances uptake is the regulatory barrier in emissions reduction regulations and initiatives discriminating against gas technologies. In recognising that gas is already lower carbon that electricity supply in Victoria, higher efficiency gas appliances should be considered as having both a positive impact on energy use reduction and energy system decarbonisation.

A key technical issue impacting this regulatory barrier is the failure to recognise dynamic efficiency of electric heat pump technologies, leading to an overestimate of their true efficiency. Once the true efficiency is considered alongside accurate and even dynamic electricity emissions intensity and cost, the benefits of heat pump over gas appliances start to diminish.

[36] Please see GAMAA Submission to the Victorian Gas Substitution Roadmap Consultation Paper on the topic of cost comparisons between gas and electric appliances.

3.3.2 Comparing electrification, hydrogen and biogas

While APGA addresses hydrogen and biogas pathways separately as framed within the VGSR Consultation Paper, APGA recognise the combination of hydrogen, biogas, biomethane, renewable synthetic methane, and all other possible renewable gases as a single combined pathway through which net zero emission gas can be achieved in Victoria.

Table 4: Technical, regulatory and economic barriers of the electrification, hydrogen and biogas decarbonisation pathways

	Technical	Regulatory	Economic
Electrification	Victorian NEM being technically able to absorb the higher load, higher variability energy demand supplied by gas, including two orders of magnitude more intraday energy storage and four orders of magnitude more deep energy storage than the Victorian big battery.	Reliability & Security Management – Refer to ESB 2025 Market Redesign Remit, including Reliability and Inertia focus.	Cost of infrastructure uplift to supply absorb the higher load, higher variability energy demand supplied by gas, including two orders of magnitude more intraday energy storage and four orders of magnitude more deep energy storage than the Victorian big battery. Cost of appliance replacement expected to be greater than cost of gas to hydrogen appliance transition
Hydrogen[37]	Existing high pressure pipeline maximum blending limit under investigation by Future Fuels CRC. Blending above limits acceptable to existing appliances will require infrastructure and appliance modification or replacement.	Currently experiencing regulatory boundaries to entry into gas infrastructure even where technically possible, as well as discriminatory emissions reduction regulations and initiatives. Lack of market mechanism to enable trading hampers market development	Cost of infrastructure and appliance modification or replacement for blending above limits acceptable to existing appliances. Cost of hydrogen can be higher than natural gas, but lower than electricity

[37] Hydrogen subject to methanation will experience Biogas technical barriers plus additional economic barrier due to combined hydrogen + methanation cost.

	Technical	Regulatory	Economic
Biogas	Identification of upper limits for minor constituent components not currently recognised by composition gas standard AS4564.	Currently experiencing regulatory boundaries to entry into gas infrastructure even where technically possible, as well as discriminatory emissions reduction regulations and initiatives. Lack of market mechanism to enable trading hampers market development	Cost of biogas can be higher than natural gas, but lower than electricity.

3.3.3 Emerging Technologies

Emerging technologies by their nature each have their own unique technical and economic barriers to overcome. This however should not be seen as a reason to not consider their potential to overcome these barriers and become viable decarbonisation technologies.

Key to enabling emerging technologies is ensuring that regulation does not impede the uptake of emerging technologies once they overcome their unique technical and economic barriers. This is currently the experience of renewable gases. State and federal legislation prevents the immediate uptake of renewable gases on anything more an a bespoke and individually accounted for basis – a situation which needs resolving.

In the Victorian experience, existing initiatives branded as emissions reduction initiatives discriminate against gaseous energy, further impeding renewable gas uptake. Ensuring that regulation and government initiatives do not represent the same barriers as those impeding renewable gases will be key to enabling emerging technologies.

3.3.4 Fugitive Emissions

As identified in the APGA submission to the Victorian Fugitive Emissions study, fugitive emissions are taken seriously within the gas transmission pipeline industry as an important but low proportion of all gas industry fugitive emissions. The APGA submission to the Victorian Fugitive Emissions study discusses technical, economic and regulatory barriers, hence APGA refers DELWP to this submission.

From a scale perspective, transmission gas pipelines contribute a remarkably small proportion of the 3% identified by the Consultation Paper. Applying the 11.8 tCO2e per kilometre NGERS Methodology 1 calculation to the 5800km of transmission gas pipelines in Victoria returns 68.4 ktCO2e per annum. This represents around 2.5% of gas industry fugitive emissions, or around 0.08% of total Victorian emissions.

Despite this low contribution, the gas pipeline industry is committed to reducing fugitive emissions. APGA would like to reinforce the relationship between action taken by pipeline operators to prevent high pressure methane loss of containment for safety reasons and actions which could potentially be taken to prevent high pressure methane loss of containment to avoid fugitive emissions.

3.4 What are the roles to be played by government, industry and how will consumers preferences be accounted for in the transition?

The gas infrastructure industry has already started to take up its role in enabling gas use decarbonisation. In recognising the inherent value of gaseous energy and the need to decarbonise, the gas industry has been actively investigating the potential of renewable gas options over the past decade.

Core to this research has been the CRC based industry research into renewable gas options, starting with the Energy Pipelines CRC (2009 – 2019) and evolving into the highly successful Future Fuels CRC[32]. APGA understands that DELWP have access to all Future Fuels CRC research and greatly encourage the VGSR to draw on any and all research material and expertise available from within the Future Fuels CRC to fully inform the VGSR on the cutting edge research and information on renewable gas uptake in Australia.

Possibly the most powerful role which the Victorian government can play in enabling decarbonisation of Victoria's gas use is through assuring Victorian citizens and businesses that all decarbonisation options are equally legitimate, safe and viable options. As recognised by the VGSR, there are now legitimate pathways to decarbonisation through renewable gases such as hydrogen and biogas. As APGA sets out in this submission, the weight of evidence points to these being viable options that will deliver benefit over full electrification.

The Victorian government has a responsibility, in recognising the equal decarbonisation validity of both the renewable electricity and renewable gas pathways, to ensure all pathways are known and trusted.

From here, delivery of robust, non-discriminatory policy, regulation and initiatives focused on emissions reduction through all available and potential mechanisms will be key. This will need to occur alongside retrospectively identifying and resolving any existing policy, regulation and initiatives which does not meet these criteria.

It is a very positive sign that the VGSR is accounting for customer choice in questioning how consumers preferences be accounted for in the transition. In recognising that all gas substitution pathways are valid pathways for gas decarbonisation, ensuring customer choice through enabling all possible pathways is recommended by APGA.

APGA do not recommend that renewable gas be preferred over renewable electricity. While this might sound contradictory, APGA believes the best possible solution will be driven by market forces once discriminatory legislation is removed and supply is available. Once Victorian households and businesses have access to lower cost, emissions free renewable gases, APGA is confident that they will choose to use it.

The renewable gas market need only be supported to exist on a level playing field to renewable electricity and customers will be able to choose which solutions work best for them. Where renewable gases are a more cost-effective approach to gas demand decarbonisation, it is expected that customers will make this choice, and that they should be allowed to do so.

3.4.1 Energy Efficiency

The energy appliance industry, both gas and electric, has a track record of continuous efficiency improvement for customer appliances.

By the very nature of being either commercial or contract carriage regulated businesses, pipeline infrastructure is already incentivised to operate as efficiently as physically practical. This cannot necessarily be said for electricity transmission systems which are regulated under a market carriage methodology.

This regulation methodology is at the heart of the electricity transmission sector bottlenecking which leads to renewable electricity being unable to enter the market due to congestion. Commercial gas contracts ensure that the capacity must exist before the supply is brought online, while operating costs are continuously optimised.

The misunderstanding of appliance efficiencies between appliances drawing from differing energy sources, including the impact on emissions and cost reduction, leads to flaws in regulation which can encourage increases in emissions intensity. Victorian Government initiatives currently incentivise the replacement of gas appliances with electric appliances. This is despite electrification of gas demand leading to increased emissions through until 2035, rather than reducing them[23, Appendix 4]. The Victorian government has the opportunity to achieve immediate gas emission reductions through expanding these incentives to facilitate the uptake of higher efficiency gas appliances.

3.4.2 Comparison between Electrification, Hydrogen and Biogas

While APGA addresses hydrogen and biogas pathways specifically as framed within the VGSR Consultation Paper, APGA recognise the combination of hydrogen, biogas, biomethane, renewable synthetic methane, and all other possible renewable gases as a single combined pathway through which net zero emission gas can be achieved in Victoria.

Table 5: Roles to be played by government and industry, and how consumers preferences will be accounted for in the transition to the electrification, hydrogen and biogas decarbonisation pathways

	Government	Industry	Accounting for Consumer Preferences
Electrification	Victorian government already supports electrification.	The pro-electrification industry has spent significant time and effort supporting the notion that electrification is the only solution to decarbonisation.	Electrification, if applied as the only solution, restricts consumer choice.
Hydrogen and Biogas	Victorian Government is in the early stages of supporting development of a hydrogen industry. Clearing regulatory roadblocks, addressing anti-hydrogen rhetoric, and enabling a tradable market are key next steps.	The gas infrastructure industry continues a decade of work creating the foundation for an Australian hydrogen industry, including developing the first pilot and commercial scale production assets.	By enabling a renewable gas pathway alongside a renewable electricity pathway, both hydrogen and biogas pathways allow for greater customer choice, including the continued use of existing gas appliances.

3.4.3 Emerging Technologies

In order to achieve the best possible outcome for Victorian citizens/households and businesses by allowing market forces lead to the best technology neutral decarbonisation outcomes and enabling decarbonisation access and choice for customers, the Victorian government should deliver robust, non-discriminatory outputs and initiatives through the VGSR. This will maintain a window for emerging technologies to enhance decarbonisation of gas use demand in the future.

The Victorian government should also continue to support scientific and industry research into emerging technologies, while industry should seek opportunities to invest in such technologies to support their commercial viability.

3.4.4 Fugitive Emissions

Government and the energy industry have a responsibility to take action on fugitive emissions in such a way that does not impede consumer choice by either holistically ruling out all sources of fugitive emissions, or making the burden of fugitive emissions surveillance and reduction more onerous than reasonably practical. A measure of what is reasonably practical may be able to be based upon the cost of offsetting such emissions.

Noting the best possible outcome for Victorian households and businesses is a net zero emissions energy system, not absolute zero emissions, accepting either of these consequences would be jeopardising the best possible outcome by expecting more from one energy pathways than is expected from others.

3.5 What are the likely timings of technical maturity and economic viability?

Economic viability is a contextual concept. As such, there is risk of economic viability being considered out of context or in dissimilar contexts. In light of the VGSR aim of decarbonising gaseous energy demand, the context needs to be relative to each alternative.

3.5.1 Energy Efficiency

Energy appliances of greater efficiency are generally technologically mature, with continuing improvements under development. While it is generally possible to purchase a more efficient like-for-like appliance than households purchased 5 – 10 years ago, energy appliances such as heating and hot water typically have a 10 to 20 year lifespan. A simple Net Present Value calculation considering the reduced electricity costs through increased efficiency and the years of operational life left in the appliance being replaced can determine the best timing of the replacement.

This becomes more complicated when considering fuel switching, such as transitioning between gas and electricity appliances. As APGA has identified, the better energy efficiency of an electric appliances does not necessarily equal lower emissions or energy costs with relation to a gas appliance.

Additionally, as will be explored more by GAMAA in their VGSR Consultation submission, the cost of fitting a non like for like appliance needs to consider modifications to the property in which they are being installed. Adding to this the transient efficiencies of electric appliances, and the equation becomes more complicated still.

APGA recommend that the VGSR undertake this calculation as part of their studies, identifying the economic viability of changing from gas to electric appliances with varying remaining economic life of the original appliance, cost of installation of non like for like appliances, differences in energy costs and the variations in efficiency considering ambient and hot side appliance temperatures for heat pump appliances.

3.5.2 Comparison between Electrification, Hydrogen and Biogas

While APGA addresses hydrogen and biogas pathways separately as framed within the VGSR Consultation Paper, APGA recognise the combination of hydrogen, biogas, biomethane, renewable synthetic methane, and all other possible renewable gases as a single combined pathway through which net zero emission gas can be achieved in Victoria.

Table 6: Timings of technical maturity and economic viability across electrification, hydrogen and biogas decarbonisation pathways

	Timing of Technical Maturity	Timing of Economic Viability
Electrification	Renewable electricity and electrification technologies all appear to be relatively technically mature, while some are still experience cost curve reductions.	It is worth noting that by nature of the current free market customer choice between gas and electricity, electrification of existing gas use cases is not economically viable today. Electrification does not necessarily equal cost reduction as detailed in Appendix 4. This is in part due to existing and future costs between each type of energy appliance and energy pathway, as well as the cost of upgrading the NEM being huge. Electrification will only be economically viable where electrical appliance efficiencies overcome gas price affordability, and where discriminatory regulation or initiatives favour electrification over renewable gas use rather than focusing on emissions reduction. This is in no small part due to the high relative cost of electrical energy transport and storage via electricity infrastructure.

	Timing of Technical Maturity	Timing of Economic Viability
Hydrogen	The CSIRO's Hydrogen RD&D Priorities publication identifies both opportunities requiring Technology Readiness Level (TRL) uplift, as well as key foundational Hydrogen technology which is at or approaching technically maturity (TRL9)[38]. TRL9 hydrogen technologies include Alkaline & PEM electrolysers, a plethora of fossil fuel conversion processes, biogas reforming, biomass gasification, as well as hydrogen pipelines, compression, pressure vessels, cryogenic tanks, fuel cells and ICE to name a few. These mature technologies are sufficient to start a hydrogen economy today, allowing other hydrogen technology to mature and manufacturing of mature technologies to improve.	CSIRO National Hydrogen Roadmap predicts economic maturity around 2030[8]. Economic viability of hydrogen at 2030 appears negative when compared to lower cost natural gas. In a decarbonisation context where natural gas is not a technical option, biogas economic viability becomes relative to biogas and electrification. Frontier Economics consider a 100% green hydrogen transition for gas networks to be more economically viable than electrification of gas demand[19]. Lower cost blue hydrogen would improve economic viability even further. Future Fuels CRC find current biomethane costs are around $15 - $18 per GJ mark, similar to the 2030 hydrogen price[39], but would not require infrastructure or appliance modification, making biogas more economically viable but potentially less accessible than hydrogen. This is in no small part due to the low relative cost of gaseous energy transport and storage via gas infrastructure.

[38] Hydrogen Research, Development and Demonstration Priorities and opportunities for Australia, CSIRO 2019 https://www.csiro.au/~/media/Showcases/Hydrogen/HydrogenRDDFullReportWEB191129.pdf
[39] Australian biogas and biomethane wholesale prices predicted by the Future Fuels CRC in an anticipated report scheduled for release in in Q3 2021

	Timing of Technical Maturity	Timing of Economic Viability
Biogas	Biogas production and biomethane upgrading technologies are internationally mature despite limited deployment in Australia, with next generation technologies also in development.	Biogas has limited deployment in Australia due to current economic comparisons being to lower cost natural gas. In a decarbonisation context where natural gas is not a technical option, biogas economic viability becomes relative to hydrogen and electrification. Future Fuels CRC find current biomethane costs are around $15 - $18 per GJ mark, similar to the 2030 hydrogen price[40], but would not require infrastructure or appliance modification, making biogas more economically viable but potentially less accessible than hydrogen. Being more commercially viable than hydrogen makes biogas automatically more commercially viable than electrification. This is in no small part due to the low relative cost of gaseous energy transport and storage via gas infrastructure.

[40] Australian biogas and biomethane wholesale prices predicted by the Future Fuels CRC in an anticipated report scheduled for release in in Q3 2021

3.5.3 Emerging Technologies

Technology maturity timelines for emerging technologies and many and varied. Key to their economic viability will be robust, non-discriminatory policy, regulation and initiatives which allow emerging technologies to enter the market unimpeded in the future.

One exceptionally interesting emerging technology is renewable synthetic methane, or methane produced through the process of methanation of renewably sourced hydrogen with renewably sourced carbon dioxide. Renewable synthetic methane would have higher production cost than hydrogen but no need for infrastructure or appliance modification like biomethane. Economic analysis of the crossover point where renewable synthetic methane becomes more commercially viable than hydrogen is recommended.

3.5.4 Fugitive Emissions

Fugitive emission reduction technologies would be considered technologically mature. Economic viability of fugitive emission reduction activities is hard to quantify as economic viability can only be considered relative to an alternative cost.

While this points towards applying a cost to fugitive emissions, it could not possibly be considered fair and reasonable to apply a cost to one source of emissions and not all sources of emissions. This is especially the case considering the 10% average NEM loss factor which has an emissions intensity the same as the NEM region that energy is lost within[41].

In the event that fugitive emission reduction is mandated, it is suggested that the economic viability of utilising carbon offsets be considered alongside the economic viability of preventing the emissions, as is available to any and all other emissions intensive activity.

3.6 What are the best ways to maintain social acceptability and consumer confidence?

Two key factors are expected to come into play with relation to social acceptability and consumer confidence – consistent trusted messaging and safe, reliable and secure delivery of energy.

The safe, reliable and secure delivery of energy can come down to trusted industry participants across the energy value chain. Participants in both the gas and electricity infrastructure industries have excellent track records of ensuring safe, reliable and secure energy delivery to customers. Many engage directly with the standards and regulatory frameworks to ensure that such frameworks enable this outcome. No matter which energy pathway is utilised, allowing energy infrastructure industry to do what it does best will enable the best possible safety, reliability and security outcome for outcome for Victorian households and businesses.

[41] Loss factors and regional boundaries, AEMO 2021 https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/market-operations/loss-factors-and-regional-boundaries

The Victorian Government has a key role to play in overseeing the safety regulatory system and also being a source of independent information demonstrating the value and important of all pathways to address the carbon impact of gas in Victoria.

3.6.1 Energy Efficiency

Social acceptability of energy efficiency is a given. It is critical governments play a role in making clear that comparing electricity and gas is not usually an apples-to-apples comparison.

3.6.2 Electrification, Hydrogen and Biogas

Strong and public government support for the uptake of renewable gases as legitimate decarbonisation pathways will be needed to gain social acceptance.

Acceptance and understanding of the potential of renewable gases will need to be based on trusted (ie not gas industry) advocates – a perfect role for government.

From a consumer confidence perspective, the gas industry is in the process of engaging on federal and state levels to identify how to fit renewable gases within existing safety, reliability and security frameworks. With significant research backing these changes, including contributions by the Future Fuels CRC, development of the necessary federal framework within which renewable gas uptake can be enabled will be readily achievable.

3.6.3 Emerging Technologies

Each emerging technology will have its own social acceptability and consumer confidence challenges. A key learning from the expected challenges above is to ensure all policies, regulations and initiatives are robust and non-discriminatory. This will ensure that the introduction of new information at a later date doesn’t result in questions or doubt of the legitimacy of the emissions reduction capabilities of a new technology as is currently being experienced by the renewable gas sector.

3.6.4 Fugitive Emissions

The gas industry understands that reducing fugitive emissions is essential to maintaining social acceptability and consumer confidence in natural gas today, leading to greater acceptance of renewable gases in the future. APGA considers that the growing recognition of this social obligation from companies across the gas supply chain will deliver major reductions without government intervention.

3.7 What are the inter-dependencies and trade-offs with other pathways (are pathways complementary or alternatives)?

As APGA has noted, the improving energy efficiency and emerging technology pathways are complementary to all others. Similarly, adressing fugitive emissions is beneficial in all circumstances. The competition between substituting natural gas with renewable gas and electrification is less complementary, often requiring a decision between alternatives.

3.7.1 Energy Efficiency

Energy efficiency reduces the overall size of the challenge, making the overall challenge easier. However, energy efficiency gains can be misconstrued when considering switching between electricity and gas. Better energy efficiency does not necessarily equal lower emissions or energy costs. Understanding the relative cost and emissions intensity when comparing energy efficiency across energy mediums, as well as any transient efficiency behaviour, are necessary to arrive at an accurate understanding of the impact of energy efficiency on decarbonisation pathway interdependencies.

3.7.2 Interdependencies between Electrification, Hydrogen and Biogas

The interdependencies between these pathways are complex and many. The pathways themselves are often mutually exclusive alternatives, particularly between electrification and the renewable gases. They include:

- The relative merits of transporting and storing energy as electricity or gas.
- The total system costs of electrifying all gas demand.
- The marginal cost of electrifying some gas demand.
- The costs to consumers of electrifying their own demand.
- The ongoing role for gas power generation in electricity generation.
- The use of electricity to manufacture some renewable gases.
- The potential for all three to replace liquid fuel in various transport applications.

Through Gas Vision 2050 and other work, APGA has reached the conclusion, in line with the International Energy Agency, that decarbonising both the gas and electricity systems delivers the most affordable, reliable, safe, secure and equitable energy system.

3.7.3 Fugitive Emissions

There is an inherent interdependency between gaseous energy, the transition to renewable gaseous energy, and fugitive emissions. Aside from industry efforts to reduce fugitive emission today, they will inherently reduce through the transition from natural gas to renewable gas.

3.8 What are the key uncertainties and potential for unintended consequences?

3.8.1 Energy Efficiency

The greatest source of energy efficiency uncertainty is in improper comparison of non like for like appliances and energy sources. Energy efficiency stated as a single number can miss the impacts of variables which significantly change energy efficiency. Considering the energy source that a particular energy efficiency applies to can also change the outcomes when comparing appliances which utilise different types of energy.

This results in unintended consequences when the improvements in emissions intensity or energy cost sought through energy efficiency improvements is counteracted by using a higher emissions energy source. Considering that Victorian NEM electricity is five times more carbon intensive than natural gas (3.7 times in 2030 [Appendix 4]) and retail gas costs three to fifteen times less than retail electricity, the unintended consequences of considering energy efficiency without considering energy source are worth investigating even before renewable gases are considered.

Once renewable gases are considered, the energy efficiency of energy systems is also worth considering. APGA estimates that on average, gas transmission pipelines use around 2% of the energy which they transport as fuel gas. This is in comparison to the 10% losses experienced by the electricity transmission sector, making gas pipelines 5 times more energy efficient than electricity transmission lines[41].

3.8.2 Electrification

APGA are not experts on electricity infrastructure and expect those who are to provide robust and objective information into the robust and objective VGSR process. What we do know is that information which is made available in the public domain, some of which can indicate system level uncertainties and potential unintended consequences.

Aside from the efficiency uncertainty identified above, APGA sees significant uncertainty in how an electricity system which is going to be challenging to decarbonise its own energy right can sustain the additional load and variability of decarbonising gaseous energy demand as well. APGA consider this an uncertainty considering the combination of the work currently being undertaken by the Energy Security Board to address electricity system reliability and security, alongside the significant differences in scale of both electricity and gas demand in Victoria[21].

The unintended consequence which APGA identifies with relation to the Electrification pathway is potential for Victorian citizens and businesses to believe that they are following the least cost decarbonisation pathway when in fact they are not. As detailed within the uncertainties, the possibility of delivering higher cost, lower reliability, lower security energy through a flawed decarbonisation pathway may not only result in a worse situation for citizens and businesses, but a possible disenfranchising of Victorians from the concept of decarbonisation.

3.8.3 Hydrogen

The primary uncertainties around the potential for the hydrogen renewable gas pathway to contribute Victorian gas demand decarbonisation come down to the rate of cost reduction, and the feasibility of hydrogen transport options. Unintended consequences mostly arise from taking discriminatory approaches to gaseous energy decarbonisation.

Just like solar, wind and battery technologies before it, hydrogen technologies are seen to be coming down a cost curve. The CSIRO National Hydrogen Roadmap estimate that hydrogen will reach the internationally targeted price of $2USD per kg by 2030. How rapidly cost reduction will occur is an uncertainty, however it is recognised that as with most cost curves, costs are driven down through greater technology deployment.

Once uncertainty which may arise in considering hydrogen substitution is uncertainty created through differences in comparison. The CSIRO chart displayed in Figure 2 also displays a number of targeted applications which are considered to be or not to be a competitive field for hydrogen uptake. While a low fidelity study may consider this sufficient basis to rule out hydrogen in these fields, a high-fidelity study such as the VGSR would need to consider competitiveness with relation to alternatives, rather than simply the incumbent market. It is possible for hydrogen substitution to be both non-competitive with existing gas supply, and competitive against electrification, especially on a whole of system basis.

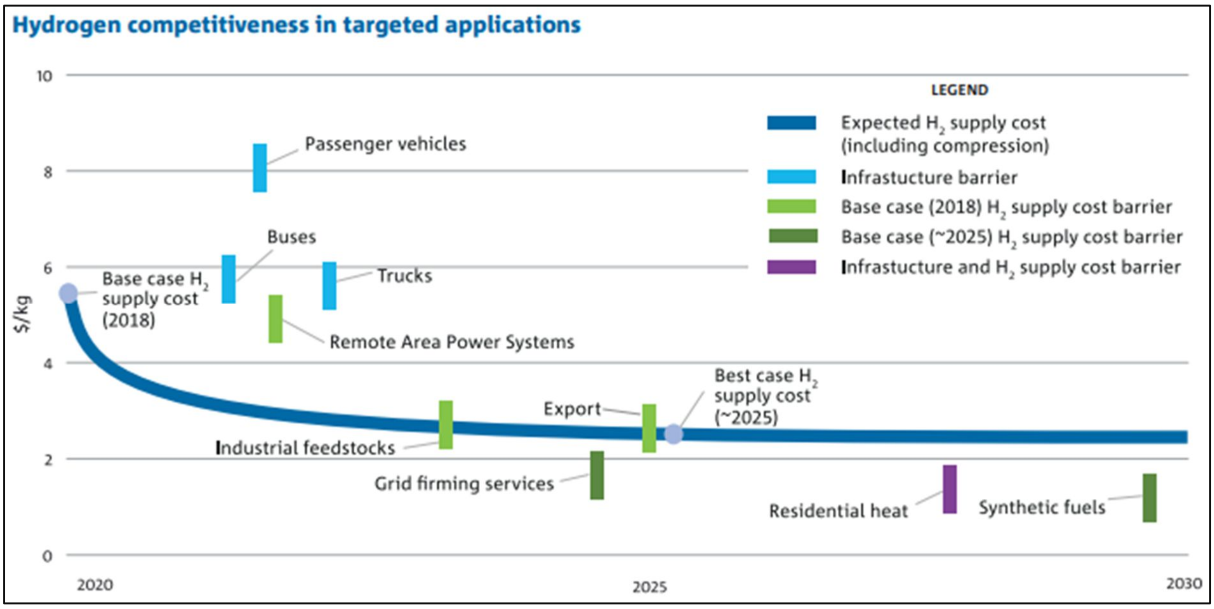

Figure 2: Hydrogen competitiveness in targeted applications[8]

Uncertainty around the feasibility of hydrogen transport through existing gas assets is steadily declining through significant global focus addressing each point of contention. What is important to note is that this uncertainty is related to existing assets and how much modification is required to allow hydrogen uptake – new assets designed for hydrogen transport and utilisation are and have been technically feasible for decades as seen in existing industrial hydrogen applications.

One uncertainty that sits between these concepts is the relative feasibility of renewable synthetic methane. Produced through methanation of renewable hydrogen and renewably sourced carbon dioxide, renewable synthetic methane has zero transport and utilisation uncertainty as it is identical to the methane being transported through todays gas assets. There will be a theoretical price point at which methanation is more cost effective than modification of gas infrastructure and appliances to accept 100% hydrogen which is worth considering within VGSR analysis.

The greatest unintended consequence with relation to hydrogen would occur through the persistence of government initiatives which are pro-electrification rather than pro-emissions reduction. Government initiatives which preference one technology over another when both achieve the same emissions reduction end disrupt market dynamics and risk Victoria not achieving least-cost decarbonisation of gaseous energy.

3.8.4 Biogas

Biogas uncertainties predominantly surround feedstock access and management of minor impurities, while like most pathways, unintended consequences arise from taking discriminatory approaches to gaseous energy decarbonisation.

Considerations as to whether or not agricultural crop reside can or cannot be considered an available feedstock for biogas production varies the available biogas feedstock potential between 5% and 27% of current Victorian gas demand. These figures grow depending on whether interstate biogas supply via Victoria's four interstate pipelines is considered a viable supply option.

Importantly, these figures disregard the possibility of developing energy crops for the purpose of biogas production. While energy cropping is controversial from an impact to scarce agricultural land perspective, it is worth understanding the scale of this potential avenue.

APGA wish to note that fact that the Biogas section of this question is smaller than the hydrogen section because there are less uncertainties with biogas than with hydrogen.

3.8.5 Emerging Technologies

All emerging technologies have the same high level of uncertainty which comes with any technology which is climbing either the technology readiness level (TRL) or commercial readiness index (CRI) scales. The greatest unintended consequence for how the VGSR approaches emerging technologies would be to put in place recommendations which impede any potential new technology in the future.

Regulatory impedance can be a significant barrier in the TRL and CRI development of any new technology. As can be seen with hydrogen and biogas, Victorian regulation which impedes injection of these carbon neutral gases into gas networks, alongside initiatives which promote switching away from gaseous energy, have both slowed the development of these renewable gas pathways. Regulation and initiatives which enable as many forms of carbon neutral energy as possible is a no-regrets approach to enabling emerging carbon neutral energy technologies, avoiding this unintended consequence.

3.8.6 Fugitive Emissions

The greatest uncertainty around fugitive emissions comes from a lack in accurate measurement of fugitive emissions around gas infrastructure, while the potential unintended consequence arises from the idea that gaseous energy would need to be totally abandoned in order to address fugitive emissions.

Due to a lack of driver to undertake accurate fugitive emission measurement, Victorian gas infrastructure companies take the least cost option of utilising NGERS Methodology 1 to report on fugitive emissions. This is despite knowing that this greatly overestimates fugitive emissions due to the simple "kilometres X emissions" calculation. Put simply, in the highly unlikely event that a gas pipeline leaks, it is highly noticeable and addressed rapidly as a safety risk. This topic can be better understood by engaging with APGA members directly as has been seen to occur throughout the VGSR process.

A potential unintended consequence can arise if the conclusion that all gaseous energy must go to abate fugitive emissions. Aside from the above recognition that gas pipelines emit significantly less fugitive emissions than reported, the bulk of fugitive emissions are seen to come from the exact same upstream production sources which renewable gas production would replace.

3.9 What are the opportunities and barriers to further reductions in fugitive emissions?

As per APGA's submission to the VGSR Fugitive Emissions Survey, fugitive emissions are taken seriously within the gas transmission pipeline industry as an important but low proportion of all gas industry fugitive emissions. In providing this feedback, and in the broader context of this consultation, APGA identify three opportunities and barriers to further reducing fugitive emissions in Victoria.

3.9.1 Opportunities

Publicly available data for fugitive emissions, even as recorded via NGERS, is hard to find. It is expected that the VGSR process should be able to access sufficient raw NGERS data to break down Victorian gas industry fugitive emissions, which have been identified as accounting for 3% of total Victorian emissions within the consultation paper. In lieu of access to such data, APGA estimates the following order of fugitive emissions sources from largest to smallest:

1. Gas Production
2. Gas Use
3. Gas Distribution
4. Gas Pipeline Transmission

This is partly backed by the limited NGERS that could be found which identifies that oil and gas exploration produced over 10 times the emissions of gas supply in FY15-16[42].

Assuming this is an accurate reflection of fugitive emission across the gas value chain, logic can be applied to identify a number of macro opportunities in fugitive emission abatement. Firstly, the largest contributor can be addressed simply though the replacement of natural gas production with other energy production sources. As such, these emissions should not be included when considering the gas value chain emissions intensity for hydrogen or biogas decarbonisation pathways.

[42] Australia's scope 1 emissions by ANZSIC subdivision for NGER reporters, Clean Energy Regulator 2017
http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/a-closer-look-at-emissions-and-energy-data/australia%E2%80%99s-scope-1-emissions-by-industry-for-nger-reporters

Secondly, the Global Warming Potential (GWP) of hydrogen is around 5.8[43] relative to methane which has a GWP of 28[44]. This means that a 100% hydrogen gaseous energy value chain would result in an 80% reduction in fugitive emissions in all three of the other gas supply chain fugitive emissions source categories.

While this reduction is not a 100% reduction in fugitive emissions, this exists alongside industry commitment to address fugitive emissions directly and efficiency improvements, as well as the practical considerations of targeting net zero emissions rather than absolute zero emissions.

3.9.2 Barriers

In providing this feedback, and in the broader context of this consultation, APGA identify three opportunities and barriers to further reducing fugitive emissions in Victoria – Accuracy, Conflation of Fugitive Emissions Information, and Comparative electricity transmission and distribution fugitive emissions.

3.9.2.1 Accuracy

A key barrier to reduce fugitive emissions is to recognise that data provided to NGERS is generally inaccurately high. In the instance for gas pipelines, this is the case due to regulatory pressure to minimise costs, and there being no reason to use more complex methodologies other than NGERS Methodology 1 – a simple pipe length x value calculation. This is despite the low probability of high-pressure pipelines releasing fugitive emissions due to the stringent safety obligations of pipeline operators to avoid even the smallest gas leak on safe operation grounds.

Until we accurately know the true extent of fugitive emissions, it will be difficult to properly target fugitive emissions for reduction.

3.9.2.2 Conflation of Fugitive Emissions Information

Reporting of all gas industry emissions as a single datapoint misses the nuance of where the greatest fugitive emissions offenders originate from. It is broadly recognised that the greatest percentage of gas value chain fugitive emissions come from natural gas production. Burdening renewable gases with an assumed equivalent fugitive emission rate unfairly dismisses the differences between natural gas and renewable gas production, and whether these differences reduce fugitive emissions from production sources.

In the event that the VGSR finds that over 50% of fugitive emissions come from gas production, this reduction could be seen to be achievable through the transition from natural gas to renewable gas alone if renewable gas production is designed to not produce fugitive emissions.

[43] Global environmental impacts of the hydrogen economy, Derwent et al 2006 http://agage.mit.edu/publications/global-environmental-impacts-hydrogen-economy
[44] Global Warming Potentials, Clean Energy Regulator 2021 http://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme/global-warming-potentials

3.9.2.3 Comparative electricity transmission and distribution fugitive emissions

Comparing gas infrastructure fugitive emissions with an assumption of zero fugitive emissions of electricity infrastructure is flawed logic missing an important part of the equation. As identified by AEMO:

"As electricity flows through the transmission and distribution networks, energy is lost due to electrical resistance and the heating of conductors. The losses are equivalent to approximately 10% of the total electricity transported between power stations and market customers."[41]

Being that this lost energy is emissions intensive, it could be considered equivalent to fugitive emissions. If this 10% loss factor applies to the Victorian NEM region, electricity transmission fugitive emissions would account for 4.1 $MtCO_2e$ per annum[41,45]. Considering the little NGERS data that can be found from FY15-16, nationally emissions from gas supply was only 2.3 $MtCO_2e$[42].

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[45] Electricity sector emissions and generation data 2019-20, Australian Government Clean Energy Regulator 2021
http://www.cleanenergyregulator.gov.au/NGER/National greenhouse and energy reporting data/electricity-sector-emissions-and-generation-data/electricity-sector-emissions-and-generation-data-2019-20

4 Consultation Paper Key Issues

4.1 Maintaining electricity reliability with new sources of demand

The cost of upgrading Victorian electricity generation, transmission and distribution infrastructure to electrify gas demand is huge. In addition, electrification of gas demand reduces total energy system reliability by placing a greater reliance on the electricity system, increasing the likelihood of failure by increasing peak loads and consequences of failure by increasing total demand. Finally, as recognised in the Discussion Paper, decarbonisation of the electricity sector and the electrification of transport are major undertakings of themselves.

Gas pathways increase energy system resilience by diversifying the system and, as they will deliver renewable gas, include all the positives of gaseous energy without the carbon footprint. Gaseous infrastructure currently delivers more energy in Victoria than electricity infrastructure and thus represents a greater opportunity than electricity infrastructure to deliver zero carbon energy..

4.1.1 What policies are needed to ensure that the electricity network can reliably serve new sources of demand from hydrogen production, electric vehicles and electrification of gas demand?

In the context of gas substitution, the best policy to ensure electricity reliability is one that focuses on decarbonisation of gas demand rather than electrification of gas demand. The electricity sector has its own major challenges that must be managed, primarily:

- Decarbonisation and the management of increasing levels of variable renewable electricity;
- Managing the new demand arising from the electrification of transport.

These both require major changes to electricity generation, storage, transmission and distribution infrastructure that will readily require the three decades to 2050 to achieve.

Gas decarbonisation is a superior policy option to electrification of gas demand because:

- Grid-sourced electricity currently has greater carbon intensity than gas. Electrifying gas demand today does not Efforts underway in the gas industry to reduce emissions from existing operations in the short and medium-term combined with the commencement of hydrogen and biogas blending should ensure the lower emission intensity of gas extends well into the next decade.
- Zero carbon biomethane produced from existing Victorian feedstocks alone has potential to supply 27% of Victorian gas demand alone. A national biomethane industry would increase this substitution potential as detailed in Appendix 2.

Importantly, it is not foreseen that bulk hydrogen production will be integrated into the NEM. While initial small volumes of hydrogen production in the ramp up to 10% hydrogen in gas distribution would likely draw on NEM connected renewable generation, the lowest cost hydrogen will be delivered to gas distribution networks by pipeline. This is based on two key facts:

- Transporting energy as a gas in a pipeline is the cheapest option
  This has been identified multiple times internationally and is the subject of both industry level research commissioned by APGA and academic level research within the Future Fuels CRC[18,32,46].
- Hydrogen for pipeline transport can access behind the meter renewable generation
  Hydrogen by electrolysis will be most economic when it captures the benefits of low-cost solar without the system expense. It will not require transformers to step in and out of the grid or redundant electricity transmission pathways; it will not incur a 10% loss factor[41]; and cheaper pipeline linepack energy storage can be used to manage intraday variations in output rather than more expensive electricity storage.

4.1.2 What is the role for gas-fired power generation and hydrogen in maintaining electricity reliability?

Gas-fired power generation (GPG), fuelled by natural gas today and renewable gas tomorrow, has a key role to play in maintaining electricity reliability. Today, GPG offers the best complement to variable renewable energy (VRE). This is currently being witnessed in the electricity generation mix of South Australia,.

As batteries and pumped-hydro play an increasing role, GPG will provide the backstop to these systems, stepping in when renewable droughts or system failures lead to extended VRE generation issues.

In 2021, APGA and the Grattan Institute have both produced modelling indicating that GPG powered by natural gas with its emissions offset allows the NEM to reach net-zero emission, with a mix of around 90% renewables and 10% gas, by 2040 at the lowest cost[26,27].

4.2 Transitioning to more sustainable gaseous fuels with minimal disruption to end-users

Changes necessary to decarbonise the gaseous energy value chain are predominantly upstream of the customer. Australian gas infrastructure businesses are committing to enabling this change, through research and pilot renewable gas production facilities today, to building frameworks to enable a wholesale renewable gas transition tomorrow.

Some options for full transition in the long term may require changes to customer appliances, however some may not. Importantly, ramp up of the renewable gas industry across the coming decade through 2030 will not likely reach a point where appliances are impacted, allowing the industry to gather important information to determine which of the renewable gas future pathways is best for each Victorian gas customer.

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[46] Hydrogen Insights - A perspective on hydrogen investment, market development and cost competitiveness, Hydrogen Council 2021 https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021-Report.pdf

4.2.1 What are the key technical challenges in converting existing gas networks to accommodate more sustainable gaseous fuels?

The key technical challenges of enabling the renewable gas transition are well known and under investigation by the Future Fuels CRC. As DELWP have access to the full suite of Future Fuels CRC research, APGA anticipates that the VGSR is already taking into account all technical challenge learnings currently under investigation.

With the ability to leverage existing gas infrastructure, it is apparent that addressing these challenges is a lower cost option to expanding electricity infrastructure to electrify gas demand [Appendix 1].

