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.

Gas Vision 2050

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.

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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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

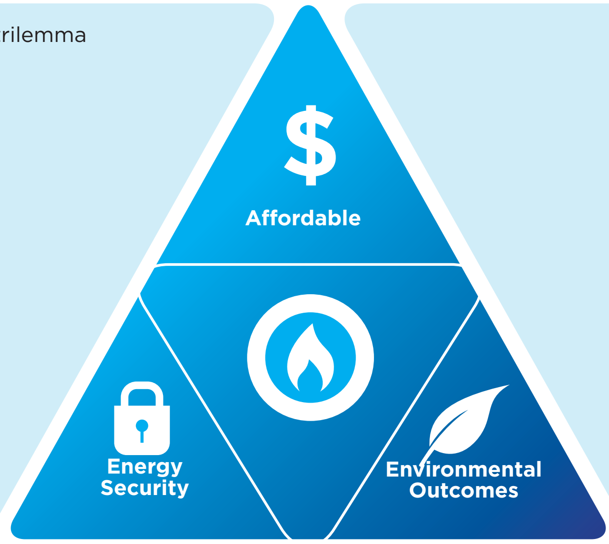
The Vision is for Australia to continue to turn its gas resources into products and services that will enhance national prosperity while achieving carbon neutrality. It identifies how gas and gas infrastructure can be used to solve the energy trilemma by balancing energy affordability, energy security 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

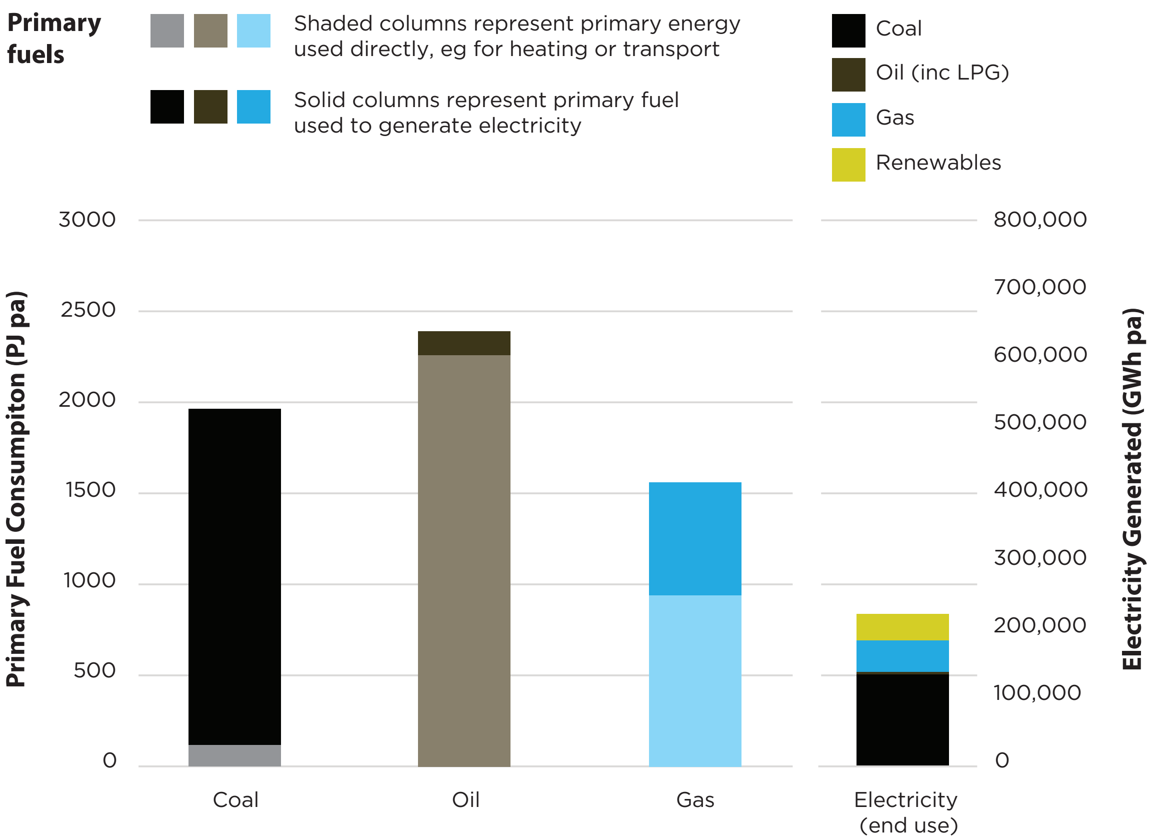
The world has agreed to make efforts to reduce emissions. Most countries, including Australia, ratified the Paris Agreement in 2016 and all Australian states and territories have set targets to achieve net zero emissions by 2050.

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

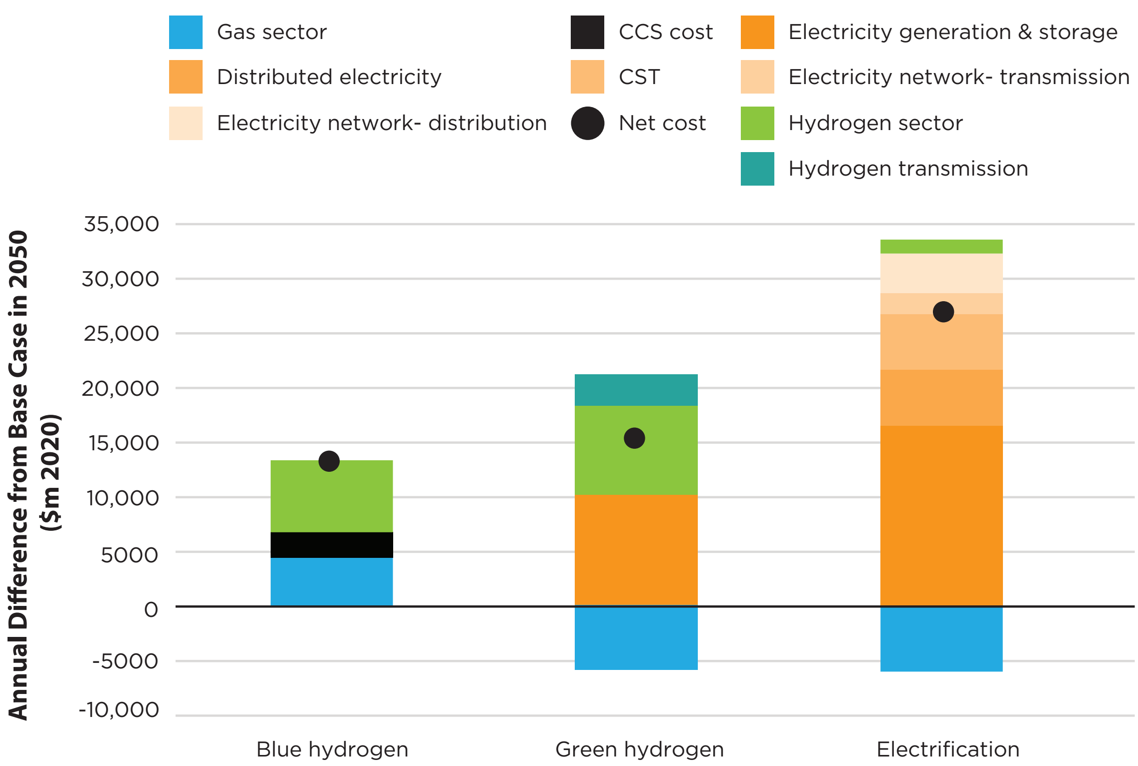
Deploying transformational technologies using existing gas infrastructure is also more economically favourable than electrification.

