Gas Vision 2050

Reliable, secure energy and cost-effective carbon reduction

APGA
appea
the voice of australia's oil and gas industry
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GAMAA
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GAS IN AUSTRALIA TODAY: CLEAN, ESSENTIAL, RELIABLE

Natural gas provides **44%** of household energy but produces only **13%** of household greenhouse gas emissions.

44% 13%

6 billion

Australia's gas infrastructure can store the same amount of energy as **6 billion Powerwall batteries.**

Almost 70 per cent of homes use mains or bottled gas: that's **6.5 million homes and growing.**

6.5 million

949,000 Jobs

Half of gas used in Australia is for mining and manufacturing, contributing **$196 billion to the economy, employing 949,000 Australians.**

380,000

There are **380,000 gas vehicles** in Australia.

20%

By 2020, Australia's LNG exports will make up **20% of global exports.**

Modern gas power generation produces **half the emissions** of high-efficient coal plants and are much cheaper to build.

HALF

Natural gas is an essential material for creating products such as fertilisers, plastics and chemicals.

Deloitte. Access Economics

Deloitte Access Economics analysis (2016) based on Australian Bureau of Statistics data.

Contents

Foreword

Today, gas is essential to our economy and modern lifestyles. In the future, gas will continue to be essential as Australia makes the transformation to a cleaner energy future.

Whether it's for hot water, domestic heating, or gas-fired cooking, gas plays a central role in the lives of over 6.5 million Australian households. Today, gas delivers 44% of Australia's household energy but only 13% of household greenhouse gas emissions.

Gas provides nearly a quarter of Australia's total energy supply. Gas also plays an important role in our economy with approximately 130,000 commercial businesses relying on gas. Major industries use gas for energy and as a feedstock for manufacturing products such as plastics, chemicals and fertilisers. Figures collated by Deloitte demonstrate that gas underpins a variety of local industries. It estimates that half of the gas consumed in Australia is used in manufacturing and mining industries that contribute $196 billion to the national economy employing 949,000 Australians.

Our vision is for Australia to turn its gas resources into products and services that will enhance national prosperity while achieving carbon neutrality.

Gas has an essential role to play in reducing emissions. In the home, gas is a cleaner fuel than electricity from the grid. Fuel switching from coal to gas offers the most immediate and risk-free option to cut emissions from the electricity generation sector. Jacobs foresees at least a tripling of gas-fired generation as part of its least cost path to achieving our nation's 2030 emissions target.

Gas-fired generators can be rapidly started making them complementary with intermittent renewable energy. Exporting gas as LNG will allow our Asian trading partners to reduce the emissions from their economies.

Over the long-term, gas will have its own decarbonisation journey. New fuels, such as biogas and hydrogen, have the potential to become mainstream and complementary energy solutions that will use existing energy infrastructure. Biogas, for instance, can make use of landfill or agricultural and forestry waste to produce a net-zero emissions fuel. Hydrogen can be produced from natural gas or through electrolysis using off-peak renewables. Carbon capture and storage is a proven technology for removing greenhouse gas emissions and can be applied to power generation, industrial processes that use natural gas, hydrogen production from methane, or even biogas production resulting in negative emissions. This leads to emission-free energy, where hydrogen can then be stored in the gas network, providing reserve energy in the same way battery technology does, in a carbon-neutral, secure and cost-effective manner, while also providing inter-seasonal energy storage.

This *Gas 2050 Vision* report is the next step in our gas journey. It reflects the ambitions of key organisations which represent Australia's gas sector. It shows that gaseous fuels have a pivotal role to play in Australia's low carbon future to 2050 and beyond. Our plan is for this *Vision* to be refined and further developed as the role of gas in Australia's energy mix continues to evolve.

Ben Wilson
Chair, Gas Committee
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Chief Executive
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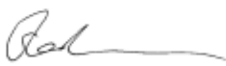

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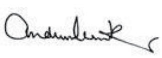

Andrew Creek AOM
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Gas Appliance Manufacturers Association of Australia

Gas's decarbonisation journey

Australia's journey towards decarbonisation will present many opportunities. The gas sector is well-placed to provide reliable and secure energy and cost-effective carbon reductions by 2050 across the entire economy, from power generation, industry, transport and within the home.