4.2.2 What are the potential costs and opportunities in switching to more sustainable gaseous fuels for consumers?

All options to decarbonise gas have costs associated with them. These costs have been actively explored by APGA and co-signatories to Gas Vision 2050 leading us to the conclusion that the costs to consumers of switching to more sustainable gaseous fuels are lower than other options [Appendix 3]. This will mean lower costs of delivered energy for consumers. APGA encourages DELWP to draw on existing findings and conduct its own work to verify the conclusion that decarbonisation of gas is the lowest cost option available.

Importantly, through emission reduction from operations and initial renewable gas blending, (a blend of at least 90% renewable sources of methane with up to 10% hydrogen will be sufficiently similar to natural gas to warrant no need to change appliances), there is great potential to reduce emissions in the period to 2030 with no cost to consumers.

In the event that a higher hydrogen blend is the end solution, there will be a cost to customers for the modification or like for like replacement of gas appliances. However, the replacement of gas appliances with electric appliances in an electrification scenario is expected to be more costly still due to factors including the lack of like-for-like appliance configurations and bolstering of electricity supply. APGA refer to the submission by GAMAA with regards to more detailed commentary on this topic.

4.3 Maintaining the reliability, affordability and safety of gas supply

Maintaining the reliability, affordability and safety of gas supply is core business for the gas infrastructure industry.

The Australian gas infrastructure sector has outstanding track records for reliability and safety. The skills, expertise and culture that have delivered these track records will not change as the gas that is transported changes.

While some (not all) renewable gas options lead to some changes in how the gas transported by gas infrastructure interacts with the infrastructure itself the operational difference for gas infrastructure is minimal.

For affordability topic, a key point throughout this submission is that the relative affordability of gaseous energy to electricity will not change as renewable gas is delivered.

While renewable methane pipelines will be equivalent to natural gas pipelines, new hydrogen pipelines are expected to be more costly in comparison. But when comparing hydrogen pipelines to the electrification equivalent, it is globally knowledge that energy transport by pipeline is cheaper than energy transport by wires[18,46].

4.3.1 What are the affordability, reliability and safety considerations related to gas supply and gas infrastructure, both in the short term and during a long-term transition to a decarbonised gas sector?

APGA refers the VGSR to Energy Safe Victoria for its perspective on the safety of gas pipeline assets and the bodies of work underway to translate the exceptional safety record of the Victorian pipeline industry to an equally safe renewable gas future.

As renewable gases entail all of the positives of gaseous energy without the carbon footprint, this includes the lowest cost energy transport pathway available to Australia – transport by gas pipeline. Despite continued scrutiny by the ACCC across the past decade, gas pipeline costs continue to be lower than electricity transmission costs. Due to the workably competitive merchant pipeline market in Australia, there is no expectation that he affordability of gas infrastructure as an energy transport pathway would become less cost effective than electricity infrastructure.

4.3.2 What policies are needed to ensure that the gas system continues to operate reliably and safely and remain affordable for end-users during this transition?

The introduction of renewable gases into the gas market do not change the fundamental structure of the market from a reliability, safety and affordability perspective. While not perfect from the perspective of the gas infrastructure industry, the current framework has led to the Victorian gas system being more safe, reliable, affordable and less carbon intensive than the Victorian electricity industry. As such, the only policies that enable renewable gases are required to ensure this continues into a renewable gas future.

4.4 Supporting Victoria's workforce, industry and the institutions that support them

The development of a renewable gas industry is a great opportunity for Victoria. Facilitating its development through the VGSR process is an excellent first step to take to support Victoria’s workforce, industry and institutions. The National Hydrogen Strategy identifies that the renewable gas opportunity represents the potential for thousands of new jobs and billions of dollars in economic growth between now and 2050.

“There is potential for thousands of new jobs, many in regional areas – and billions of dollars in economic growth between now and 2050”

The Future Fuels CRC and CSIRO both have a focus on developing of upskilling programs for existing gas industry staff[32,47]. Leveraging these and other initiatives as well as the NERA Hydrogen Clusters to upskill existing gas industry staff to be renewable gas ready will put Victoria's workforce on the front foot for the renewable gas transition.

4.4.1 What workforce skills and industry capabilities are required to transition to new and emerging energy sources?

Please refer to research undertaken by both the Future Fuels CRC and CSIRO on this topic[32,47].

4.4.2 How can government, industry and unions best work together, including through the Victorian TAFE and Training system, to help to build these skills and capabilities, and support existing workers through the transition?

Please refer to research undertaken by both the Future Fuels CRC and CSIRO on this topic[32,47].

4.4.3 How do we maximise local job opportunities, including for industry training centres such as that operated by the Plumbing Industry Climate Action Centre, to prepare workers for the future?

Please refer to research undertaken by both the Future Fuels CRC and CSIRO on this topic[32,47].

Bioenergy offers a major new local job opportunity for Victoria. The bioenergy supply chain will be extensive, having a footprint covering the entire state as organic waste is gathered, transported to centralised production facilities and converted to renewable methane and other biofuels. It offers the opportunity of a new income stream to all sources of organic waste, including agriculture, food processing and hospitality.

Similarly, local production of hydrogen will offer many new opportunities for Victoria.

For both industries, there is potential for Australia and Victoria to not just produce energy locally, but to develop the manufacturing capability to build the plant and equipment locally.

4.5 Managing uncertainty in the transition

The most powerful tool for managing uncertainty in the transition lays in the style of advice and/or recommendations which this study derives. Producing robust, non-discriminatory outputs and initiatives in order to maintain options for the future will be key to enabling market forces to lead to the best technology neutral decarbonisation outcomes. By enabling decarbonisation access and choice for customers in this way, Victoria can ensure that is

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[47] CSIRO ARC Training Centre for the Global Hydrogen Economy, CSIRO 2020 https://research.csiro.au/hyresource/arc-training-centre-for-the-global-hydrogen-economy/

does not miss out on achieve the best possible outcome for Victorian households and businesses.

4.5.1 What key uncertainties should the Roadmap take into account, and what is the government's role in reducing these uncertainties?

There is a huge international push to develop the renewable gas industry, with demonstration projects and early commercialisation projects happening globally. While the development journey is full of uncertainties, its future role should be taken as a given.

In its 2021 report, Net Zero by 2050 A Roadmap for the Global Energy Sector, the International Energy Agency (IEA) forecasts that renewables gases will account for 13% of global energy demand in 2050. APGA notes that the IEA also forecasts natural gas will provide 6.5% of global energy demand. This is an expanded contribution above the 14% of global energy demand that natural gas provides today.

Further, neither of these figures include the contribution of GPG and the IEA forecasts the role of renewable gas will be even greater if widescale deployment of carbon capture and storage technology is not achieved.

A critical role for the Victorian Government in reducing uncertainties is to commission and publish comprehensive, objective information and use it to support policy decisions. Misinformation about policy decisions, especially misinformation about renewable gases, will undermine their potential success.

APGA appreciates that the information it presents in this submission will be viewed by some as biased and self-serving. In recognition of this, APGA endeavours to be conservative when working with economic modellers to produce reports and findings and welcomes further investigation by the Victorian Government of any information presented in this submission.

4.6 Transitioning the Victorian economy efficiently and equitably

The best possible outcome for Victorian households and businesses is the lowest cost net zero emissions energy system. Market forces lead to the best technology neutral decarbonisation outcomes. As such, focus should be on enabling decarbonisation access and choice for customers. This is particularly important for energy equity, especially considering the transient energy efficiency impacts leading to electrification not necessarily equalling decarbonisation or cost reduction.

4.6.1 How can we ensure that the costs of transition to lower emissions energy sources are borne equitably?

Ensuring that the costs of transition to lower emissions energy sources are borne equitably will be enabled through the robust and objective VGSR process producing robust, non-discriminatory outputs and initiatives which maintaining all decarbonisation options for the future. In this way, market forces lead to the best technology neutral decarbonisation outcomes.

A key piece of this puzzle will be enabling the contracting of renewable gas as a decarbonisation option. This will mean that those who cannot afford the expense of changing to a more efficient appliance will still be able to achieve carbon neutrality. Ensuring that Victoria's least fortunate aren't expected to pay an unnecessary price for energy decarbonisation is a significant factor in ensuring that the best possible gas decarbonisation outcome is achieved for all Victorian households and businesses, not just those who can afford it.

Victorian government initiatives which favour gas appliance replacement rather than a reduction in emissions intensity need to change to enable gas appliance upgrading and/or contracting of renewable gases. This will also help ensure that all Victorians have access to the cheapest decarbonisation options in the years to come.

4.6.2 How can we help low-income and vulnerable households manage any upfront costs in changing energy sources?

Victoria can either completely avoid the need for vulnerable households to manage the upfront costs in changing energy sources, or minimise these costs, through the uptake of renewable gases.

This question assumes that a change is necessary. With renewable sources of methane in particular, there is absolutely no need for vulnerable households to make any change in appliances to decarbonise. Even with Hydrogen, the cost of appliances transition between like for like appliances are much less than the costs of an electrification transition. APGA refers the VGSR to GAMAA's submission for more in depth information on this topic.

Once it is recognised that a change is either unnecessary or lower cost with hydrogen than electrification, Victorian initiatives to electrify energy demand appear misguided. Alternately, Victorian initiatives could be upgraded to targeting emissions reduction rather than gas avoidance to ensure the most cost-effective solutions are invested in by the Victorian government.

4.6.3 What are the barriers for households in improving the efficiency of their use of gas for heating, cooking and hot water and/or switching to solar/pump hot water in existing homes?

As already covered, switching to a solar or heat pump hot water is neither necessary, lower cost or lower emissions when renewable gas is an option.

The barriers for households in improving the efficiency of their use of gas for heating, cooking and hot water are the same as the barriers for households in improving the efficiency of their use of electricity for heating, cooking and hot water. Uniform application of initiatives addressing the efficiency upgrade barrier to all appliance types will help overcome these burdens in a non-discriminatory manner.

4.6.4 What are the opportunities for the Victorian Energy Upgrades program to incentivise efficient gas use, thermal upgrades of buildings (e.g. insulation) and electrification?

As already covered, electrification is neither necessary, lower cost or lower emissions when renewable gas is an option.

There are immediate opportunities for the Victorian Energy Upgrades program to incentivise gas use efficiency upgrades and thermal upgrades of buildings. Discriminatory initiatives which support electrification as the only solution to emissions reduction should be reassessed. Transitioning to non-discriminatory programs which target emissions reductions rather than gas reduction will help enable a broader, lower cost range of emissions reduction solutions.

4.6.5 What issues and elements do you see as most important to improve the energy and emissions performance of new homes?

Gaseous infrastructure represents a greater opportunity than electricity infrastructure to deliver zero carbon energy. Despite this, gas use is currently discriminated against in considerations of improvements to energy and emissions performance. Addressing this discrimination against gaseous energy will enable the growth of the lower cost renewable gas opportunity for Victorian households and businesses.

Appendices

Appendix 1: Gaseous energy is high-quality, affordable energy

It is no accident that gaseous energy has been such an important part of the energy mix in Victoria, in Australia, and around the world. The innate qualities of gaseous energy are behind this success and are perfectly matched to address the challenges experienced by renewable electricity. Importantly, these innate qualities exist regardless of the source of the gas, be it carbon intensive, decarbonised or renewable.

There are three innate qualities which make gaseous energy so valuable. Firstly, gaseous energy is versatile. Being able to be used either as thermal energy or motive force through combustion, or as chemical energy or a feedstock through chemical reactions, many users are able to access the many and varied forms of energy they need in an instant with gaseous energy[48].

Secondly, gaseous energy is energy dense. This in part enables its versatility. The electrification industry strives to replicate the energy density of chemical potential energy found in gas molecules through ever improving battery design. For illustration, lithium-ion batteries strive to achieve energy densities above 260Wh/kg, while methane and hydrogen boast energy densities of 15kWh/kg and 39kWh/kg respectively[49]. Actual volumetric energy density is a more important measure of energy density, which for gaseous energy is variable.

Thirdly, gaseous energy is compressible. While energy density is a feature of solid and liquid forms of energy as well energy, gaseous energy is the only source of energy which can experience an increase in energy density through compression. This leads to simple, flexible energy storage[50]. Further, as learned in high school physics, high pressure gases naturally flow to low pressure, leading to simple, easy movement and handling.

The innate versatility, energy density and compressibility of gaseous energy lead to gaseous energy being one of the most usable, transportable and storable energy sources available. It is through being more usable, transportable and storable than other forms of energy that makes gaseous energy more of the most affordable forms of energy for customers, be they households, businesses, heavy industry or electricity generation.

Importantly, the innate qualities of gaseous energy are perfectly aligned with the challenges faced by renewable electricity. Renewable electricity is predominantly variable in supply, and must either be used immediately, either by a customer or by conversion into another form of energy for storage which is generally relatively expensive.

Gaseous energy can be used in place of electrical energy, including when electrical energy isn't available. Further, gaseous energy is cheap and easy to store, can easily absorb supply and demand imbalances over hours and seasons, and can be both created through

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[48] APPEA Bright-r Website
https://bright-r.com.au/
[49] What is the Energy Density of a Lithium-Ion Battery?, Flux Power 2020
https://www.fluxpower.com/blog/what-is-the-energy-density-of-a-lithium-ion-battery
[50] What is "linepack"
https://www.equitylifting.com/single-post/2017/10/25/linepack-explained

electricity use and create electricity through its use. Even without the ability to be created through electricity use, the availability of a natural gas energy pathway in Victorian has helped make sure that Victoria's more costly electricity system didn't have to grow to several times its current size to absorb the hourly and seasonal variations in thermal energy demand.

These innate qualities are internationally recognised. The International Energy Agency has identified that 19% of total global energy will be provided by gaseous energy in their net zero emissions 2050 roadmap, with 13% of total global energy to be provided by renewable gases[10]. Renewable gas uptake isn't a maybe option for the IEA as is the case for the uptake of CCS. In fact, the backup option considered by the IEA for CCS is more renewable gases.

With the commercial development of renewable and decarbonised gases in Victoria, all of the innate qualities of gaseous energy can be made available without the carbon footprint. The energy affordability of a highly usable, transportable and storable energy medium, thanks to the innate versatility, energy density and compressibility of renewable gaseous energy.

Appendix 2: Renewable gas is viable and being developed around the globe

Maximum technology readiness level (TRL) renewable gas production technologies are available today[51]. PEM and alkaline electrolysis, biogas, landfill gas and biomethane upgrading technologies are all globally recognised as being at the maximum TRL of TRL9[38,52,53,54]. As seen in the CSIRO Hydrogen RD&D report, there are some next-generation renewable gas technologies, as well as renewable gas supporting technologies, which are still below TRL9. These aside, the key renewable gas production, transport, storage and utilisation technologies are mature.

That is not to say that renewable gas technologies are commercially mature. Just like renewable electricity production technologies such as solar PV in past decades, technology readiness needs to be followed by and uplift in Commercial Readiness Index (CRI)[55]. As seen in renewable electricity, a lack of market forces can result in slower than desired uptake. The targeted support seen for the renewable electricity industry demonstrates that this slow uptake of newly mature technologies through commercialisation is not a reason to abandon these technologies – rather, it is a reason to support these for more rapid uptake[56].

The VGSR Consultation Paper considers two renewable gas pathways – hydrogen and biogas. The following sections will provide additional context for these two pathways. While these two pathways are the most well-developed renewable gas pathways to date, APGA recognises that there are several next generation renewable gases which may play a role in the renewable gas transition in decades to come[57]. In particular, the opportunity for renewable synthetic methane to enter the renewable gas mix could help solve the opposing constraints of hydrogen and biogas simultaneously.

Hydrogen technologies

Hydrogen technologies have been well explored by a range of documents under the National Hydrogen Roadmap. APGA directs the VGSR towards this foundation of knowledge around

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[51] Technology Readiness Levels for Renewable Energy Sectors, ARENA 2014 https://www.arena.gov.au/assets/2014/02/Technology-Readiness-Levels.pdf

[52] The 'European Biomethane Map 2020' shows a 51% increase of biomethane plants in Europe in two years, European Biogas Association 2020 https://www.europeanbiogas.eu/the-european-biomethane-map-2020-shows-a-51-increase-of-biomethane-plants-in-europe-in-two-years/

[53] Landfill Gas, EDL 2021 https://edlenergy.com/what-we-do/landfill-gas/#:~:text=EDL%20owns%20and%20operates%20a%20large%20portfolio%20of,otherwise%20be%20released%20to%20the%20atmosphere%20or%20flared

[54] Basic Information about Landfill Gas, United States Environmental Protection Agency 2021 https://www.epa.gov/lmop/basic-information-about-landfill-gas

[55] Commercial Readiness Index for Renewable Energy Sectors, ARENA 2014 https://arena.gov.au/assets/2014/02/Commercial-Readiness-Index.pdf

[56] Victoria's Renewable Energy Roadmap, Victorian Government Department of Environment, Land, Water and Planning 2015 https://www.energy.vic.gov.au/__data/assets/pdf_file/0026/57914/Victorias-Renewable-Energy-Roadmap.PDF

[57] Renewable Methane Webinar Combined Slide Pack, Southern Green Gas 2020 https://www.southerngreengas.com.au/uploads/1/2/0/7/120747157/southern_green_gas_webinar_11_november_2020.pdf

the technologies progressing through CRI uplift in the hydrogen sector. Further, APGA recommends the VGSR engage with the Future Fuels CRC who have been progressing the leading edge of industry research into how to address remaining technical questions to enhance commercialisation.

The CSIRO estimates technologically mature hydrogen technologies to produce at $6 per kg, or around $42 per GJ[8]. Global projections for hydrogen price reduction display a consistent convergence to $2.5 per kg or $17.60 per GJ by 2030[8]. Time will tell whether such a rapid reduction will eventuate. Positive indications lay in the experience of rapid solar PV cost reduction alongside evidence that electrolyser uptake is occurring at a faster pace than solar PV, with electrolyser uptake currently sitting at around solar PV mid 1990's levels, up from around mid-1980's levels 5 years ago[58,59].

Hydrogen technologies have one key positive and one key constraint. On the positive side, hydrogen technologies are as scalable as renewable electricity. In fact, by producing hydrogen at the renewable electricity source, the cost of managing additional variable renewable electricity in the NEM can be avoided. This can enable the lowest cost renewable electricity to be used for hydrogen production via electrolysis.

The greatest constraint is that hydrogen uptake above 10% blends with methane will require changes to or replacement of appliances and some infrastructure. This does need to be considered relative to the alternatives, including the perceivably higher cost of transitioning to higher cost electric appliances using higher cost net zero electricity, as well as renewable sources of methane which would require zero appliance or infrastructure change.

Biogas, landfill gas, and other biomethane technologies

Despite not experiencing much CRI uplift uptake to date, biogas, landfill gas, and other pathways to biomethane have been technically mature globally for some time. This is perceivably due to needing to compete with lower cost natural gas to date. While there is a National Bioenergy Roadmap imminently due for release, this has led to less concise information about the potential of pathways to biomethane in Australia.

One datapoint commissioned in part by Bioenergy Australia is a Deloitte study published in 2018. This identified that considering Victoria's biogas feedstock availability and high gas consumption, around a quarter of Victorian gas demand could be met with biogas[60]. Table 3.5 of this report shows that the majority of Victorian feedstock resources consist of agricultural crop residue which is currently not included under the Biomethane Emissions Reduction Framework methodology. Gaining access to this feedstock, or additional feedstocks currently not considered, could both reduce biogas uncertainty.

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[58] The History of Solar, US Department of Energy circa 2003
https://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf
Note: Electrolyzer development is currently around mid-1990's level[59]

[59] Capacity of electrolysers for hydrogen production by commissioning year and intended use of hydrogen, 2010-2020, International Energy Agency 2020
https://www.iea.org/data-and-statistics/charts/capacity-of-electrolysers-for-hydrogen-production-by-commissioning-year-and-intended-use-of-hydrogen-2010-2020

[60] Decarbonising Australia's gas distribution networks, Deloitte 2018
https://www2.deloitte.com/au/en/pages/economics/articles/decarbonising-australias-gas-distribution-networks.html

Table 3.5 Estimated biogas potential by biomass stream (PJ), and potential biogas supply as a share of regional gas consumption from the distribution network (%)

State	Urban waste	Agricultural crop residue	Livestock residue	Food processing residue	Total biogas (PJ)	Biogas potential (excluding agricultural crop residues)	Total biogas potential
NSW	3.5	75	8.8	0.6	88	15%	103%
VIC	2.4	38	6.8	0.4	48	5%	27%
QLD	8.6	66	8.8	0.6	84	70%	327%
SA	3.3	40	1.9	0.2	46	17%	142%
WA	1.7	100	1.4	0.4	103	13%	384%
TAS	0.2	0.4	0.4	0.0	1	23%	36%
ACT	0.2	0.0	0.0	0.0	0.3	2%	3%
Total	**19.9**	**319.4**	**29.3**	**2.2**	**371**	**14%**	**102%**

Source: Deloitte analysis based on biomass and waste data from (AREMI, n.d.). Benchmark biogas yields from (Sustainable Energy Authority of Ireland)

Figure 3: Estimated biogas potential by biomass stream[60]

Research from the Future Fuels CRC demonstrates that technologically mature biomethane is already available at lower cost than both hydrogen and predicted net zero NEM electricity prices[61]. Case studies across a range of biogas feedstocks identified several viable cases in the $15 - $18 per GJ price range are possible today. Sensitivity analysis further demonstrates possible price improvements in the -$3 to -$8 per gigajoule range being possible with variations in CAPEX, digestate selling price, biomass transport cost and biomass price, leading to potential biomethane prices in line with Victorian wholesale natural gas prices in FY2020-2021.

Like hydrogen, pathways to biomethane have one key positive and one key constraint. Importantly, once processed into biomethane, sources of biogas and landfill gas supplies will by definition meet the required gas specification for transport, storage and utilisation of gas in Australia under AS4564. This means that the cost and difficulty of either transitioning to hydrogen or electrification of gas demand can be avoided.

It is worth noting that a range of constituent components which can be found in biogas which are not currently considered by gas composition standard AS4564. These components are the focus of a current study underway within the Future Fuels CRC which intends on identifying preliminary upper acceptable limits of these components which are expected to be acceptable for gas infrastructure and appliance consumption[62]. This is anticipated to be an important but minor hurdle for the biogas pathway to overcome in comparison to similar challenges relating to hydrogen uptake.

The key constraint to biogas uptake is that current Victorian biogas feedstocks are insufficient to supply total current Victorian gas demand. This constraint exists due to a number of artificial boundaries being applied to the consideration of biogas uptake in Victoria. Firstly, this assumes that biogas is not imported from other states. Looking to excess biogas production potential in states connected to Victoria by existing gas pipelines,

[61] Australian biogas and biomethane wholesale prices predicted by the Future Fuels CRC in an anticipated report scheduled for release in in Q3 2021
[62] RP3.2-09, Future Fuels CRC https://www.futurefuelscrc.com/project/rp3-2-09-biomethane-impurities/

an additional 42% of Victorian demand could potentially be supplied by interstate biogas production.

Secondly, biogas does not necessarily have to go it alone. It is possible to utilise other renewable gases, including renewable synthetic methane and up to 10% hydrogen, alongside biogas. This is, in essence, at the core of APGA's suggestion for enabling all renewable gases, as a solution which utilises multiple technologies has a better theoretical chance of successfully delivering the best case gaseous energy decarbonisation outcome for Victorian households and businesses. In a similar vein but not as advantageous, it is not absolutely necessary for all gas networks to use the same gas.

Controversially, it is theoretically possible for the production of energy crops to be used to supplement existing biogas feedstocks. The concept of energy cropping is controversial due to the possibility of viable agricultural land being diverted from the food supply chain into the energy supply chain. That said, it is also theoretically possible to regulate such an energy cropping industry such that it neither has access to existing agricultural land, nor grows large enough to impact the incumbent agricultural industry. If rapid uptake of renewable gases is being considered by the Victorian government, a study into the impacts of energy cropping may be worthwhile.

Biogases also represent a possible negative emission renewable gas pathway where scope 1 & 2 emissions are considered[63]. While APGA are only claiming the carbon neutrality of renewable gases, The International Council on Clean Transportation identifies that some biogas feedstocks result in carbon negative biogas. Biogas produced from crop residues, biowaste or livestock manure have been identified as having an emissions intensity of less than zero kgCO2e per GJ.

Feedstock	Carbon intensity (gCO_2e/MJ)	Greenhouse gas savings relative to natural gas (gCO_2e/MJ)	Included in 2018 analysis on renewable methane potential and cost?
Silage maize	54	18	No
Biowaste	-26	98	Yes
Crop residues	-6	78	Yes
Livestock manure	-264	336	Yes
Sewage sludge	19	53	Yes

Figure 4: Carbon intensities of biomethane pathways using common feedstocks[63]

It is noted that some feedstocks identified within the referenced ICCT paper are carbon positive on a Scope 1 & 2 emissions basis. Considering these differences, for the purposes of the VGSR, APGA believe it is reasonable to consider renewable gases from biogenic sources as being carbon neutral from a scope 1 emissions perspective, and recommend necessary further analysis to determine scope 2 carbon intensity for each biogenic feedstock through a relevant Guarantee of Origin scheme or similar[64].

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[63] Biomethane potential and sustainability in Europe, 2030 and 2050, The International Council on Clean Transportation 2021 https://theicct.org/publications/biomethane-potential-europe-FS-jun2021

[64] Hydrogen Guarantee of Origin scheme: discussion paper, Australian Government Department of Industry, Science, Energy and Resources 2021 https://consult.industry.gov.au/climate-change/hydrogen-guarantee-of-origin-scheme-discussion/

Appendix 3: Gas infrastructure provides reliable, cost-effective energy delivery, representing a huge opportunity for Victoria

Victorian gas infrastructure currently delivers more energy to Victorians at lower emission intensity and lower cost than the Victorian electricity system. Leveraging this system to deliver renewable gas represents a greater opportunity than existing electricity infrastructure to deliver renewable energy to Victorian households and businesses. This system can deliver renewable energy at a lower delivered cost to consumers thanks to the lower cost of new and existing gas infrastructure, and the resultant low cost of gaseous energy transport, distribution and storage.

Existing Asset Base

A key factor in the lower cost of gaseous energy is the deliverability of gas. Put simply, gas is easier to transport and store than electricity. This translates to lower-cost infrastructure delivering more energy to consumers. This is evidenced by the data published in the AER's 2019 operational reports for electricity and gas and AEMO's demand reports.

Table 2: Costs and deliveries of Victoria's energy infrastructure (2019)[11 - 17]

Transmission and Distribution Infrastructure	Regulated Asset Base ($m)	Actual Annual Revenues ($m)	Actual Energy Delivered (GWh)	Max Demand Capacity (MW)
Electricity	17,329	2,825	41,480	8,684
Gas	5,631	774	64,722	23,250

It costs six times more to deliver each MWh using electricity infrastructure than it does to deliver the same amount of energy via gas infrastructure. It costs 10 times more to meet each MW of maximum demand using the electricity network as it does to meet each MW of maximum gas network demand. These figures are despite gas infrastructure being more capable than electricity infrastructure, delivering 56% more energy than electricity infrastructure does annually and supplying peak demand 268% that supplied by electricity infrastructure.

Based on existing asset costs, the average energy efficiency of electric appliances over gas appliances would need to reach over 820% (or COP of 8.2) before the cost of electricity infrastructure upgrades would be lost costly than additional gas infrastructure. This fact should be considered when determining whether gas connections should be maintained in new suburban developments.

Cost to supply peak demand is important as all energy systems must be sized for peak demand regardless of how often this occurs. Peak demand places the system under its greatest strain, putting it most at risk of failing at the most critical time. The costs associated with sizing and system security increase as peak demand increases, but do not increase at the same rate for gas and electricity infrastructure.

Gas infrastructure capital costs scale in line with the diameter of the pipeline. If you double the diameter of the pipeline, the cost of the pipeline will double. However, doubling the diameter of the pipeline quadruples the volume, and therefore the capacity, of the pipeline.

Electricity infrastructure capital costs and capacity both scale in line with the amount of power lines installed. If you double the power lines, you double the cost and double the capacity. Electricity infrastructure also requires more redundancy than gas infrastructure as explored in the upcoming section on reliability, leading to a steeper cost incline.

New Asset Cost

This difference in infrastructure cost is not surprising once the cost of individual aspects of gas infrastructure are understood. From a new build perspective, gas infrastructure is known to be more affordable than electricity infrastructure. While this is generally accepted on a natural gas basis, the European Hydrogen Backbone has confirmed this on a hydrogen basis as well as seen in Figure 5 below. APGA has commissioned research to confirm the cost effectiveness of energy transport by pipeline in comparison to powerlines in modern Australian circumstances, with a report due for release in Q3 2021.

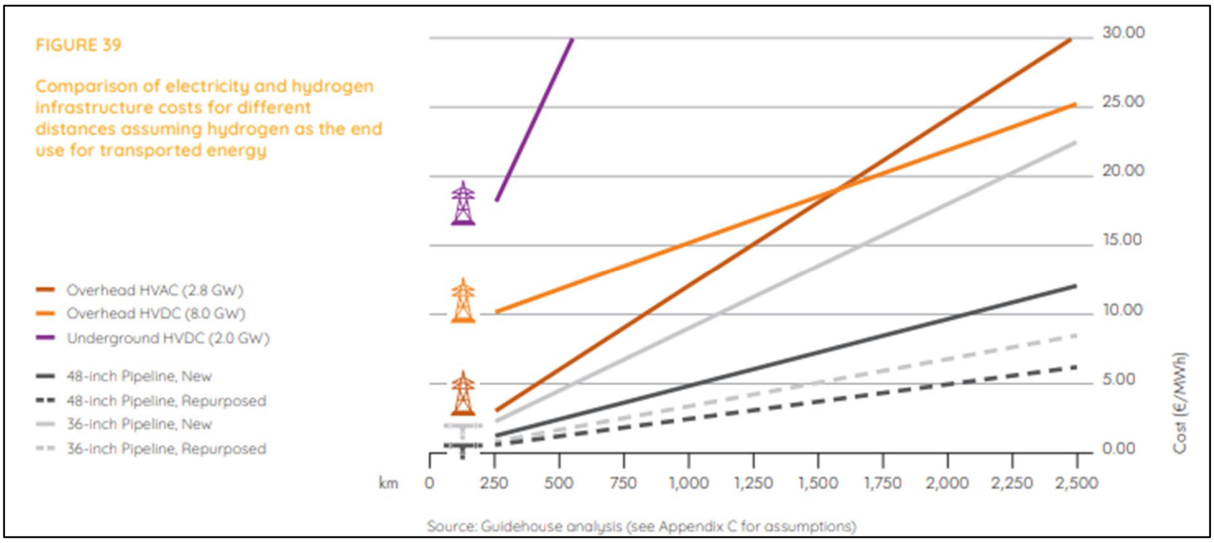

Figure 5: Figure 39 from the European Hydrogen Backbone[18]

Additionally, the cost of gas storage is substantially lower than the cost of electricity storage. Gas storage is so much cheaper than electricity storage that transmission pipeline operators don't charge extra for hour to hour gas storage, with the difference between ,maximum daily quantity and maximum hourly quantity limits in gas transportation agreements generally account for several hours' worth of storage at zero additional charge. Beyond hour to hour storage, pipeline linepack storage can cost as high as $2.88/MWh per day, and 6-month inter-seasonal underground storage reaching as high as $18 per MWh at Iona gas storage facility[65].

[65] Gas Inquiry 2017 – 2025 Interim Report January 2021, Australian Competition & Consumer Commission 2021
https://www.accc.gov.au/system/files/Gas%20Inquiry%20-%20January%202021%20interim%20report_3.pdf

Reliability

The cost effectiveness of gas infrastructure is also a factor of the superior reliability of gas infrastructure. It can be clearly observed that where electricity transmission infrastructure requires multiple parallel transmission pathways, often in a ring main configuration, gas transmission infrastructure is sufficiently reliable to only require a single path for a desired capacity. While some pipelines are looped, this is almost exclusively to increase throughput or storage capacity, rather than to provide a 100% redundant pathway.

Reliability can be a difficult metric to measure in dissimilar energy systems. Anecdotally, fewer people complain about gas outages as do about electricity outages. A Google search for “electricity outage Australia” returns around 2.4 times as many search results across FY2020-21 as “gas outage Australia”.

Aside from anecdotal evidence, one way to measure relative reliability is by observing the frequency at which energy markets react to short supply. Across FY2020-21, the Victorian NEM experienced 15 times more frequent price spikes above three times the average market price when compared to the DWGM. With each price spike representing an imbalance between supply and demand, this is one way in which the Victorian gas system can be seen to be more reliable than the Victorian NEM.

APGA recognises the need for an effective measure of reliability across both electricity and gas infrastructure which can be used to determine the relative reliability of each system. Once this has been achieved, it is anticipated that gas infrastructure will demonstrate higher reliability than electricity infrastructure in Victoria.

Victorian NEM Ability to Absorb Gas Demand

The above electricity and gas infrastructure facts sit alongside the assertion that there is room within the Victorian NEM to absorb the electrification of gaseous energy demand. This assertion is generally predicated on the Victorian NEM experiencing peak demand during the summer, leaving additional headroom to absorb electrification of peak winter gas demand. Figure 6 and Figure 7 go some way to dispelling this myth, noting the above analysis identifying that winter gas demand reaches 268% of electricity system demand.

On a daily demand basis, demand spikes occur during both the winter and the summer within the Victorian NEM. Looking back on FY2020-21 in Figure 6, the capacity difference between the highest winter electricity demand spike appears to be around 8GWh or an average of 333MW across the day. This equates to 8% of a 1-in-2 year demand day for the Victorian Declared Transmission System (DTS).

This analysis would be more accurately undertaken on an hourly or instantaneous basis. APGA expects that should the VGSR undertake analysis of hourly Victorian NEM data alongside maximum hourly DTS data, the results will uncover a similarly small margin for electrification of gaseous energy demand within the Victorian NEM.

Looking broader afield however, while daily (and presumably hourly) electricity demand is at its highest in summer, Figure 7 demonstrates that sustained weekly energy demand is at its highest in winter. This means that the demand for dispatchable electricity reserves in the event of a renewable electricity drought will be greatest in winter.

Adding demand during the period when sustained electricity demand is at its highest would only increase reliance on dispatchable electricity generation which is generally carbon intensive in the period approaching 2030. Looking towards a net zero Victorian NEM post 2030, large quantities of seasonal renewable electricity storage would be required to address existing winter electricity demand, let alone increased winter electricity demand accounting for the electrification of gas demand.

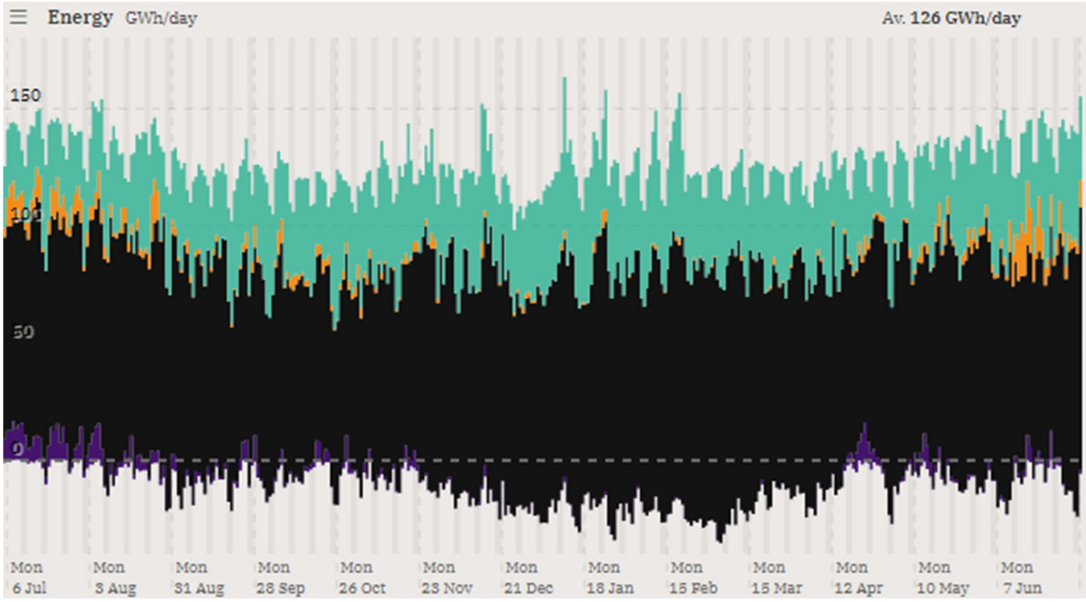

Figure 6: Daily Victorian NEM Demand FY2020-21[66]

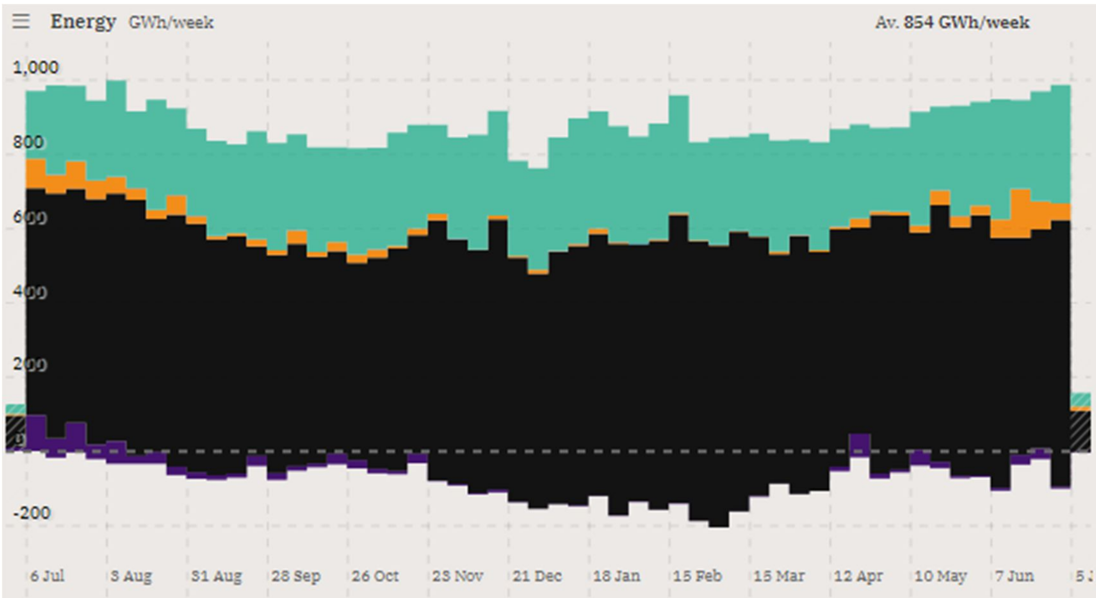

Figure 7: Weekly Victorian NEM Demand FY2020-21[66]

[66] OpenNEM, Melbourne Energy Transition Hub 2021
https://opennem.org.au/
Note: Colours reflect **Imports** **Coal** **Gas** and **Renewable** generation

Decarbonised Energy Projections to 2050

Through a desire to understand the cost effectiveness of different gas use decarbonisation options in a net zero 2050 scenario, contributors to Gas Vision 2050 commissioned Frontier Economics to analyse projections of three decarbonisation scenarios – 100% electrification, 100% green hydrogen, and 100% blue hydrogen. As can be seen in Figure 8, even taking the most-costly renewable gas approach by decarbonising gas demand through 100% green hydrogen results in a lower annual cost in 2050 than the electrification scenario.

Having seen the low cost of renewable gas in comparison to renewable electricity, and the low cost of gas infrastructure in comparison to electricity infrastructure, these results should be unsurprising. APGA acknowledges that this report was prepared for the Australian gas industry and welcomes detailed examination of its findings, which are consistent with both the views expressed in the National Hydrogen Strategy and by the International Energy Agency on the advantages of renewable gas.