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

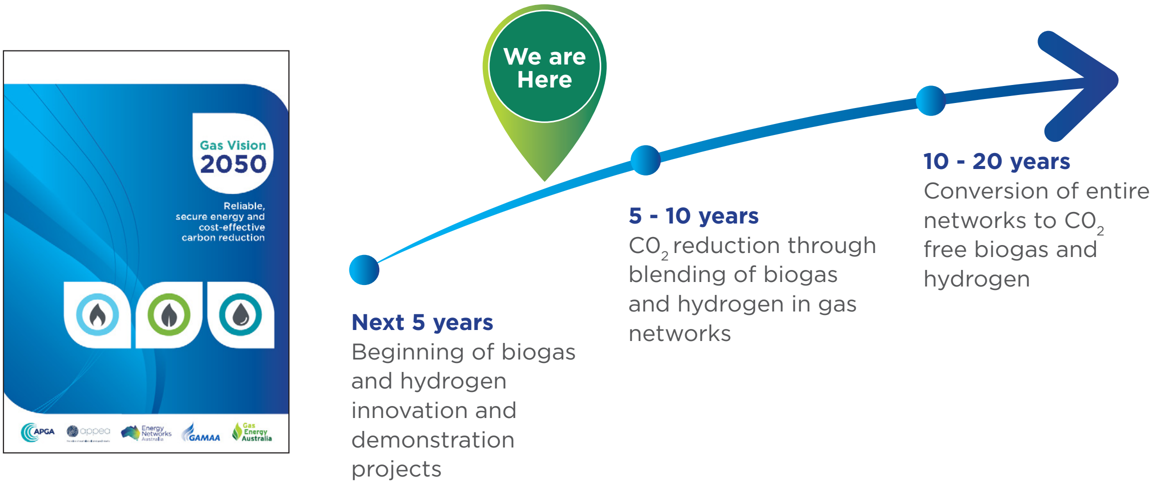
Gas provides major services to customers and to the economy and these services need to be decarbonised. There are a range of options available and the gas industry is continuing to lead the development and demonstration of these technologies. This is balanced with customers seeking options to voluntarily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

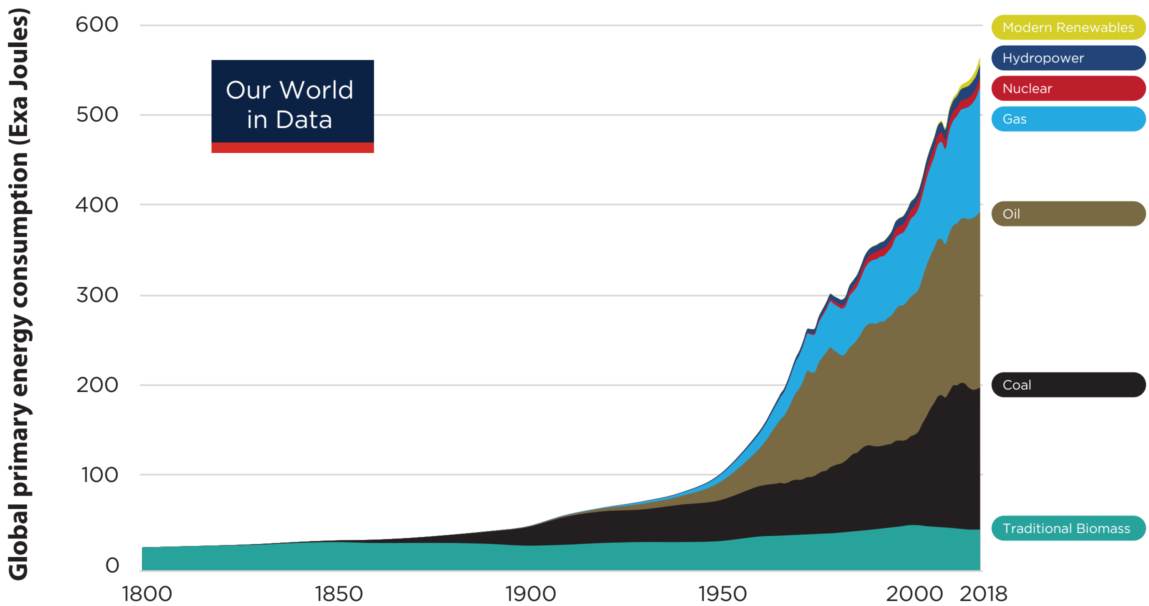
Nevertheless, global energy consumption continues to grow as a reflection of both population growth and that population becoming more energy intensive. While there is ongoing opportunity to reduce energy consumption through efficiency, the chart below demonstrates exponential growth in global energy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

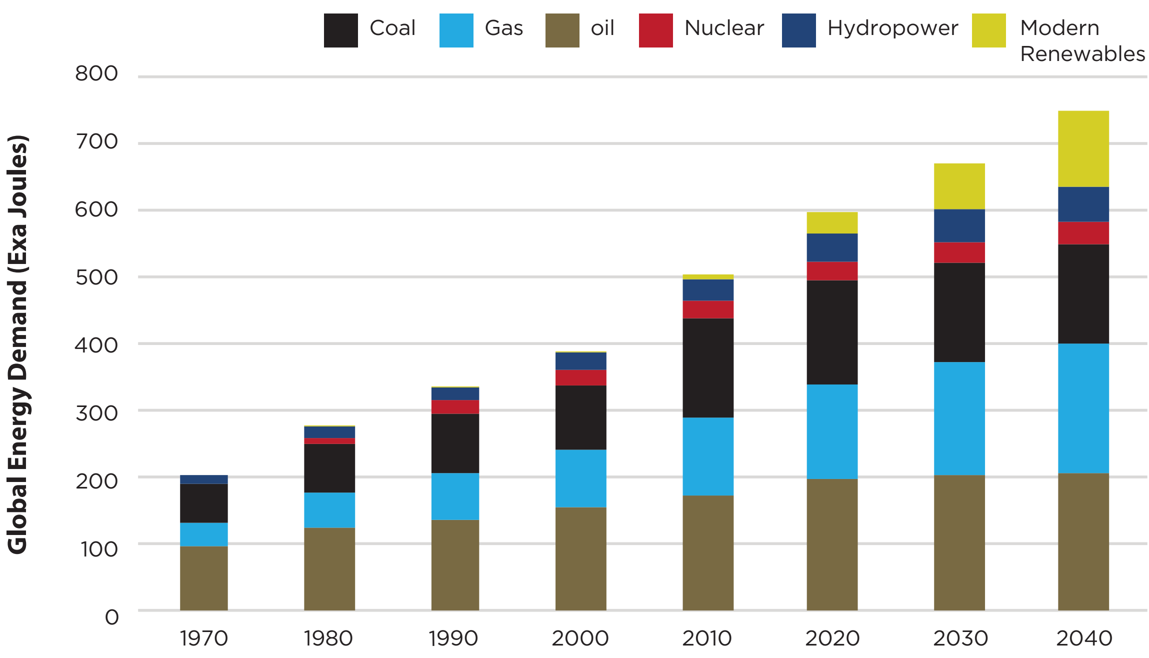
1 Pumped hydro is a storage of energy reliant on one of the other energy sources mentioned.
2 Wind power has historically been used to provide mechanical energy used in agriculture (eg pump water, crush grains) but modern wind power generates electricity from wind.
3 The "Our World in Data" shows a total 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.

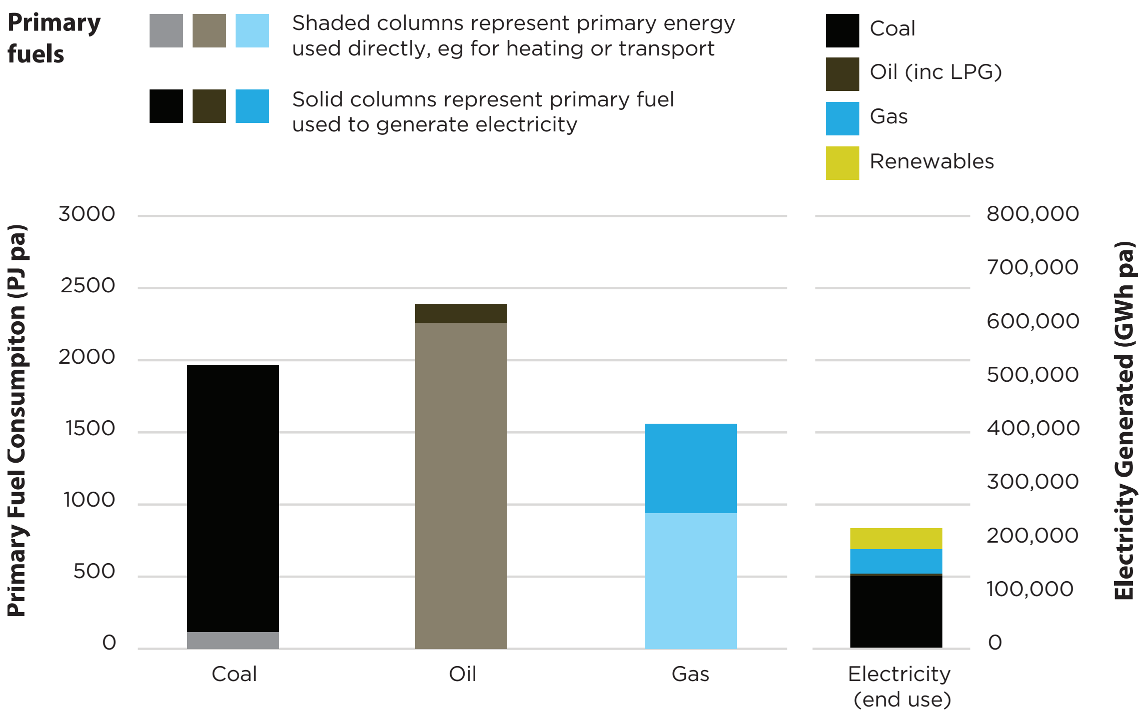
Gas' main component is methane, which can be burnt directly to provide heat or generate electricity and is also used as a feedstock in many industries. The domestic gas production industry contributes $47 billion to GDP and the Australian oil and gas exploration and production sector supports 80,000 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)