These opportunities will require deployment of three key transformational technologies:

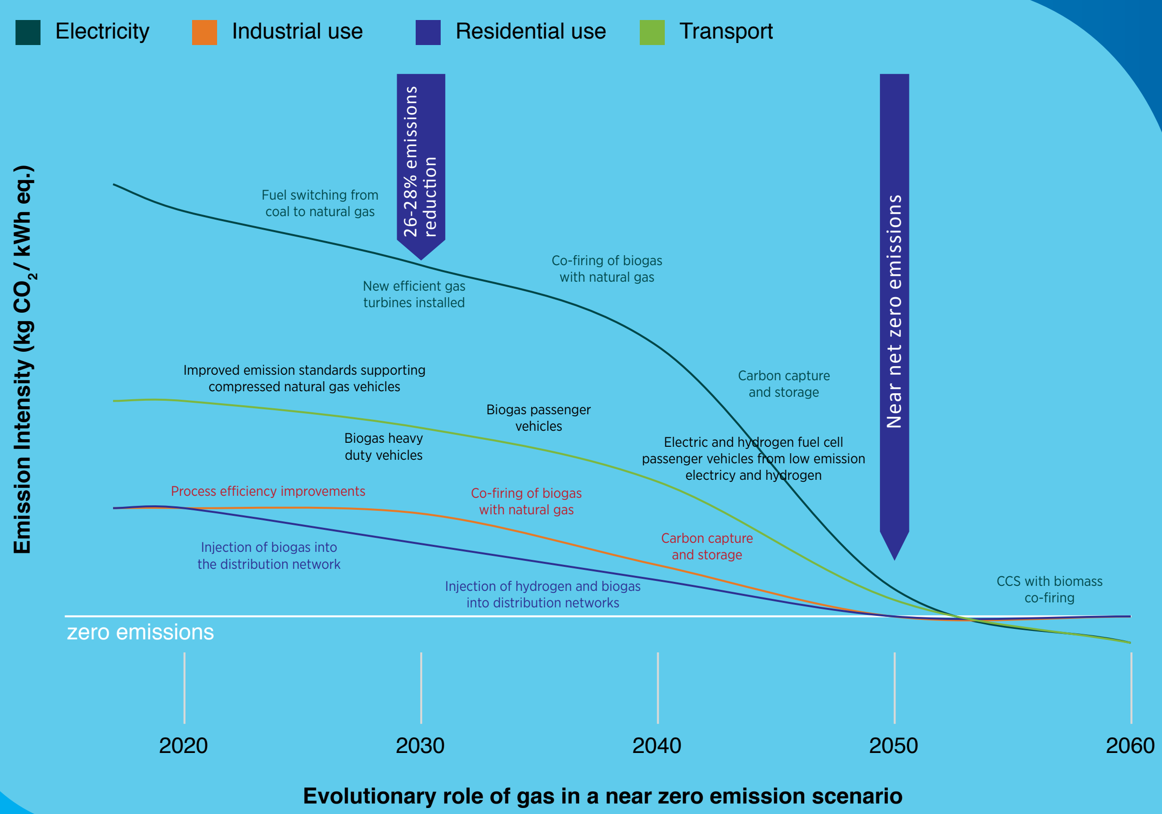
- biogas production
- carbon capture and storage
- hydrogen.

One illustrative decarbonisation pathway of gas is shown below.

3 key transformational technologies:

- biogas production
- carbon capture and storage
- hydrogen

Figure 1: Illustrative decarbonisation pathway for gas



Source: Energy Networks Australia analysis (2016).

Gas: supporting the energy transformation to 2030

The Australian energy sector is undergoing a major transformation.

One of the major drivers for this transformation is the decarbonisation of the energy sector in line with the COP21 Paris agreement. This agreement seeks to reach global peak emissions as soon as possible and achieve net-zero emissions in the second half of this century so as to limit global warming to 2°C. Australia has committed to this agreement and has a 2030 emission target of 26 to 28% below 2005 levels.

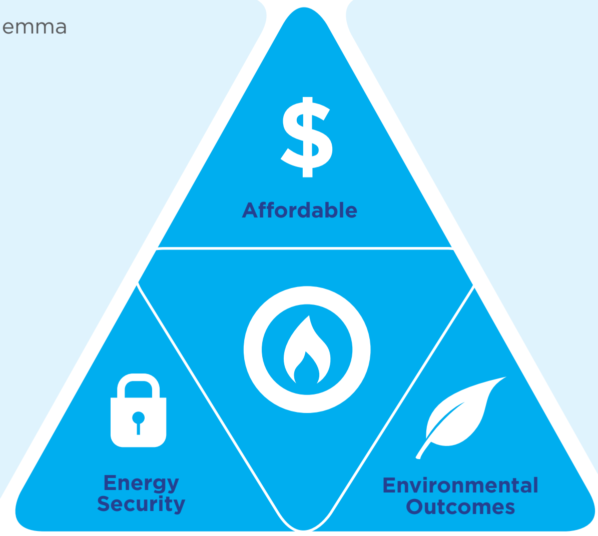
Achieving these emission reductions will require major changes to the energy system that will include how energy is used in households and by industry, as well as to the energy mix for power generation. This needs to be carefully managed to ensure an optimum solution is implemented that balances environmental outcomes (clean), energy security (reliable) and costs (affordable), a challenge that is known as the energy trilemma.