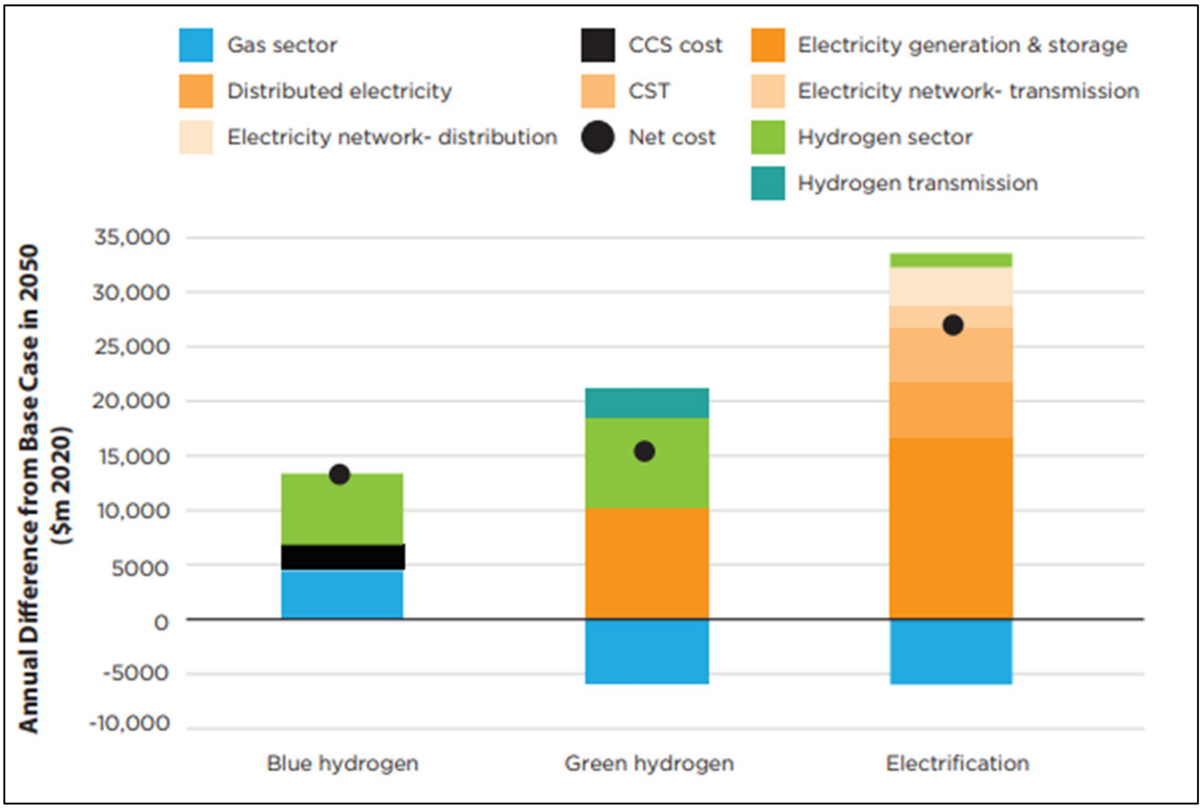

Figure 8: Cost Benefit Analysis Summary by Components ($2020)[19]

Appendix 4: The gas system offers superior emission outcomes in the short-term

As of today, the Victorian gas system delivers energy at a substantially lower emissions intensity and lower price than the Victorian electricity system. Despite this, the idea that electrification of gaseous energy demand results in lower emissions and cost reduction has taken. This idea is predicated on a number of false dichotomies, including:

- Natural gas is carbon intensive, while renewable electricity is not
- Natural gas prices have gone up while renewable electricity boasts the cheapest energy production costs
- Renewable gases are more expensive than natural gas while renewable electricity has the cheapest energy production costs
- Heat pump efficiencies are greater than 100% while gas appliance efficiencies are less than 100%

While each individual fact above is true, APGA identify these as false dichotomies on the basis of the following six facts:

- The Victorian NEM is more carbon intensive than natural gas today, and is forecast to be past 2030
- Rooftop solar is not necessarily carbon neutral due to the on-selling of Small Generation Certificates
- Renewable gases are carbon neutral, just the same as renewable electricity
- Victorian NEM electricity prices are higher than natural gas on both a wholesale and retail basis, and are forecast to be past 2050
- Renewable gases will continue to be cheaper than Victorian NEM electricity on a delivered basis unless impeded by regulation
- Heat pump transient efficiencies can result in heat pump being more carbon intensive and costly to the customer than gas appliances.

This section will seek to dispel the above false dichotomies through the exploration of the above six facts.

The Victorian NEM is more carbon intensive than natural gas today, and is forecast to be past 2030

APGA is not suggesting that burning natural gas is the solution to Victoria reaching net zero by 2050. Rather, an understanding of current electricity and gas emissions intensity is key foundation knowledge upon which an emissions reduction plan can be derived. This information is key in understanding the points which follow.

It is not a given that every electric appliance will be supplied by renewable electricity. To either contract in renewable electricity, or to install rooftop solar, are both choices which are not a given. These choices often come down to the expense of contracting or installing renewable electricity, as well as the ability to do so in the case of rental properties. In all other cases, electric appliances use Victorian NEM electricity.

Future Fuel CRC research has demonstrated that switching natural gas demand to electricity in 2021 will increase Victoria's emissions, and indicates that appliance switching from gas to electricity will not deliver emissions reduction in Victoria before 2035 through forecasts emission intensity of Victoria's electricity supply. Gaseous energy is not only the lowest cost pathway to net zero emissions in 2050, it is the lowest emission pathway to 2030 too (Future Fuels CRC Report attached).

The reality that the Victorian NEM is more carbon intensive than natural gas is an incontestable fact. The Victorian NEM 2020 national greenhouse accounts emissions factor is 0.98 tCO2e per MWh[2]. The emissions factor for the combustion of natural gas is 0.186 tCO2e per MWh or 51.53 kgCO2e per GJ[3]. Note that 51.53 kgCO2e per GJ already includes 0.1 kgCO2e per GJ from the emission of methane.

This makes Victorian NEM electricity more than five times more carbon intensive than burning natural gas. Based on 2020 data, for an electric appliance to be less carbon intensive than a natural gas appliance, it would need to be more than five times more energy efficient than the natural gas appliance.

It is possible approximate where Victorian NEM electricity emissions intensity is expected to reach by 2030. Considering the Victorian Government commitment to reach 50% renewable energy by 2030, it is reasonable to expect that Victoria will increase its 27.7% share of renewable electricity generation in 2020 up to 50% in 2030[67,68]. Additionally, the pre 2030 Yallourn closure is expected to remove 22% of Victorian generation supply while reducing emissions by around 30%[45,69].

Assuming that the full 22% of Yallourn generation is able to be replaced by renewable generation, the above data can be used to predict a 30% reduction in current emissions, down from 0.98 tCO2e per MWh to 0.686 tCO2e per MWh – only 3.7 times that of natural gas. At this stage, for an electric appliance to be less carbon intensive than a natural gas appliance, it would need to be 3.7 times more energy efficient than the natural gas appliance.

This concept can be taken one step further, however. Considering the high-resolution NEM data which is made available by AEMO, it is possible to consider not only the emissions intensity of individual days, but individual times of the day. Dispatchable carbon intensive generation is generally utilised to supply peak electricity demand once the sun sets. APGA recommends investigation into time of day emissions intensity in the Victorian NEM when considering the carbon intensity of using electric appliances at specific times of day, especially in considering a transition which will occur across multiple decades.

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[67] Clean Energy Australia Report 2021, Clean Energy Council 2021 https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2021.pdf

[68] Victoria's renewable energy targets, Victoria State Government Department of Environment, Land, Water and Planning 2021 https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-targets

[69] Energy Australia announces the early retirement of Yallourn, Australian Energy Market Operator 2021 https://aemo.com.au/en/newsroom/media-release/energy-australia-announces-the-early-retirement-of-yallourn

Rooftop solar is not necessarily carbon neutral due to the on-selling of Small Generation Certificates

One of the great successes in renewable energy uptake has been the federally administered renewable energy target. This scheme, supported both large and small deployment of renewable electricity through a Large-scale Renewable Energy Target and a Small-scale Renewable Energy Target[70]. Both schemes created renewable energy "certificates", which wholesale purchasers of electricity, mainly electricity retailers, could buy to meet their renewable energy obligations.

Through the Small-scale Renewable Energy Target, households and businesses were able to receive financial incentive for their installation, in the form of either an upfront discount off their system cost, or a quantity of small-scale technology certificates (STCs) which can be created and sold following installation to recoup some of the cost[71]. While extremely successful in incentivising rooftop solar installation, this program creates a potential risk of double counting renewable generation.

For those households and businesses that chose to create and on-sell STCs to recoup the some of the cost of their system have on-sold the right to class the electricity they generate as renewable. By allowing electricity retailers to claim the STCs created by their solar panels, a household or business provides the certificate purchaser the right to claim this renewable energy generation as their own in place of other carbon intensive generation.

This renders the household or businesses generation as carbon intensive. If this is not the case, then double counting of renewable generation will occur. Just how carbon intensive is up for debate, however. Resultant carbon intensity could either be considered as the same intensity as the carbon intensive generation the STCs have been used to offset, or at the intensity of the NEM region they draw electricity from.

APGA advises the VGSR to consider this potential for double counting when making assumptions around rooftop solar generation emissions intensity. While not experts on carbon accounting, it would appear rational to ensure that renewable generation is only considered once, either at generation or certificate claim, and that whichever approach is chosen to be kept consistent across all relative analysis.

Renewable and decarbonised gases are equally as carbon neutral as renewable and decarbonised electricity

Just like renewable electricity, it is generally considered that s cope 1 emissions from renewable gas combustion are considered zero[64,72]. While this is easy to imagine from a renewable hydrogen perspective, this is also the case for renewable sources of methane due. For biogenic sources of methane such as biogas to the concept of the short carbon

[70] About the Renewable Energy Target, Australia Government Clean Energy Regulator 2018 http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target

[71] Financial Incentives, Australia Government Clean Energy Regulator 2017 http://www.cleanenergyregulator.gov.au/RET/How-to-participate-in-the-Renewable-Energy-Target/Financial-incentives

[72] The contribution of the biogas and biomethane industries to medium-term greenhouse gas reduction targets and climate neutrality by 2050, European Biogas Association 2020 https://www.europeanbiogas.eu/wp-content/uploads/2020/04/20200419-Background-paper_final.pdf

cycle[72]. This means that from a scope 1 emissions perspective, using one unit of renewable gas has the same carbon intensity outcome as using one unit of renewable electricity.

This is important when considering historical claims about the need to electrify gas demand. Historically, gaseous energy has by default been considered as carbon intensive. As such, claims such as *[gas use] electrification opportunities reduce emissions*, *[gas use] electrification upgrades will offer increasing emissions reduction*, and *moving from gas to electricity will save consumers money as well as reducing emissions* have all been reasonable where renewable electricity supply is assumed.

These are not reasonable statements when renewable gases are commercially available. When renewable gases are commercially available, a transition to renewable gas use provides *opportunities to reduce emissions*; renewable gases *offer increasing emissions reduction*; and renewable gases *will save consumers money as well as reducing emissions* when compared to the cost of electrification.

Similarly, decarbonised electricity and decarbonised gases have the common feature of having significantly lower, but not zero, emissions intensity. The IEA identify both decarbonised electricity and decarbonised gases through a combination of fossil fuel and CCS processes as being critical to their net zero emissions 2050 roadmap[10]. While these should not be considered as carbon neutral, the Hydrogen Guarantee of Origin Scheme consultation paper proposes that the relative emissions intensity of decarbonised gases be considered[64].

Both renewable gases and renewable electricity have scope 2 emissions profiles. While there is debate around whether scope 1 or scope 1 & 2 emissions should be considered with relation to renewable energy, APGA recommends that consideration for scope 2 emissions should at least be consistent across all renewable energy. This includes consideration of recognised scope 2 emissions for solar PV and wind generation technologies, as well as the potential for negative emissions from some renewable gases.

There are a range of international studies which identify scope 2 emissions for solar PV. A pair of studies from the US National Renewable Energy Laboratory and the journal Nature Energy put solar PV lifecycle emissions somewhere between 12 to 40 kg CO2e per MWh[73,74]. A journal of Cleaner Production article identifies a lifecycle emissions range of 5 to 53 kg CO2e per MWh (discounting one small 0.4kw outlier at 116 kg CO2e per MWh)[75].

Looking to scope 2 emissions for biogas leads to opposite conclusions. The International Council on Clean Transportation has identified that while some biogas feedstocks lead to marginal positive emissions, some lead to marginal or significant negative emissions[63]. Published as scope 1 & 2 emissions, negative emissions are noted as being achievable from

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[73] Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics, National Renewable Energy Laboratory 2013
https://www.nrel.gov/docs/fy13osti/56487.pdf
[74] Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling, Nature Energy 2017
https://www.nature.com/articles/s41560-017-0032-9
[75] Life cycle greenhouse gas emission from wind farms in reference to turbine sizes and capacity factors, Journal of Cleaner Production Volume 277 2020
https://www.sciencedirect.com/science/article/pii/S0959652620334302

feedstocks such as livestock manure (-264 kg CO2e per GJ), biowaste (-26 kg CO2e per GJ) and crop residues (-6 kg CO2e per GJ), while positive emissions are noted from silage maize (54 kg CO2e per GJ) and sewage sludge (19 kg CO2e per GJ).

Each of these are scope 2 emissions calculations are circumstantial. As such, if scope 2 emissions are to be considered, they should be considered in the context of each individual project, or at least in a localised context, and consistently between renewable electricity and renewable gases.

Victorian NEM electricity prices are higher than natural gas on both a wholesale and retail delivered basis, and are forecast to be past 2050

One key reason that gas has been so successful within the Victorian energy system is that is it undeniably cheaper than electricity on a unit by unit basis. Quick analysis of the most recent wholesale and retail energy prices across both electricity and gas shows that electricity costs around three times the price of gas on both a wholesale and retail basis. Based on this data, for an electric appliance to cost less to operate than a natural gas appliance, it would need to be just shy of three times more energy efficient than the natural gas appliance.

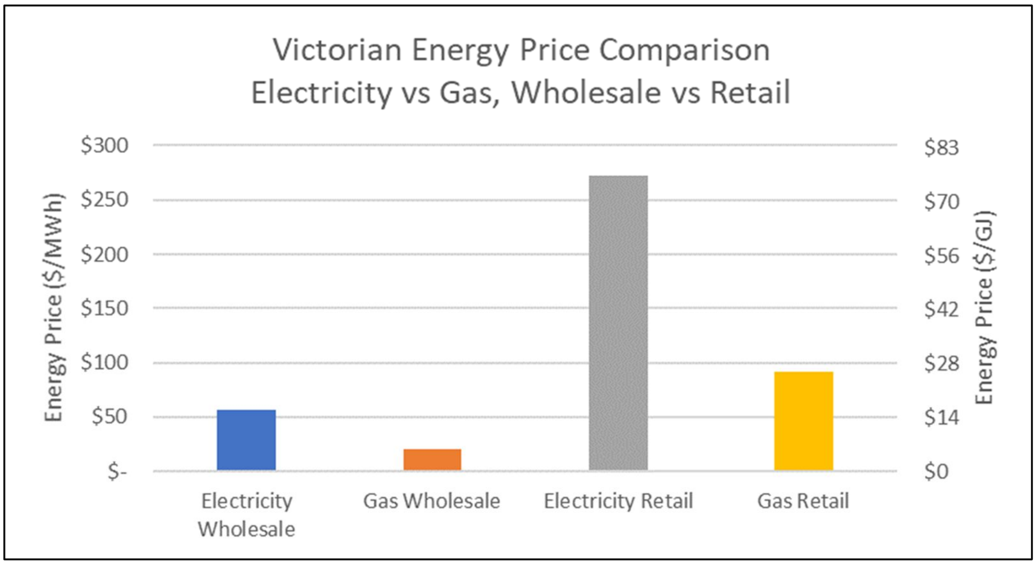

Figure 9: Energy Price Comparison Electricity vs Gas, Wholesale vs Retail[66,76,77]

The low retail cost of gas in Victoria is in no small part due to the relatively large gas demand in Victoria. Due to this high demand, the system costs of operating gas infrastructure are spread between a large number of customers, reducing the individual burden. This is demonstrated by the fact that retail gas in Victoria is the cheapest in the nation. The value of having the cheapest retail gas in Australia should not be lost upon the VGSR, and consideration should be given to the potential of losing this value if gaseous energy demand decreases.

[76] State of the Market 2021 - Retail energy markets, Australian Energy Regulator 2021 https://www.aer.gov.au/system/files/State%20of%20the%20energy%20market%202021%20-%20Chapter%206%20-%20Retail%20energy%20markets.pdf
[77] Declared Wholesale Gas Market Data, Australian Energy Market Operator 2021 https://aemo.com.au/energy-systems/gas/declared-wholesale-gas-market-dwgm/data-dwgm/

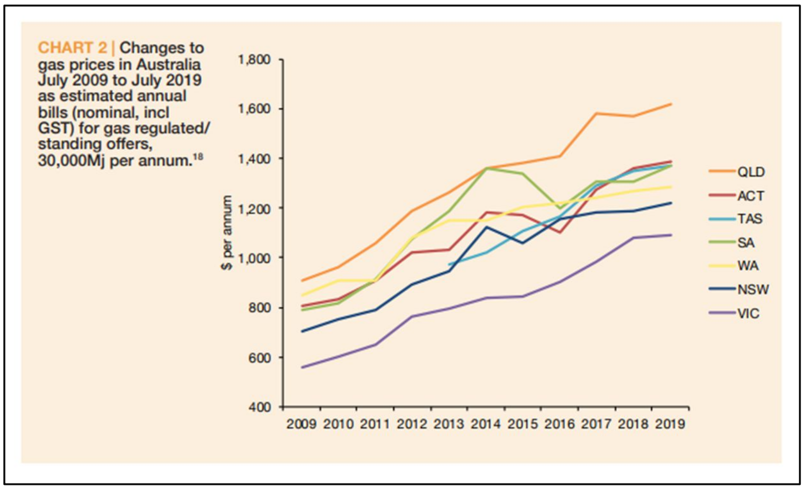

Figure 10: Changes in Gas Price in Australia, St Vincent de Paul Society[78]

Renewable gases will continue to be cheaper than Victorian NEM electricity on a retail delivered basis unless impeded by regulation

The Gratton Institute predicts a best-case net zero NEM wholesale electricity price to be around the $100/MWh mark. This is with the support of gas power generation, without which Gratton suggests this price would be higher. On a purely wholesale cost basis, this leaves room for wholesale gas to reach $28/GJ before costing more per unit energy than wholesale electricity.

Biomethane prices already modelled to be $15 to $18 per GJ today, while hydrogen prices predicted to be around the $2.5 per kg or $17.60 per GJ mark by 2030[8,61]. Hydrogen prices do have a long way to come however, currently siting around the $42/GJ mark, however there is significant national and international collaboration towards reaching the H2 Under $2/kg goal[79,80]. Without demand destruction, it is reasonable to predict that wholesale renewable gas prices will remain below that of a least cost net zero Victorian NEM[81].

All energy system costs being equal, the affordability of retail renewable gases appears even more advantageous than retail net zero electricity in Victoria. Wholesale energy costs account for an average of 37% of retail electricity costs, and 43% of retail gas costs[76]. Retail electricity prices increase by 21% adding the predicted $100/MWh 2050 NEM cost. This leaves headroom for renewable gases to cost seven times the current wholesale price before retail renewable gases are as expensive as net zero electricity from the NEM.

That said, energy system costs are not anticipated to be equal. As explored further in Appendix 3, APGA anticipates that the energy system cost for electrification of gas use will

78 The NEM – The Umpire Strikes Back, St Vincent de Paul Society 2019 https://www.vinnies.org.au/icms_docs/313286_National_Energy_Market_-_The_umpire_strikes_back.pdf
79 The Future of Hydrogen, International Energy Agency 2019 https://www.iea.org/reports/the-future-of-hydrogen
80 Growing Australia's hydrogen industry, Australian Government Department of Industry, Science, Energy and Resources 2021 https://www.industry.gov.au/policies-and-initiatives/growing-australias-hydrogen-industry
81 Australian biogas and biomethane wholesale prices predicted by the Future Fuels CRC in an anticipated report scheduled for release in in Q3 2021

be greater than that of gas system modification for hydrogen uptake. Both are anticipated to be much greater than the virtually nil gas system modification costs for renewable methane uptake.

This last point may be more important than initially realised. There will be a cost point at which renewable synthetic methane, despite being more expensive than renewable hydrogen, becomes more cost effective on a whole of energy system basis than both renewable hydrogen and net zero electricity. This prospect makes investigation into renewable synthetic methane a priority recommendation for the VGSR.

Heat pump transient efficiencies can result in heat pump being more carbon intensive and costly to the customer than gas appliances.

A significant proportion of the value of electrification often based upon the relative energy efficiency of electric heat pumps. Unlike gas appliances however, heat pumps experience transient variations in energy efficiency. While heat pumps are not an area of expertise for APGA, there is sufficient freely available information to raise concerns about the possibility that heat pump efficiencies could be misrepresented within modelling if transient energy efficiencies are not taken into account, especially in the Victorian context.

Alongside the following analysis, APGA refers to the GAMAA submission to the VGSR Consultation Paper as addressing concerns around heat pumps and heat pump efficiencies in greater detail.

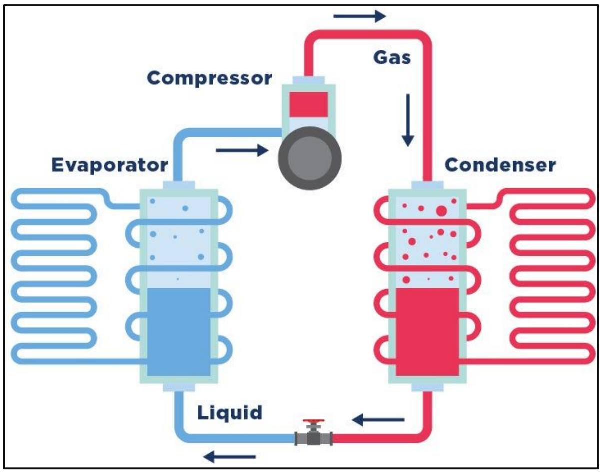

Figure 11: Basic working principle of a heat pump[82]

APGA notes two primary sources of transient heat pump efficiency – ambient (evaporator) side temperature, and hot (condenser) side temperature. Commonwealth data on heat pump hot water systems relative to ambient temperature test conditions can be seen in Figure 13. This figure shows the results of a 2012 study demonstrating the potential variation of 13 heat pump hot water heater efficiencies across a range of Ambient temperatures, resulting in energy efficiency differences of near 2 COP.

[82] Heat pumps - What they are and why you need one, Bord Gáis Energy 2021 https://www.bordgaisenergy.ie/home/heat-pump-guide?utm_source=facebook&utm_medium=social&utm_campaign=sustainability_article_4&utm_term=heat_pumps&utm_content=link_post

While overall efficiencies in heat pump have improved since 2012, this variation due to temperature is still displayed in modern heat pump systems such as the Mitsubishi Electric PLA-M71EA-A[83]. This high efficiency heat pump model experiences efficiency losses of between 60 – 125% between 15° – 20° and -5° – 5° wet bulb conditions which are typical for Victorian winters.

this means that if heat pumps are rated at the Melbourne Design Dry Bulb Temperature for the coldest month (~16°[84]), the actual efficiency of heat pumps could experience COP reductions of 0.6 to 1.25 when operating in mean to low temperature conditions in Melbourne (mean min 6.0°, decile 1 min 2.1°[85]) or rural Victorian cities like Ballarat (mean min 3.2°, decile 1 min -0.7°[85]). APGA note that it is unclear what conditions are used to rate heat pump efficiencies.

PLA-M71EA-A:SUZ-M71VAD-A
CAPACITY: 8.0KW - RATED OUTPUT

	OUTDOOR WB (°C)															
INDOOR	-15		-10		-5		0		5		10		15		20	
DB(°C)	Q	INPUT	Q	INPUT	Q	INPUT	Q	INPUT	Q	INPUT	Q	INPUT	Q	INPUT	Q	INPUT
15	**4.00**	1128	**5.04**	1411	**6.08**	1693	**7.12**	1910	**8.16**	2062	**9.20**	2192	**10.16**	2257	**11.20**	2300
21	**3.76**	1202	**4.80**	1519	**5.76**	1801	**6.80**	1996	**7.76**	2148	**8.80**	2257	**9.76**	2322	**10.76**	2409
26	**3.28**	1302	**4.32**	1628	**5.36**	1910	**6.32**	2105	**7.36**	2257	**8.40**	2365	**9.36**	2430	**10.40**	2496

Note: Q : Capacity (kW) INPUT : Total power input (W)
This diagrams show the case where the operation frequency of a compressor is fixed.

Figure 12: Heating capacity data for Mitsubishi Electric PLA-M71EA-A (COP = Input /Q) [83]

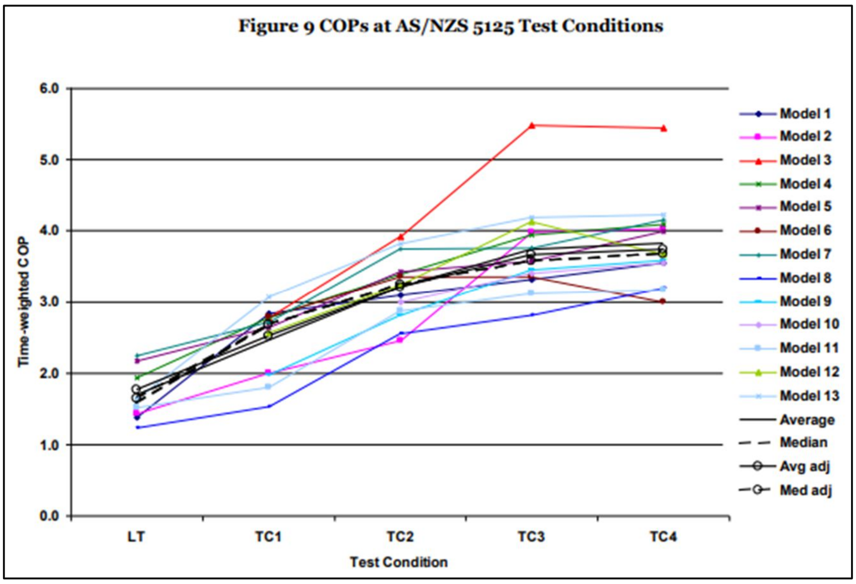

Figure 13: Heat Pump Hot Water System COP at AS/NZS 5125 Test Conditions[86]

[83] Heating Capacity Chart – Ceiling Cassette, Mitsubishi Electric 2021
https://www.mitsubishi-electric.co.nz/materials/Aircon/Performance_Charts/@PLA-M,%20PKA-M,%20PA-M,%20PEAD-M,%20PEA-M_2021-JUNE.pdf
[84] Design conditions for MELBOURNE, Australia, ASHRAE 2005
http://cms.ashrae.biz/weatherdata/STATIONS/948680_s.pdf
[85] Monthly climate statistics, BOM 2021
http://www.bom.gov.au/climate/averages/tables/cw_086071_All.shtml
[86] Product Profile: Heat Pump Water Heaters, Commonwealth of Australia 2012
https://www.energyrating.gov.au/sites/default/files/documents/Heat-Pump-Water-Heater-Product-Profile-June-2012-1_0.pdf
Note: Test Condition Definitions: LT 0° – 2°, TC1 <10°, TC2 18° – 20°, TC3 20° – 35°, TC4 20° – 35° (Higher Humidity)

Further to the variations in heat pump energy efficiency caused by ambient side temperatures is the variations in heat pump energy efficiency caused by hot side temperatures. Commonwealth data on heat pump hot water systems relative to ambient temperature test conditions can be seen in Figure 14. While not as important for space heating where hot side temperatures are in the order of 18° – 24°, hot side temperature impacts are critical in considering the energy efficiency of heat pump hot water systems.

The Victorian Building Authority identify that hot water systems need to remain at or above 60° in order to avoid bacteria growth, and that plumbing laws require a maximum outlet temperature of 50°[87]. These figures are important when noting that Figure 14 demonstrates a 0.5 - 1.5COP drop in energy efficiency when comparing heat pump hot water systems heating from a hot side temperature of cold to 45° versus 45° to max.

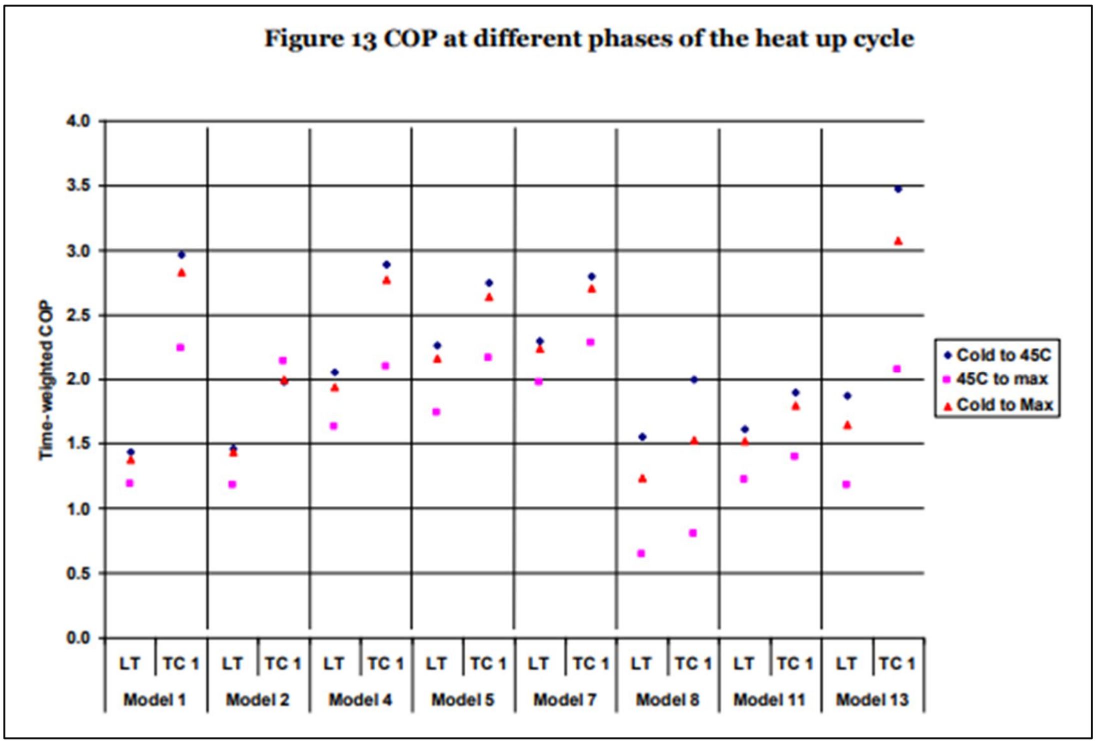

Figure 14: Heat Pump Hot Water System COP at different phases of the heat up cycle[86]

This means that every heat pump hot water system that is not used to the point of a user noticing a drop in hot water temperature is operating their heat pump hot water system with a significant reduction in energy efficiency. It is anticipated that very few Australians would consider it acceptable to notice a dip in hot water temperature before finishing a shower, meaning that operation in this lower energy efficiency state is highly anticipated.

Consider now that both of these circumstances could occur simultaneously. Heat pump hot water systems which are not set up to take advantage of daytime solar will likely be operating on off-peak electricity in the cold of a winters night, leading to cold side efficiency losses. Simultaneously, Victorians will be unlikely to accept a hot water system that leaves them cold after a winter shower, so it is likely that these heat pump hot water systems are

[87] Hot Water Safety, Victorian Building Authority 2021 https://www.vba.vic.gov.au/consumers/guides/hot-water-safety

experiencing hot side efficiency reductions too. Combined, these could equal a 1.1 to 2.75 COP reduction in energy efficiency.

A variation in energy efficiency of 1.1 to 2.75 COP could have significant impacts to energy system modelling. If energy system modelling takes into account a Heat Pump COP of 3 or 4 as identified by heat pump advocates, these could actually have as low as 1.25 to 2.9 COP[88,89]. While the impact is not quite as extreme for space heating, the cold side efficiency losses are still important, especially when temperatures are below 5° – when space heating is needed the most.

APGA do not know how the VGSR modelling is considering heat pump efficiencies, nor is it in a position to recommend specifically how heat pump efficiencies be modelled. That said, it is expected that the above observations should be enough to ensure that modelling of transient heat pump efficiencies are being considered in line with the ultimate goal of delivering the best-case decarbonisation outcome for Victorian households and businesses.

Energy Efficiency does not necessarily equal lower emissions or lower energy cost

Energy efficiency does not determine the carbon intensity or energy of an appliance alone. Rather, energy efficiency is applied to the carbon intensity or cost of the energy source supplying the appliance. When considering two appliances supplied by the same energy source, energy efficiency will correlate with carbon intensity and energy cost. However, when considering two appliances supplied by different energy sources, such as electricity and gas, then these correlations do not necessarily hold.

While important in a net zero future too, this understanding is critical when considering a transition to a net zero future. In a net zero future where renewable electricity and renewable gases are available, the use of either in any appliance will result in a zero emissions outcome. This will make energy efficiency important only in energy cost comparisons and the general ideal of minimising energy use.

Prior to this net zero future, the pathway of reaching net zero will include different appliances with different efficiencies utilising energy from sources of different emission intensities and with different energy costs.

As a starting point, it is possible to have an appliance with a higher energy efficiency supplied with a higher cost and higher emissions intensity energy result in a higher cost and higher emissions outcome than an appliance with a lower energy efficiency supplied with a lower cost and lower emissions intensity energy. In light of the observations detailed in previously in Appendix 4, APGA stress the importance of looking beyond energy efficiency to actual energy cost and emissions outcomes as part of the VGSR analysis.

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[88] The Complete Guide To Choosing Your Perfect Hot Water Heat Pump, Australian Energy Foundation 2020
https://www.aef.com.au/wp-content/uploads/2020/07/Hot-Water-Heat-Pump-Guide.pdf

[89] Explainer: Why hot-water heat pumps are great for homes with or without solar PV, Renew Economy 2021
https://reneweconomy.com.au/explainer-why-hot-water-heat-pumps-are-great-for-homes-with-or-without-solar-pv/

To investigate this concept, APGA has compared the emissions intensity of heat pump and gas appliances across a range of efficiencies as seen in Figure 15. Gas appliances which do not materially vary in efficiency due to temperature have been considered at the regulated space heating and hot water minimum efficiencies of 70% and 75% respectively, as well as a conservative high efficiency of 90%[90,91]. Heat Pump efficiencies have been considered across their reasonably variable range of efficiencies for ambient temperatures below 10° as seen previously in Appendix 4.

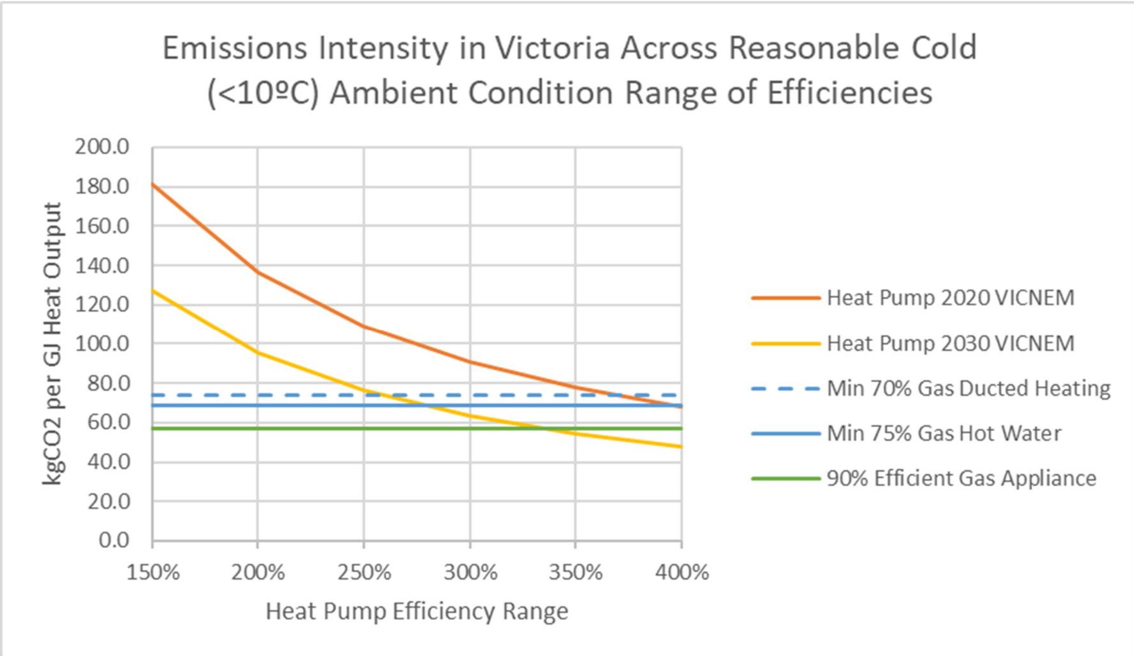

Figure 15: APGA analysis of emissions intensity relative to energy efficiency

As of today, electric appliances not directly supplied by or contracted to use renewable electricity are using Victorian NEM electricity, while gas appliances are currently using natural gas. As suggested by heat pump advocates, heat pumps can have up to 300% to 400% efficiency[88,89]. But as observed previously in Appendix 4, evidence suggests that these appliances can potentially experience transient efficiency drops down to between 125% and 290% in cold conditions when heating load is the highest.

As can be seen through Figure 15, even if these transient efficiency drops don't occur, heat pump hot water with COP below 4 are more carbon intensive when using NEM electricity today, as are heat pump space heaters with COP below around 3.6. If these transient efficiencies are in fact experienced, the emissions intensity of heat pumps rise, so much so that even the planned lower emissions 2030 Victorian NEM will deliver more emissions intensive heating and hot water for appliances experiencing COP drops below 2.5 – 2.75.

This same relationship impacts energy cost. Figure 16 shows the cost per gigajoule of heat output for a range of heat pump efficiencies considering the range of retail electricity and gas prices available in Victoria. As before, Gas appliances which do not materially vary in

[90] Advice on minimum allowable efficiency standards for gas space heaters and hot water systems provided by GAMAA
[91] Gas Heater Efficiency Comparison, Elgas 2021 https://www.elgas.com.au/blog/449-star-ratings-for-gas-heaters-gas-wall-furnaces-a-gas-fireplaces/

efficiency due to temperature have been considered at the regulated space heating and hot water minimum efficiencies of 70% and 75% respectively, as well as a conservative high efficiency of 90%.

This figure demonstrates the importance of retail energy pricing. When considering the opportunity for a user to simultaneously access the cheapest off-peak electricity and the cheapest gas supply, an average COP above 4 is required for the electrification option to be lower cost than the gas use option. Off peak electricity is not available at all times however and accessing the lowest cost normal electricity price would require an average heat pump COP above 6.5. This is all in the context of the transient COP reductions as a result of hot and cold side temperatures. The COP required to compete with gas rise even further in comparison to the 90% efficient gas appliances which are readily available today.