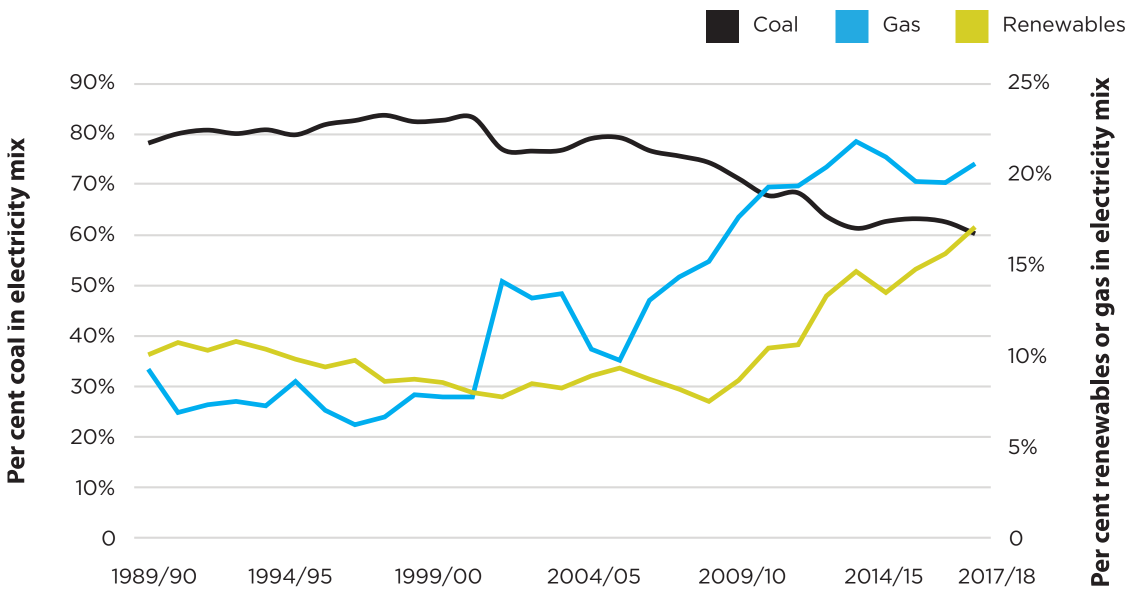
Source: Australian Government (2019), Australian Energy Update 2019, Energy Networks Australia analysis (2020)

- 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

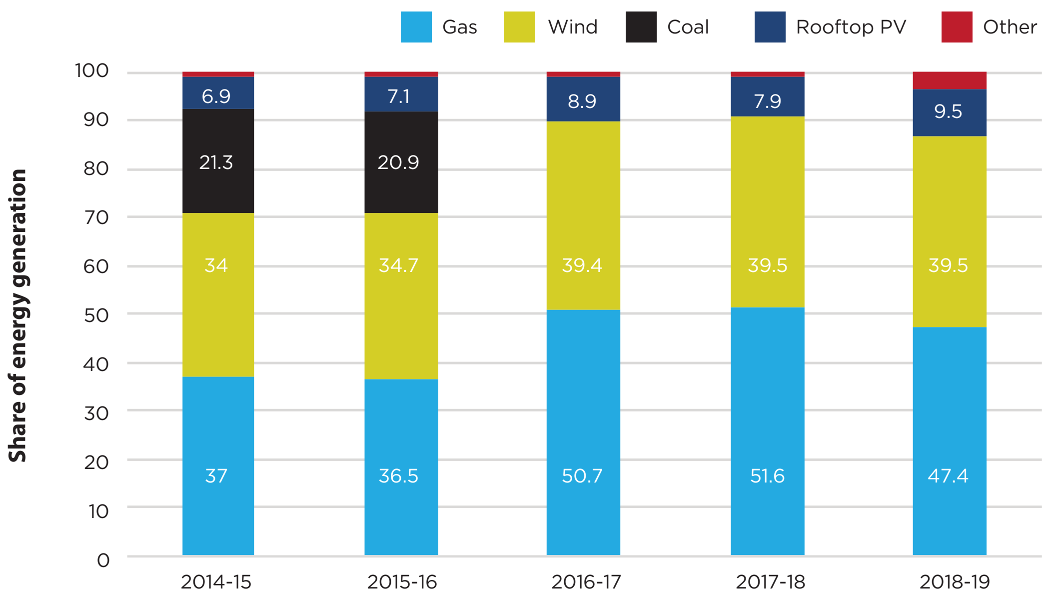
South Australia is often showcased as Australia's renewable energy success story. But there is another side of the story that depends on gas. The reliance on gas has increased since the closure of South Australia's last coal fired power station in 2016/17 and provides almost 50 per cent of the total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

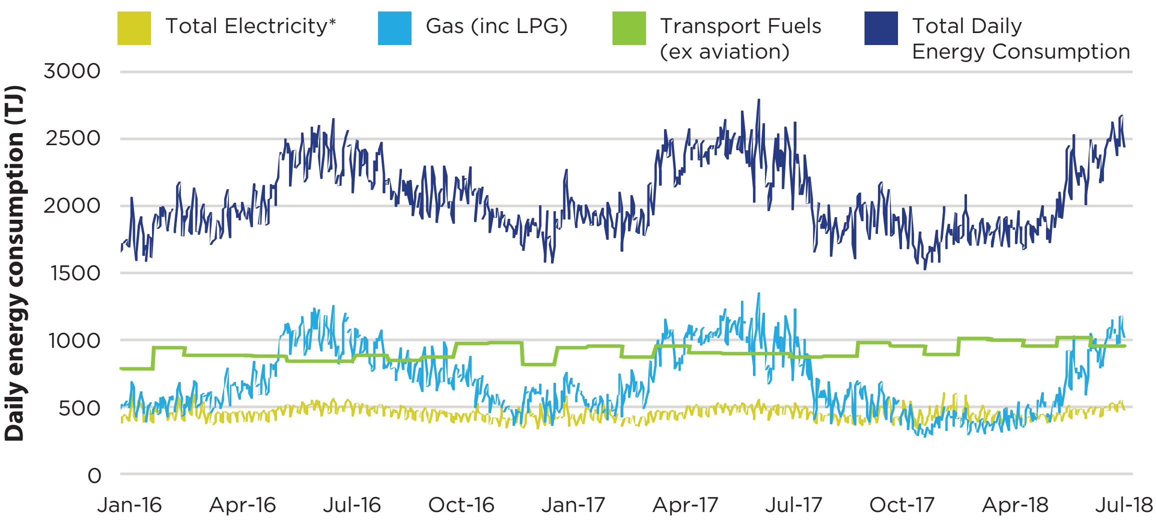
An annual overview only tells part of the importance of gas to our overall energy mix. More insights about the inter-seasonal and intra-day role of gas can be gained by looking at daily and hourly energy consumption. Victoria makes a good case study due to its seasonally high gas demand for space heating 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 162ºC, 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.

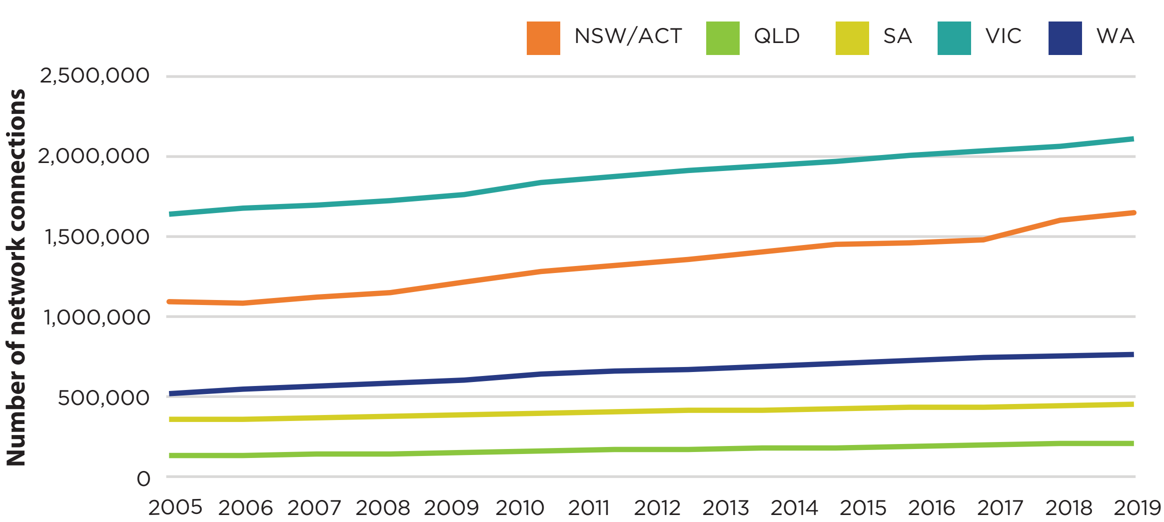
LNG projects require major investment in processing plants, port and shipping facilities. The magnitude of this investment requires access to substantial reserves of gas, which may be sourced through the project owner's interests in gas fields, joint venture arrangements with gas producers, and/or contracts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

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.