Gas is already a cleaner energy source than grid-sourced electricity. Beyond 2030, additional effort will be required to ensure the emission intensity of gas continues to reduce in line with international carbon abatement goals.

There are many other factors that will influence the transformation of the energy sector. These include:

- Australia's ageing power fleet and the closure of coal-fired power stations, such as the planned closure of Victoria's Hazelwood power station in early 2017.
- The increased level of residential rooftop photovoltaic (PV) throughout the network will reduce electricity generation demand from other sources. It is projected the number of rooftop PVs installed will continue to grow, even with reduced government subsidies.
- The projected growth in electrical vehicles will require additional electricity generation.
- Gas infrastructure already reaches 6.5 million homes. Leveraging this existing infrastructure makes economic sense.
- Growing gas distribution networks to new regions in Australia.
- Reduction of household gas consumption due to improved housing efficiency and warming weather.
- The intermittent nature of renewable generation and the additional cost for energy storage to allow it to be dispatchable.
- A tighter gas supply market with exploration and development restrictions for onshore gas in many Australian jurisdictions.

Figure 2: The Energy Trilemma



Gas will play a central role during this transformation and provides the following benefits to the Australian economy to 2030 and beyond.

In the home, direct use of gas will continue to offer lower emissions compared to electricity from the grid. Compared to electric resistance hot water systems[1], gas provides a cheaper option for hot water services within the home. Natural gas provides 44% of household energy but produces only 13% of household greenhouse gas emissions. Almost 70 per cent of homes use mains or bottled gas: that's 6.5 million homes and growing.

In cities, gas plays an important role within business districts and commercial buildings. It is used as a preferred energy source in restaurants. In businesses, such as laundries, or hospitals, gas provides hot water and steam. By using co-generation or tri-generation technologies, it can also provide heating, cooling and electricity to these organisations.

Within industry, gas is an essential feedstock for many chemical manufacturing processes, including plastics and fertilisers. In turn, these products can then be used in manufacturing or agriculture. Gas is also a preferred energy source as it provides high quality and clean heat to industrial processes. The opportunities for replacing gas in industry with renewables are quite limited as solar energy cannot provide the same quality of heat[2]. Half of the gas consumed in Australia is used in manufacturing and mining industries that contribute $196 billion to the national economy employing 949,000 Australians.

For power generation, gas continues to provide energy security as the level of renewable generation increases and base load, coal fired power stations are decommissioned. Gas generates electricity at lower emissions than coal fired power, so increasing the amount of gas used for electricity also helps reduce Australia's greenhouse gas emissions from power generation. Efficient gas power generation produces half the emissions of new high-efficiency coal plants and are much cheaper to build.

Gaseous fuels such as CNG, LNG and LPG enable regional and remote communities to enjoy the many benefits of gas and can also be used as transport fuels in passenger vehicles, public transport, trucks, railway and shipping. Over time, these fuels can be supplemented by biogas

The International Energy Agency[3] forecasts the Asian demand for natural gas to more than double between 2014 and 2040. This demand will provide good opportunities for LNG exports from Australia to supply the growing energy demands of our region. By 2020, Australia is expected to be the world's largest LNG exporter and will make up 20% of total global LNG exports.

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1 Core Energy Group (2014), Gas Network Sector Study, available from: www.energynetworks.com.au/ena-gas-network-sector-study-core-energy-group

2 ITP Renewables (2015), ARENA Report - Report on renewable energy options for Australian industrial gas users, www.itpau.com.au/re-for-australian-industrial-gas-users

3 International Energy Agency (2016), World Energy Outlook 2016 – Chapter 4.

The role of gas to 2030 and beyond requires the use of existing infrastructure and future network investment to support the needs of gas consumers. Using existing gas infrastructure is a sustainable and efficient approach to supporting future supply of energy. Increasing the proportion of electricity in the future energy mix would require building new electricity infrastructure.