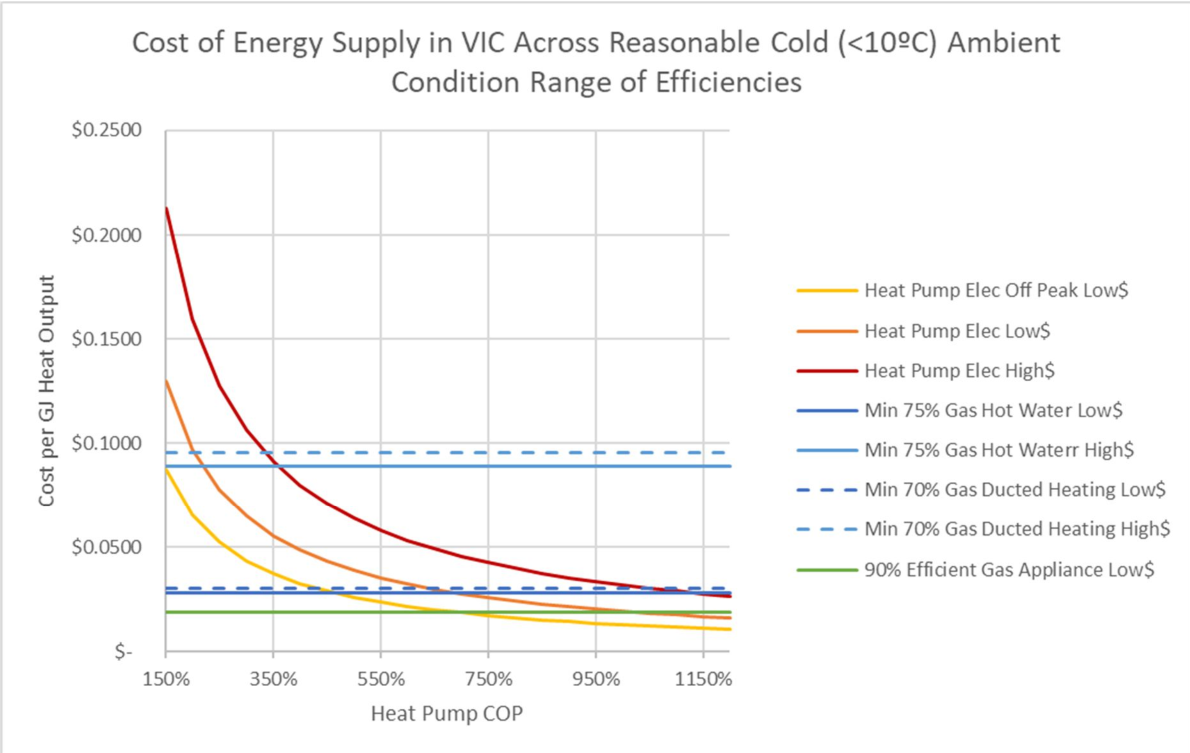

Figure 16: Cost of Energy Supply in VIC Across Reasonable Cold (<10ºC) Ambient Condition Range of Efficiencies

This analysis so far has been a comparison of existing retail gas and electricity, alongside the planned emissions intensity of the 2030 Victorian NEM. This is not the intended end state which APGA envisages, however. APGA envisages a future where both electricity and gas systems decarbonise with the combination of renewable electricity and renewable gases.

As identified previously in Appendix 4, while retail gas prices are expected to rise in this future, retail electricity prices will rise more. This is an important combined understanding which leads to the conclusion that the relative emissions intensity and cost of energy for gas and electric appliances, with energy efficiency considered, will continue to make gaseous energy the lower emissions, lower cost option as this transition continues. That is, of course, unless impeded by discriminatory regulation or initiatives.

It is also worth noting that this is only an observation of energy cost, ignoring the additional cost of replacing gas appliances with electric appliances. The additional cost involved in replacing gas appliances with electric appliances will be explored further in the GAMAA submission to this consultation.

Contracting 100% renewable energy is not unique to renewable electricity

Setting aside the troubling suggestion that people can simply “pay more” to contract renewable electricity in the form of solar panel and battery installation, the notion that renewable electricity is better than renewable gas because 100% renewable electricity can be contracted does not logically hold. renewable gases are just as capable of being contractually accessed as renewable electricity.

To say that VIC NEM emissions intensity can be ignored for a customer contracting renewable electricity is somewhat reasonable. That said, this means that similarly, it must be possible to put a commercial framework in place such that a customer can contract 100% renewable gas, hence making their gaseous energy use as carbon intensive as contracting 100% renewable electricity.

This will require time for the renewable gas market to develop, however this is already being developed for the first time in the Sydney distribution market. Gas infrastructure business Jemena, who own the gas distribution system in NSW, is putting in place a privately facilitated green gas certification program. This is a foundation for enabling customers on their network to purchase green MJ of gas if they choose.

While this privately facilitated approach is a first step, the hope is that governments, either state or federal, put in place gas certification schemes which enable customers to access 100% renewable gas in the exact same way as they are able to access 100% renewable electricity.

Appendix 5: Gas is a key contributor to a net-zero electricity sector

Ensuring that the gaseous energy system is not degraded to a point at which gas power generation can no longer support the least cost Victorian NEM should be front of mind when developing the Victorian Gas Substitution Roadmap to deliver the best possible gaseous energy decarbonisation solution for Victorian households and businesses. As identified within the Infrastructure Victoria Towards 2050: Gas infrastructure in a zero emissions economy – Interim report:

"Gas also plays a critical backstop function in electricity generation as its ability to quickly ramp production up and down can balance variations in supply from other sources. This 'firming', or stabilising, role is likely to become more important as the proportion of electricity supplied from renewable energy sources grows"[25]

The Gratton Institute took this understanding one step further in their 2021 Go for Net Zero report[26]. Through this report, Gratton proposes that Australia target 'net-zero emissions', not 'zero emissions' or '100 per cent renewables', and that Governments should target net-zero emissions for the NEM for the 2040s. Importantly, Gratton's proposed 90% Renewable scenario included a slightly larger role for gas in balancing renewable output, with gas power generation the only non-renewable generation being offset with negative-emissions carbon sinks.

This conclusion is closely aligned with a Frontier Economics report commissioned by APGA to investigate the role of gas power generation in a cost optimised, variable renewable generation maximised NEM[27]. Where Gratton found a 90% renewable generation NEM to be the most cost effective, Frontier Economics found a 93% renewable generation NEM, supported by 7% gas power generation, to result in optimised energy system cost.

Whether 7% or 10%, gas power generation can be seen as a key component to achieving a least cost Victorian NEM. This is in large part due to the low-cost storage and intraday flexibility which is inherent in the nature of gas infrastructure, and which requires dedicated investment to replicate in electricity infrastructure. Further, the above reports only consider the impacts of natural gas, leaving the possibility of an even greater electricity decarbonisation outcome through running gas power generation on renewable gases.

Appendix 6: Robust objective process requires sufficiently large scope

There are a number of items within the consultation paper imply that the discussion around which options are best comes down to simple characteristics such as energy production cost or energy efficiency. Such implications miss the importance of considering the broader context which these characteristics exist within.

Analysis of systems as complex and impactful as the Victorian gaseous energy industry need to consider entire energy value chain, including the coupling of the gas and electricity energy value chains. This includes consideration of energy reliability, security and affordability as impacted by energy system storage and flexibility, across the individual, interconnected and combined energy systems.

Each type of energy is interlinked and interdependent both physically and economically on each other type. Every choice of an energy source is a choice between types of electricity, gaseous, solid or liquid energy supply. As such, all interact with each other. Not considering the entire energy industry could lead to misleading conclusions.

One example of this is the potential impact of the various pathways which the liquid fuel decarbonisation pathway could take. With both BEV and FCEV technologies entering the market, additional demand could arise for both the electricity and hydrogen pathways. There may be additional benefits in reducing the impact of BEV uptake on the electricity system by ensuring there is a vibrant hydrogen industry to supply both current gaseous energy demand and some of the vehicular energy market.

Further, if counting on electrification to decarbonise all liquid energy appears achievable and counting on electrification to decarbonise all gaseous energy demand appears achievable, it needs to also be considered whether decarbonising both liquid energy and gaseous energy through electrification appear achievable simultaneously? It is APGA's expectation that neither of these three options are achievable.

Large questions like this need to be considered on a whole of energy system basis. Additionally, the energy industry does not exist in isolation. The energy industry exists within the global economic and geopolitical system. This means that the impacts of these interdependencies need to be considered on this basis as well.

In the event that supply chains become overburdened, human rights controls around slave labour and other human rights become more difficult to manage. Where rare minerals become valuable, civil or international conflicts have the potential to arise over limited supplies. This raises questions around the need for the Victorian government to consider the potential human rights impacts which may arise as a result of overburdened supply chains.

These are just two examples of the risk involved in making deterministic or restrictive recommendations based upon a study with insufficiently large scope. APGA are confident that the VGSR is conscious of these risks, hence will deliver recommendations which avoid these risks by enabling all possible decarbonisation pathways for gaseous energy demand.

Appendix 7: Robust objective process needs to produce non-discriminatory outputs and initiatives

There is a likely chance that in a scenario analysis considering six parallel pathways, there will be more than one possible solution alongside uncertainty about the role each solution will play. If multiple parallel decarbonisation pathways are identified for Victoria, the resultant recommendations can take lessons from sociology in order to avoid unintended consequences. In particular, principles derived in the field of Diversity and Inclusion can be applied to gain the best possible outcome where multiple potentially viable pathways have been identified.

Developing recommendations on a foundation of equality

In recognising that there are multiple, equally viable options for decarbonisation, recommendations that follow must treat all options equally. This means putting in place recommendations that target emissions reduction, rather than the favouring one ahead of another. By enabling equality across decarbonisation options, the best solution for each gas user can be accessed on the basis of market forces.

Retrospective review of discriminatory legislation

Once it is recognised that there is more than one viable pathway, legislation, regulation and programs already in place need to be reviewed to ensure that these do not discriminate against the equally applicable options.

There is evidence of legislation, regulation and programs mentioned within the consultation paper discriminating against renewable gaseous energy. For example, energy efficiency initiatives which incentivise the replacement of gas appliances with electric appliances, but not more efficient gas appliances, are discriminatory against gaseous energy.

It would be inconsistent for the VGSR process to identify the renewable gas pathways as viable decarbonisation pathways as potentially viable pathways yet continue to discriminate against gaseous energy.

Once discriminatory legislation against a viable pathway has been removed, action should be taken to support the growth in this viable pathway, reversing the negative impacts of prior discrimination. This includes initiatives which focus on such pathways specifically, addressing the fact that they have been inhibited during a period where they could have been progressing and developing as a viable decarbonisation pathway.

Appendix 8: Gas Use Decarbonisation Scenario Analysis

The VGSR has been set the task of developing a roadmap to achieve 45% - 50% state-wide emissions reduction by 2030 and net zero emissions by 2050. APGA's key points from Section 2 can be used to anticipate how each of the six Consultation Paper pathways could impact Victorian citizens and businesses while achieving this emission reduction goal. Similar to how Shell use scenarios to consider how extremes in global societal change will impact energy demand across the decades, APGA has sought to contextualise the key points raised in this submission by undertaking a simple scenario analysis [92,93].

APGA foresee four macro scenarios which the Victorian Government could pursue to decarbonise gas use in Victoria. Each scenario considers relative differences in how electrification and renewable gas pathways could be pursued across the coming decades. Energy efficiency and fugitive emissions reduction apply across each scenario, while emerging technologies are not discussed for simplicity.

Drive Electrification
With Victorian citizens and businesses unwilling to pay a premium to rapidly electrify their gas demand, the Victorian Government chooses to spend state funds on electrifying 45% - 50% of gaseous energy demand by 2030, and 100% of gaseous energy demand by 2050.

Enable Everything
The Victorian Government sets all renewable energy technologies on a level playing field, removing all policies impeding renewable gases, and enabling market forces to drive uptake of either electrification or renewable gases as customers see fit.

Support Renewable Gases
The Victorian Government replicates its support for renewable electricity across past decades through similarly targeted programs in support of renewable gases, incentivising both the production and utilisation of renewable gases over the coming decade, creating a strong foundation upon which the industry can build towards net zero emissions by 2050.

Drive Renewable Gases
With Victorian citizens and businesses unwilling to pay a premium to enable the rapid uplift in renewable gas supply, the Victorian Government chooses to spend state funds on underwriting sufficient renewable gas production to cover 45% - 50% of gaseous energy demand by 2030, and 100% of gaseous energy demand by 2050.

APGA compares these four scenarios side by side across the 2021 – 2030 and 2031 – 2050 horizons, a summary of which can be found on the following page. The scenarios explore how the concepts raised throughout this submission can be expected to influence the

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[92] What Are Shell Scenarios?, Shell International 2021
https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/what-are-scenarios.html
[93] The Energy Transformation Scenarios, Shell International 2021
https://www.shell.com/promos/energy-and-innovation/download-full-report/_jcr_content.stream/1627553067906/fba2959d9759c5ae806a03acfb187f1c33409a91/energy-transformation-scenarios.pdf

Victorian energy industry, households, and businesses in the transition to a net zero economy.

In comparing the scenarios, APGA have considered how each scenario will impact the three energy trilemma pillars of energy emissions, energy affordability and energy reliability, alongside the expected social difficulty of such a change and the expected impact on jobs as a result of the change. A five-point grading system has been used to indicate expected relative impacts for each category, which is then averaged to grade the scenario. While undertaken at a high level here, APGA recommends the VGSR undertake similar analysis in the lead up to determining recommendations.

Table 7: Gas Use Decarbonisation Scenario Analysis Summary

Gas Use Decarbonisation Scenarios across 2021 – 2030 Horizon	
Drive Electrification: 1.6 Gas Emissions: 1 Energy Affordability: 2 Energy Reliability: 2 Social Difficulty: 1 Jobs Impact: 2	**Enable Everything: 3.8** Gas Emissions: 3 Energy Affordability: 4 Energy Reliability: 4 Social Difficulty: 5 Jobs Impact: 3
Support Renewable Gases: 4.0 Gas Emissions: 4 Energy Affordability: 3 Energy Reliability: 5 Social Difficulty: 4 Jobs Impact: 4	**Drive Renewable Gases: 3.4** Gas Emissions: 5 Energy Affordability: 2 Energy Reliability: 3 Social Difficulty: 2 Jobs Impact: 5
Gas Use Decarbonisation Scenarios across 2031 – 2050 Horizon	
Drive Electrification: 1.6 Gas Emissions: 4 Energy Affordability: 1 Energy Reliability: 1 Social Difficulty: 1 Jobs Impact: 1	**Enable Everything: 4.2** Gas Emissions: 5 Energy Affordability: 4 Energy Reliability: 4 Social Difficulty: 4 Jobs Impact: 4
Support Renewable Gases: 4.0 Gas Emissions: 5 Energy Affordability: 3 Energy Reliability: 4 Social Difficulty: 4 Jobs Impact: 4	**Drive Renewable Gases: 3.4** Gas Emissions: 5 Energy Affordability: 2 Energy Reliability: 3 Social Difficulty: 2 Jobs Impact: 5

In review of the summary table, APGA recommends the VGSR consider that while there are numerous ways to achieve net zero emissions, the pathway to achieving this end goal is just as important as the destination. All three renewable gas outcomes secure better energy affordability and reliability while experiencing better social acceptance and jobs implications than the electrification scenario. Importantly, while some support can improve 2030 outcomes, too much can negatively impact other aspects, and simply enabling uptake has a better outcome for the net zero by 2050 goal. This can also be seen in the Scenario Fitness for Purpose Trajectories chart in Figure 17.

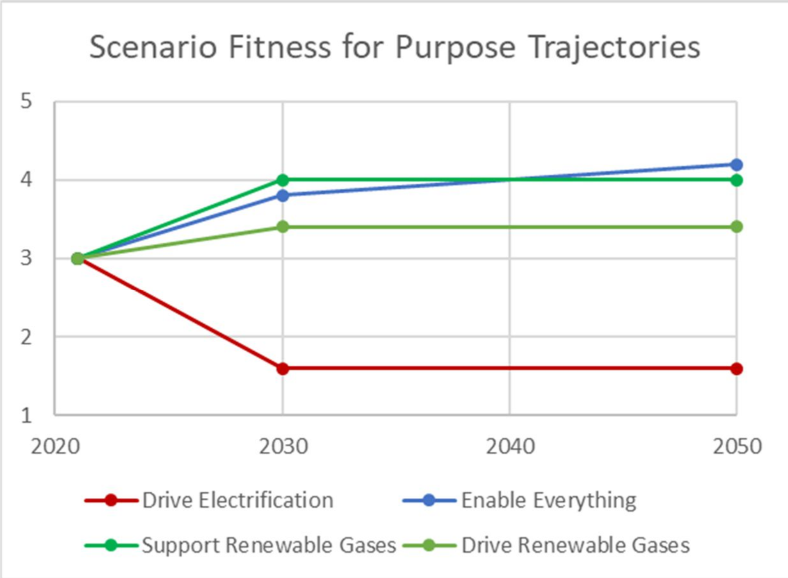

Figure 17: Scenario Fitness for Purpose Trajectories

Drive Electrification

With Victorian citizens and businesses unwilling to pay a premium to rapidly electrify their gas demand, the Victorian Government chooses to spend state funds on electrifying 45% - 50% of gaseous energy demand by 2030, and 100% of gaseous energy demand by 2050.

2021- -2030

Emissions: 1; **Affordability:** 1; **Reliability:** 1; **Social Difficulty:** 1; **Jobs:** 2

In order to drive electrification of gaseous energy demand, the State of Victoria has had to fund both the transition of household appliances and an uplift in electricity infrastructure capability to 50% - 150% of current capacity. While the latter costing around $8.5B to $26B alone, cost of appliance transition is the greatest of any scenario across this horizon. The source of these funds is unknown, either needing to come from other parts of the budget or from other revenue sources, potentially taxes.

Energy affordability is reduced as more variable renewable generation plus electricity storage is required to deliver electricity during peak heating periods and seasons. The mass reduction in gas demand also reduces the dilution of network costs between less customers, increasing gas price. State emissions intensity increases due to Victorian electricity maintaining a high emissions intensity through 2035, unless additional funds are spent on renewable electricity production, exacerbating the cost to the State.

Underestimation of peak energy demand due to heat pump transient efficiencies results in a reduction of energy security and affordability, with an increased likelihood of evening peak load shedding to secure an overloaded Victorian NEM. Gas appliances energy efficiency opportunities are abandoned due to imminent industry collapse, with widespread job losses from gas value chain, gas use and gas appliances industries. Impacted customers and workers rebel against the transition.

2031 – 2050

Emissions: 4; **Affordability:** 1; **Reliability:** 1; **Social Difficulty:** 1; **Jobs:** 1

With the halving of gas demand triggering an ever-increasing price death spiral in gas use, electrification is locked in as the only pathway to 2050 regardless of whether net zero emissions are met. With the gas death spiral triggered, state funding of electrification could be replaced by customer expense, but with an increase in public dissatisfaction, energy poverty, and lower likelihood of achieving net zero by 2050.

The possibility of cascade abandonment of gas use could lead to greater energy security destabilisation than the need to increase electricity infrastructure scale by another 50% - 150% of 2020 scale. Emissions reduction may be made more difficult, with the high electricity prices of the previous decade coupling with the abandonment of gas fired power, leading to longer financial viability of coal fired power. This may even be required to stabilise the Victorian NEM.

With all electrifiable appliances addressed, any renewable hydrogen or methane would need to be generated at the customer, making it the most expensive scenario for the 2050 cost of renewable gases, collapsing industries which cannot electrify or absorb the higher renewable gas cost. Achieving zero fugitive emissions would require restrictive regulation to stop gas companies transporting gaseous energy within Victorian borders. Similar regulation would be required to force rural Victorians to stop using LPG, leading to either significantly higher decarbonisation expense or energy poverty for rural Victorians.

Enable Everything

The Victorian Government sets all renewable energy technologies on a level playing field, removing all policies impeding renewable gases, and enabling market forces to drive uptake of either electrification or renewable gases as customers see fit.

2021- -2030

Emissions: 3; **Affordability:** 4; **Reliability:** 4; **Social Difficulty:** 5; **Jobs:** 3

Spending 2022 addressing regulation, policy and initiatives which restrict renewable gas uptake, the Victorian Government opens all decarbonisation options to all Victorian households and businesses. This opens the way for the first contracts to start forming between renewable gas developers, retailers, and gas users. The industry is seeded through those who want to a sell green product, and those who see the change to renewable gas costing less than electrification.

Gas appliance energy efficiency is now considered a viable emissions reduction option, leading to around 5% to 10% reduction in gas use across the decade through natural appliance turnover. A growing hydrogen market targets both vehicles and gas use, improving commercial viability and providing access to bottled hydrogen for regional customers wishing to switch from LPG. Hydrogen is capped at 10% of reticulated gas, enabling biogas to grow alongside, reaching a combined 5% - 15% market share by 2030. With total emissions down by 9.5 – 23.5%, the transition may lead to Victoria falling slightly short of the 45% - 50% emission reduction target.

Through this period, energy affordability for those who don't choose to purchase renewable gases stays flat, while energy reliability and security get a boost from new supply sources. With no one being forced out of a job or into making constrained choices, social difficulty primarily comes from in the form of criticism of an appearance of doing too little. Social licence around fugitive emissions can start a move of offsetting these emissions with carbon offsets, potentially purchased from negative emission biogas production which is also contributing to a modest increase in rural jobs.

2031 – 2050

Emissions: 5; **Affordability:** 4; **Reliability:** 4; **Social Difficulty:** 4; **Jobs:** 4

With the renewable gas industry established as a viable, accessible pathways to gas use decarbonisation, uptake moves into the early majority phase in the 2030's. The pressure of social expectations and customer choice drive households and businesses to make emissions reduction choices, the easiest choice being to pay slightly more for renewable gas rather than undergo the expense of electrification only to pay more for their energy afterwards.

Unable to hide behind the illusion of carbon neutrality like electricity, gas supply will need to prove carbon neutrality. This will lead to gas retailers needing to prove their net zero credentials to customers, ultimately leading to net zero retail gas. This may lead to some additional hardship to vulnerable customers and marginal businesses, but less than the hardship of the Drive Electrification scenario. Gas appliance efficiencies are expected to exceed 90% for all by 2050.

Choices around which renewable gases will reach 100% utilisation in which infrastructure regions start to be made to ensure sufficient supply for growing demand. The track record of gas infrastructure development leads to energy reliability being maintained. Electricity system reliability is maintained as well with limited natural gas supply enabling a net zero NEM through gas power generation, with these and fugitive emissions offset by more negative emission biogas production.

Support Renewable Gases

The Victorian Government replicates its support for renewable electricity across past decades through similarly targeted programs in support of renewable gases, incentivising both the production and utilisation of renewable gases over the coming decade, creating a strong foundation upon which the industry can build towards net zero emissions by 2050.

2021- -2030

Emissions: 4; **Affordability:** 3; **Reliability:** 5; **Social Difficulty:** 4; **Jobs:** 4

Alongside opening all decarbonisation options to all Victorian households and businesses as in the Enable Everything scenario, the Victorian Government look to what has worked in the past. Reviewing programs used to drive the uptake of renewable electricity, Victoria now replicating these to incentivise the uptake of renewable gas. By either directing state funds into the development of the industry or requiring gas retailer supply portfolios to include a certain percentage of renewable gas supply, the scheme may result in equal or better energy affordability than the Enable Everything scenario while possibly targeting a 2030 level of uptake conducive to ensuring net zero by 2050.

Targeting renewable gas uptake in line with ensuring net zero gaseous energy by 2050 results in a 2030 target of around 10% to 20%. Funding high efficiency gas appliances for rental properties and businesses ensures all have access to low cost renewable energy through the most efficient appliances. With energy efficiency improvements promoting a 15% reduction in gas demand, these initiatives combine to reduce overall gas emissions by 28% to 36%.

This reduction is sufficient to reduce total Victorian emissions by 45% to 50% by 2030 without necessarily reducing gas emissions by 45% to 50% as other higher intensity, cheaper to abate emissions are reduced first. Energy affordability is improved over the Enable Everything scenario, while increased gas supply leads to improved energy reliability and increased job numbers. Taking visible action while not forcing Victorian households and businesses to make costly electrification choices leads to overall lower social difficulty despite some climate denial opposition.

2031 – 2050

Emissions: 5; **Affordability:** 3; **Reliability:** 4; **Social Difficulty:** 4; **Jobs:** 4

This scenario leaves Victoria even better placed to achieve net zero emission gaseous energy by 2030, with uptake being well into the early majority phase by 2030. As renewable electricity has entered the 2020's following the federal Renewable Energy Target scheme, renewable gases enter the 2030's on a strong growth trajectory. While tough choices still need to be made around which regions ultimately expand to 100% renewable gas through which specific gases, the demand is well on its way to driving the infrastructure investment required to enable supply.

The financial support of the 2020's could be followed by additional financial support through this period, in particular to enable the full uptake of highly efficient appliances, or to support regions which choose to undertake the transition to hydrogen appliances. Transitioning a network to 100% hydrogen will be less costly than electrifying, but more costly than a transition to renewable methane, making this cost to customers ideal for government intervention.

Ultimately, by starting from an even stronger foundation, this scenario achieves the same net zero result as the Enable Everything scenario with greater certainty, at the cost of some cost to the Victorian Government and/or its citizens and businesses over the preceding years.

Drive Renewable Gases

With Victorian citizens and businesses unwilling to pay a premium to enable the rapid uplift in renewable gas supply, the Victorian Government chooses to spend state funds on underwriting sufficient renewable gas production to cover 45% - 50% of gaseous energy demand by 2030, and 100% of gaseous energy demand by 2050.

2021- -2030

Emissions: 5; **Affordability:** 2; **Reliability:** 3; **Social Difficulty:** 2; **Jobs:** 5

In order to drive sufficient renewable gas uptake to achieve 45% - 50% uptake by 2030, the State of Victoria has had to fund an unsustainable uplift in renewable gas production. With insufficient time to target the transition of 45% to 50% of Victorian gas customers to 100% hydrogen prior to 2030, the only practically achievable approach would be to fund the development of all of Victoria's biogas resources so that they may be online in 2030, while targeting isolatable rural townships for hydrogen deployment. Such an uplift would not only be exceptionally costly (although not as costly as the electrification pathway), it would also create an unsustainable uplift in biogas production which would fall in the years following 2030 to be backfilled with natural gas.

To achieve such an uplift, all funds would have to be state based, resulting in artificially high energy affordability coupled with aggressive state revenue raising activities to support the uplift. There would be room for efficiency improvements to reduce demand, but with the level of funds required to drive production uplift, it would be unlikely that sufficient funds would remain to support appliance transitioning.

While forcing such a transition would result in extensive job creation, the rapid transition would likely risk some reliability through not learning operational lessons with new gases in early stages of production uplift. Rapid transition would likely result in significant social difficulties, from a rapid pace of appliance transition, challenges around dictating certain regions receive certain gases, and the impacts of revenue raising activities required to fund the rapid transition.

2031 – 2050

Emissions: 5; **Affordability:** 2; **Reliability:** 3; **Social Difficulty:** 2; **Jobs:** 5

Unless corrected for by the introduction of energy cropping, the overproduction of biogas in the leadup to 2030 leads to a drop in production in the early 2030's, resulting in a resurgence of natural gas uptake or a collapse of the gas market if natural gas growth has been regulated against. If natural gas is allowed to cover the drop in supply, the following two decades are dedicated to replicating the gaseous energy value chain with 100% hydrogen technologies.

Once again, the larger uplift will require state funds to drive, resulting in two more decades of revenue raising activities to fund the artificial market growth and transition away from biogas supply. Areas close to existing biogas production will likely need to be maintained as biogas supplied networks, meaning that the majority of hydrogen uplift will need to come from within Melbourne – a more expensive proposition than transitioning rural townships.

Where other renewable gas pathways could be directed by market choices when deciding which areas transitioned to which gas, a more central planning approach has been applied in this scenario. While achieving net zero by any means necessary results in many jobs, it was forced through in a similar way as the electrification pathway, increasing social difficulty of the scenario.

Appendix 9: Bibliography

1. Australian Energy Update 2020, Australian Government Department of Industry, Science, Energy and Resources 2020 https://www.energy.gov.au/publications/australian-energy-update-2020
2. National Greenhouse Accounts Factors, Australian Government Department of Industry, Science, Energy and Resources 2020 https://www.industry.gov.au/sites/default/files/2020-10/national-greenhouse-accounts-factors-2020.pdf
3. National Greenhouse and Energy Reporting (Measurement) Determination 2008, Australian Government 2008 https://www.legislation.gov.au/Details/F2020C00600
4. Australian Energy Market Operator Website 2021 https://aemo.com.au
5. State of the energy market 2021 – Retail Energy Markets, Australian Energy Regulator 2021 https://www.aer.gov.au/system/files/State%20of%20the%20energy%20market%202021%20-%20Chapter%206%20-%20Retail%20energy%20markets.pdf
7. The Energy Trilemma – What matters the most to consumers?, CSIRO 2019 https://www.csiro.au/-/media/EF/Files/Energise-insights/Insight-40-Energy-Trilemma.pdf
8. National Hydrogen Roadmap, CSIRO 2018 https://www.csiro.au/-/media/Do-Business/Files/Futures/18-00314_EN_NationalHydrogenRoadmap_WEB_180823.pdf
9. Australian biogas and biomethane wholesale prices predicted by the Future Fuels CRC in an anticipated report scheduled for release in in Q3 2021
10. Net Zero by 2050 A Roadmap for the Global Energy Sector, IEA 2021 https://iea.blob.core.windows.net/assets/20959e2e-7ab8-4f2a-b1c6-4e63387f03a1/NetZeroby2050ARoadmapfortheGlobalEnergySector_CORR.pdf
11. Electricity DNSP - Operational performance data - 2006-2019, The Australian Energy Regulator 2020 https://www.aer.gov.au/system/files/Electricity%20DNSP%20-%20Operational%20performance%20data%20-%202006-2019.xlsm
12. Victorian Gas Planning Report Update, AEMO 2020 https://aemo.com.au/-/media/files/gas/national_planning_and_forecasting/vgpr/2020/2020-vgpr-update.pdf?la=en
13. AER Annual Reporting – APA GasNet Australia (Operations) Pty Ltd, Australian Energy Regulator 2021 https://www.aer.gov.au/system/files/VTS%20%28APA%20GasNet%29%202020%20-%20Annual%20-%20RIN%20Response%20-%20Consolidated%20-%2030%20April%202021%20-%20PUBLIC%20%2312%2C211%2C975.xlsx
14. APA Victorian Transmission System pipeline information - RIN responses, Australian Energy Regulator 2021 https://www.aer.gov.au/networks-pipelines/performance-reporting/apa-victorian-transmission-system-pipeline-information-rin-responses
15. Multinet Gas pipeline information - RIN responses, Australian Energy Regulator 2021 https://www.aer.gov.au/networks-pipelines/performance-reporting/multinet-gas-pipeline-information-rin-responses
16. AusNet Services Gas pipeline information - RIN responses, Australian Energy Regulator 2021 https://www.aer.gov.au/networks-pipelines/performance-reporting/ausnet-services-gas-pipeline-information-rin-responses
17. Australian Gas Networks (Victoria/Albury) Gas pipeline information - RIN responses, Australian Energy Regulator 2021 https://www.aer.gov.au/networks-pipelines/performance-reporting/australian-gas-networks-victoria-albury-gas-pipeline-information-rin-responses
18. Analysing future demand, supply, and transport of hydrogen, European Hydrogen Backbone 2021 https://gasforclimate2050.eu/?smd_process_download=1&download_id=718

19. The Benefit of Gas Infrastructure to Decarbonise Australia, Frontier Economics 2020 https://www.apga.org.au/sites/default/files/uploaded-content/field_f_content_file/frontier-2020-decarbonise-australia.pdf
20. Black System South Australia 28 September 2016, Australian Energy Market Operator 2017 https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf
22. Energy Security Board Website, Australian Energy Market Commission 2021 https://esb-post2025-market-design.aemc.gov.au/
23. Integrated Electricity and Gas System Studies: Electrification of Heating, Future Fuels CRC https://www.futurefuelscrc.com/project/regional-case-studies-on-gas-and-electricity-system-integration-rp1-1-02/
24. Methane Guiding Principles Website, Methane Guiding Principles 2021 https://methaneguidingprinciples.org/
25. Towards 2050: Gas infrastructure in a zero emissions economy – Interim report, Infrastructure Victoria 2021 https://www.infrastructurevictoria.com.au/wp-content/uploads/2021/07/Gas-Infrastructure-Advice-Interim-Report-FINAL-4.pdf
26. Go for Net Zero, Gratton Institute 2021 https://grattan.edu.au/wp-content/uploads/2021/04/Go-for-net-zero-Grattan-Report.pdf
27. Potential for Gas-Powered Generation to support renewables, Frontier Economics 2021 https://www.apga.org.au/sites/default/files/uploaded-content/field_f_content_file/210219_potential_for_gpg_to_support_renewables_-_final_report.pdf
28. Energy Australia gives green light to Australia's first net zero emissions, hydrogen/gas power plant, Energy Australia 2021 https://www.energyaustralia.com.au/about-us/media/news/energyaustralia-gives-green-light-australias-first-net-zero-emissions
29. SWER Workshop - Appendix C, Victorian Department of Environment, Land Water and Planning 2010 https://www.energy.vic.gov.au/safety-and-emergencies/powerline-bushfire-safety-program/Reports-and-regulations/swer-workshop-appendix-c
30. SWER still going strong, Energy Source & Distribution 2014 https://esdnews.com.au/swer-still-going-strong/
31. GEA Response to the Regulation Impact Statement 'Residential Tenancies Regulation 2020', Gas Energy Australia 2019 https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/1516/1060/1053/Rental_housing_regulations_-_Gas_Energy_Australia.PDF
32. Future Fuels CRC Website, Future Fuels CRC 2021 https://www.futurefuelscrc.com
34. National Gas Decarbonisation Plan: Decarbonising Australia's Gas Pipelines and Networks by DNV-GL is due for release in Q3 2021.
37. Energy Pipelines CRC Website, Energy Pipelines CRC 2021 https://www.epcrc.com.au
38. Hydrogen Research, Development and Demonstration Priorities and opportunities for Australia, CSIRO 2019 https://www.csiro.au/~/media/Showcases/Hydrogen/HydrogenRDDFullReportWEB191129.pdf
42. Loss factors and regional boundaries, AEMO 2021 https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/market-operations/loss-factors-and-regional-boundaries
43. Australia's scope 1 emissions by ANZSIC subdivision for NGER reporters, Clean Energy Regulator 2017 http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/a-closer-look-at-emissions-and-energy-data/australia%E2%80%99s-scope-1-emissions-by-industry-for-nger-reporters
44. Global environmental impacts of the hydrogen economy, Derwent et al 2006 http://agage.mit.edu/publications/global-environmental-impacts-hydrogen-economy

45. Global Warming Potentials, Clean Energy Regulator 2021
http://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme/global-warming-potentials
46. Electricity sector emissions and generation data 2019-20, Australian Government Clean Energy Regulator 2021
http://www.cleanenergyregulator.gov.au/NGER/National greenhouse and energy reporting data/electricity-sector-emissions-and-generation-data/electricity-sector-emissions-and-generation-data-2019-20
47. Hydrogen Insights - A perspective on hydrogen investment, market development and cost competitiveness, Hydrogen Council 2021
https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021-Report.pdf
48. CSIRO ARC Training Centre for the Global Hydrogen Economy, CSIRO 2020
https://research.csiro.au/hyresource/arc-training-centre-for-the-global-hydrogen-economy/
49. APPEA Bright-r Website
https://bright-r.com.au/
50. What is the Energy Density of a Lithium-Ion Battery?, Flux Power 2020
https://www.fluxpower.com/blog/what-is-the-energy-density-of-a-lithium-ion-battery
51. What is "linepack"
https://www.equitylifting.com/single-post/2017/10/25/linepack-explained
52. Technology Readiness Levels for Renewable Energy Sectors, ARENA 2014
https://www.arena.gov.au/assets/2014/02/Technology-Readiness-Levels.pdf
53. The 'European Biomethane Map 2020' shows a 51% increase of biomethane plants in Europe in two years, European Biogas Association 2020
https://www.europeanbiogas.eu/the-european-biomethane-map-2020-shows-a-51-increase-of-biomethane-plants-in-europe-in-two-years/
54. Landfill Gas, EDL 2021
https://edlenergy.com/what-we-do/landfill-gas/#:~:text=EDL%20owns%20and%20operates%20a%20large%20portfolio%20of,otherwise%20be%20released%20to%20the%20atmosphere%20or%20flared
55. Basic Information about Landfill Gas, United States Environmental Protection Agency 2021
https://www.epa.gov/lmop/basic-information-about-landfill-gas
56. Commercial Readiness Index for Renewable Energy Sectors, ARENA 2014
https://arena.gov.au/assets/2014/02/Commercial-Readiness-Index.pdf
57. Victoria's Renewable Energy Roadmap, Victorian Government Department of Environment, Land, Water and Planning 2015
https://www.energy.vic.gov.au/__data/assets/pdf_file/0026/57914/Victorias-Renewable-Energy-Roadmap.PDF
58. Renewable Methane Webinar Combined Slide Pack, Southern Green Gas 2020
https://www.southerngreengas.com.au/uploads/1/2/0/7/120747157/southern_green_gas_webinar_11_november_2020.pdf
59. The History of Solar, US Department of Energy circa 2003
https://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf
60. Capacity of electrolysers for hydrogen production by commissioning year and intended use of hydrogen, 2010-2020, International Energy Agency 2020
https://www.iea.org/data-and-statistics/charts/capacity-of-electrolysers-for-hydrogen-production-by-commissioning-year-and-intended-use-of-hydrogen-2010-2020
61. Decarbonising Australia's gas distribution networks, Deloitte 2018
https://www2.deloitte.com/au/en/pages/economics/articles/decarbonising-australias-gas-distribution-networks.html
63. RP3.2-09, Future Fuels CRC
https://www.futurefuelscrc.com/project/rp3-2-09-biomethane-impurities/
64. Biomethane potential and sustainability in Europe, 2030 and 2050, The International Council on Clean Transportation 2021
https://theicct.org/publications/biomethane-potential-europe-FS-jun2021
65. Hydrogen Guarantee of Origin scheme: discussion paper, Australian Government Department of Industry, Science, Energy and Resources 2021
https://consult.industry.gov.au/climate-change/hydrogen-guarantee-of-origin-scheme-discussion/
66. Gas Inquiry 2017 – 2025 Interim Report January 2021, Australian Competition & Consumer Commission 2021

https://www.accc.gov.au/system/files/Gas%20Inquiry%20-%20January%202021%20interim%20report_3.pdf
67. OpenNEM, Melbourne Energy Transition Hub 2021
https://opennem.org.au/
68. Clean Energy Australia Report 2021, Clean Energy Council 2021
https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2021.pdf
69. Victoria's renewable energy targets, Victoria State Government Department of Environment, Land, Water and Planning 2021
https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-targets
70. Energy Australia announces the early retirement of Yallourn, Australian Energy Market Operator 2021
https://aemo.com.au/en/newsroom/media-release/energy-australia-announces-the-early-retirement-of-yallourn
71. About the Renewable Energy Target, Australia Government Clean Energy Regulator 2018
http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target
72. Financial Incentives, Australia Government Clean Energy Regulator 2017
http://www.cleanenergyregulator.gov.au/RET/How-to-participate-in-the-Renewable-Energy-Target/Financial-incentives
73. The contribution of the biogas and biomethane industries to medium-term greenhouse gas reduction targets and climate neutrality by 2050, European Biogas Association 2020
https://www.europeanbiogas.eu/wp-content/uploads/2020/04/20200419-Background-paper_final.pdf
74. Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics, National Renewable Energy Laboratory 2013
https://www.nrel.gov/docs/fy13osti/56487.pdf
75. Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling, Nature Energy 2017
https://www.nature.com/articles/s41560-017-0032-9
76. Life cycle greenhouse gas emission from wind farms in reference to turbine sizes and capacity factors, Journal of Cleaner Production Volume 277 2020
https://www.sciencedirect.com/science/article/pii/S0959652620334302
77. State of the Market 2021 - Retail energy markets, Australian Energy Regulator 2021
https://www.aer.gov.au/system/files/State%20of%20the%20energy%20market%202021%20-%20Chapter%206%20-%20Retail%20energy%20markets.pdf
78. Declared Wholesale Gas Market Data, Australian Energy Market Operator 2021
https://aemo.com.au/energy-systems/gas/declared-wholesale-gas-market-dwgm/data-dwgm/
79. The NEM – The Umpire Strikes Back, St Vincent de Paul Society 2019
https://www.vinnies.org.au/icms_docs/313286_National_Energy_Market_-_The_umpire_strikes_back.pdf
80. The Future of Hydrogen, International Energy Agency 2019
https://www.iea.org/reports/the-future-of-hydrogen
81. Growing Australia's hydrogen industry, Australian Government Department of Industry, Science, Energy and Resources 2021
https://www.industry.gov.au/policies-and-initiatives/growing-australias-hydrogen-industry
83. Heat pumps - What they are and why you need one, Bord Gáis Energy 2021
https://www.bordgaisenergy.ie/home/heat-pump-guide?utm_source=facebook&utm_medium=social&utm_campaign=sustainability_article_4&utm_term=heat_pumps&utm_content=link_post
84. Heating Capacity Chart – Ceiling Cassette, Mitsubishi Electric 2021
https://www.mitsubishi-electric.co.nz/materials/Aircon/Performance_Charts/@PLA-M,%20PKA-M,%20PA-M,%20PEAD-M,%20PEA-M_2021-JUNE.pdf
85. Design conditions for MELBOURNE, Australia, ASHRAE 2005
http://cms.ashrae.biz/weatherdata/STATIONS/948680_s.pdf
86. Monthly climate statistics – Melbourne, BOM 2021
http://www.bom.gov.au/climate/averages/tables/cw_086071_All.shtml
87. Product Profile: Heat Pump Water Heaters, Commonwealth of Australia 2012
https://www.energyrating.gov.au/sites/default/files/documents/Heat-Pump-Water-Heater-Product-Profile-June-2012-1_0.pdf

88. Hot Water Safety, Victorian Building Authority 2021
https://www.vba.vic.gov.au/consumers/guides/hot-water-safety
89. The Complete Guide To Choosing Your Perfect Hot Water Heat Pump, Australian Energy Foundation 2020
https://www.aef.com.au/wp-content/uploads/2020/07/Hot-Water-Heat-Pump-Guide.pdf
90. Explainer: Why hot-water heat pumps are great for homes with or without solar PV, Renew Economy 2021
https://reneweconomy.com.au/explainer-why-hot-water-heat-pumps-are-great-for-homes-with-or-without-solar-pv/
91. Advice on minimum allowable efficiency standards for gas space heaters and hot water systems provided by GAMAA
92. Gas Heater Efficiency Comparison, Elgas 2021
https://www.elgas.com.au/blog/449-star-ratings-for-gas-heaters-gas-wall-furnaces-a-gas-fireplaces/
93. What Are Shell Scenarios?, Shell International 2021
https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/what-are-scenarios.html
94. The Energy Transformation Scenarios, Shell International 2021
https://www.shell.com/promos/energy-and-innovation/download-full-report/_jcr_content.stream/1627553067906/fba2959d9759c5ae806a03acfb187f1c33409a91/energy-transformation-scenarios.pdf

Attachments

Attachment 1: Gas Vision 2050

Gas Vision 2050

Delivering a Clean Energy Future

September 2020

Australian Gas Industry Trust
APGA
appea
the voice of australia's oil and gas industry
Energy Networks Australia
GAMAA
Gas Energy Australia

Gas is essential for Australia

Gas provides around 21 per cent of Australia's end-use energy consumption

almost 1/4

5.2 million connections to gas networks – growing at 100,000 per year

Gaseous fuels are essential to provide high temperature heat and feedstock to manufacturing

79%

of Victorian homes kept warm during winter with gas

2020

First green hydrogen to residential customers

Flexibility of gas enables **higher levels of renewable** electricity

2 million

Australian households use LPG indoors which is supplied through virtual pipelines

$5.8 billion

paid in taxes and royalties in 2017-18 to support essential infrastructure and services such as hospitals, schools and roads

$180 million

invested to future fuels research and projects

$47 billion

of export trade resulting in cleaner air in our region

Over 18.1 million gas and LPG appliances.