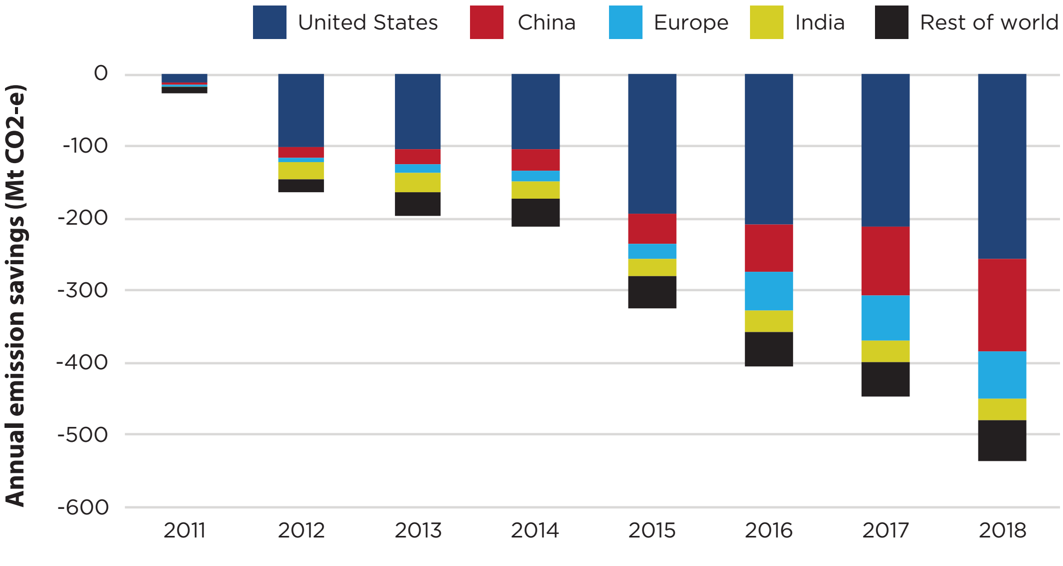
This is the equivalent of putting an extra 200 million electric vehicles on the road running on zero-carbon electricity over the same period.

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.

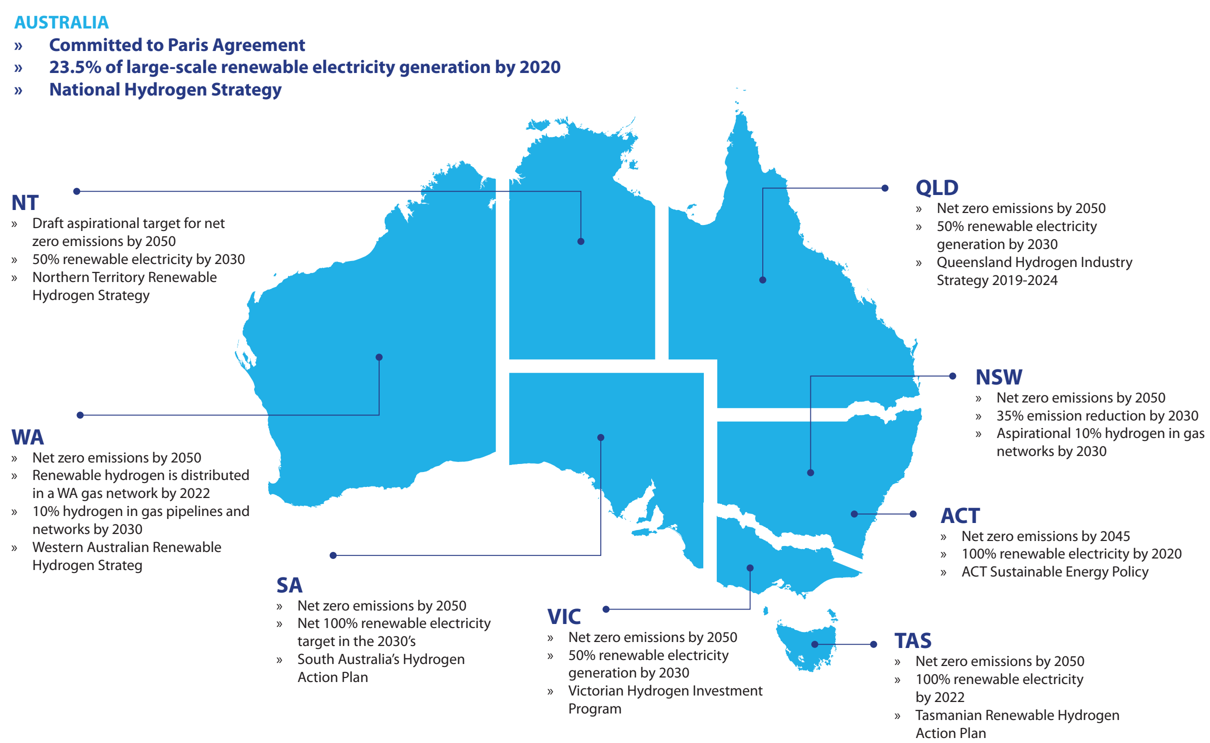
The Australian Commonwealth Government has signed up to the *Paris Agreement* and set a target of between 26 to 28 per cent reductions by 2030[18], and a commitment to net-zero in the second half of the century – in line with the *Agreement*. Separately, Australian states and territories have set an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

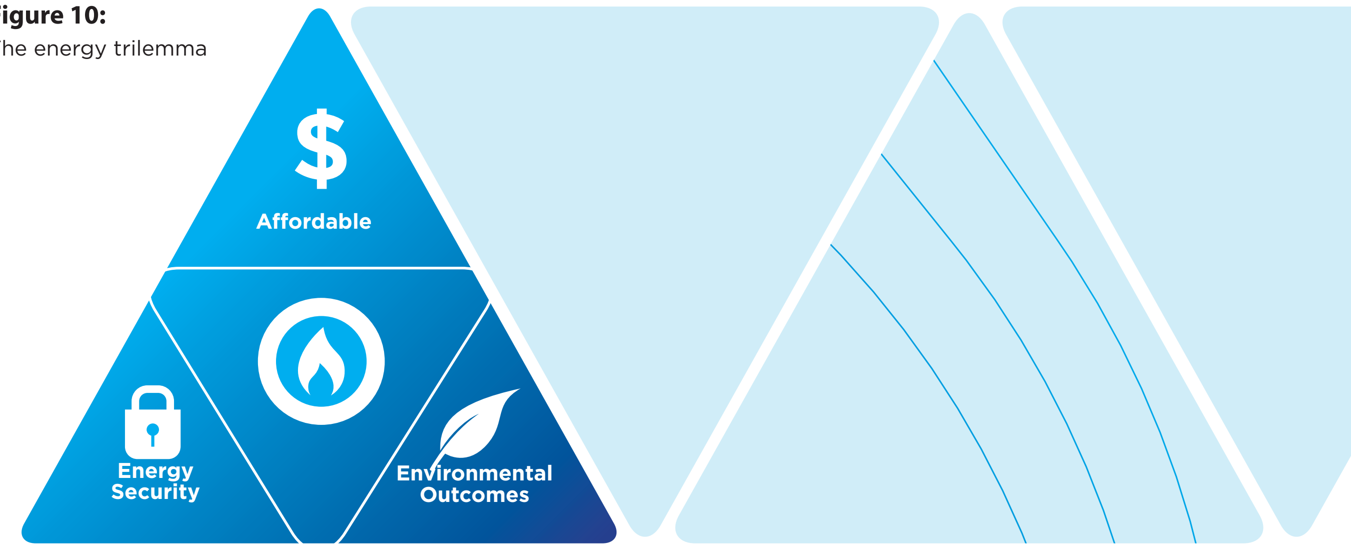
In 1994, inspired by their customers, Interface, a global commercial flooring company, set out to transform its business to have zero negative impact on the planet by the year 2020. They called it Mission Zero™. In 2019 they celebrated Mission Zero™ success by transforming their supply chain, products 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



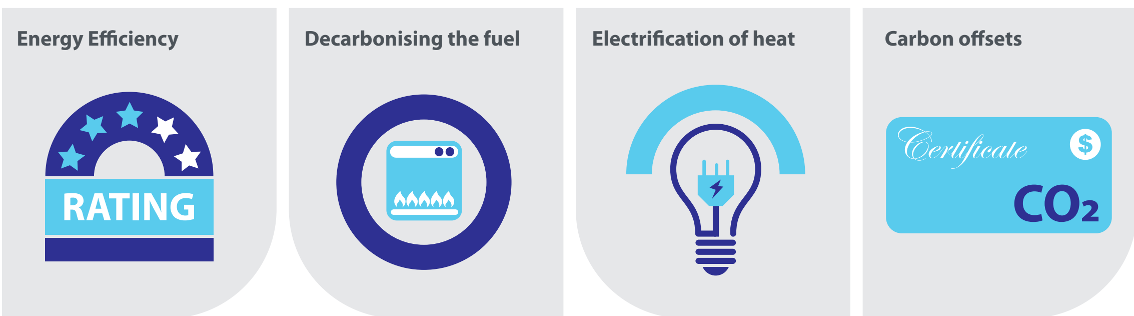
Customers are seeking a clean energy future and are engaged in achieving emission reductions from gas use. This is to be achieved through the widespread deployment of transformational technologies, including biogas, hydrogen and carbon capture and storage. All these technologies, alongside renewable 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.

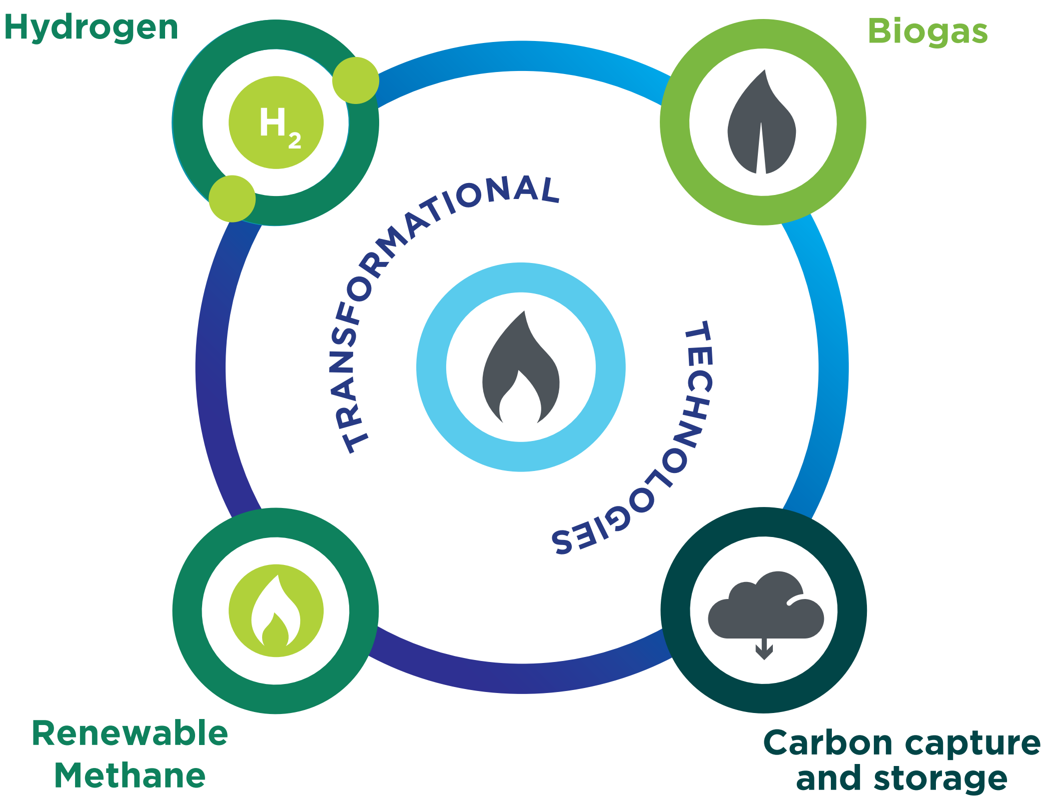
There are three options for reducing emissions from gas use:

» 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



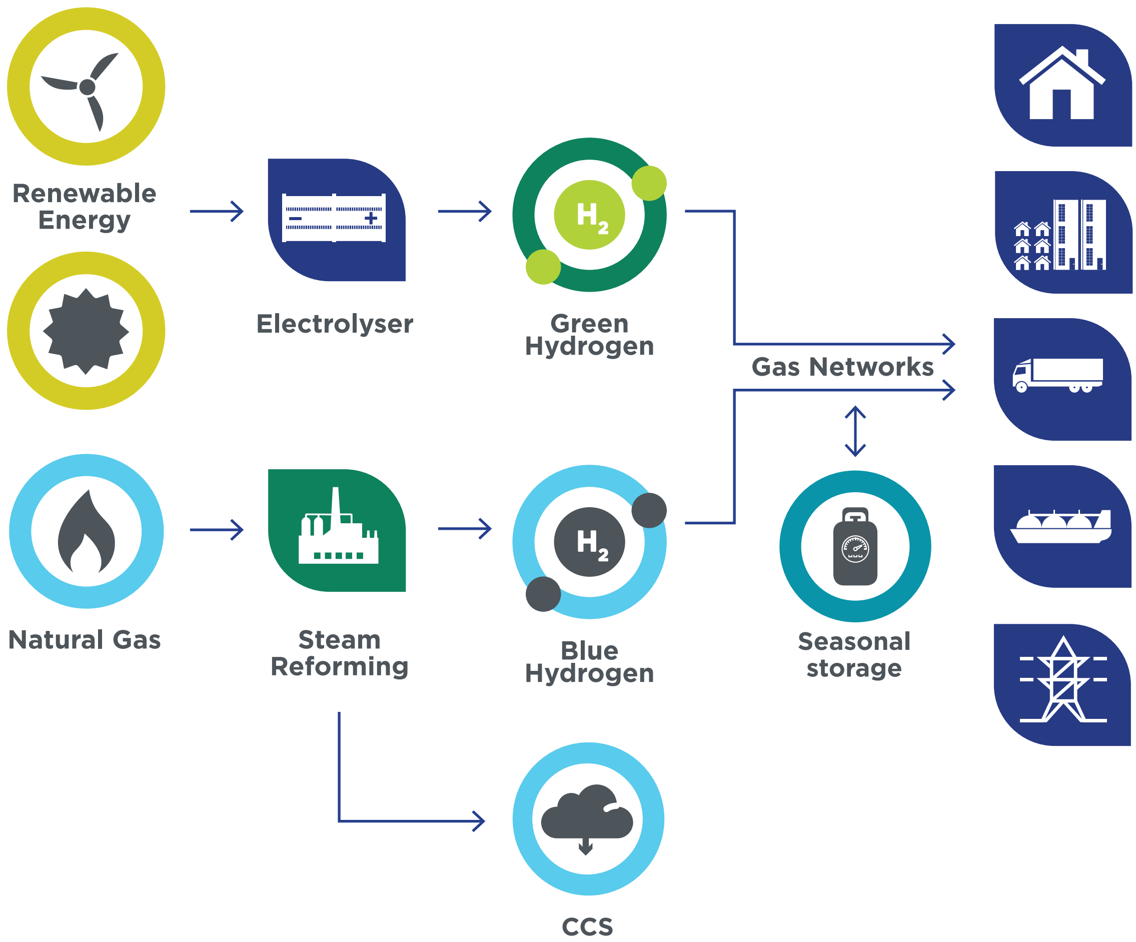
Decarbonising the Fuel

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

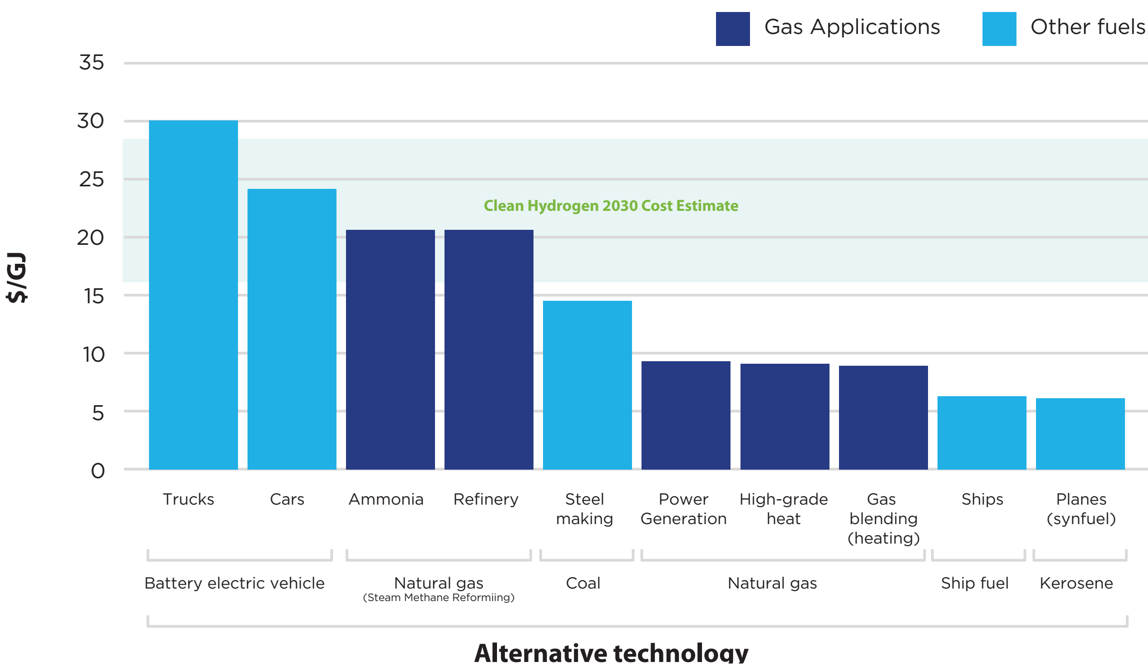
There are several ways hydrogen can be produced from either natural gas[24] or from electricity:

- 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.

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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.

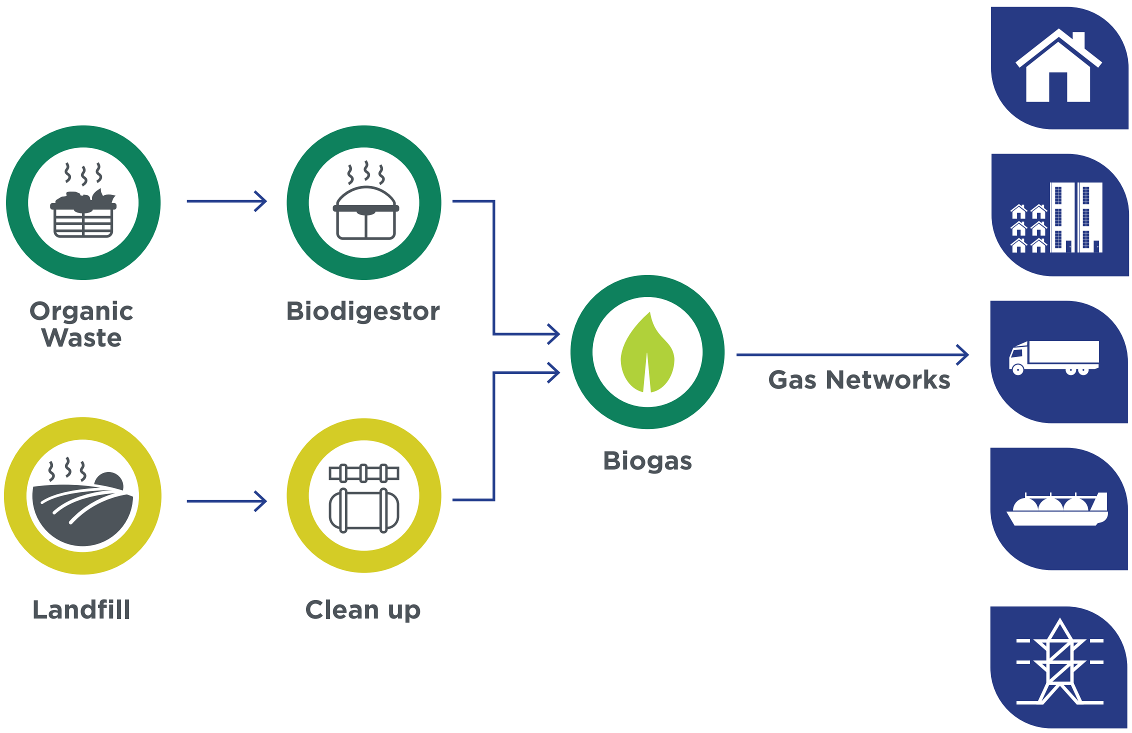
Bioenergy is also already widely used in transport where renewable biofuels are blended with either diesel or petroleum fuels.

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.

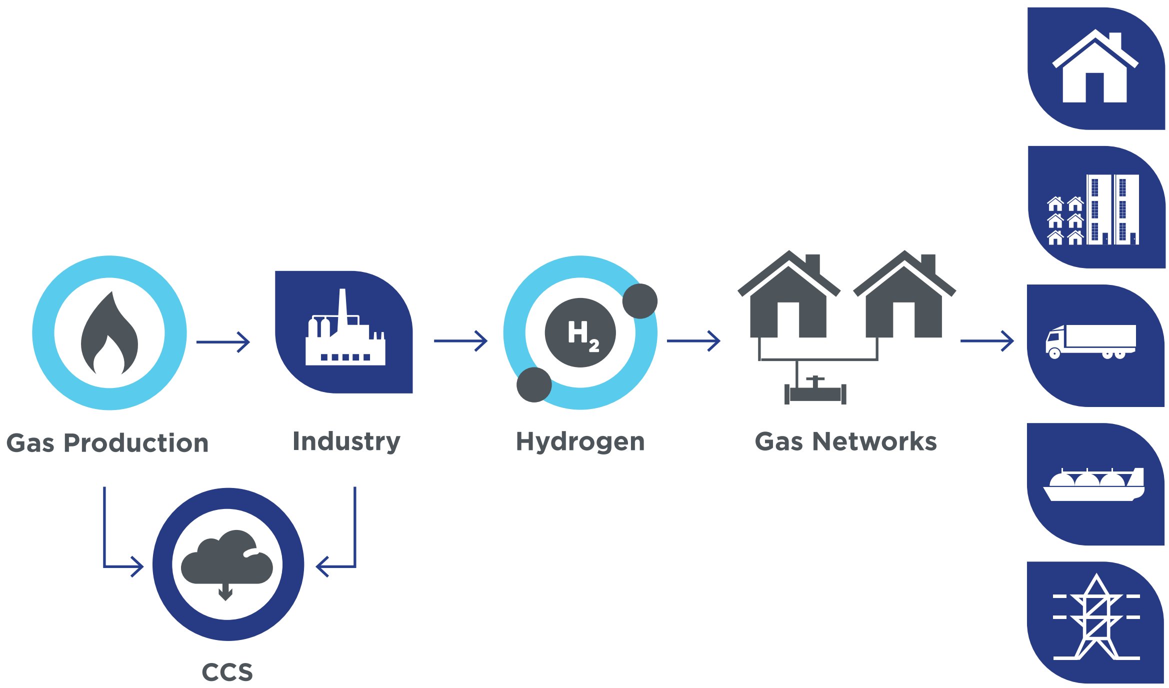
The early days of CCS focussed on its potential role to reduce emissions from coal fired power generation. The focus in recent years has broadened to different sectors including gas processing, hydrogen production and industry.

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.

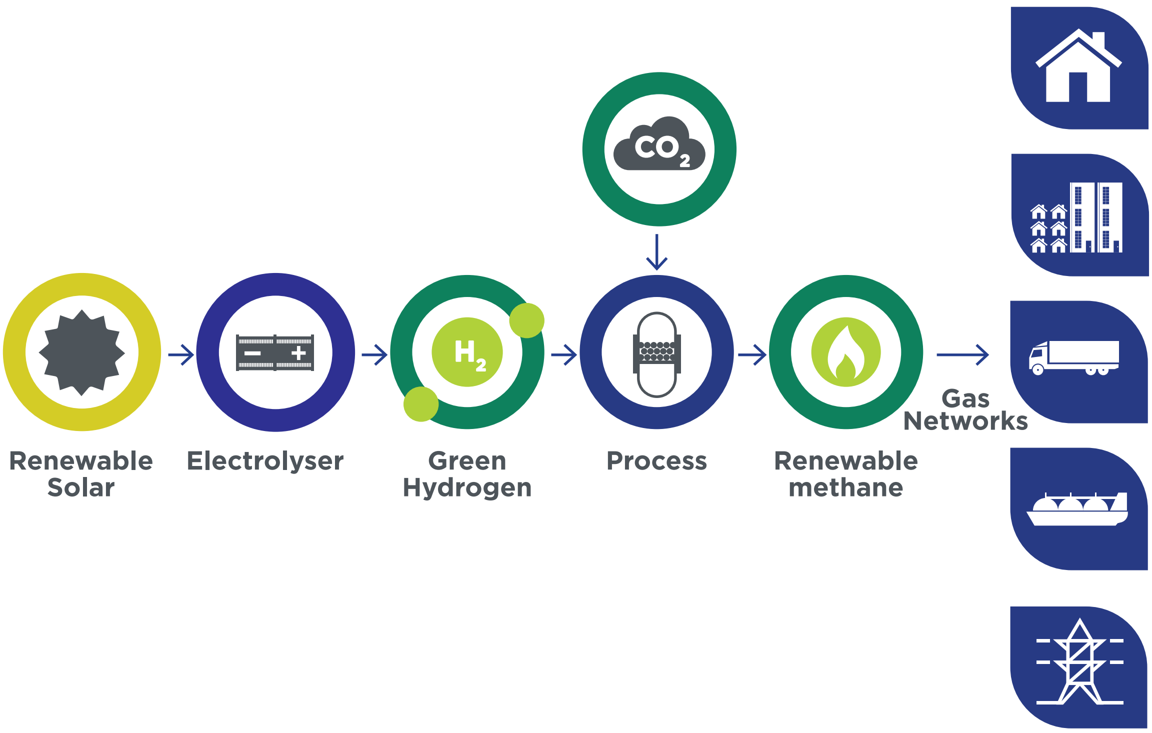
The Sabatier[42] process can be used to convert hydrogen into methane. Similar approaches can also be used to convert hydrogen into methanol and other fuels. The conversion efficiency of these reactions is currently low and consequently, the fuel produced is expensive.