Gas infrastructure delivers more energy than the electricity infrastructure

Australia is on a pathway to decarbonise the gas sector to help meet our nation's emission reduction commitments under the Paris Agreement on climate change.

Today, residential and commercial customers use gas for cooking, space heating and hot water, and in industrial processes gas is used to provide heat and is a major feedstock to produce common goods such as plastics and fertilisers. Gas also plays a significant role in the reliability and stability of our power system by providing peak generation to back up renewable electricity. Gas is one of Australia's most important exports, contributing $47 billion to our economy in 2019-20.

The value of the infrastructure that delivers this energy should not be overlooked. Continuing to use gas infrastructure can reduce emissions at half the cost to customers than electrifying the services provided by gas. This is because electrification will impose massive system-wide costs for grid reinforcements on customer bills.

In the three years since the launch of Gas Vision 2050, the need to reduce emissions has continued to gain community support and many energy supply businesses are offering carbon-neutral products in response to this demand. There is a growing domestic and international interest to decarbonise gas. Industry has responded by leading the development of research, pilot and commercial scale projects to demonstrate this.

Gas Vision 2050

In the next few years, natural gas, LPG and LNG will be supplemented by other gaseous fuels such as hydrogen, biomethane and renewable gas, creating exciting new opportunities. Indeed, in 2020, the first Australian homes will receive a blend of green hydrogen in their gas. The work we are doing aims to minimise impacts to customers while creating additional options to reduce emissions. Initially this will involve blending at low concentrations, followed by scaling up as we learn by doing.

We are on this pathway, but more work needs to be done. In this document we describe the strong progress that has been made in advancing the transformational technologies outlined in Gas Vision 2050 and outline key steps for the next decade to decarbonise Australia's gas sector.

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Chief Executive, Australian Petroleum Production & Exploration Association

Steve Davies
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Ross Jamieson
President, Gas Appliance Manufacturers Association of Australia

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Australian Gas Industry Trust · APGA · appea the voice of australia's oil and gas industry · Energy Networks Australia · GAMAA · Gas Energy Australia

Contents

Executive Summary

Individuals, councils, governments and businesses have proactively implemented net-zero emission targets. While most of the focus has been to reduce emissions from electricity use, attention is also turning to what leadership in reducing emissions from gas use looks like.

Strong support has emerged from residential and commercial customers for cleaner gas options. In turn, energy businesses are offering low emissions energy solutions and demonstrating new zero-emissions technologies.

Published in March 2017, Gas Vision 2050 set its sights on what gas use in our homes, cities, industrial centres and power generators would need to look like in the year 2050.

This is a need, not a want. In line with the 2015 Paris Agreement on climate change, gas must decarbonise and adapt. We have now embarked on this journey and it's creating significant new opportunities in the energy sector.

The Vision

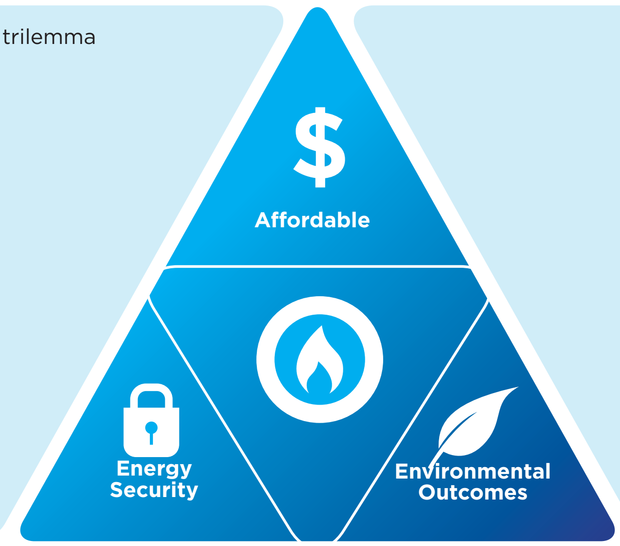
The Vision is for Australia to continue to turn its gas resources into products and services that will enhance national prosperity while achieving carbon neutrality. It identifies how gas and gas infrastructure can be used to solve the energy trilemma by balancing energy affordability, energy security and environmental outcomes. A strategic approach to reducing emissions can utilise developing technologies to also deliver jobs, growth and export benefits for Australia.

Customers are seeking a clean energy future and are engaged in achieving emissions reduction from gas use. This is to be achieved through the widespread deployment of transformational technologies, including biogas, hydrogen and carbon capture and storage. These innovative technologies, alongside renewable electricity, energy efficiency and others, will be used across the economy to decarbonise gas.

A recent joint letter by the Australian Hydrogen council and Bioenergy Australia calling for supportive policy settings for hydrogen and biogas was supported by many businesses and associations across the energy supply chain including customers, technology providers, and energy companies.

Significant progress has been made to achieve the Vision.

Figure ES-1: The energy trilemma



This report provides an update on the progress of this journey made since the launch of Gas Vision 2050 and identifies key priority areas.

Table ES-1: The Vision articulated how technologies would be adopted in different sectors of the economy.

Gas in a 2050 home is one where distributed energy resources and sustainable gas work in harmony. During the day, households generate much of their own electricity through solar PV. Hydrogen fuel-cell or battery electric vehicles are the main mode of family transportation. Zero-emission hydrogen – via the distribution network from the local hydrogen production facility – provides the home with fuel flexibility and powers the family's hydrogen vehicles.

Alternatively, zero-emission methane, produced from biogas and hydrogen, could meet home energy requirement with appliances similar to what we have today.

Gas in cities in 2050 envisions city blocks as an integrated energy system where excess electricity generated from solar PV on buildings can be exported to charge utility-scale batteries or be converted to hydrogen and zero-emissions methane, which can also be produced from biogas. These gases can then be used to power transport around the city or be converted back to electricity. Hydrogen and/or zero-emissions methane production facilities can be located on the edge of cities allowing gas to be injected back into the distribution network for cooking or heating to restaurants, businesses and entertainment venues.

Gas for industrial uses in 2050 will see carbon capture and storage used to ensure that the CO_2 from industry and gas production is not emitted into the atmosphere. This will mean cleaner energy can be exported to our neighbours in Asia as LNG. Alternatively, the CO_2 is used to manufacture specialty chemicals and materials, resulting in zero emissions from industry.

Waste materials from the food, agricultural and forestry sectors are processed to produce biogas that is shipped around the country for use in remote regions such as camping or remote mine sites, or for portable use around the home and city.

Natural gas can be used directly or as hydrogen as an important feedstock and energy source for materials manufactured domestically, such as fertiliser to support the growing agricultural sector, or plastics, cement and metals to support a growing construction sector.

Gas for 2050 power generation will be decarbonised and widely distributed using a wide range of technologies. While houses and cities generate their own power, the electricity grid provides additional resilience and connects the electrical demand of cities with power generation including large scale hydro, wind, solar thermal and gas. Energy is stored in utility-scale batteries, as hydrogen gas (produced from electrolysis of excess renewable energy), biogas and in traditional pumped hydro. Along with natural gas, these provide frequency and peaking support for the grid during times of high demand. These technologies combine to provide secure, lowest cost and low emissions electricity for use across the economy.

Delivering on the vision

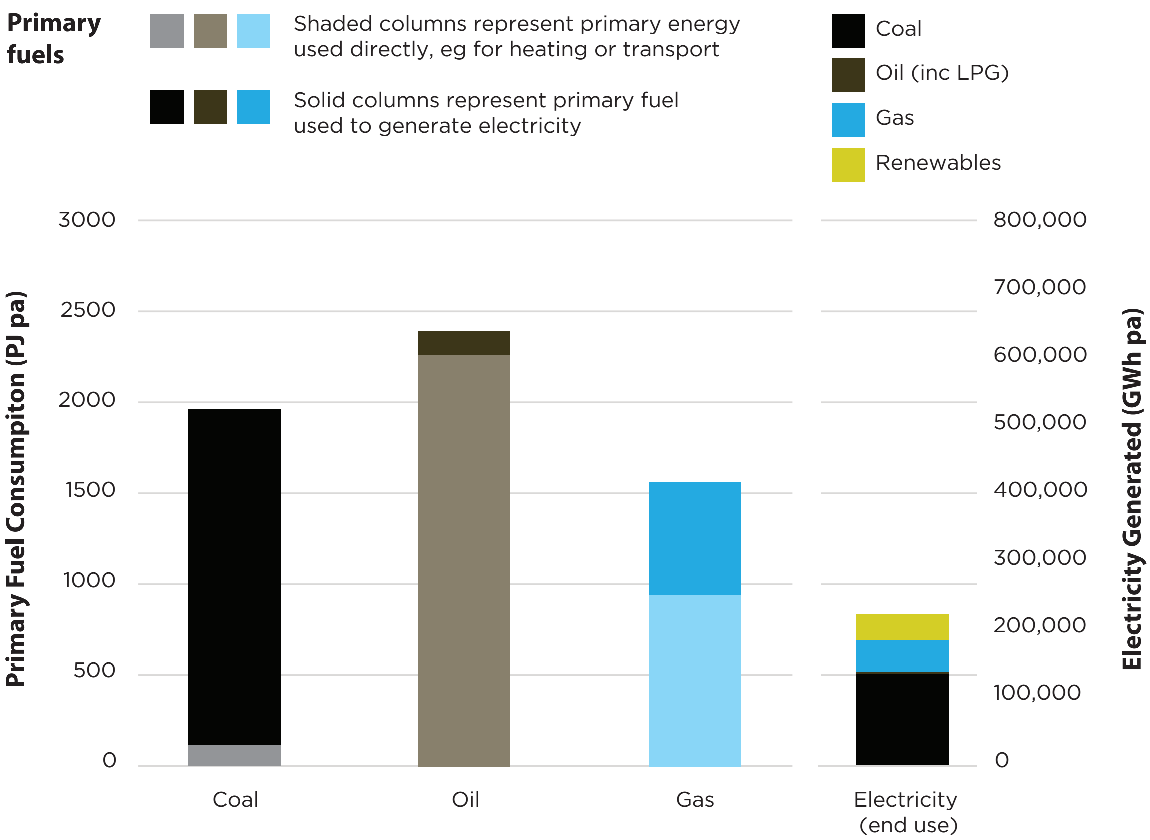
The world has agreed to make efforts to reduce emissions. Most countries, including Australia, ratified the Paris Agreement in 2016 and all Australian states and territories have set targets to achieve net zero emissions by 2050.

While most effort to date has been on reducing emissions from electricity, that effort is mostly about replacing coal fired generation with renewables. Coal provided 1,961 PJ of primary energy to Australia in 2017/18, mostly for power generation. Gas, on the other hand, provided 1,555 PJ of primary energy with 39 per cent of this used for power generation and the remaining 943 PJ as direct end-use.

This direct-use of energy of natural gas exceeds Australia's total electricity end-use of 835 PJ. **Natural gas has the broadest application of all primary fuels being used directly in households, businesses and industry as well as to generate 21 per cent of Australia's electricity and its use as a fuel in transport.**

Natural gas provides many other benefits besides fuel. The Australian oil and gas exploration and production sector supports 80,000 direct and indirect Australian jobs and hundreds of thousands more in the manufacturing sectors that rely on natural gas. Downstream, **there are many jobs reliant on natural gas** including energy and appliance retailers, gas fitters, appliance manufacturing and also those industries that use natural gas such as hospitality. As a feedstock, it is used by many manufacturing industries.

Figure ES-2: Australia's energy consumption (2017/18)



Through our exports, similar economic and job benefits are provided in other countries. Moreover, when natural gas in used to replace coal in power generation, it provides cleaner air in those countries providing better health for those populations, as well as reducing greenhouse gas emissions.

Transformational technologies to realise gas decarbonisation are being adopted by industry, including hydrogen, biogas, bio-LPG, renewable methane and carbon capture and storage (CCS). Hydrogen can be produced through renewable electricity in electrolysis to produce green hydrogen or from natural gas combined with CCS to produce blue hydrogen.

While these are different processes, they both provide decarbonised gas. Industry is already investing and moving beyond the research and development phase with demonstration projects underway to deploy a broad range of these technologies as well as commercial-scale CCS project at Gorgon Carbon Dioxide Reinjection Project in Western Australia.

Some of the achievements to date are shown in Table ES-2

Table ES-2: Gas Vision 2050 key achievements to date

Hydrogen

- The progress in hydrogen has been the most publicised – led by the development of Australia's National Hydrogen Strategy as well as strategies by each state. The development of the strategy and the Future Fuels CRC have been highly influenced by Gas Vision 2050. Hydrogen offers opportunities in many sectors and Australia's gas infrastructure is well placed to decarbonise residential and commercial gas use by adopting hydrogen. While hydrogen is already produced commercially, its current role has been limited as a feedstock and not as an end use fuel in appliances.
- The gas industry has invested in demonstrating renewable hydrogen production facilities and supporting research through the Future Fuels CRC to accelerate the uptake of hydrogen in the economy.
- Producing renewable hydrogen is already being demonstrated in Canberra and Perth, and soon two more projects – in Adelaide and western Sydney – will come online. Across these projects, more than 2 MW of hydrogen production capacity will be installed that will deliver renewable hydrogen to households. A further hydrogen blending project is planned for the city of Gladstone in Queensland allowing hydrogen to be provided to both residential, commercial and industrial customers.
- The Australian Hydrogen Centre was established in early 2020 to develop feasibility studies on 10 per cent renewable hydrogen in the gas distribution networks of South Australia and Victoria and develop a pathway to make the transition to 100 per cent hydrogen networks.
- Governments are backing hydrogen projects. The Commonwealth government has allocated a further $370 million towards scaling up hydrogen electrolysis projects and all states and territories are also making funding available to advance hydrogen.

Table ES-2: Gas Vision 2050 key achievements to date (continued)

Natural Gas

- The Future Energy Exports Cooperative Research Centre (FEnEx CRC) will execute cutting-edge, industry-led research, education and training to help sustain Australia's position as a leading LNG exporter, and enable it to become the leading global hydrogen exporter. The CRC is a national collaboration of 28 industry, government and research partners. Over the next decade, the collaboration will develop new knowledge and demonstrate innovative technologies aimed at making LNG and hydrogen production more efficient while also lowering their emissions.
- Carbon offsets are already being widely used by supporting activities that reduce emissions in other parts of the economy. Residential, commercial and industrial natural gas users can purchase offset certificates on the market to achieve net-zero emissions from gas use.

Carbon capture and storage

- In carbon capture and storage, the Gorgon project commenced its CO_2 Injection Project in 2019. It is the biggest CO_2 storage project in the world, storing 3.4 to 4.0 million tonnes of CO_2 per year. Research supported by the gas industry is ongoing at CO2CRC and in various parts of Australia to identify and develop suitable geological storage opportunities that can be used to decarbonise Australia's energy sector.

Bio-methane

- A bioenergy roadmap is under development by the Commonwealth Government, which will outline the opportunities of bioenergy to decarbonise the economy. Biogas is already produced in Australia but is generally directed towards producing renewable electricity as that is incentivised through the Renewable Energy Target. Biogas – easily upgraded to biomethane or bio-LPG - has an opportunity to decarbonise the use of gas. The technology is well proven overseas and Australian gas utilities are developing projects to demonstrate the technology locally.

Renewable gas

- The production of renewable gas is a new decarbonisation technology. This builds on the production of renewable hydrogen but continues its reaction to produce methane, which is completely compatible with natural gas. The technology is being demonstrated by industry.

Value of gas and gas infrastructure

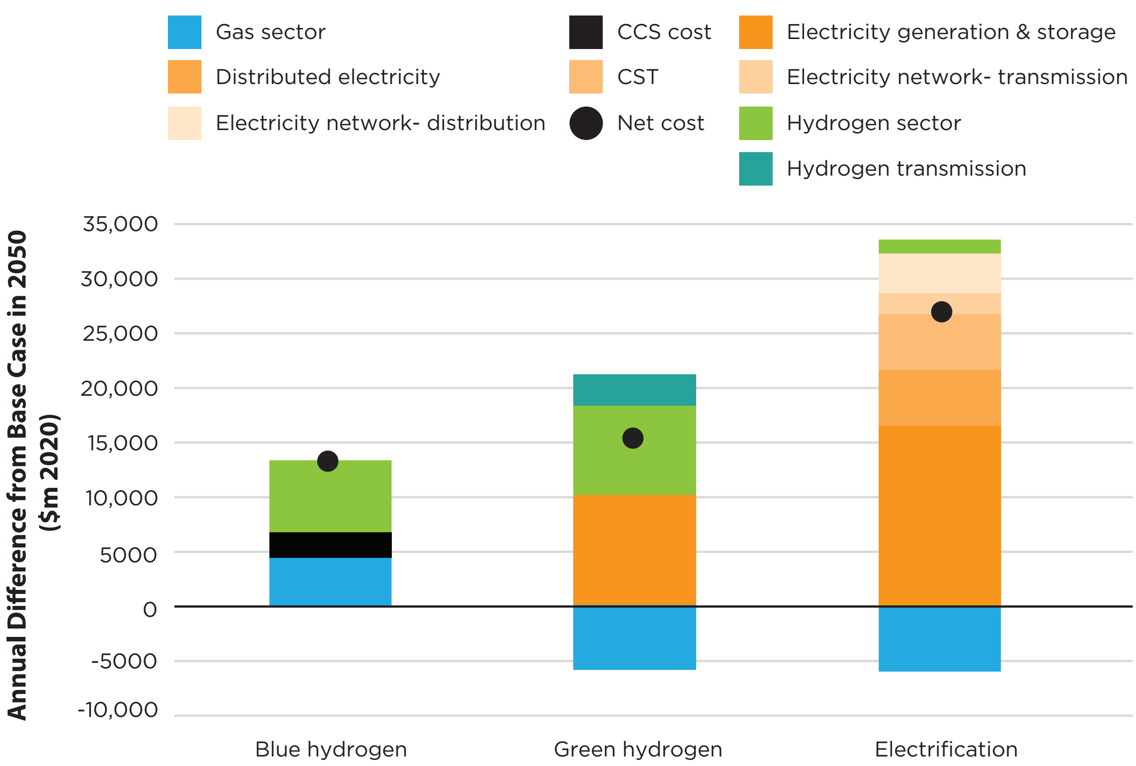
Deploying transformational technologies using existing gas infrastructure is also more economically favourable than electrification.

Frontier Economics completed a study to investigate and evaluate options of the roles of gas and gas infrastructure to achieve a net-zero economy by 2050. The study focused on ongoing capital and operating costs in 2050 assuming a transition to a decarbonised economy was made by then.

The annual costs of different decarbonisation scenarios were modelled. These scenarios were compared to a base case where the electricity sector reached net zero emissions in 2050 while unabated gas use continued to supply heat and feedstock to industry. These scenarios achieved net-zero emission from gas use and included blue hydrogen, green hydrogen and electrification.

- **The blue hydrogen scenario is lowest cost at a net increase of $13.3 bn compared with the base case.** This reflects that more gas is used in this scenario than the base case and that there are extra costs for CCS. The ongoing use of the gas transmission and distribution networks means there are no additional costs for upgrades for electricity generation and the electricity transmission and distribution networks.
- **The green hydrogen scenario ranks second at a net increase of $15.3 bn compared with the base case.** This reflects additional costs of electricity production, hydrogen production and storage and hydrogen transmission. Ongoing use of the gas distribution networks in this scenario means that there are no additional costs of electricity distribution in this scenario.

Figure ES-3: Net cost of decarbonising gas by scenario



- **The most costly scenario is electrification at a net increase of $27.5 bn compared with the base case.** Similar to the green hydrogen scenario, there are savings in the cost of gas supply but additional costs for electricity generation, storage, transmission and distribution. Further, this scenario also incurs costs for hydrogen production to provide feedstock to industrial processes.
- **Moreover, the blue and green hydrogen scenarios are conservative and further cost reductions could be achieved by including the opportunities provided by:**
  - **low cost biogas;**
  - **cost improvements in electrolysis technology; or**
  - **the repurposing of natural gas pipelines to transport hydrogen.**

  These opportunities were not considered in the analysis.

The major conclusions from this scenario analysis are:

- **Net-zero emissions can be reached with hydrogen at half the cost of electrification.**
- Making continued use where possible of existing gas transmission and distribution networks to deliver energy can help avoid the material costs of building new assets such as augmentation of the electricity transmission and distribution networks.
- The finding that both the blue and green hydrogen scenarios are lower cost than electrification suggests that there is value in continuing to make use of Australia's gas infrastructure and Australia's natural gas resources to deliver gaseous fuels to end-use customers.
- This finding also suggests that policies to achieve net zero emissions should be broad-based and not focus solely on promoting the electrification of all stationary energy end-use.

The next decade – accelerating decarbonisation of gas

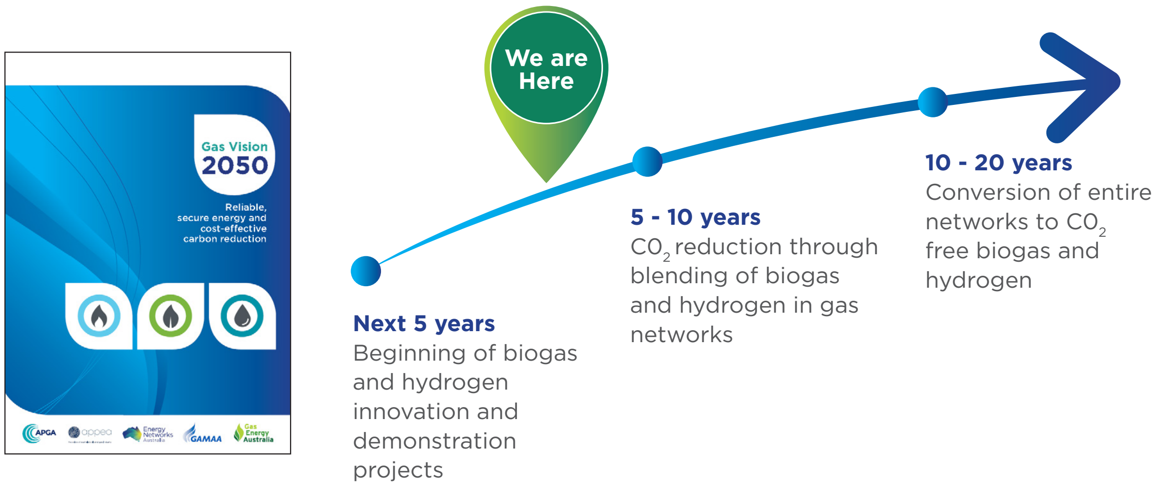
Gas provides major services to customers and to the economy and these services need to be decarbonised. There are a range of options available and the gas industry is continuing to lead the development and demonstration of these technologies. This is balanced with customers seeking options to voluntarily reduce their emissions.

While CCS and carbon offsets are commercially mature, the focus has been on the transformational technologies of hydrogen and biogas, which are still at an early level of commercial development. Hydrogen and biogas for gas are the wind and solar PV for electricity. We are well on track to demonstrate these technologies, showing customers the possibilities of reducing emissions from gas use and are progressing towards demonstrating blending in gas networks.

The next decade must focus on key activities so we are in a position to convert entire networks in the 2030s to hydrogen and biogas. Key steps include:

- developing a certification scheme for low carbon biogas and hydrogen allowing it to be recognised and traded as an emission free product;
- establishing blending and technology targets;
- establishing zero emissions gas contracting arrangements – similar to power purchase agreements for electricity – to create a market for hydrogen and biogas;
- scaling up the production of low carbon gases, through the use of blending in networks, leading to major cost reductions that will ensure conversions of entire network to zero emissions gas;
- continuing research and development of new technologies, or applications of existing technologies to accelerate the reductions of emissions;

Figure ES-4: Pathway to decarbonise gas networks



- demonstrating the safe use of hydrogen in appliances;
- sharing the learnings from the diverse range of demonstration projects underway and use these learnings to inform market and policy settings;
- in conjunction with the broader industry, undertaking large scale demonstrations of transformational technologies to demonstrate their emission reduction potential across the industry; and
- deploying transformational technologies in early commercial opportunities.

Achieving net-zero by 2050 is essential if we are to make a meaningful contribution to global efforts to avoid the worst impacts of climate change. And it is something our customers want us to focus on.

Decarbonising the gas sector requires a long-term focus and a systems approach to energy production, transportation and consumption. Alternative options to decarbonise gas also exist through carbon offsets, energy efficiency and electrification.

In practice, all will be needed to decarbonise the economy, but the transformational technologies being pursued in Gas Vision 2050 provide a wider range of options and additional flexibility to decarbonise the sectors dependent on gas.

For the gas sector, this requires the ongoing development and demonstration of a range of technologies, supported by the right policy and market settings. Industry is dedicated to continuing to progress the transformational technologies to the commercial scale, supported by research, development and demonstration projects. Completing key steps in the 2020s through setting blending and technology targets for 2030 will allow large scale deployment to achieve the desired outcomes in line with the Paris Agreement on climate change. The right policy settings will be required to ensure commercial take-up of those technologies.

Gas in the global economy

The global economy depends on energy.

This energy is often transported across national boundaries from energy rich countries to energy poor countries via shipping and trains, gas and oil pipelines, or high voltage transmission cables. Global markets depend on energy and economic shocks, such as COVID-19, have major impacts on energy markets by effecting demand and creating major price disturbances.

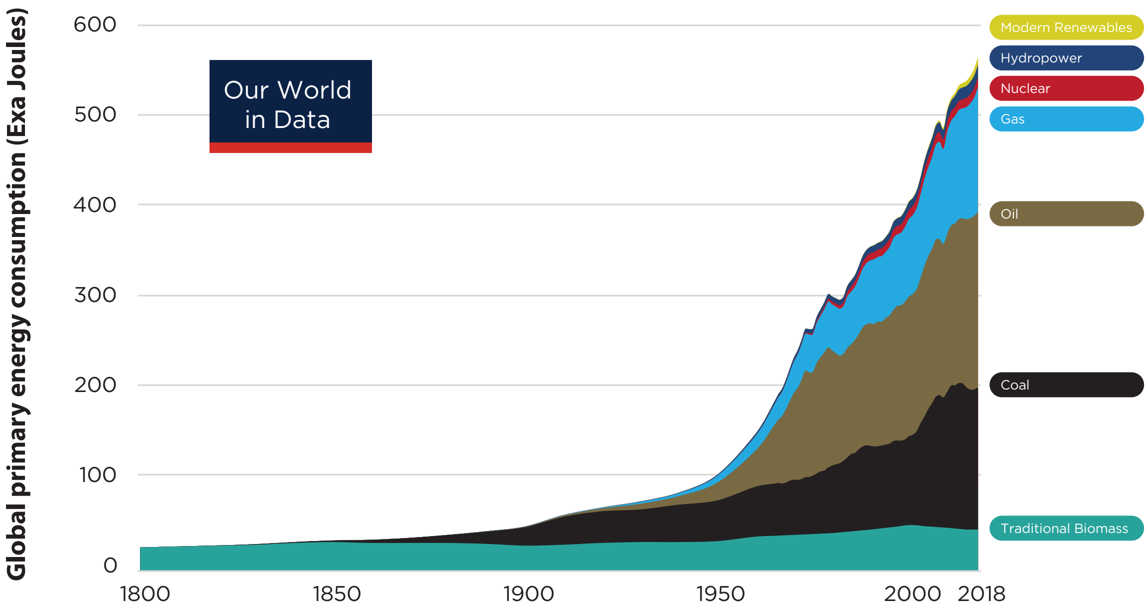
Nevertheless, global energy consumption continues to grow as a reflection of both population growth and that population becoming more energy intensive. While there is ongoing opportunity to reduce energy consumption through efficiency, the chart below demonstrates exponential growth in global energy consumption.

The main forms of global energy in the 1800s were traditional bioenergy, and a similar level of bioenergy is still used today. In the middle of the 19th century, coal became a major fuel source, oil in the early 20th century and gas towards the middle of the 20th century. The current global energy mix includes fossil fuels, nuclear, traditional renewables such as biomass and hydropower[1] and modern renewables such as solar photovoltaics, wind power and modern bioenergy[2].

In 2018, global energy consumption was 565 EJ[3], having nearly tripled from global energy consumption 50 years earlier of 207 EJ[4]. Fossil fuels provided 81.1 per cent of the energy consumption in 1968, and this proportion has risen to 87 per cent in 2018. The use of all fossil fuels continues to grow in absolute numbers, but gas is growing fastest.

Renewable energy – in the form of biomass – was used before the discovery of fossil fuels and continues to be used. Today, hydropower also contributes as a traditional renewable fuel.

Figure 1: Global primary energy consumption



Source: https://ourworldindata.org/energy

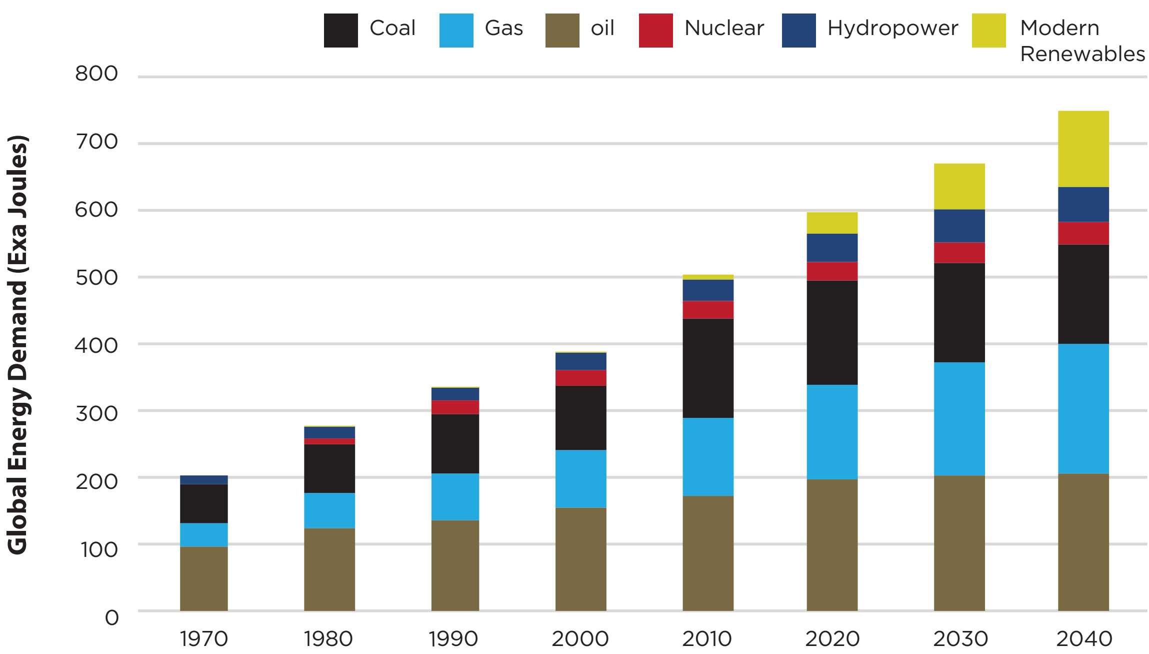
1 Pumped hydro is a storage of energy reliant on one of the other energy sources mentioned.
2 Wind power has historically been used to provide mechanical energy used in agriculture (eg pump water, crush grains) but modern wind power generates electricity from wind.
3 The “Our World in Data” shows a total of 157,064 TWh in 2018. Conversion factor of 1 TWh = 0.0036 EJ has been used.
4 The “Our World in Data” shows a total of 57,467 TWh in 1968.

The proportion of these traditional renewable fuels declined from almost 100 per cent in 1800 to 9.7 per cent in 2018, while delivering triple the amount of energy. Modern renewables such as solar photovoltaics and wind power have grown strongly in the last two decades. While some countries and regions (e.g. Denmark, Germany and South Australia (SA)) are reporting high levels of renewables penetration into their energy systems, this mainly covers electricity and not the broader energy sector including heat, industrial feedstocks and transport energy. Although some transport fuels have been replaced with renewables as either biomethane or as ethanol drop-in fuels. Globally, modern renewable energy provided 1.6 per cent of global energy consumption in 2018. This proportion will continue to grow due to increasing investment in the renewable sector compared with traditional fuels.

The key point from this historic data is that new fuel sources continue to be added to the energy mix, but the incumbent fuels have not been displaced at the global level.

Many energy forecasts show that primary energy demand will continue to grow to mid-century, in line with forecast increases in population. Different assumptions in this forecasting impact on the energy mix by 2050, but fossil fuels remain the most dominant energy supply source even though renewables will grow the fastest. In the International Gas Union forecast, global gas consumption overtakes coal consumption by 2040. It should also be noted that modern renewables almost triple in that timeframe.

Figure 2: Projected global growth in primary energy demand



Source: International Gas Union (2019), Global natural gas insights

The role of gas in Australia

Within Australia, gas is a diverse fuel providing many benefits across the economy. It contributes around 21 per cent to domestic end-use energy consumption. It is also one of Australia's biggest sources of export income alongside iron ore, thermal coal and metallurgical coal.

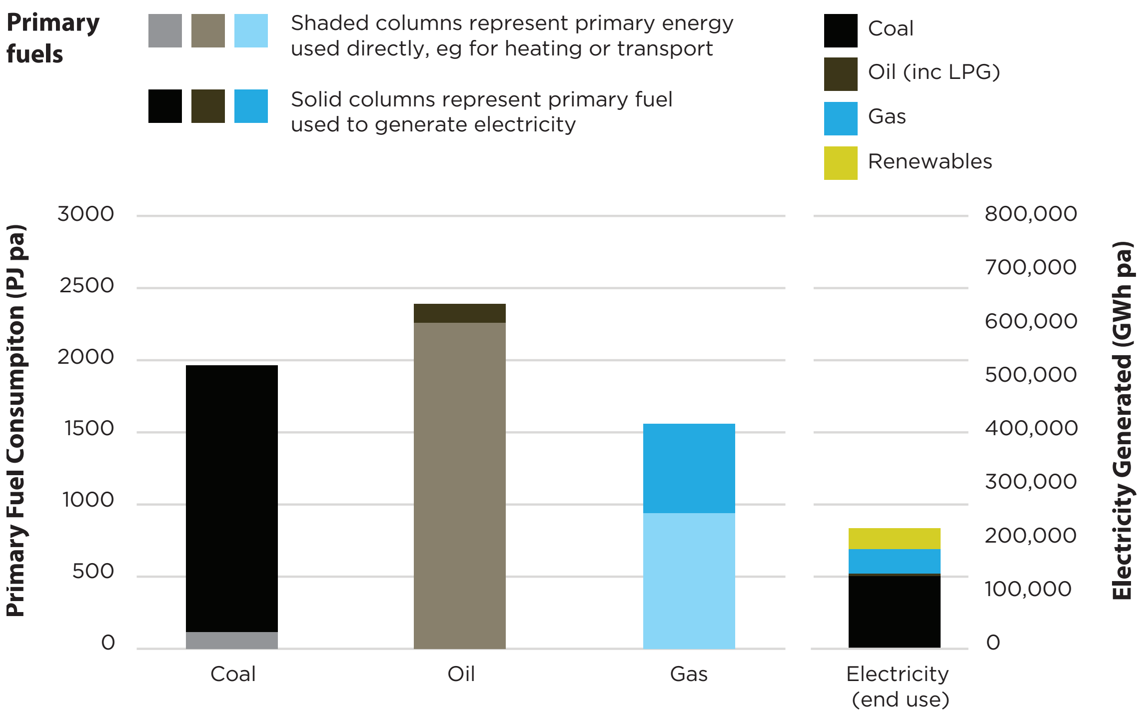
Gas' main component is methane, which can be burnt directly to provide heat or generate electricity and is also used as a feedstock in many industries. The domestic gas production industry contributes $47 billion to GDP and the Australian oil and gas exploration and production sector supports 80,000 direct and indirect jobs and hundreds of thousands more in the manufacturing sector that rely on gas. Downstream, there are many jobs reliant on natural gas including energy and appliance retailers, gas fitters, appliance manufacturers and also those industries that use natural gas such as hospitality.

Through its widespread use, it supports the economy more broadly in mineral processing, manufacturing, construction and hospitality, and through the products enabled by gas, it plays a role in all our lives.

Australia's consumption of primary fuels focuses on producing electricity or direct use for heating and transport. Figure 3 shows Australia's total primary energy consumption for 2017/18 as well as Australia's electricity consumption for the same period. The key features are:

- More end-use energy is provided by gas compared with electricity. Gas provides 1,555 PJ/pa of primary energy with 39 per cent used in power generation and the remaining 943 PJ as direct end-use. This direct end-use of energy of natural gas exceeds Australia's total electricity end-use of 835 PJ/pa.
- Most coal consumed in Australia is for power generation, with about 5 per cent of domestic coal consumption used directly in metal processing.