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.

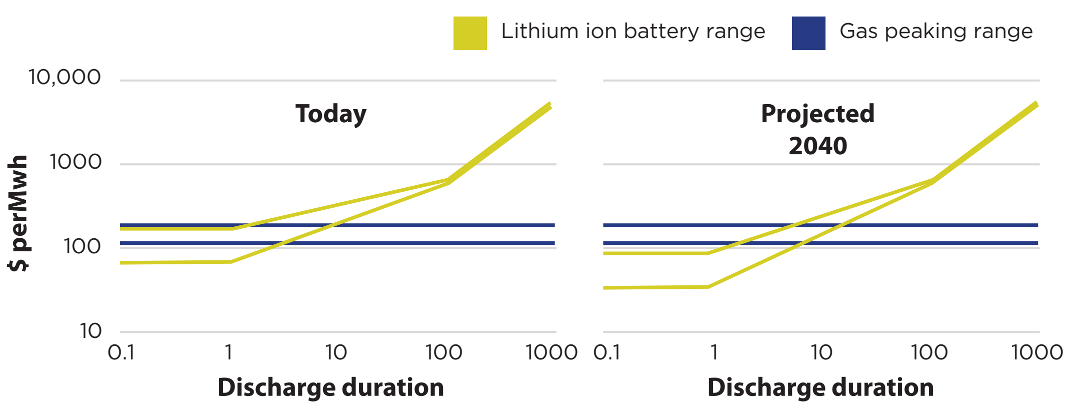
BOX 10: Comparison of storage technology

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).

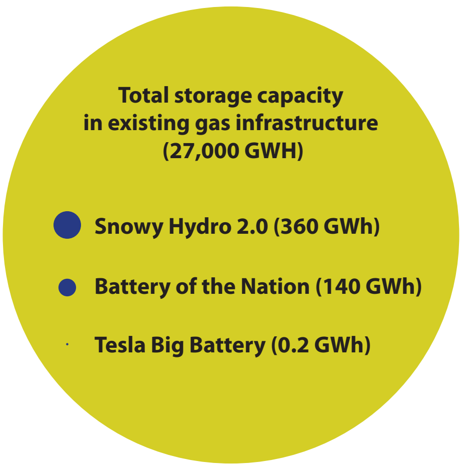
Scenarios adopting decarbonisation options for gas were developed and analysed to achieve net-zero emissions from the combined gas and electricity sectors. These scenarios are in many ways simplifications of the future energy system but are useful representations to compare different technology options. 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

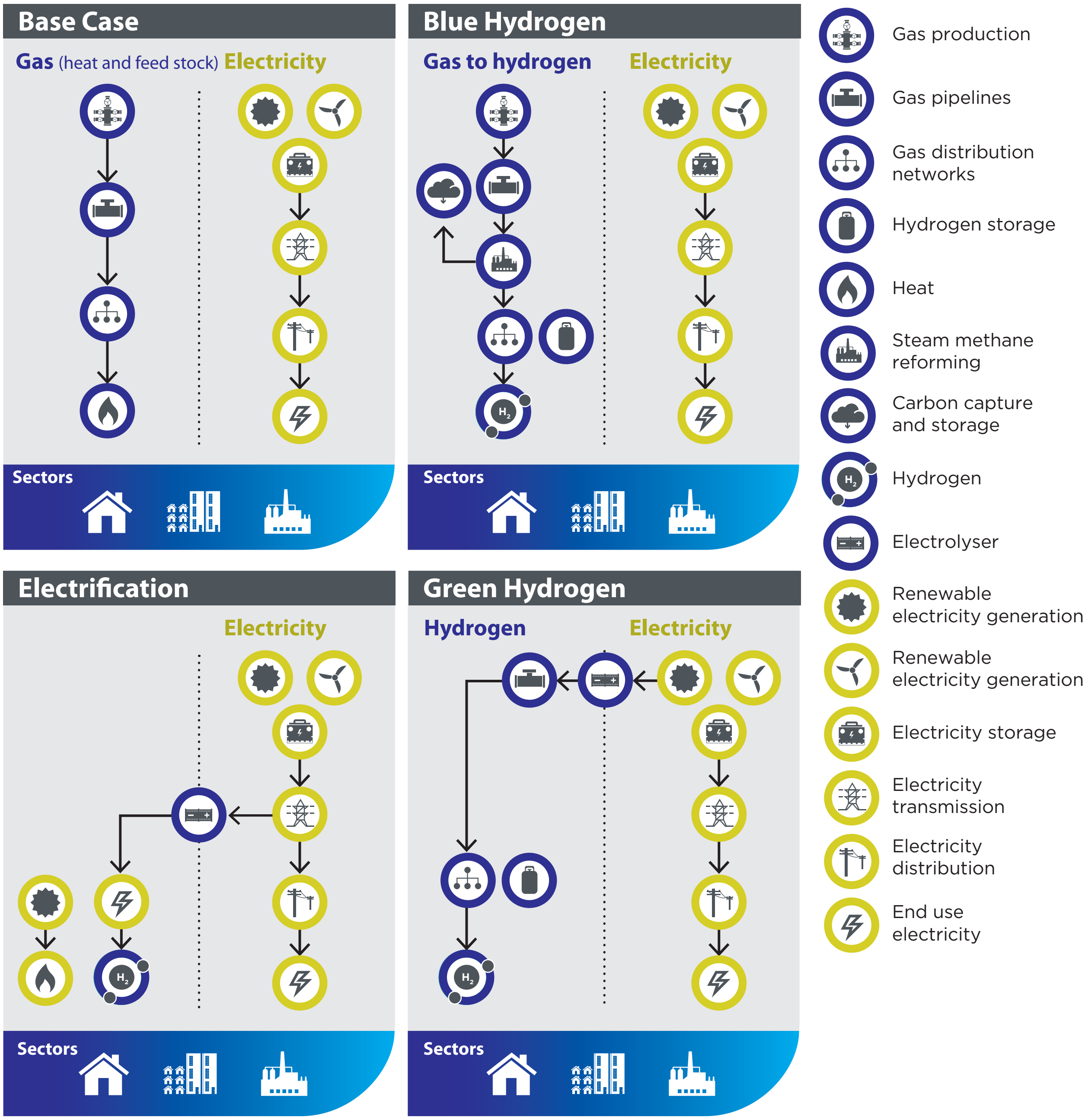


Source: Jemena submission in response to Australia's Technology Investment Roadmap: discussion paper, 23 June 2020.

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]

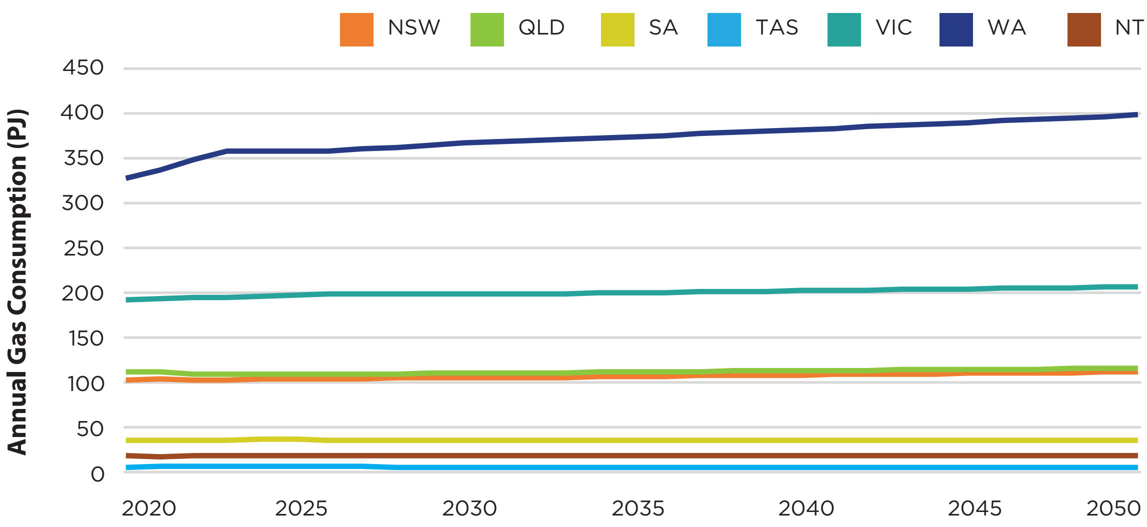
The seasonal variation of gas consumption was considered as that impacts on the amount of gas storage required. As gas is used as a source of heat energy and as a feedstock, the different end uses of gas, especially in industry, were also considered. The infrastructure and fuel supply costs change from 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.