Figure 3: Australia's energy consumption (2017/18)



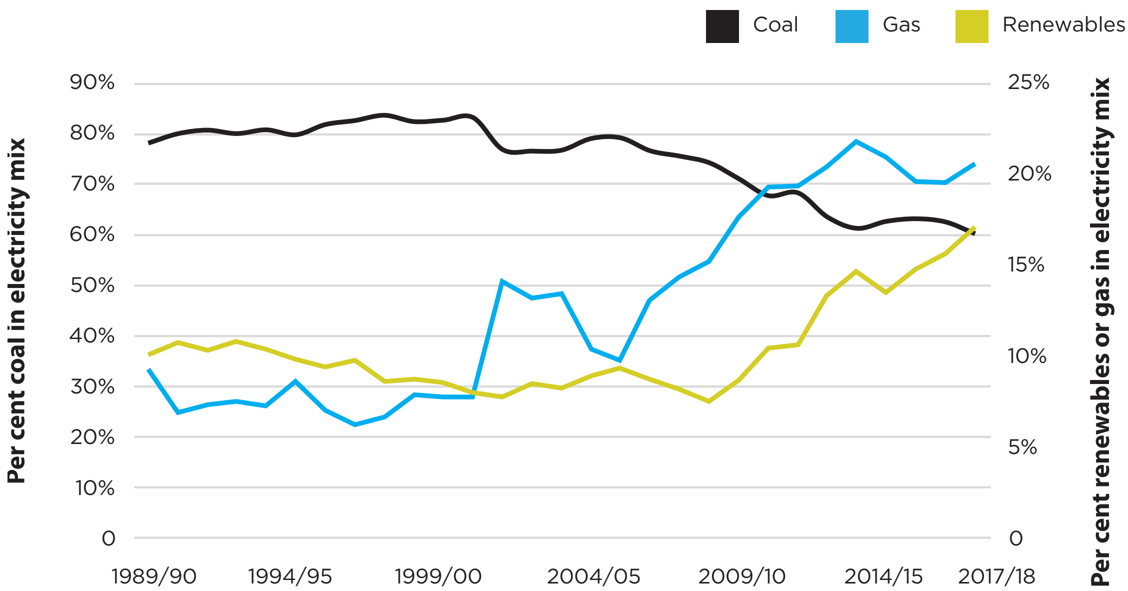
Source: Australian Government (2019), Australian Energy Update 2019, Energy Networks Australia analysis (2020)

- About 5 per cent of oil products are used for power generation, predominantly by diesel generators. The remainder of oil derived products are used in the transport sector. The *Australian Energy Statistics* includes LPG in the total oil component.
- 39 per cent of gas consumption in Australia is for power generation. The other 61 per cent is used directly by industry for heating or industrial feedstock and by Australian homes and businesses for heating, hot water and cooking.
- Renewables generate about 17 per cent of Australia's electricity. This includes traditional renewables such as hydropower and bioenergy, as well as the modern renewables of wind, utility scale solar PV and rooftop solar PV. The proportion of renewable generation has grown in the past two years and has reached the 33,000 GWh level set under the *Large-scale Renewable Energy Target*.
- Most electricity continues to be supplied from coal, although the total contribution that coal makes to the mix has decreased in the past 30 years.

The contribution from coal to power generation in Australia has decreased from 80 per cent in the early 1990s to about 60 per cent today. This has largely been a result of the ageing coal fleet resulting in retiring coal plants. This lost capacity has been replaced with a mix of renewables and gas for power generation, showing the complementary roles that gas and intermittent renewables (especially solar) play in maintaining a reliable electricity supply. The proportion of gas varies between states with Western Australia (WA), SA and the Northern Territory (NT) generating more than 50 per cent of their electricity from gas while New South Wales (NSW) and Victoria (VIC) generate less than 10 per cent of their electricity from gas. Gas power generation is dispatchable and in some states it provides part of the 'base load' capacity while in other regions, it is used for quick dispatch during peak electricity demand periods to complement the intermittent nature of renewable generation. Nationally, power generation from gas has increased in the past decade.

Gas clearly plays a diverse and important role in Australia's energy mix.

Figure 4: Australia's electricity generation mix



Source: Australian Government (2019), Australian Energy Update 2019, Energy Networks Australia analysis (2020)

BOX 1: The role of gas in SA's power supply

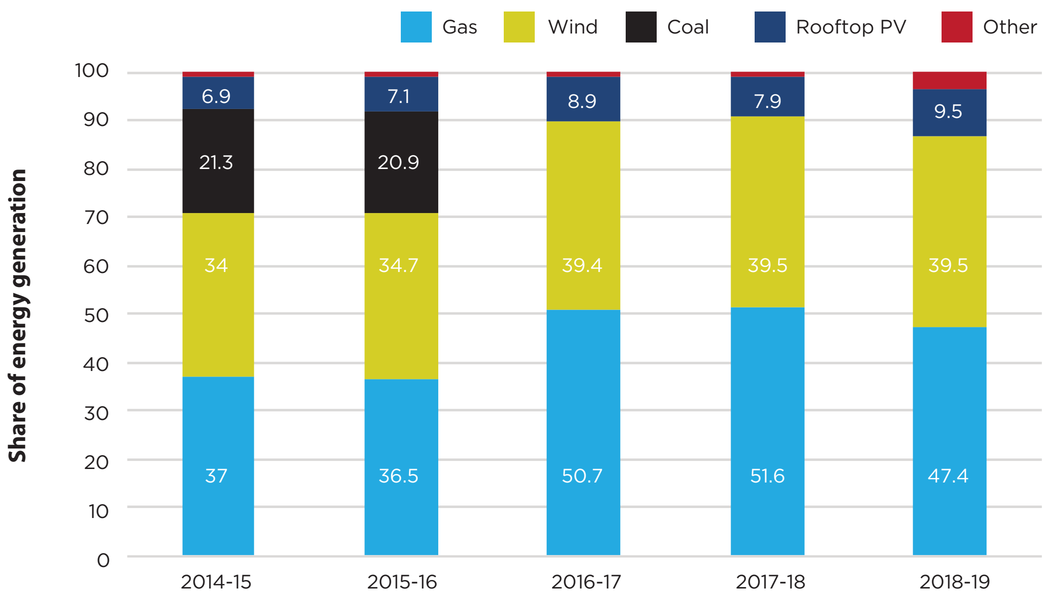
South Australia is often showcased as Australia's renewable energy success story. But there is another side of the story that depends on gas. The reliance on gas has increased since the closure of South Australia's last coal fired power station in 2016/17 and provides almost 50 per cent of the total generation in the state.

AEMO[5] reports that 50 per cent of scheduled generation capacity for Summer 2019/20 and Winter 2020 comes from gas.

As renewable generation continues to grow, there will be an increased need for technologies that can complement its natural variability and provide rapid start capabilities and a high level of operational flexibility. The gas-fired Barker Inlet Power Station is an example of this capability. It can achieve maximum operation within five minutes at a higher level of efficiency that the pre-existing gas power generators.

Both gas power generation and interconnectors are needed to meet SA's demand in periods when the sun is not shining and there is little or no wind.

Figure 5: South Australian energy generation by fuel type



Source: Australian Energy Market Operator (2019)

5 Australian Energy Market Operator (2019), South Australian Electricity Report 2019

Daily consumption

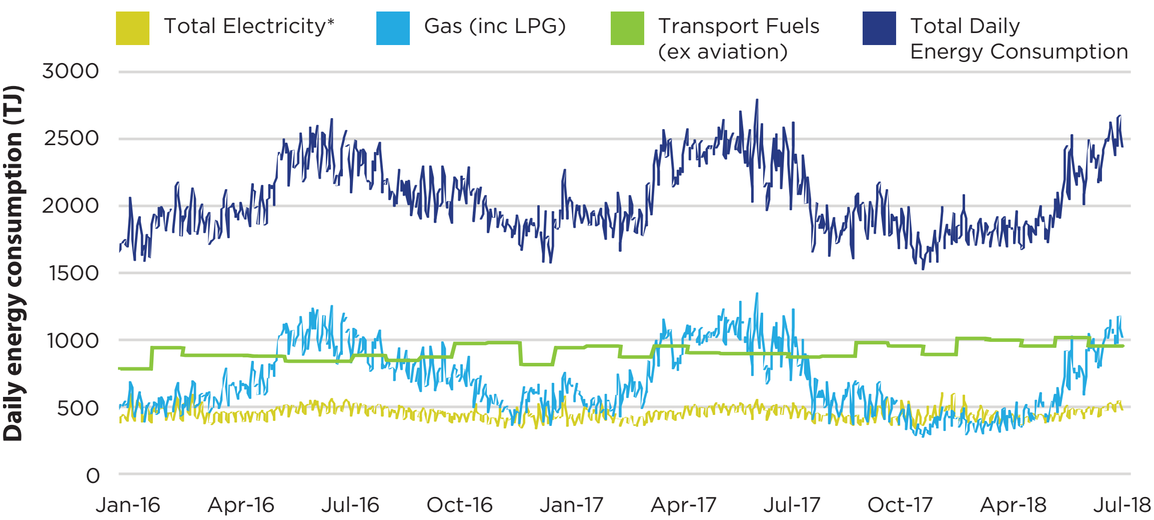
An annual overview only tells part of the importance of gas to our overall energy mix. More insights about the inter-seasonal and intra-day role of gas can be gained by looking at daily and hourly energy consumption. Victoria makes a good case study due to its seasonally high gas demand for space heating during winter.

Figure 6 illustrates how energy is used in Victoria. It shows the energy used as electricity, as gas (including LPG) and in transport and the total of the three as shown by the dark blue line in the chart. This data shows a seasonal trend of high natural gas use during winter for heating. To date, decarbonisation has focussed on electricity, but the challenge requires all energy sectors to have their own decarbonisation journeys.

Of the three sectors, transport fuels represent 47 per cent of the total energy consumption in 2017/18, gas 32 per cent (including LPG use) and electricity 21 per cent. Some gas was used to generate electricity and this overlap is not counted in the total. Victoria generated 21 per cent of its 2018/19 electricity from renewable generation, or an equivalent of 4 per cent of its energy consumption including transport and gas energy. Power generation still includes brown coal resulting in the highest electricity emission intensity in Australia. While Victoria has legislated a 50 per cent renewable energy target by 2030, the definition in the act[6] indicates this applies only to electricity generation. Assuming gas and transport energy consumption remain at current levels, the 50 per cent renewable target will cover just over 10 per cent of Victoria's energy use.

Given the size and seasonal nature of this sector, it would appear unrealistic to electrify it as massive investments would be required to build new electricity infrastructure to meet the seasonal demands.

Figure 6: Victoria's daily energy consumption



Note: *Total electricity includes electricity from gas and renewables, total gas includes gas used for power generation. Total consumption removes this double count.

Source: AEMO data, Deloitte Access Economic analysis (2019), Energy Networks Analysis (2020)

6 Renewable Energy (Jobs and Investment) Amendment Bill 2019, https://www.legislation.vic.gov.au/bills/renewable-energy-jobs-and-investment-amendment-bill-2019

Gas exploration and production

The upstream gas industry, responsible for natural gas exploration and production, has invested about $350 billion over the past decade developing oil and gas projects for domestic and export use.

The supply of gas to customers begins with the exploration and appraisal of potential reserves for commercial viability. Gas discoveries are extracted through wells, then processed to separate the methane and ethane from impurities (such as nitrogen, carbon dioxide and sulphur dioxide), and to remove and treat any water. Gas is then provided to domestic and export markets. Some gas is stored (often in depleted gas fields or LNG tanks) and can be used to augment supply at peak times.

Exported gas is liquefied as LNG for shipping to export markets. The gas is chilled to minus 162°C, which reduces its volume by 600 times and makes it economic to store and ship in large quantities. Most Australian LNG is shipped to Asia, where it is stored, regasified and injected into local gas pipeline networks.

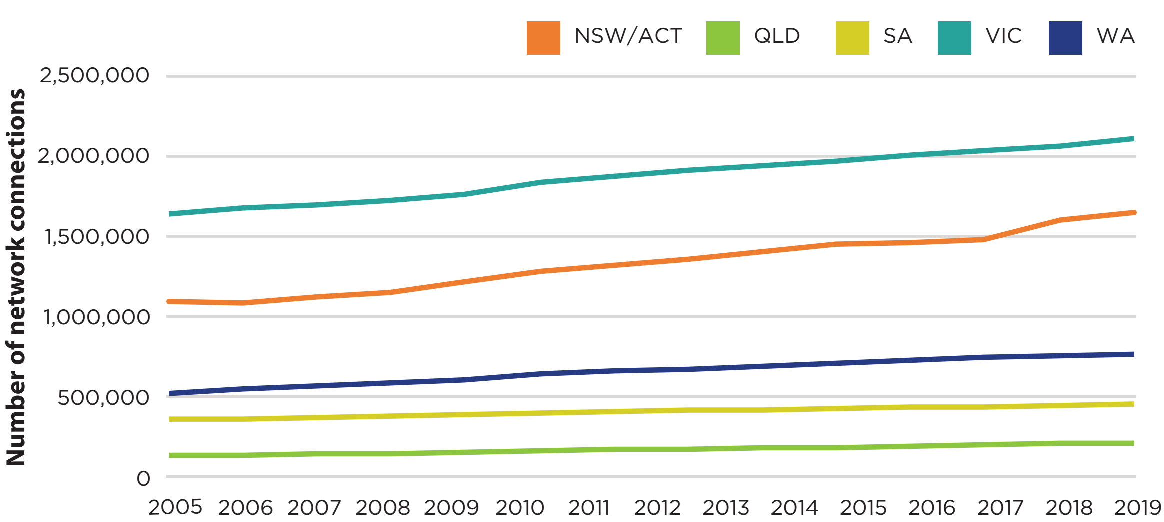
LNG projects require major investment in processing plants, port and shipping facilities. The magnitude of this investment requires access to substantial reserves of gas, which may be sourced through the project owner's interests in gas fields, joint venture arrangements with gas producers, and/or contracts with third party producers.

Gas networks

Gas is provided across Australia via gas transmission pipelines and distribution networks. These connect gas fields to residential, commercial and industrial gas customers, including exporting facilities.

Gas transmission pipelines play a critical role in providing consumers with access to gas. Australia has more than 40,000 kilometres of gas transmission pipelines that transport gas from production regions to gas users – an increase of about 6,500 kilometres from 10 years ago.

Figure 7: Connection to Australia's gas networks



Source: Energy Networks Australia analysis, 2020

The past decade has seen strong investment in the gas transmission pipeline sector, particularly in the eastern states, where capital investments have facilitated the development of an interconnected grid of gas transmission pipeline infrastructure covering QLD, NSW, NT, VIC, SA, TAS and the ACT. In addition to the development of an interconnected gas transmission pipeline network, these capital investments have transformed most of the gas transmission pipelines into bi-directional pipelines, providing gas consumers with greater flexibility in terms of contracting and trading.

Gas networks provide the connections from the high-pressure transmission pipelines to end-use customers. These networks are continuing to grow at a rate of about 100,000 new connections a year and are at 5.2 million connections. While overall consumption appears to be dropping, this is attributed to increased energy efficiency and growth in renewables, especially solar hot water, which reduce the demand for gas. Nevertheless, this data shows that customers continue to regard gas as a valuable energy source for their homes and businesses. It is estimated there are more than 12 million household appliances using natural gas in Australia.

BOX 2: New developments prefer gas

Natural gas is now flowing to the new waterfront development at Barangaroo, Sydney, marking a significant milestone in the development's timeline.

Jemena constructed mains and pipelines to deliver natural gas to the 5.2 hectare precinct, allowing plumbers, gas fitters and other trades to connect gas to properties.

It is estimated the Barangaroo project will support some 23,000 permanent jobs, provide 3,500 residential homes and contribute more than $2 billion a year to the NSW economy.

Connecting natural gas to the precinct was not without its challenges including the laying the new, high pressure steel service, which had to be fed through a precast sleeve installed in the concrete slab two years prior. This highly complex process required specialists welding crews provided by Zinfra, part of the Jemena Group. Connecting natural gas to a project this size demonstrated that demand for gas remains strong in NSW.

From industrial and large commercial customers to small businesses and homes, we continue to receive connection requests across the Jemena Gas Network, as people choose gas as their fuel choice across cities and regional NSW.

Source: Jemena (2020)

Gas beyond network coverage

In regions where gas pipelines do not reach, 'virtual pipelines' allow gas – in the form of Liquid Petroleum Gas (LPG) – to be provided to customers. LPG is a combination of propane and butane. Propane is used predominantly for domestic heating and cooking applications, whereas butane is used in special commercial applications. A mix of both is used as a transport fuel.

More than 80 per cent of Australia's LPG production comes from the processing of natural gas, with the remainder produced by our oil refineries. LPG contributes more than $3.5 billion per annum to the national economy and supports about 2,500 direct jobs. Australia is also a net exporter of LPG, with 1,444 kilotonnes exported in 2018-19.

In Australia, about two million households and businesses, most in regional areas, rely on LPG for water and home heating, cooking and a variety of commercial and industrial applications.

In addition, there are an estimated nine million LPG leisure cylinders in circulation today, which are mostly used to fuel the iconic Aussie barbeque. It is estimated there are about six million LPG-fired barbeques in Australia.

LPG is widely used in Australia as a transport fuel commonly referred to as autogas. There are more than 3,000 autogas refueling station capable of supporting two million LPG vehicles on the road without adding more refueling infrastructure[7]. Nevertheless, autogas consumption has declined in recent years, so new markets are being developed. One example is the heavy-duty dual fuel (HDDF) system which substitutes LPG for diesel in heavy vehicles. Sixteen Volvo HDDF prime movers operated by national freight and logistics company Rivet Energy have been fitted with modified engines which substitute LPG for diesel by 23 per cent. These HDDF trucks operate across VIC, NSW, SA and QLD and deliver LPG on bulk and multi-drop delivery runs to businesses every day of the year. On average a year, each vehicle saves about seven per cent in fuel costs and reduces emissions by almost 8,000 kilograms.

BOX 3: Remote power generation using LNG

Wesfarmers Evol LNG supplies LNG to power the Carosue Dam, Daisy Milano, Dalgaranga, Darlot, Deflector and Mt Marion mines in Western Australia, which employ hundreds of workers.

Each year, this reduces their combined diesel fuel consumption by 55 million litres, saving a total of $7.6 million on their fuel costs and reducing CO_2 emissions by 27,000 tonnes.

Source: Gas Energy Australia (2020)

7 Source: Gas Energy Australia – Elgas: https://www.elgas.com.au/blog/688-the-forgotten-fuel-autogas-lpg-conversions

Box 4: LPG's portability supporting disaster relief

With its portability and mobile infrastructure, LPG plays a significant role in improving the energy resilience of regional communities across Australia that often must deal with natural disasters.

In February 2013, in the aftermath of ex-tropical Cyclone Oswald, a landslide cut off the road into Coopers Creek, leaving 140 residents without access to essential services.

While an NSW State Emergency Service (SES) helicopter was delivering food and medicine to residents, they had no access to energy. Working together, the local Elgas branch manager and the SES arranged for LPG cylinders to be airlifted by helicopter to residents, including the local Coopers Creek School. The Elgas manager also showed residents how to connect the LPG cylinders to power their generators, refrigerators and cooking facilities.

Source: Gas Energy Australia (2020)

LNG Exports

LNG is now Australia's second largest export commodity after iron ore, providing export revenue of a $51 billion in 2018-19 and $47 billion in 2019-20. This has more than doubled over the past two years from $22 billion in 2016-17.

Australia exports LNG to a range of countries in Asia including Japan, China, South Korea, India, Taiwan and many others around the world. Australia's extensive resources of natural gas and proximity to growing markets make us well placed to meet the global climate change challenge while substantially contributing to Australia's economic growth.

While the demand for energy as part of the industrialisation of Asian economies is a key driver, the properties of natural gas as a lower emitting and cleaner burning fuel are also driving much of the international demand for LNG.

As the International Energy Agency (IEA) found in its *2019 World Energy Outlook* (2019 WEO)[8], the use of natural gas is expected to grow consistently over the *Outlook* period to 2040 under all emissions reduction scenarios.

For example, in its *Stated Policies Scenario*[9], the IEA forecasts global natural gas demand to grow by around 36 per cent by 2040. Average annual growth of 1.4 per cent means natural gas increases its share in global primary energy demand from 22 per cent today to 25 per cent in 2040. In the 'Sustainable Development Scenario'[10], gas use plateaus from the 2030s, but the IEA notes:

> " ...as a clean and flexible fuel, gas still sees its share increasing."

Most of the growing demand for natural gas will come from China as part of a long-term and deliberate coal to gas switching program[11] and from India and other countries in Asia which are turning increasingly to natural gas. This will lead to major emission reductions.

LNG offers lower emissions

In an Australian context, a recent landmark report by the CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA) confirmed the greenhouse gas emissions benefits from increased use of natural gas in domestic and export markets.

The report[12], *Whole of Life Greenhouse Gas Emissions Assessment of a Coal Seam Gas to Liquefied Natural Gas Project* analysed life-cycle emissions including extraction, transportation and usage of coal seam gas (CSG) in Queensland's Surat Basin.

This is the first time estimates of life-cycle greenhouse gas emissions associated with an operating CSG to LNG project in Australia have been used – and it provides valuable data about the benefits of natural gas for electricity generation. The report presents a comparison of greenhouse gas emissions from electricity production in Australia from Queensland thermal coal or natural gas derived from CSG operations which finds a reduction in emissions of up to 50 per cent when incorporating the full life cycle of greenhouse gas emissions from all parts of the supply chain. This is the first time estimates of life-cycle greenhouse gas emissions associated with an operating CSG to LNG project in Australia have been used and it demonstrates the benefits of natural gas for electricity generation.

The report found:

> " ... considerable climate benefits are possible where natural gas replaced coal for electricity generation; particularly in developing countries."

According to recent Australian Government estimates, Australian LNG exports in the year to December 2019 have the potential to reduce greenhouse gas emissions by 164 million tonnes in customer nations[13]. This figure represents more than 30 per cent of Australia's emissions.

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8 See www.iea.org/weo for more information.

9 See www.iea.org/weo/weomodel/steps for an overview of the 'Stated Policies Scenario'.

10 See www.iea.org/weo/weomodel/sds for an overview of the 'Sustainable Development Scenario'.

11 For an overview of the role natural gas, including Australian LNG, plays in China's coal-to-gas switching program, see Oxford Institute for Energy Studies (2018), The Outlook for Natural Gas and LNG in China in the War against Air Pollution, December (available at www.oxfordenergy.org/publications/outlook-natural-gas-lng-china-war-air-pollution).

12 See gisera.csiro.au/project/whole-of-life-cycle-greenhouse-gas-assessment for more information.

13 See www.minister.industry.gov.au/ministers/taylor/media-releases/emissions-fall-2019 for more information.

BOX 5: Switching to natural gas lowers emissions from power generation

Experience in the United States demonstrates how quickly emissions from the electricity sector can be cut by fuel switching. Data from the US Government's Energy Information Administration (EIA)[14] shows energy related emissions in the US in the first six months of 2016 were at their lowest since 1991, having fallen about 13 per cent from their peak in 2007. This was made possible in part because the US is developing its abundant natural gas resources.

This is evidenced in other countries too. The International Energy Agency[15] estimated that fuel switching from coal to gas in the past decade has reduced annual emissions from power generation by 536 million tonnes a year.

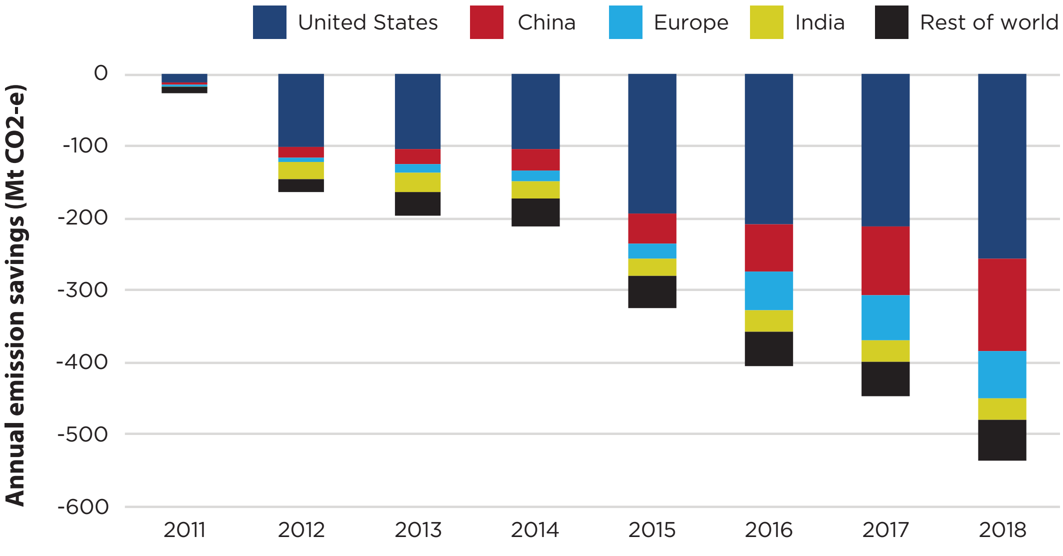
This is the equivalent of putting an extra 200 million electric vehicles on the road running on zero-carbon electricity over the same period.

The IEA report also highlighted a significant opportunity in the global electricity generation sector to reduce emissions by switching from coal-fired power plants to gas-fired power plants, which presented "a potential quick win for emissions reductions". The report found:

» There is potential in today's power sector to reduce up to 1.2 gigatonnes of CO_2 emissions by switching from coal to existing gas-fired plants, if relative prices and regulation support this potential.

To put this opportunity in perspective, the potential for emission reductions across the global economy of 1.2 gigatonnes is more than double Australia's total annual emissions over the year to the December quarter 2019[16].

Table 8: Emission reduction by switching from coal to gas for electricity generation



Source: Energy Networks Australia, Australian Petroleum Production & Exploration Association (2020)

14 See www.eia.gov/todayinenergy/detail.php?id=28312 and www.eia.gov/todayinenergy/detail.php?id=30712 for more information.

15 International Energy Agency - https://www.iea.org/data-and-statistics/charts/co2-savings-from-coal-to-gas-switching-in-selected-regions-compared-with-2010-2018

16 Quarterly Update of Australia's National Greenhouse Gas Inventory for December 2019

Essential roles of gas

Gas contributes to many parts of Australia's economy. It provides energy to households and businesses, energy and feedstock to industrial processes and fuel for electricity generation and export. The main roles vary by region as highlighted below.

- In Victoria, Southern NSW and the ACT, gas is essential in providing heating to households during winter. More than 80 per cent of homes in these regions are connected to the gas network and gas delivers more energy to homes than electricity.
- In SA, WA and the NT, gas is essential for power generation. Almost all power in the NT is generated from gas.
- In QLD, NT and WA, gas is important as an LNG export industry, providing many regional jobs and generating state and federal royalties and taxes[17] that support many activities to benefit all Australians.
- Across the country, gas is an essential component of industry, whether it is to provide low or high temperature heating, or whether it is used as a feedstock like in ammonia production.

Table 1 provides a qualitative assessment of the role of gas by region around the country. Gas clearly makes an essential contribution in every region.

Table 1: Contribution of natural gas by region

Region	Residential	Commercial	Industrial	Power Gen	Exports
ACT	✓✓✓	✓✓	✓	NA	NA
NSW	✓✓	✓✓✓	✓✓✓	✓	NA
NT	NA	✓	✓✓	✓✓✓	✓✓✓
QLD	✓	✓✓	✓✓✓	✓	✓✓✓
SA	✓✓✓	✓✓✓	✓✓	✓✓✓	NA
TAS	✓	✓	✓✓✓	✓✓	NA
VIC	✓✓✓	✓✓✓	✓✓	✓	NA
WA	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓

Code: ✓✓✓ = essential contribution; ✓✓ = major contribution; ✓ = minor contribution

17 In 2017/18, these royalties and taxes amounted to $5.8 billion.

BOX 6: LNG-fuelled shipping

New sulphur reduction regulations, which are being mandated around the world by the International Maritime Organization, are encouraging the use of LNG as an alternate marine fuel.

Compared with diesel, LNG can achieve 100 per cent SOx emissions reductions, 85 per cent NOx emissions reductions for low pressure engines, 40 per cent NOx emissions reductions for high pressure engines (diesel cycle), 95 to 100 per cent particulate reductions and around 25 per cent CO_2 reductions, while also being a commercially viable option.

The Woodside supply vessel Siem Thiima and the SeaRoad vessel Mersey II are already using LNG in Australia, while TT Line has two LNG-fuelled newbuild ferries on order.

Source: Gas Energy Australia (2020).

Reducing emissions from gas

The science of global warming is well accepted and shows that greenhouse gas emissions from human endeavours are increasing and leading to rising temperatures across the globe.

The global ambition is to reach peak emissions as soon as possible and then to achieve net-zero emissions in the second half of the century, in line with the *Paris Agreement* on climate change of 2015. Many countries have set targets to achieve net-zero emissions by 2050 or earlier.

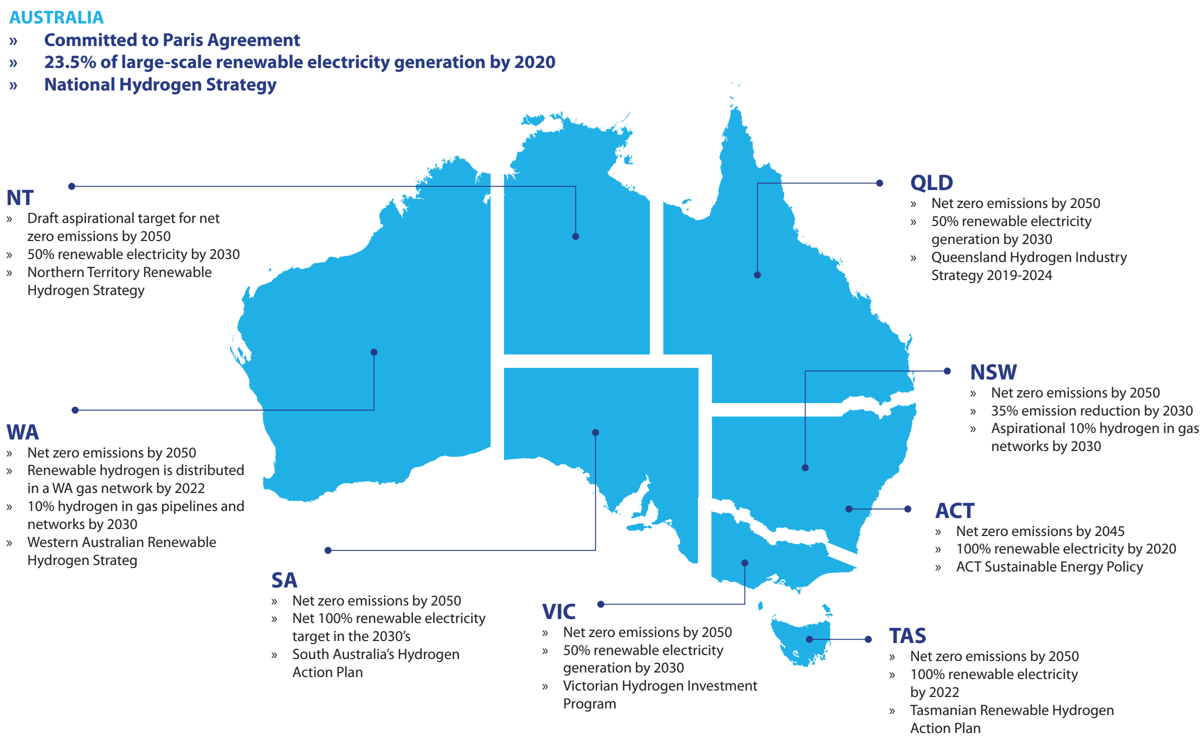
The Australian Commonwealth Government has signed up to the *Paris Agreement* and set a target of between 26 to 28 per cent reductions by 2030[18], and a commitment to net-zero in the second half of the century – in line with the *Agreement*. Separately, Australian states and territories have set an ambition of reaching net-zero emissions by 2050 or earlier.

Some have also set interim targets, but these are commonly focussed on the electricity sector and do not cover all energy or all emissions. Almost all regions have also committed to a hydrogen strategy. The Commonwealth Government is also developing a technology roadmap featuring the role of gas.

Reducing emissions from gas

Individuals, councils, governments and businesses are being pro-active to implement net-zero emission targets. While most of the focus has been to reduce emissions from electricity use, attention is also turning to what leadership in reducing emissions from gas use looks like.

Figure 9: Emission reduction commitment by jurisdiction



Source: Energy Networks Australia analysis (2020)

18 www.minister.industry.gov.au/ministers/taylor/transcripts/doorstop-camden-nsw

Strong support has emerged from residential customers engaging in recent gas networks plan through to renewable gas champions, such as Interface carpets, consistently voted as one of the most sustainable businesses in the world. In turn, energy businesses are offering low emissions energy solutions and demonstrating new zero-emissions technologies.

The Vision is for Australia to continue to turn its gas resources into products and services that will enhance national prosperity while achieving carbon neutrality. It identifies how gas and gas infrastructure can be used to solve the energy trilemma by balancing energy affordability, energy security and environmental outcomes. A strategic approach to reducing emissions can utilise developing technologies to also deliver jobs, growth and export benefits for Australia.

Box 7: Interface Mission Zero Case Study

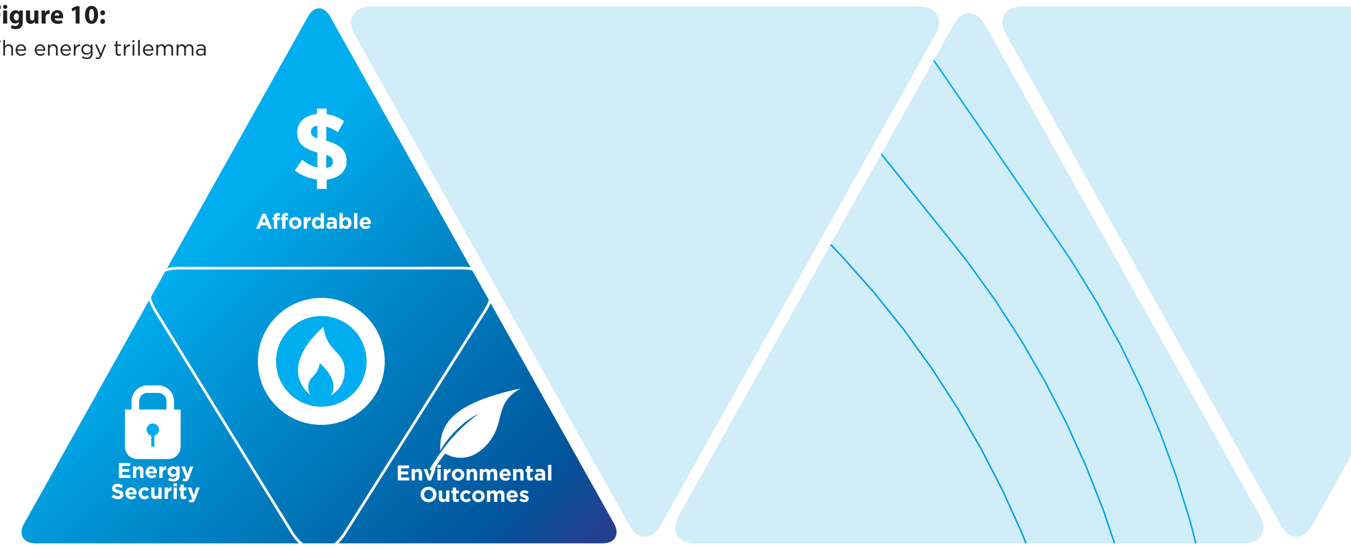
In 1994, inspired by their customers, Interface, a global commercial flooring company, set out to transform its business to have zero negative impact on the planet by the year 2020. They called it Mission Zero™. In 2019 they celebrated Mission Zero™ success by transforming their supply chain, products and implementing new business models.

Here in Australia Interface is a vocal advocate for developing a renewable gas market in Australia to more cost effectively reduce local manufacturing emissions in the future.

"We look forward to being able to procure zero emissions renewable gas in Australia very soon. Having the ability to enter into renewable gas purchase agreements – which provide the investment needed to blend biomethane and hydrogen into gas networks – will assist us in driving the sustainability of our products to new levels, and in the most cost-effective way. We can already enter into renewable electricity PPA's, so extending these arrangements to gas is an obvious next step."

Aidan Mullan, Sustainability Manager, Interface Australia

Figure 10:
The energy trilemma



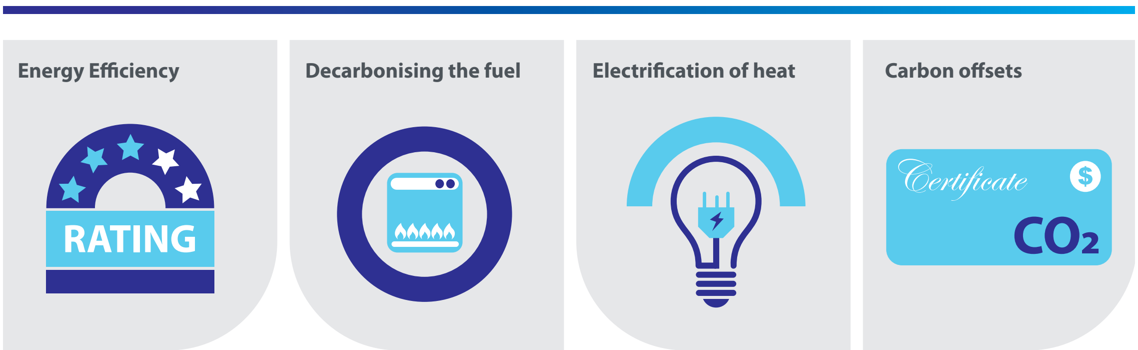
Customers are seeking a clean energy future and are engaged in achieving emission reductions from gas use. This is to be achieved through the widespread deployment of transformational technologies, including biogas, hydrogen and carbon capture and storage. All these technologies, alongside renewable electricity, energy efficiency and others, will be used across the economy to decarbonise gas.

Most greenhouse gas emissions are associated with energy use, although significant emissions also occur in other parts of the economy. Some sectors, such as aviation and agriculture, are more difficult to decarbonise than others.

Nevertheless, action is required across all sectors and jurisdictions to reach net-zero emission targets.

In the energy sector, the focus has been on reducing emissions from electricity generation, but gas is also on a decarbonisation journey. This journey focusses on reducing emissions from the services provided by gas, namely heat and industrial feedstocks. There are four groups of actions that are being taken, either separately or in combination, that can reduce emissions from the services of gas. These are outlined below.

Figure 11 Options to reduce emissions from gas



Direct and indirect emission reductions

Energy Efficiency

Gas is a valuable resource, so producing it and using it as efficiently as possible makes economic sense and reduces emissions.

Gas appliance manufacturers have already developed highly efficient condensing appliances that consume less gas for the same energy output, such as condensing space heaters and water heaters. Many households and businesses have already achieved reductions in energy use through improved building insulation, reducing air infiltration, better glazing, more efficient appliances and better use of energy (e.g. reducing space heating temperatures and reduced flow rates of heated water fixtures). These initiatives have been a major contributor to emission reductions to date and offer further opportunities.

Carbon offsets

Carbon trading and carbon offsets can be used to reduce emissions from the use of electricity, gas, or transport. There are a range of retailers that sell carbon offsets and many energy businesses are offering carbon offset options on their products.

Offset schemes are common. For the use of gas, offsets can be purchased through offset providers that will invest in activities to remove emissions from the atmosphere (e.g. planting forests) commensurate with the emission that is being offset.