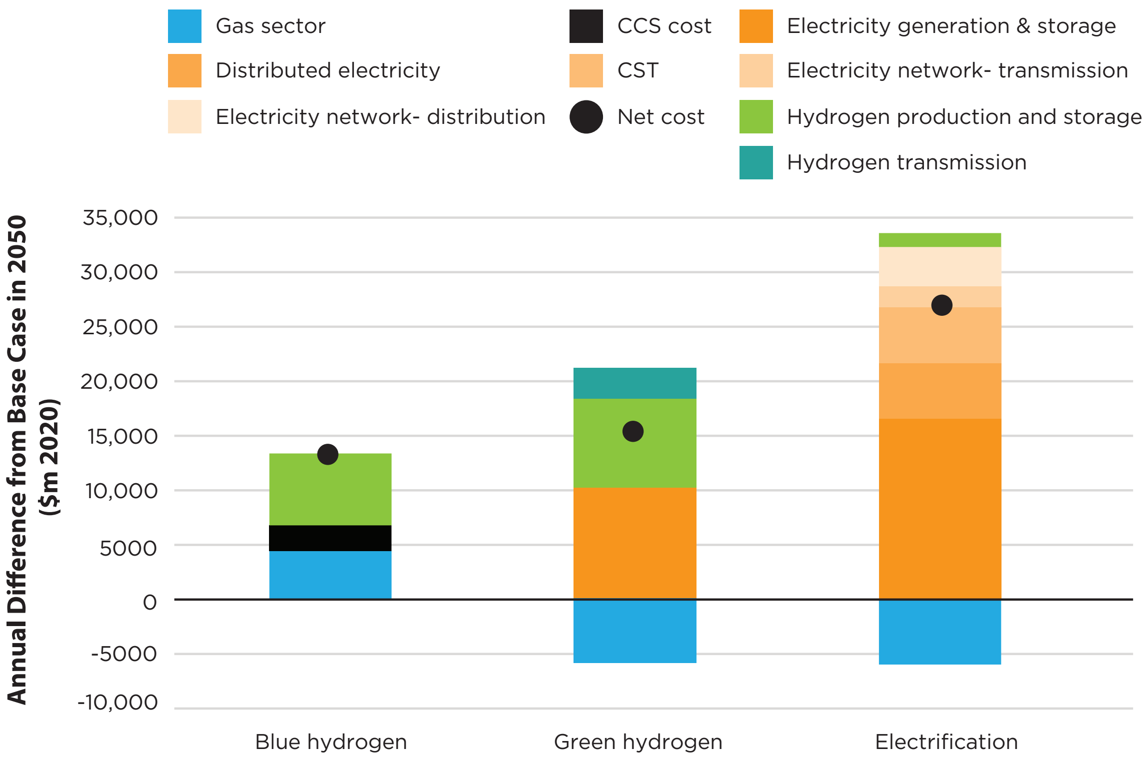
The modeling also demonstrated that gaseous fuels are essential as industrial feedstock in all the scenarios. Some industries, such as mineral processing and chemical manufacture, cannot operate without these fuels, and the electrification scenarios required new infrastructure to deliver this feedstock, 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

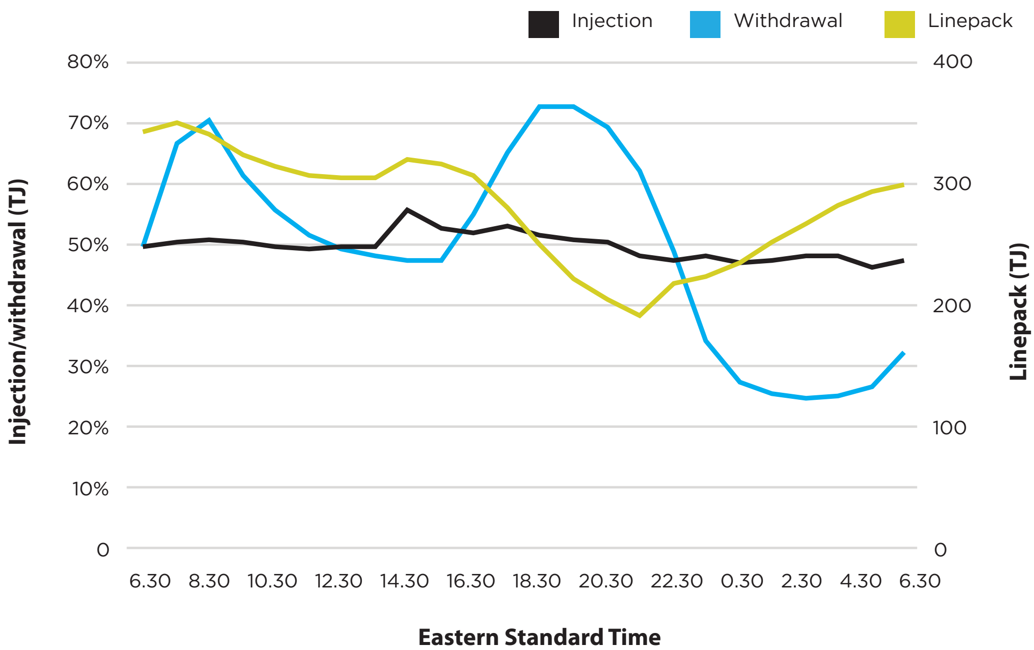
Gas demand varies throughout the day while hourly gas production is relatively constant. Demand during the day can fluctuate balmost 200 per cent between the minimum and maximum demand with the upper range occurring during winter when residential space heating is used – hence a peak in the morning about 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.

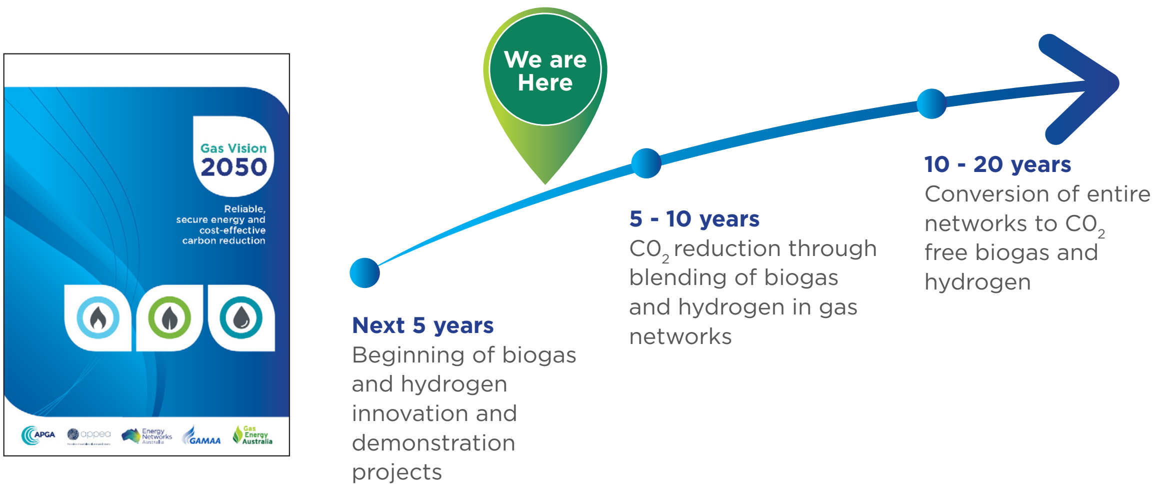
It is important to recognise that technology uptake can take decades from invention to widespread deployment – estimated to be between 20 and 70 years[48] depending on the technology. For example, the invention, development and demonstration of grid connected solar photovoltaics was estimated to take 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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Acknowledgement
The associations are grateful for the funding received from the Australia's Gas Industry Trust to produce this report.