For example, the *Darwin LNG* project is a leader in emission abatement through a partnership with the *West Arnhem Land Fire Abatement* (WALFA) project, the pioneer of the *Savannah Burning* abatement methodology. With a cumulative total abatement since inception of more than two million tonnes CO_2-e, WALFA is the second largest greenhouse gas offset program in Australia and has been the catalyst for more than 80 other similar projects across northern Australia[19].

It is an option available for air travel, where for a few extra dollars, the greenhouse gas emission created from an individual's travel can be offset. Some gas producers are already offering offsets as part of their services. For example, Origin sells a Green LPG product[20] that reduces the impact of LPG consumption on the environment through carbon offsetting.

AGL[21] will be offering carbon-neutral options on all its products from 2021. Internationally, Shell[22] delivered two cargoes of carbon neutral LNG in July 2019 to GS Energy and Tokyo Gas. Carbon credits from nature-based projects compensate in full the CO_2 emissions generated from exploring for and producing natural gas. These projects also have additional benefits such as creating income sources for local communities, improving soil productivity, cleaning air and water and maintaining and improving biodiversity.

While emissions from gas could be reduced to near-net-zero using the above actions, from a whole-of-economy viewpoint it may be more cost effective to use offsets for sectors that are more difficult to abate. For example, the use of a small amount of gas while camping may be more practical than using an alternative gaseous fuel such as hydrogen or using an electrical appliance. The emissions from the associated gas use could be offset through purchasing certificates in other parts of the economy, for example through reforestation.

It may not be practical to make capital investments to upgrade an industrial facility to use hydrogen and then make additional investments in producing the hydrogen and delivering it to site. A technical alternative to reaching net-zero would be to purchase certificates equal to the ongoing emissions from that industrial site. This would be most effective if underpinned by an international carbon market that would then direct capital to the lowest cost alternatives for reducing emissions, while being technology neutral.

19 See www.appea.com.au/wp-content/uploads/2020/06/Industry-Action-on-Emissions-Reduction.pdf for more information.

20 www.originenergy.com.au/for-home/lpg/lpg-plans/greenlpg.html#cq-gen462

21 www.agl.com.au/about-agl/media-centre/asx-and-media-releases/2020/june/agl-gets-on-with-the-business-of-transition-for-australias-energy-sector

22 www.shell.com/business-customers/trading-and-supply/trading/news-and-media-releases/tokyo-gas-and-gs-energy-to-receive-worlds-first-carbon-neutral-lng-cargoes-from-shell.html

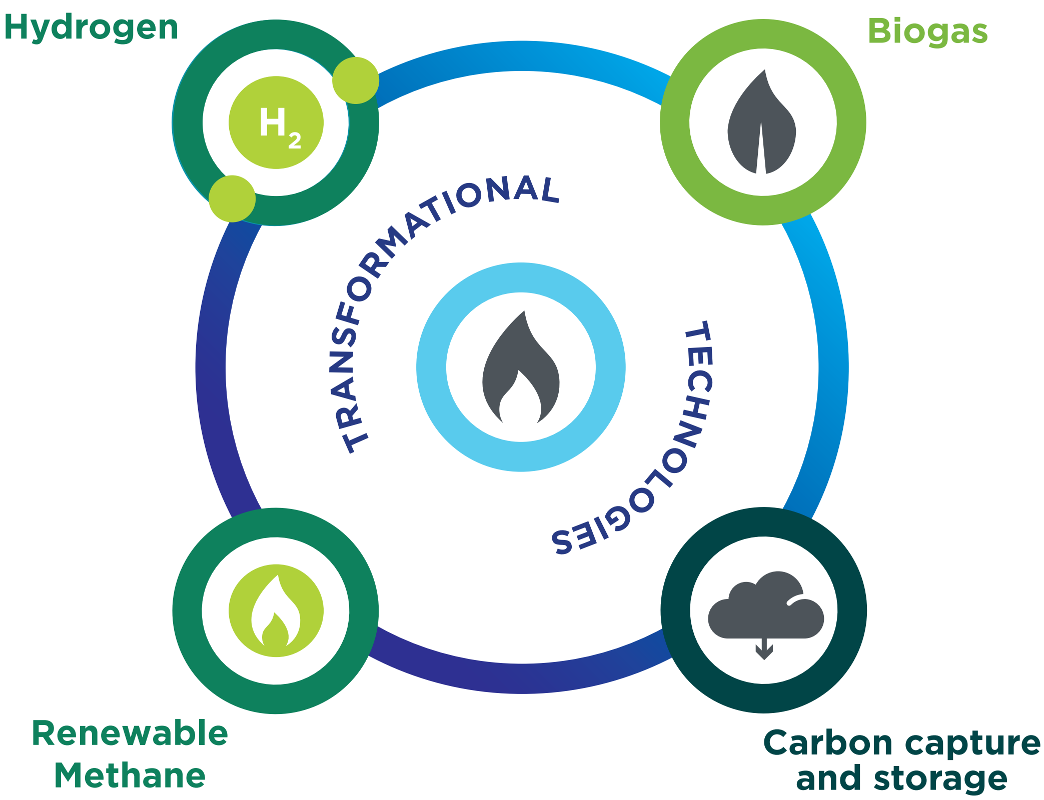
Lower emission alternatives

Fuel-switching has typically involved switching from coal to gas in industry or for power generation. Indeed, the US has been successful at reducing its emissions from power generation in the last few years by changing from coal to natural gas.

There are three options for reducing emissions from gas use:

- decarbonising the fuel, which could include transformational technologies such as:
  - applying carbon capture and storage (CCS) to gas use;
  - substituting natural gas (or using it as an input to the production of hydrogen) with hydrogen (either via electrolysis or steam methane reforming with CCS) to be used in networks;
  - use of bio-methane to supplement natural gas use; or
  - creation of renewable gas from hydrogen and atmospheric or biogenic CO_2;
- electrification of heating processes; or
- any combination of the above.

Figure 12: Integration of low emission transformational technologies with gas



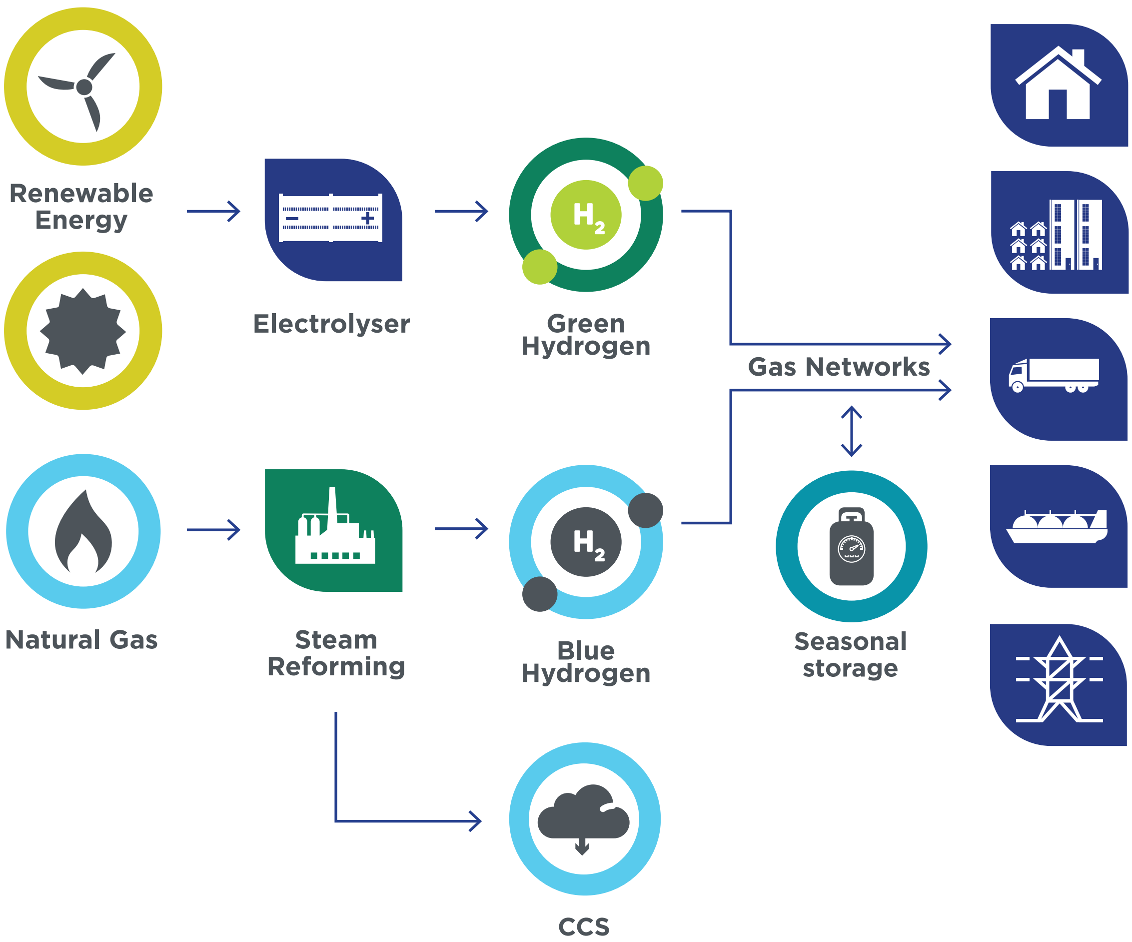
Decarbonising the Fuel

Gas Vision 2050 considers four transformational technologies to decarbonise the fuel: hydrogen, biogas, carbon capture and storage and renewable gas.

The combustion of hydrogen produces no greenhouse gas emissions. There have been waves of hydrogen development in recent history, mainly linked to the price of oil and concern about climate change[23]. However, it appears that the momentum in the current wave is larger and more applications for hydrogen are being considered.

Like natural gas, hydrogen is an odourless and colourless gas that burns in air to provide heat. This heat can be used in many applications like gas such as space heating. Hydrogen can also be reacted in a fuel-cell to produce both low-grade heat and electricity where the electricity can be used to power the grid or in vehicles. Hydrogen is also a feedstock that can be used by industry. Most gas that is used as feedstock today is converted to hydrogen (e.g. in oil refining or fertilizer production) so there are advantages to being able to use hydrogen directly. Some industries will need a hydrocarbon feedstock to produce plastics and materials so this may require an alternative source of feedstock.

Figure 13: Hydrogen production pathways



23 International Energy Agency (2019), The Future of Hydrogen

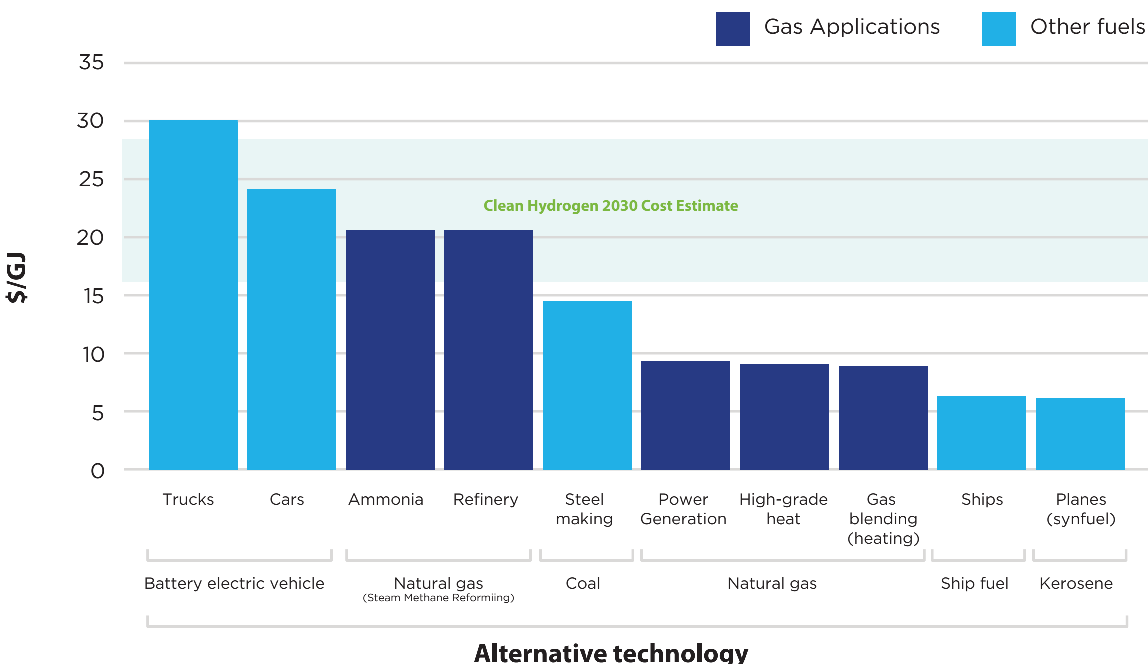
There are several ways hydrogen can be produced from either natural gas[24] or from electricity:

- Hydrogen can be produced from reacting natural gas with steam at high temperature and under pressure. This produces a mixture of steam, hydrogen and carbon dioxide, so the hydrogen needs to be separated from the other components before it can be used. This is already the world's most popular way to produce hydrogen. When the CO_2 is treated with CCS, the resulting hydrogen is called blue hydrogen.
- Hydrogen can be produced directly from applying an electric current to water. This splits the water into its elements of hydrogen and oxygen so once again, the hydrogen needs to be separated. When the electricity used for this process is renewable, the hydrogen that is produced is referred to as green hydrogen.
- There is also research underway[25] to produce hydrogen using photocatalytic reactions that may be more efficient than electrolysis.

There is a lot of momentum to develop a hydrogen industry in Australia. The Commonwealth Government produced a *National Hydrogen Strategy* in November 2019 and every state or territory has some sort of hydrogen strategy or interest. The focus is on capturing the possible export market while recognising the role hydrogen can also play to decarbonise the domestic economy by applying it to gas networks, for remote power, for mobility and as a feedstock to industry (e.g. green steel).

The Commonwealth Government[26] has set a target of achieving a production cost of hydrogen of $2 per/kg[27]. The *National Hydrogen Strategy*[28] illustrated that a range of options would become cost-competitive at this cost by 2030.

Figure 14: Breakeven cost of hydrogen against alternative technologies for major applications, in 2030



Source: COAG Energy Council (2019), Australia's national hydrogen strategy

24 Hydrogen can also be produced from other fossil fuels, but the majority of globally produced hydrogen is based on the natural gas pathway.
25 www.futurefuelscrc.com/research/future-fuel-technologies-systems-and-markets
26 Department of Industry, Science, Energy and Resources (2020), Technology Investment Roadmap Discussion Paper.
27 This equals $16.70/ GJ using the lower heating value of hydrogen, which is 120 MJ/ kg.
28 Council of Australian Government – Energy Council (2019), Australia's National Hydrogen Strategy

Further innovation will be needed to make hydrogen competitive with natural gas in networks beyond 2030.

The Hydrogen Council[29] showed that renewable hydrogen production costs can decrease by 60 per cent by 2030, driven by the reductions in capital costs for electrolysis plants and lower costs of renewable energy.

Hydrogen also provides an opportunity to decarbonise gas networks. Gas infrastructure businesses are actively leading hydrogen blending demonstration projects with more than $180 million allocated to projects located in WA, ACT, NSW and SA. Across these projects, more than 2 MW of renewable hydrogen capacity will be installed that will deliver renewable hydrogen to households. A further hydrogen blending project is planned for the City of Gladstone, QLD. These projects will:

» produce renewable hydrogen;
» demonstrate blending of hydrogen into gas distribution networks;
» trial hydrogen-blend appliances;
» engage with local communities on the role of hydrogen;
» evaluate the role of hydrogen as support to the electricity networks;
» demonstrate the role of hydrogen blends in industry; and
» demonstrate the use of hydrogen as a transport fuel.

The Australian Hydrogen Centre was established in early 2020 to develop feasibility studies on 10 per cent renewable hydrogen in the gas distribution networks of South Australia and Victoria and develop a pathway to make the transition to 100 per cent hydrogen networks.

The *National Hydrogen Strategy's* 10 per cent kick start project[30] identified no significant regulatory and technical barriers for blending up to 10 per cent hydrogen in gas distribution networks. This represents more than 15 PJ of hydrogen, requiring more than 500 MW of electrolyser capacity supported by renewable electricity from the grid.

Blending at higher volumes and conversion to 100 per cent hydrogen networks may require modification of end use appliances. A dedicated work program is being carried out at Future Fuels CRC to better understand how residential and industrial appliances perform with changing fuel mixes, starting with hydrogen blends and considering 100 per cent hydrogen.

On the export front, Australia's LNG export success story means the Australian gas industry has the technology, expertise and commercial and trade relationships to make hydrogen exports a reality. These skills mean Australia is well placed to capitalise on our already abundant natural advantage.

Hydrogen is already being produced overseas from LNG exported from Australia. Woodside Energy Ltd is the pioneer of the LNG industry in Australia and its experience in producing and exporting LNG, underpinned by strong customer relationships, positions it well for complementary opportunities in large-scale hydrogen[31]. In June 2018, Woodside signed a non-binding memorandum of understanding with Korea Gas Corporation to cooperate on hydrogen opportunities, and with Pusan National University in South Korea to jointly explore technology applications across the hydrogen value chain. In March 2020, Woodside also signed an agreement with Japanese companies JERA Inc, Marubeni Corporation and IHI Corporation to undertake a joint study examining the large-scale export of hydrogen as ammonia for use in decarbonising coal-fired power generation in Japan.

Governments are backing hydrogen projects. The Commonwealth government has allocated a further $370 million towards scaling up hydrogen electrolysis projects and all states and territories are also making funding available to advance hydrogen. Both NSW and WA have set an aspirational 10 per cent hydrogen blending target in their gas networks.

29 Hydrogen Council (2020), Path to hydrogen competitiveness – a cost perspective
30 COAG Energy Council (2019), Hydrogen in the gas distribution networks – a report by FFCRC, GPA Engineering and the SA Government
31 www.woodside.com.au/innovation/hydrogen

BOX 8: Hydrogen ready appliances

Existing natural gas appliances can accept a proportion of hydrogen in the gas mix. This proportion varies by the type of appliance.

It has already been demonstrated in Australia that hydrogen can be successfully used as a fuel in relatively simple appliances such as barbecues.

Work on developing and demonstrating more complex appliances such as residential and commercial hydrogen heating, cooking and hot water appliances is being carried out overseas through the £25 million Hy4Heat program supported by the UK's Department for Business, Energy & Industrial Strategy.

While the results of Hy4Heat will be informative, they may have limited application to Australia given the unique nature of the Australian market for such appliances in terms of construction practices, climate and end use. Nevertheless, Australian gas appliance manufacturers have a long history of developing appliances for specific gaseous fuels and are confident in their ability to develop appliances dedicated for operation on specific mixtures of natural gas and hydrogen or 100 per cent hydrogen that are suited to the unique requirements of the Australian market.

Australian appliance manufacturers are working collaboratively with other industry and government stakeholders to establish certainty around timings, scale and necessary financial support so that Australia can fully leverage this opportunity.

Source: Hy4Heat, https://www.hy4heat.info

Use of bio-methane to supplement gas use

Bioenergy is already used in Australia to produce heat, electricity and as a transport fuel.

In 2018, bioenergy generated 3,412 GWh of Australia's electricity (or 1.5 per cent of the total[32]). This electricity was generated using a range of solid biomass and biogas from landfills or anaerobic digestors and was financially supported through *Renewable Energy Target* certificates. These plants generally use combined heating and power technology to provide local heating to industrial sites, and then to export the electricity to benefit from the renewable electricity incentives.

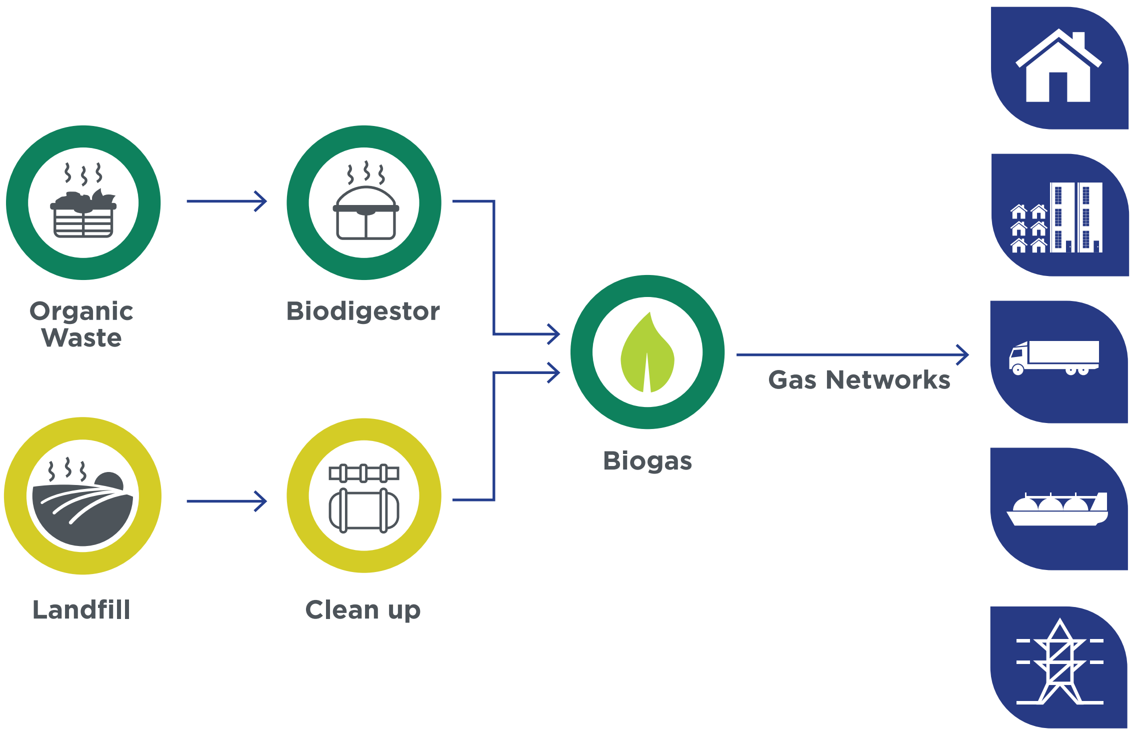
Bioenergy is also already widely used in transport where renewable biofuels are blended with either diesel or petroleum fuels.

This fuel is generally sourced from specific energy crops and the programs are supported by state legislation mandating different proportions of biofuel in the fuel mix.

Biogas is a form of bioenergy that can be used to decarbonise gas. It can utilise a range of feedstocks and different processes. The produced biogas needs to be upgraded to bio-methane before it can be used as natural gas.

Bio-methane provides opportunities to decarbonise gas. The IEA Bioenergy Taskforce[33] noted that there were more than 14,000 biogas production projects in the world, with Germany clearly leading with about 10,000 projects. Most of these projects produce heat and electricity with more than 500 projects including an upgrade to biomethane so that the gas can be injected into the network (e.g. UK, France and Denmark), or for use as vehicle fuel (e.g. Sweden and Germany).

Figure 15: Bio-methane production pathways



32 Clean Energy Council (2019), Clean Energy Australia Report 2019, pg 9
33 IEA Bioenergy Task 37 (2019), Country Report Summaries 2019, pg 6

Deloitte Access Economics[34] estimated that bio-methane potential from urban waste, livestock residue (animal manure) and food processing residue could provide 14 per cent of the energy of gas supplied via Australia's distribution networks. This proportion increased to 102 per cent when agricultural crop residues were included.

When biogas is produced, it is generally a low-quality gas that can easily be converted to electricity using engines. Alternatively, the quality of the gas could be improved to meet network gas specification, allowing this biogas to be blended in networks as bio-methane. The cost of producing bio-methane is highly dependent on the feedstock and the process used, with the lowest cost option being the collection of gas from landfills. Cropping and livestock residue provides a significant opportunity to provide bio-methane but requires additional effort to collect the waste stream.

The production cost by itself does not necessarily drive the economics of a bio-methane facility as other costs and revenues also need to be considered such as:

» generation of green energy certificates, feed-in tariffs or other incentives;
» grants;
» cost of upgrading the gas to meet network specifications;
» avoidance of waste disposal fees; and
» sale of other products such as compost from the facility.

Biogas – after being upgraded to network quality – is a direct low carbon option for gas in networks. Existing gas infrastructure and industrial and household appliances can continue to be used as biogas is chemically the same as natural gas. It will also have the same heating value so gas meters will still accurately measure gas consumption.

Combining this with carbon capture and storage at an industrial scale biogas facility would mean that the CO_2 emissions could be captured and stored underground. This process could provide a means for negative greenhouse gas emissions. Examples of this application are already happening at an ethanol facility[35] in the US, where up to one million tonnes of produced CO_2 from ethanol manufacturing is captured and stored in a dedicated geological storage site.

Industry is actively involved in the development of projects to blend bio-methane into networks. Individual network businesses are working with landfill operators, wastewater operators, other members of the bioenergy sector and funding agencies. The Commonwealth Government recently announced that it is developing a *Bioenergy Roadmap* for Australia.

34 Deloitte Access Economics (2017), Decarbonising Australia's gas distribution networks, pg 45

35 Global CCS Institute (2019), Bioenergy and Carbon Capture and Storage – a perspective by Chris Consoli, available from www.globalccsinstitute.com

BioLPG

LPG is described as hydrocarbon mixtures in which the main components are propane and butane. Bio Liquefied Petroleum Gas (BioLPG) is any of the above that is from a 'biological' source, rather than a 'fossil' source. BioLPG was launched in 2018, mainly produced as a by-product of renewable diesel/renewable jet fuel, via hydrotreated vegetable oil technology.

Since then, it has gained significant interest around the world with global production of BioLPG today at about 200 kilotonnes/year, just under 0.1 per cent of all LPG production. However, it is estimated[36] that if "advanced chemical processes are commercialised to process cellulosics and mixed waste feedstocks, and if bio-oil hydrotreating is maximised, enough BioLPG could be produced in 2030-2050 to cover up to one third of global LPG production".

BioLPG has the same chemical composition as conventional LPG. This means it can be injected and stored in LPG distribution or transmission networks or in cylinders and used as a transportable gaseous fuel in areas where the gas network does not extend. This effectively provides renewable energy on demand.

Internationally there have been examples of BioLPG being used by residential and commercial consumers substituting LPG while continuing to utilise existing infrastructure. For example, in 2018 Calor Gas Ltd, the United Kingdom's (UK) leading supplier of LPG, began supplying BioLPG to homes and businesses across the UK. This is vital for the estimated 400,000 homes and businesses that rely on distributed power generation and are increasingly difficult to decarbonise.

The future of BioLPG in Australia is dependent on the correct policy settings to support its production, along with other incentives such as tax rebates or subsidies and recognition of the broader environmental benefits of renewable gas fuels.

36 Atlantic Consulting (2018) 'BioLPG the Renewable Future', World LPG Association, www.wlpga.org/wp-content/uploads/2018/10/BioLPG-The-Renewable-Future-2018.pdf

Applying carbon capture and storage (CCS) to gas use

CCS involves large volumes of captured CO_2 being safely injected and stored deep underground rather than released to the atmosphere. An alternative is carbon capture, use and storage (CCUS) where the CO_2 that has been captured is used in an industrial process to make a product, preventing the emissions from being released.

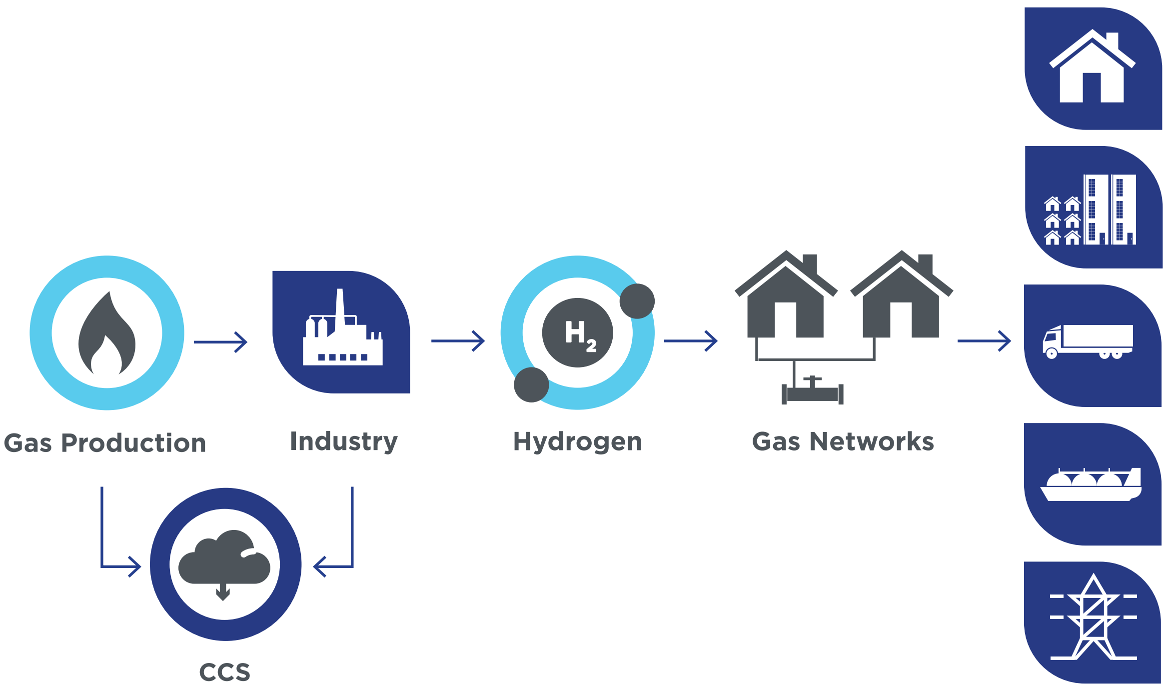
The early days of CCS focussed on its potential role to reduce emissions from coal fired power generation. The focus in recent years has broadened to different sectors including gas processing, hydrogen production and industry.

CCS is well established as a safe, large scale, permanent abatement solution. In 2019, the number of large-scale CCS facilities reached 51[37]. Those in operation and construction have the capacity to capture and permanently store about 40 million tonnes of CO_2 every year. This is expected to increase by another million tonnes in the next 12 to 18 months.

When all the current projects reach maturity, more than 100 million tonnes of CO_2 will be permanently stored each year. In addition, there are 39 pilot and demonstration scale CCS facilities operating or about to be commissioned and nine CCS technology test centres[38].

Since 1996, the global oil and gas industry has led the world in the practical deployment of this technology. For example, Equinor is operating large projects alongside its Sleipner and Snøhvit gas processing operations in offshore Norway[39] and in Canada, Shell has developed the Quest CCS project[40].

Figure 16: Applying carbon capture and storage to gas use



37 Global Carbon Capture and Storage Institute (2020), Global Status of CCS 2019,

38 Global Carbon Capture and Storage Institute (2020), “Global CCS Institute welcomes the 20th and 21st large-scale CCS facilities into operation”, Media Release, 3 June

39 www.equinor.com/en/what-we-do/carbon-capture-and-storage.html

40 www.shell.ca/en_ca/about-us/projects-and-sites/quest-carbon-capture-and-storage-project.html

In Australia, the oil and gas industry has been at the leading edge of researching and deploying greenhouse gas storage technologies. The industry instigated significant research efforts into greenhouse gas storage in the late 1990s through the Australian Petroleum Cooperative Research Centre which undertook the first assessments of possible storage sites across Australia. Several years later that work was continued by CO2CRC Limited.

The CO2CRC is recognised as one of the world's leading collaborative research organisations focused on carbon capture and storage and continues to receive significant backing from the Australian oil and gas industry.

The Australian industry has invested several hundred million dollars undertaking detailed storage site and project scoping assessments in the Perth, Carnarvon, Browse, Bonaparte and Cooper Basins as well as assisting other organisations to undertake storage site assessments in the Gippsland and Perth Basins.

CCS is a transformational technology that can be used to decarbonise the direct use of natural gas at industrial scale including gas processing, power generation and manufacturing.

BOX 9: CCS at industrial scale in Australia

Gorgon Carbon Dioxide Injection Project

The Gorgon Project on WA's Barrow Island, operated by Chevron, includes the Gorgon Carbon Dioxide Injection Project, the safe underground injection and storage of between 3.4 to 4.0 million tonnes CO_2-e greenhouse gases per year, or about 100 million tonnes over the life of the project[41].

The Gorgon Carbon Dioxide Injection Project is the biggest greenhouse gas mitigation project undertaken by industry in the world. The Gorgon Project is itself one of the world's largest LNG projects and the biggest single resource project in Australia's history.

In addition to assessing potential storage sites, the Australian oil and gas industry has played a pivotal role in the development of legislative and regulatory regimes to enable the technology to be deployed. The legislation enabling the Gorgon Carbon Dioxide Injection Project is believed to be the world's first storage specific legislation and the project was the first large-scale development to have its environmental impact assessed under State and Federal environmental laws.

The experience at Gorgon was subsequently used to help develop the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* and continues to be a test case for regulatory developments in other areas such as the reporting of storage site emissions.

41 australia.chevron.com/our-businesses/gorgon-project

BOX 9: CCS at industrial scale in Australia (continued)

Santos CO_2 capture

Santos has entered front end engineering design (FEED) for the Moomba CCS project.

The project proposes to capture the 1.7 million tonnes of CO_2 currently separated from natural gas at the Moomba gas processing plant each year and to reinject it into the same geological formations that have safely and permanently held oil and gas in place for tens of millions of years.

The CO_2 would be compressed, dehydrated (removing any water) and transported to a target field nearby for injection. Santos is collaborating with experts including Occidental Petroleum, which has world-leading operational expertise in CO_2 injection in the United States.

In 2020, Santos will complete the design phase and be ready to make a final investment decision (FID), subject to the required Government policy being in place. CO_2 injection could commence from as early as 2022.

With the right policy settings to accelerate CCS deployment, the Cooper Basin could become a large-scale, commercial CCS hub capturing emissions not only from oil and gas, but from other industries such as power generation, steel, cement and chemicals.

Source: Chevron Australia (2019), Australian Petroleum Production & Exploration Association (2020)

Creation of renewable gas from hydrogen and atmospheric or biogenic CO_2

Renewable gas can also be created from reacting hydrogen with atmospheric or biogenic CO_2.

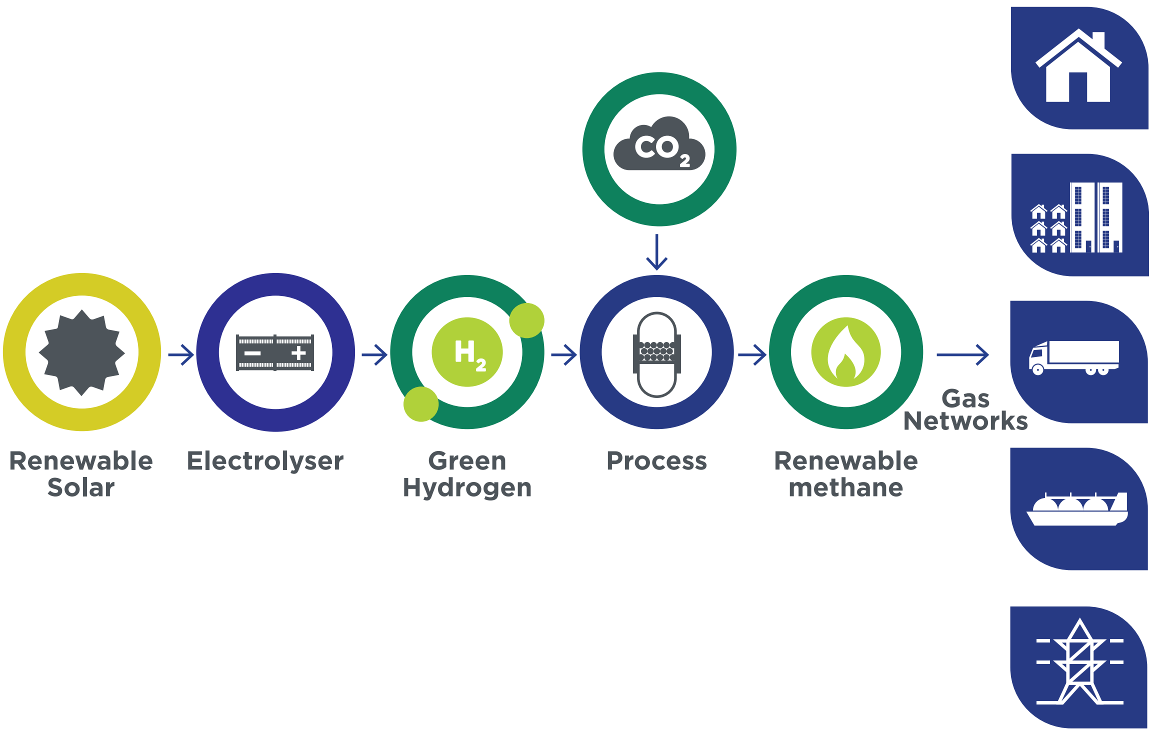
The Sabatier[42] process can be used to convert hydrogen into methane. Similar approaches can also be used to convert hydrogen into methanol and other fuels. The conversion efficiency of these reactions is currently low and consequently, the fuel produced is expensive.

Like biomethane, renewable methane is carbon neutral but chemically the same as natural gas. A major advantage of this is that all the downstream infrastructure and appliances can continue to be used without modifications.

APA Group is working with Southern Green Gas on the Wallumbilla Renewable *Methane Demonstration Project* in southern Queensland. The process used in this project combines renewable hydrogen, made from water and solar energy, with CO_2 extracted from the air. The aim of the project is to demonstrate the technical and commercial benefits of an integrated hydrogen electrolysis (from solar electricity) and renewable methane production system. It will generate cost and technical data to be used to assess the feasibility of larger, commercial scale, renewable methane production for use in the existing east coast gas grid.

The $2.2 million project will comprise one production module. The Australian Renewable Energy Agency (ARENA) is contributing $1.1 million in grant funding to the project under its Advancing Renewables Program.

Figure 17: Renewable gas production pathway



42 The Sabatier process involves the reaction of hydrogen with carbon dioxide at elevated temperatures and pressures in the presence of a catalyst to produce methane and water.

Electrification of heating processes

Gas is generally used to generate heat and as an industrial feedstock. Some of these uses could be electrified and if the electricity is from renewable sources, it will result in lower emissions.

Emission reduction in some residential uses may be achieved with heat pump technologies. The emissions advantage from electrification is based on the potential high efficiencies of heat pumps but is highly dependent on the ambient conditions and the emission intensity of electricity generation. Heat pumps may also be applied to industrial applications up to temperatures of about 150°C.

Higher temperatures can be achieved from electrification by concentrating solar thermal or with electrical technologies such as electrical resistance heating, electric arc furnaces and induction furnaces[43]. However, very high temperatures (>1,300°C) and chemical feedstock will still require a gaseous fuel source.

Electrification will increase the load on the electricity generation, transmission and distribution networks, especially during peak times when gas is currently used to provide heat. These systems costs are generally not considered by electrification advocates. The real cost competitiveness and effectiveness of electrification options to replace gas requires a total energy system to be considered.

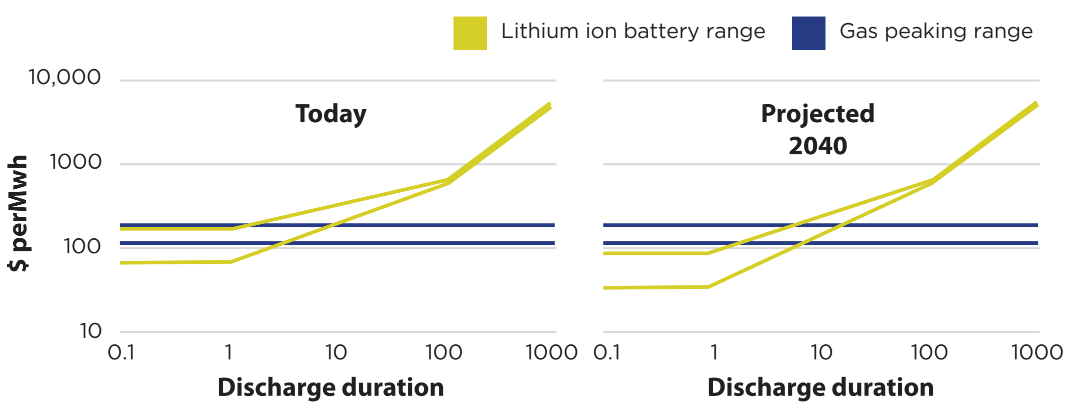
BOX 10: Comparison of storage technology

Cost of storage

Energy storage is inherent in energy infrastructure. The growing levels of intermittent renewable electricity generation are increasing the need for energy storage to provide support. While there are a range of complementary storage solutions available, many of these have certain applications, for example short term battery storage to balance out daily variations in solar PV output or longer term storage for overcast days.

Analysis provided by the International Gas Union indicates that using gas peakers continues to provide a lower cost option for durations greater than 10 hours of electricity generation. Hence gas peakers provide a perfect back-up solution to variable renewables.

Figure 18: Comparison of storage technology costs



Source: International Gas Union (2020), Gas Technology and Innovation for a Sustainable Future

43 Frontier Economics (2020), value of gas infrastructure, pg 28.

Decarbonising using gas and gas infrastructure

Frontier Economics[44] completed a study to investigate and evaluate options of the roles of gas and gas infrastructure to achieve a net-zero economy by 2050. The study focused on ongoing capital and operating costs in 2050 assuming a transition to a decarbonised economy was made by then.

A *base case* was established where electricity supply was assumed to be net-zero emissions in 2050. This was based on cost assumptions by AEMO and reflects that many states and territories have established net-zero emission targets for electricity by 2050. It is expected there will still be a role for gas power generation to support electricity supply at that point but that these emissions would be offset through other parts of the economy or by using decarbonised gas.

The *base case* assumed that unabated gas will continue to be supplied to end customers (including residential, commercial and industrial).

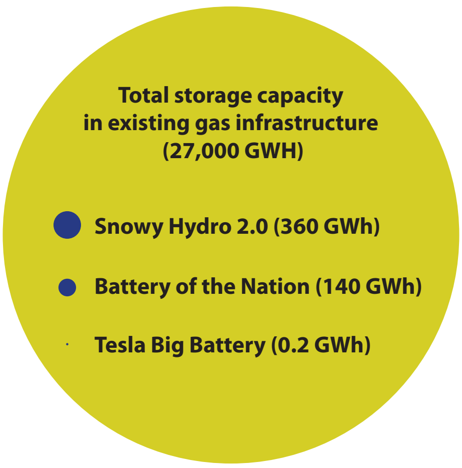
Scenarios adopting decarbonisation options for gas were developed and analysed to achieve net-zero emissions from the combined gas and electricity sectors. These scenarios are in many ways simplifications of the future energy system but are useful representations to compare different technology options. The scenarios are illustrated in Figure 20.

BOX 11: Interseasonal storage

Gas infrastructure also provides massive underground energy storage. This is essential – especially in colder climates - to meet seasonal heating demand for gas, which show that gas consumption during winter is multiple times that during summer.

The existing gas storage capacity represents 27,000 GWh, or an equivalent of 77 Snowy Hydro 2.0 scheme. This storage infrastructure, pipelines and networks are already in place and have been designed to meet heating load. Determining how this gas storage capacity can be used for hydrogen storage is being assessed by the FFCRC.[45]

Figure 19: Comparison of storage technology costs

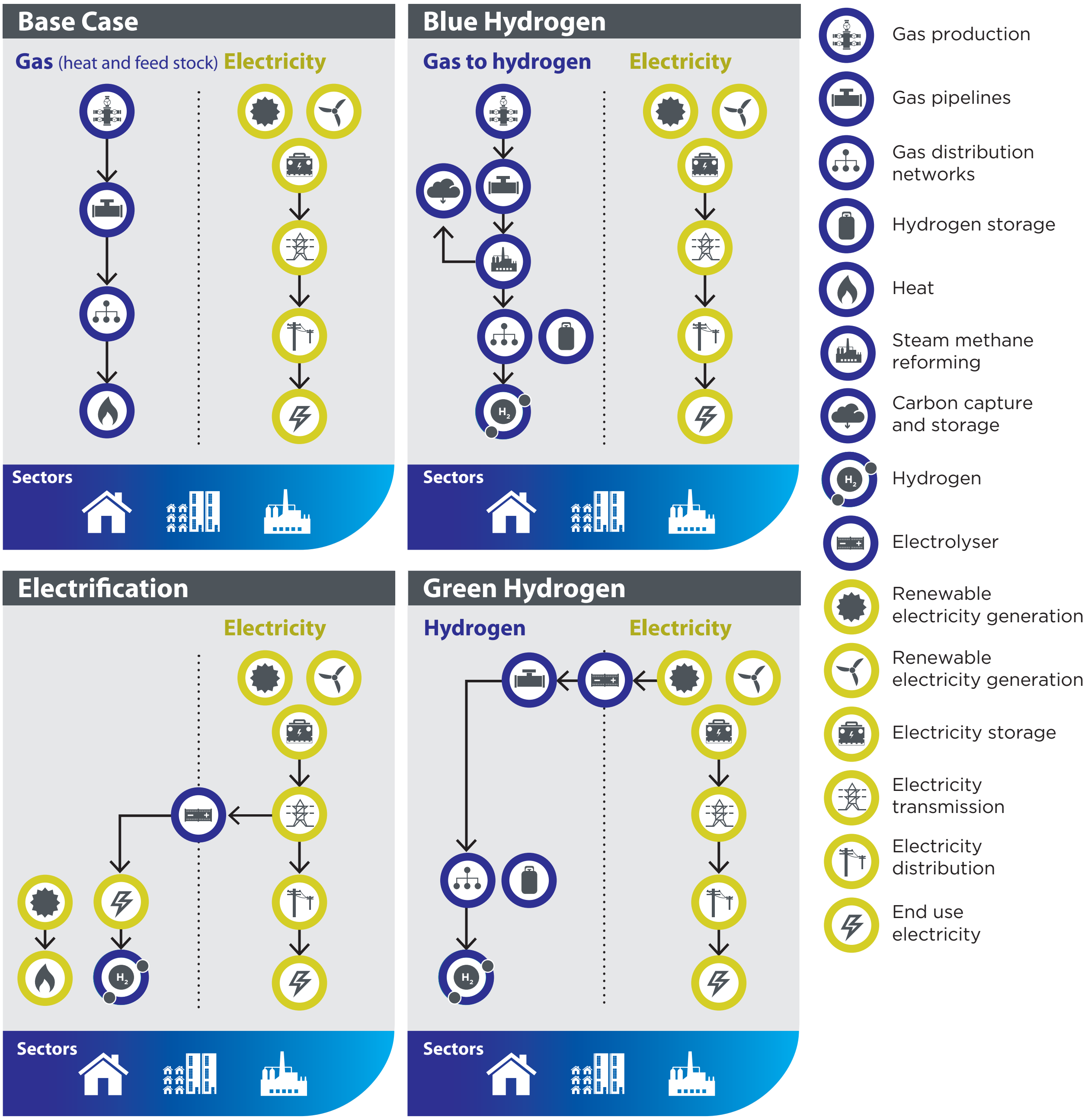


Source: Jemena submission in response to Australia's Technology Investment Roadmap: discussion paper, 23 June 2020.

44 Frontier Economics (2020), The Benefits of Gas Infrastructure to Decarbonise Australia, available from www.energynetworks.com.au/gas-vision-2050

45 Jemena (2020), Response to Australia's Technology Investment Roadmap: discussion paper, 23 June 2020.

Figure 20: Net-zero emission scenarios



Source: Frontier Economics (2020), Energy Networks Australia analysis (2020)

Gas forecast in Base case

Frontier Economics provided an outlook for natural gas demand out to 2050, based on AEMO forecasting data. This demonstrates growing gas demand to provide heat for homes, businesses and industry and provide feedstock to industry.[46]

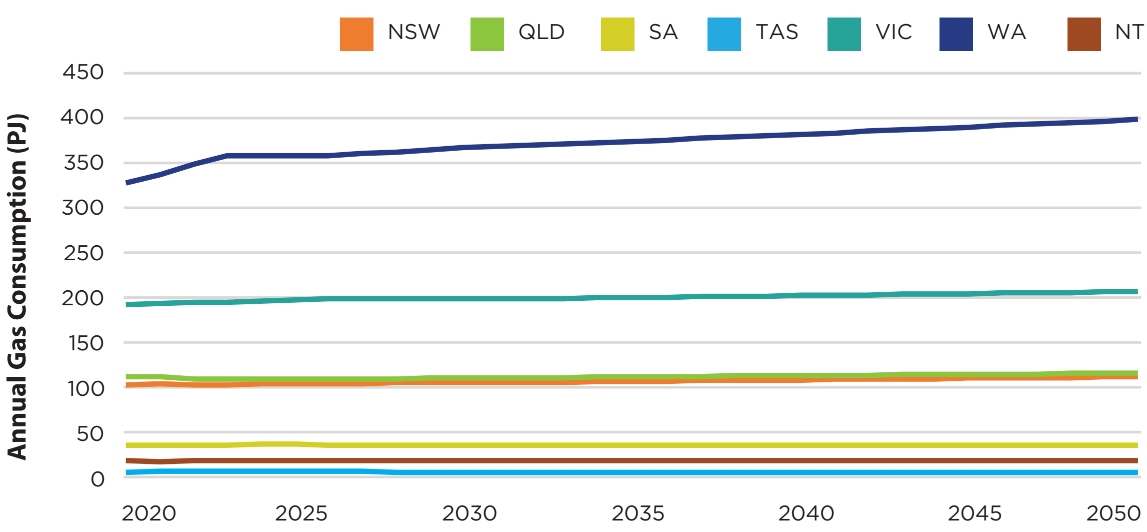
The seasonal variation of gas consumption was considered as that impacts on the amount of gas storage required. As gas is used as a source of heat energy and as a feedstock, the different end uses of gas, especially in industry, were also considered. The infrastructure and fuel supply costs change from the *base case* was calculated across both the gas and electricity supply chains for each of the scenarios. This calculation produced a net cost change from the *base case*.

The transition pathways costs were excluded. It was assumed that any transition required would have occurred by 2050. Moreover, there are a many possible transition paths and many of those will be influenced by policy settings.

For example, policy settings requiring a faster trajectory to decarbonise a sector of the economy will bring costs forward compared with a policy setting where a more gradual trajectory is supported to reach the same 2050 objective. Those policy settings could also influence the energy mix. Nevertheless, for a specified energy mix – which has been assumed in the *scenarios* – the ongoing capital and operating costs from 2050 onwards should not change.

Building on the *base case*, three different scenarios for decarbonising gas were analysed. Each of these scenarios resulted in net-zero emissions from the combined gas and electricity sectors. The scenarios represent different roles of gas, and gas and electricity infrastructure to meet the same greenhouse gas outcome, that is, zero emissions by 2050.

Figure 21: Gas forecast in the base case



46 Source: Frontier Economics, 2020

Blue hydrogen

The first scenario considered the use of natural gas to produce hydrogen to replace the end use of gas. In this scenario, natural gas will be reacted with steam to form hydrogen and the resultant CO_2 will be captured and stored using carbon capture and storage resulting in a decarbonised fuel. This process is more commonly referred to as blue hydrogen. More natural gas will be required in this scenario to compensate for the conversion efficiency to hydrogen.

Transmission pipelines will continue to be used to provide gas to gas reforming plants, which were assumed to be near the injection points to distribution networks. The hydrogen will then be supplied to networks where it will be delivered to customers. By 2050, when network businesses will complete their mains replacement programs, most of Australia's gas distribution networks will comprise hydrogen compatible materials.

The costs of additional infrastructure needed for CO_2 sequestration were included in the cost for CO_2 storage.

It was assumed that hydrogen produced from natural gas can also replace the direct use of natural gas as a chemical feedstock in industry. This is indeed favourable in processes such as ammonia production where natural gas is typically used to produce hydrogen, which is subsequently used to produce ammonia and fertiliser. In other processes such as plastics manufacturing, supplying hydrogen directly is a simplifying assumption made in all scenarios, and hence any adjustments to provide a different feedstock to these industries would not change between scenarios. For example, the production of plastics needs hydrocarbons as a feedstock, not just hydrogen. For these industrial facilities, those hydrocarbons could be provided through direct delivery of natural gas or LPG with carbon offsets, or via locally produced biogas. The answer is unclear at this stage, but the same issue arises in each of the scenarios, so it will not affect the difference between scenarios.

Green hydrogen

The second scenario considered the production of hydrogen from electrolysis powered by renewable electricity, commonly known as green hydrogen.

This scenario avoids the costs of gas supply as electricity is used to create the hydrogen.

The amount of electricity required to produce a given amount of hydrogen using electrolysis was determined from the gas supply (in PJ) in the *base case* and the efficiency of electrolysers. The cost of electricity is expected to be the largest cost component of hydrogen production in 2050. For this reason, the capacity of hydrogen electrolysers and hydrogen storage are assumed to be sized to take advantage of cheap electricity costs. In other words, the focus of hydrogen production (and storage) aimed to minimise the electricity costs.

Renewable generation and hydrogen production is assumed to occur in the renewable energy zones identified by AEMO. The hydrogen will be transported to industrial customers and the injection points on distribution networks via a new hydrogen transmission pipeline network.

The cost of electricity is expected to be the largest cost component of hydrogen production in 2050.

Electrification

The third scenario reflects a common policy proposal by renewable energy advocates which is to electrify the entire gas load, replacing consumption of gas by end-users with direct use of electricity.

This scenario avoids the costs of gas supply and infrastructure.

This scenario is more complicated as the options that are available to switch to electricity vary by customer and end use, and that for some appliances or uses there are differences in efficiency, which needs to be accounted for in determining electricity consumption.

One of the difficulties in this scenario was to identify electrification options for the category of very high temperature processes and feedstock options required by industry. There is uncertainty about the practicality of switching high temperature heat sources for industry to grid-sourced electricity. In some applications, the use of concentrating solar thermal was included to achieve the temperatures required.

One of the limitations of the electrification option is that renewable electricity cannot replace chemical feedstocks. As the purpose of electrification is to avoid the use of gas networks, an alternative option had to be included to provide this feedstock. It was assumed that this feedstock, in the form of renewable hydrogen (the same amount – in energy - as per the other two scenarios) would be produced through on-site electrolysers powered by distributed electricity.

A note on scenario simplifications

Hydrogen was used as a proxy for renewable gas in the scenarios. Biogas, BioLPG and renewable methane are also options that could be considered in 2050. Including these other gases in the scenarios would increase the complexity of the modelling task as the cost and availability of those fuels would differ significantly by region due to the availability of biomass and the variability in biogas production processes.

In future, it is expected that a diversity of fuels will contribute to decarbonisation and that the cheapest cost options would be developed.

The use of existing transmission gas pipelines was limited to transporting gas in the *blue hydrogen* scenario. Additional value could be created from transmission pipelines if they were to be repurposed for hydrogen transport over long distances.

The Frontier Economics study did not include the role of gas transmission pipelines for hydrogen transport to reflect the recommendations for further work expressed in the *National Hydrogen Strategy* in relation to hydrogen blends in existing pipelines. Instead, Frontier Economics developed a new hypothetical hydrogen transmission network connecting renewable energy generation sites to hydrogen demand centres. This network is around 9 per cent longer than the current onshore gas transmission network.

It should be noted that hydrogen pipelines are already in operation globally[47] and that the repurposing of existing pipelines is a major focus for the industry supported by the Future Fuels CRC.

Pipelines are known to be able to transport higher levels of energy per unit capital cost compared with electricity transmission lines and offer inherent and considerable energy storage capacity.

47 Source: www.energy.gov/eere/fuelcells/hydrogen-pipelines

Modelling outcomes

The modeling showed that each of the net-zero emissions scenarios by 2050 can be achieved, although entail additional costs compared with the *base case*, where unabated gas continued to be used.

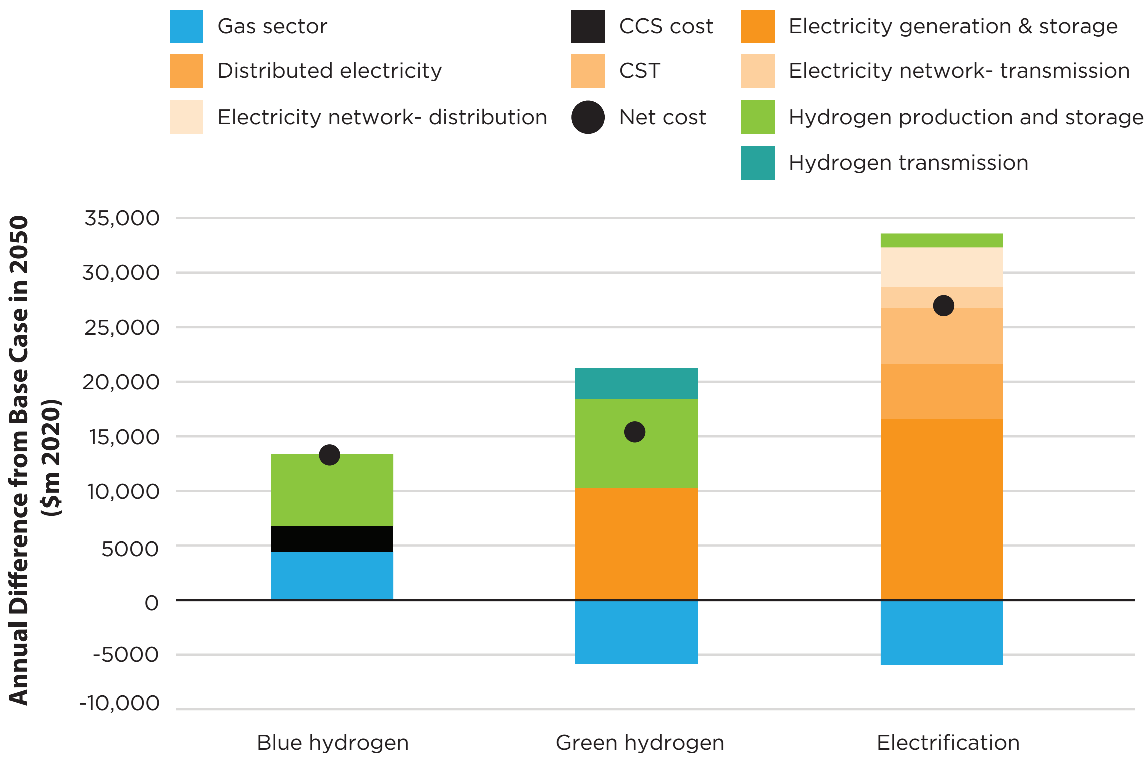
The modeling also demonstrated that gaseous fuels are essential as industrial feedstock in all the scenarios. Some industries, such as mineral processing and chemical manufacture, cannot operate without these fuels, and the electrification scenarios required new infrastructure to deliver this feedstock, through localised hydrogen production.

The net costs of the scenarios – compared with the *base case* – are shown in Figure 22.

The results of the modelling showed:

- The **blue hydrogen** scenario is lowest cost at a net increase of $13.3 billion compared with the *base case*. This difference reflects that more gas is used in this scenario and extra costs for CCS. The ongoing use of the gas transmission and distribution networks means there are no additional costs for upgrades for electricity generation and the electricity transmission and distribution networks.
- The **green hydrogen** scenario is more costly at a net increase of $15.3 billion compared with the *base case*. Compared with the *base case* and the *blue hydrogen* scenario, there are additional costs of electricity production, hydrogen production and storage and hydrogen transmission. Ongoing use of the gas distribution networks in this scenario means that there are no additional costs of electricity distribution in this scenario.

Figure 22: Net costs of decarbonising gas by scenario



Source: Frontier Economics (2020)

- The most-costly scenario is **electrification** at a net increase of $27.5 billion compared with the *base case*. Like the *green hydrogen* scenario, there are savings in the cost of gas supply but additional costs for electricity generation, storage, transmission and distribution. This scenario also incurs costs for hydrogen production to provide feedstock to industrial processes.

The major conclusions from this scenario analysis are:

- Net-zero emissions can be reached with hydrogen at half the cost of electrification.
- Making continued use of existing assets to deliver energy, such as the existing gas transmission and distribution network, can help avoid the material costs of investing in new assets to deliver energy, such as augmentation of the electricity transmission and distribution networks.
- The finding that the *blue* and *green hydrogen* scenarios are lower cost than the *electrification* scenario suggests there is value in continuing to make use of Australia's gas infrastructure and Australia's natural gas resources to deliver gaseous fuels to end-use customers.
- This finding also suggests that policies to achieve net-zero emissions should be broad-based and not focus solely on promoting the electrification of all stationary energy end use.
- There is significant uncertainty about technological developments and costs over the period to 2050. This means that the actual costs of the scenarios will change over time as technological improvements occur and new options become available.

Details of the Frontier Economics study are available on the Energy Networks Australia website.

BOX 12: Services provided by gas infrastructure

Between the wellhead and the meter, gas pipelines and networks do more than just transport gas. Here we explain some of the other services provided.

Daily storage to balance supply and demand

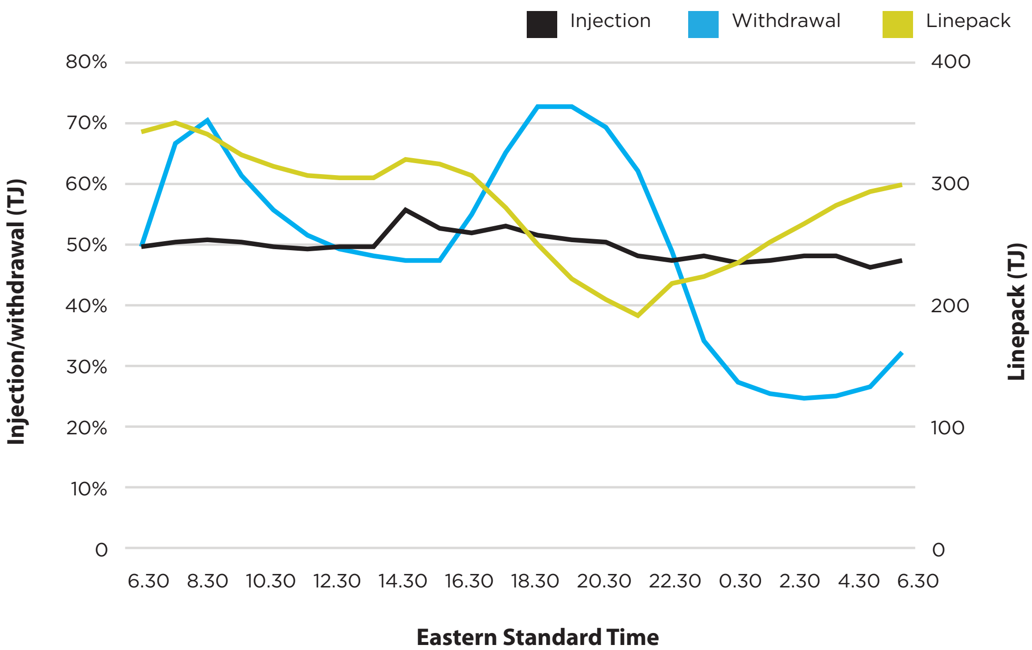
Gas demand varies throughout the day while hourly gas production is relatively constant. Demand during the day can fluctuate balmost 200 per cent between the minimum and maximum demand with the upper range occurring during winter when residential space heating is used – hence a peak in the morning about 7am and a second peak in the evening about 6pm. Gas is stored under pressure in networks and pipelines and this pressure is reduced at the meter into the house.

Storing gas under pressure provides energy storage referred to as 'linepack'.

For distribution networks, the amount of linepack equals a few days of gas demand while for pipelines the linepack represents weeks of demand. This built-in storage capacity allows a constant supply of gas to be produced and injected into the network while drawing out variable amounts throughout the day to meet demand.

As shown by data from AEMO, during peak demand line pack decreases but this recovers through constant injections throughout the day, meaning that the linepack at the start of the day and the end of the day are the same.

Figure 23: Injections, withdrawals and system linepack of gas infrastructure



Source: AEMO (2013), *Technical Guide To The Victorian declared Wholesale Gas Market*

BOX 12: Services provided by gas infrastructure (Continued)

Bidirectional flow

An area of pipeline innovation in the past decade was investment in bi-directional pipelines. These capital investments have transformed most of the gas transmission pipelines into bi-directional pipelines, allowing gas to flow in both directions in the pipeline, providing gas consumers with greater flexibility in terms of contracting and trading. Traditionally, long transmission pipelines have linked remote gas production basins with a demand centre such as a manufacturer or city – necessitating only a one-way flow of gas. In recent years, there has been a proliferation of linkages between major pipeline networks and these now provide pipeline operators with the ability to redirect gas flows in response to regional shortages or excess supply.

Renewable gas blending

Biomethane produced from landfill gas or wastewater treatment is chemically compatible with natural gas. Blending this gas into pipelines will provide a product with lower greenhouse gas emissions. Existing pipelines, networks and appliances can all continue to operate safely and efficiently with blending biomethane.

Blends of hydrogen are also possible with a 10 per cent blend target providing a commercial driver for hydrogen production. This is an important steppingstone to reaching pure hydrogen networks.

Capacity trading

Pipeline capacity refers to the right to transport gas through a transmission pipeline. The users of gas transportation services (known as "shippers") buy capacity on transmission pipelines to have gas transported from producers to end-users. These capacity rights are tradeable; market participants can transfer pipeline capacity held by one shipper who no longer requires it, to another shipper who does.

Capacity trading services in the east coast market were centralised and enhanced in March 2019 when a voluntary capacity trading platform (CTP) and a mandatory day-ahead auction (DAA) of contracted but un-nominated capacity were launched by AEMO. The CTP is a voluntary market where shippers can sell any contracted capacity they don't plan to use. The DAA is a mandatory auction for any remaining contracted but "un-nominated" capacity, enabling other shippers to procure residual capacity on a day-ahead basis after nomination cut-off, with a zero-reserve price.

The purpose of the CTP and DAA was to provide market participants with greater access to pipeline capacity. Source: Australian Pipelines and Gas Association, Energy Networks Analysis (2020)

Delivering on the Vision

As illustrated in earlier sections, gas plays essential roles to Australia's economy. These roles will still need to be fulfilled in a future decarbonised economy. There are several transformational technologies available to decarbonise gas by 2050. Much work needs to be done and prioritising activity in the next decade to achieve the longer-term objective is essential.

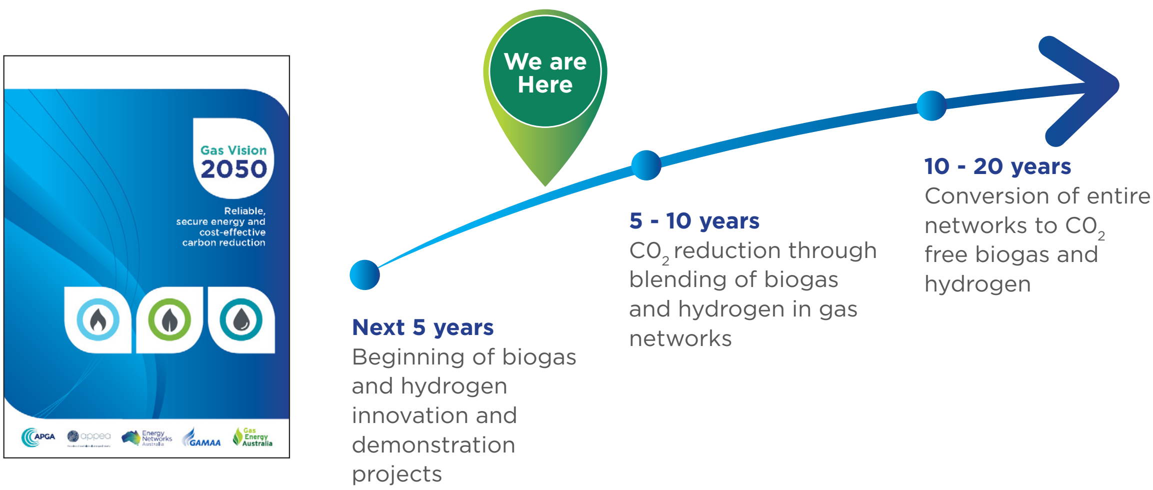
It is important to recognise that technology uptake can take decades from invention to widespread deployment – estimated to be between 20 and 70 years[48] depending on the technology. For example, the invention, development and demonstration of grid connected solar photovoltaics was estimated to take 37 years from 1954 to 1991 and then the market deployment another 18 years to 2009 – a total of 55 years. Since then, vast amounts of solar PV have been built resulting in continuing cost reductions.

Nevertheless, modern renewables – covering both wind and solar PV – are contributing less than two per cent of global energy demand. Similarly, the time taken to reach widespread market deployment of the gas transformational technologies can take many years. Based on history, it would be unreasonable to assume this can be achieved in a few years.

Nevertheless, delivering the Gas Vision will require technology development to be accelerated. Achieving the emissions targets required by the Paris Agreement will require most clean energy technology to be deployed at much higher rates than in the past. The timeline below provides an illustrative pathway to reach commercial maturity for gas transformational technologies.

Some technologies are more advanced than others and more detailed roadmaps of these technologies are under development.

Figure 24: Illustrative pathway to reach commercial maturity for gas transformational technologies



Source: Energy Networks Australia (2020)

48 Gross R, et al (2018), How long does innovation and commercialisation in the energy sectors take? Historical case studies of the timescale from invention to widespread commercialisation in energy supply and end use technology, Energy Policy, 123, pp 682-699

Research

Research enables new technologies to be developed, or new methods to be applied to existing technologies. Several research organisations are focussed on the role of gas in a low emissions future or the decarbonisation of gas:

- CO2CRC is leading the way to better understand geological storage in Australia. While capture technology is generally accepted as being mature and already demonstrated and commercially available, the variation in geological storage sites proves to be the most uncertain in CCS.
- FFCRC is an industry focussed research, development and demonstration partnership enabling the decarbonisation of Australia's energy networks. It focusses on research in three areas:
  - future fuel technologies, systems and markets;
  - social acceptability, public safety and security of supply; and
  - network lifecycle management.
- The CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA) is a collaboration between CSIRO, Commonwealth and state governments and industry established to undertake publicly reported independent research. The purpose of GISERA is for CSIRO to provide quality assured scientific research and information to communities living in gas development regions. It is focussed on social and environmental topics including greenhouse gas and air quality research, which aims to improve characterisation and management of gas industry greenhouse gas and air quality impacts. The governance structure for GISERA is designed to provide for and protect research independence and transparency of research outputs.
- The Future Energy Exports Cooperative Research Centre will execute cutting-edge, industry-led research, education and training to help sustain Australia's position as a leading LNG exporter, and enable it to become the leading global hydrogen exporter. It focussed on four core research areas:
  - efficient LNG value chains;
  - hydrogen export and value chains;
  - digital technologies and interoperability; and
  - market and sector development.
- There are many other research organisations with an interest in this space including industry centres directly funded by industry, universities and the CSIRO (including GISERA).
- Ongoing support to research organisations will ensure innovation continues to be applied over the next decade. It is essential that continued funding is directed towards this research and development.

Demonstration projects

There are a range of demonstration project underway around the country to demonstrate transformational technologies[49]. These projects are key in understanding how technologies operate in a real environment.

The priority for pilot and demonstration projects should be on technical aspects associated with:

- evaluating additional options of geological storage for natural gas;
- evaluating options of geological storage for blue hydrogen;
- production of blue hydrogen;
- production of renewable hydrogen;
- reducing emissions associated with gas production;

49 Energy Networks Australia (2019), Gas Vision 2050 – Hydrogen Innovation

- evaluation of infrastructure with different hydrogen blends;
- assessing hydrogen storage opportunities;
- integration of renewable hydrogen with the electricity network;
- blending biomethane into the network;
- development of BioLPG or other alternatives; and
- testing appliance performance with changing gas compositions.

These projects also enable understanding of the social acceptance and the economic possibilities of scaling up the technology from the research stage.

The projects should provide learnings that can be applied to the commercial demonstration of the technologies. It is important to recognise that demonstration projects are not an end in themselves. They are an important stepping-stone to commercial-scale deployment and the results from demonstration projects should inform policy options.

Market design

While there is a growing interest from suppliers and customers to provide carbon-neutral products, the main option available to gas users at present are voluntary carbon offsets.

Blending of gases other than natural gas into the gas network would need to comply with the *National Gas Law* (NGL). The NGL is the primary legal instrument for Australia's gas market. The objective of the NGL[50] is to promote efficient investment in, and efficient operation and use of, natural gas services for the long-term interest of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas.

The *National Hydrogen Strategy* recommended that a review of the legislative framework be completed to identify any potential regulatory ambiguity, to remove unnecessary regulation and improve the consistency of laws across jurisdictions. This may be relevant to blue and green hydrogen, biomethane and renewable gas.

Individual states have an ability to offer exemptions for injecting gases different to that specified in the NGL but resolving this high priority action will ensure that a nationally consistent approach can be adopted.

Furthermore, hydrogen export opportunities will require international certification schemes to be developed and implemented.

Blending target

A blending target for hydrogen has been recommended by the WA and NSW governments. These targets generally align with a 10 per cent blend in the network. Australia's east coast gas distribution networks[51] have recently issued a call for expression of interests[52] from international vendors on the feasibility, approach and cost of achieving 10 per cent by volume renewable hydrogen across our gas networks. This is an industry led scheme to activate the local market.

A similar target approach could be established for biomethane. Differentiating between targets for hydrogen and bio-methane is important as both are at different stages of development, but both will be needed. As a comparison, the *Renewable Energy Target* resulted in mainly wind energy being constructed in the early stages as that was the more economically efficient option at that time. The original policy settings did not provide adequate support to deploy utility scale solar photovoltaic generation.

50 National Gas Law, section 23.
51 These gas networks businesses are Australian Gas Infrastructure Group, AusNet Services, Evoenergy and Jemena.
52 www.agig.com.au/media-release---greater-hydrogen-use

A targeted funding program[53] by ARENA provided an opportunity for this technology to become commercially competitive. Similarly, separate technology targets (or targeted incentives) would allow both biomethane and hydrogen to contribute to large-scale demonstration of these technologies.

Oakley Greenwood[54] identified several potential design options to support renewable gas blending and concluded that on balance, a certificate style scheme is likely to be the most appropriate means of incentivising the blending of renewable gas into Australia's gas networks. It noted that:

- A certificate scheme, if designed correctly, decouples the production of renewable gas from the location where the liability is generated; hence, everything else being equal (e.g., transportation costs), incentivising the production of renewable gas to be located where it is cheapest to produce.
- The sale of certificates generates certificate prices, and hence costs, that reflect underlying market fundamentals, which overcomes the inherent issue with a feed-in tariff arrangement that relies on a centrally administered, ex ante rate being set (with all the associated risks that stem from that).
- A certificate scheme for renewable gas blending mimics the existing Renewable Energy Target scheme, hence the existing suite of governance and institutional arrangements should be able to be utilised (or require minimal change to be used).

Oakley Greenwood also noted that such a scheme could be easily expanded to include blue hydrogen.

The design of a well-functioning market is essential to support both large-scale demonstrations but more importantly to support widespread deployment of technologies.

Commercial-scale demonstration

Commercial demonstration has already been completed for many of the transformational technologies, including CCS and production of hydrogen from natural gas.

At the stage of commercial demonstration, technologies are generally not competitive against the market. In the present case, the incumbent is unabated gas. Setting renewable gas blending targets in networks creates an opportunity to build scale and contribute towards cost reductions of these technologies. A renewable gas blending target for networks and appropriately developed incentives could facilitate the introduction of renewable gas in Australia. Over time, these incentives should be adjusted as the technology becomes widely deployed and commercially competitive.

Suitable incentives and specific policy support will be required, just as they were for renewable energy technologies, which benefited from the renewable energy target, separate state government schemes and feed-in tariffs.

Widespread deployment

Widespread deployment of any technology is essentially driven by markets and the market signals regarding reducing carbon emissions. This will depend on the technology and its applications. It is generally expected that widespread deployment will commence in the 2030s after learnings from pilot and demonstration projects and commercial scale demonstrations.

53 https://arena.gov.au/funding/large-scale-solar

54 Oakley Greenwood (2019), Renewable Gas Blending Scheme, Report for Energy Networks Australia

Focus of the 2020s

Gas provides major services to customers and to the economy and these services need to be decarbonised. There are a range of options to do so and the gas industry is continuing to lead the development and demonstration of these technologies. This is balanced with customers seeking options to voluntarily reduce their emissions.

While CCS and carbon offsets are commercially mature, the focus has been on the transformational technologies of hydrogen and biogas, which are still at an early level of commercial development. Hydrogen and biogas for gas are the wind and solar PV for electricity. We are well on track to demonstrate these technologies in demonstration projects, showing customers the possibilities of reducing emissions from gas use and are progressing towards demonstrating blending in gas networks.

The next decade must focus on key activities so we are in a position to convert entire networks in the 2030s to hydrogen and biogas. Key steps include:

- develop a certification scheme for low carbon biogas and hydrogen allowing it to be recognised and traded as an emission free product;
- establish blending and technology targets;
- establish zero emissions gas contracting arrangements – similar to power purchase agreements for electricity – to create a market for hydrogen and biogas;
- scale up the production of low carbon gases, through the use of blending in networks, leading to major cost reductions that will ensure conversions of entire network to zero emissions gas;
- continuing research and development of new technologies, or applications of existing technologies to accelerate the reductions of emissions;
- demonstrate the safe use of hydrogen in appliances;
- share the learnings from the diverse range of demonstration projects underway and use these learnings to inform market and policy settings;
- in conjunction with the broader industry, undertake large scale demonstrations of transformational technologies to demonstrate their emission reduction potential across the industry; and
- deploy transformational technologies in early commercial opportunities.

Achieving net-zero by 2050 is essential if we are to make a meaningful contribution to global efforts to avoid the worst impacts of climate change. And it is something our customers want us to focus on.

Decarbonising the gas sector requires a long-term focus and a systems approach to energy production, transportation and consumption. Alternative options to decarbonise gas also exist through carbon offsets, energy efficiency and electrification. In practice, all will be needed to decarbonise the economy, but the transformational technologies being pursued in Gas Vision 2050 provide a wider range of options and provide additional flexibility to decarbonise the sectors dependent on gas.

For the gas sector, this requires the ongoing development and demonstration of a range of technologies, supported by the right policy and market settings. Industry is dedicated to continuing to progress the transformational technologies to the commercial scale, supported by research and development and demonstration projects. Completing key steps in the 2020s through setting blending and technology targets for 2030 will allow large scale deployment to achieve the desired outcomes in line with the Paris Agreement on climate change. The right policy settings will be required to ensure commercial take-up of those technologies.

Glossary

AEMO	Australian Energy Market Operator
ARENA	Australian Renewable Energy Agency
CCS	Carbon capture and storage
CCUS	Carbon capture, utilisation and storage
CO_2	Carbon dioxide
CSG	Coal Seam Gas
CSIRO	Commonwealth Science and Industrial Research Organisation
EJ	Exa Joule – $1*10^{18}$ Joules, commonly used to express global energy consumption
FFCRC	Future Fuels Cooperative Research Centre
GISERA	CSIRO's Gas Industry Social and Environmental Research Alliance
GJ	Giga Joule – $1*10^{9}$ Joules, commonly used to express the cost of gas on $/ GJ
GWh	Giga watt hours – a metric used for electricity generation
IEA	International Energy Agency
LNG	Liquified natural gas
LPG	Liquified petroleum gas, consisting mainly of propane and butane
MW	Megawatt – $1*10^{6}$ watts
NGL	National Gas Law
NOx	Nitrous oxides produced in high temperature combustion processes
PJ	Peta Joule – $1*10^{15}$ Joules, commonly used to express national energy consumption
SOx	Sulphur oxides produced in small quantities from the combustion of coal and/ or oil
TJ	Tera Joule – $1* 10^{12}$ Joules, commonly used to express daily national consumption of gas

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