> **"Global demand for gas is forecast to increase."**
>
> **International Energy Agency, 2016**

Potential transformation opportunities

Modelling completed by AEMO[4] and Jacobs[5] shows that the level of gas consumption will remain largely unchanged for households, businesses and industry out to 2030. Additional gas consumption is forecast in power generation in line with Australia's emission reduction targets. The study by Jacobs focused on this abatement outcome and found that gas used in power generation will see at least a tripling by 2030 to achieve the required emissions reduction from the electricity sector.

Separate work by McKinsey[6] found that there were commercially attractive opportunities for switching to gas in the transport sector. These opportunities reflect the use of CNG or LNG in heavy transport such as trucking, mining, buses, ships and rail.

The global demand for gas is forecast to increase, as per the International Energy Agency's projections, leading to greater potential export opportunities for Australia. This will require ongoing exploration and development of both conventional and unconventional gas fields with the correct policy settings to facilitate this activity.

Gas-fired generation supports the security and reliability of the power system[7]. Gas plays a key role in providing energy security as demonstrated by the return to service of older gas-fired plants in South Australian and Tasmania recently to supply power during the 2016 outage of Basslink to Tasmania and the Heywood connector to South Australia. Gas can continue to provide energy security as older generation assets retire.

There will be challenges but the opportunities for gas out to 2030 and beyond are clear. It is important to ensure the correct policy settings so gas can contribute to addressing the challenges of the energy trilemma.

Deeper decarbonisation will depend on three transformational technologies that can be demonstrated by 2030 and then widely deployed between 2030 and 2050.

> **"Gas-fired generation supports the security and reliability of the power system."**

4 AEMO (2016), National Gas Forecasting Report for eastern and south-eastern Australia, December 2016, available from www.aemo.com.au

5 Jacobs (2016), Australia's Climate Policy Options – Modelling of Alternate Policy Scenarios, available from www.energynetworks.com.au

6 McKinsey & Company (2016), The role of natural gas in Australia's future energy mix, June 2016, available from www.appea.com.au

7 Finkel, A. (2016), Independent Review into the Future Security of the National Electricity Market – Preliminary Report, December 2016.

BOX 1 : GLOBAL GAS MARKETS.

The International Energy Agency[8] (IEA) recognises that gas is the least carbon intensive of the fossil fuels and thus burning gas is a much more efficient way to use a limited carbon budget than combusting coal or oil. The 2016 World Energy Outlook provides a New Policies Scenario that represents the pledges made by more than 180 countries in how they will reduce their greenhouse gas emissions as part of the COP21 Paris agreement. The outlook for the medium term indicates that markets for coal, oil and gas are all oversupplied until the 2020s and that global gas demand will continue to grow at 1.4% per year until 2020. The longer-term modelling shows that global gas demand continues to grow on average by 1.5 % to 2040.

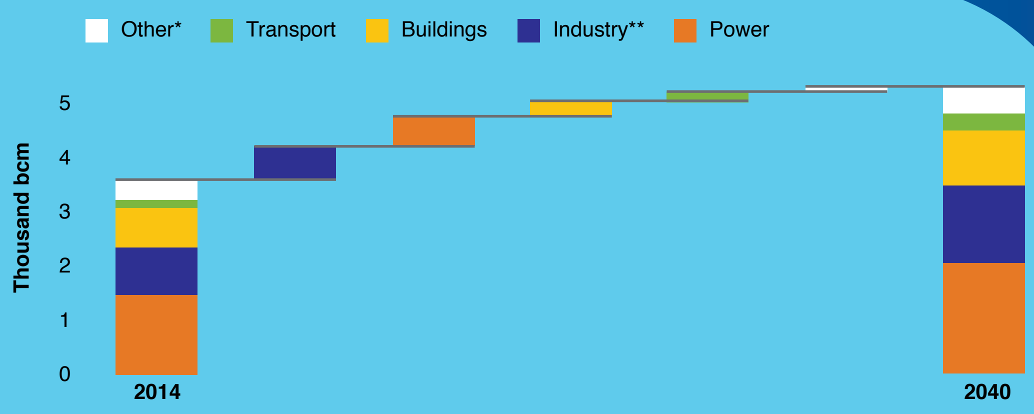
The power sector is the largest gas consuming sector, accounting for 40% of worldwide gas demand today, and it contributes 35% to global gas growth – the same as industry. However, this sector also faces the greatest uncertainty because of the number of competing fuels for power generation ranging from coal to renewables. The IEA notes that gas-fired technologies entails a far lower capital cost compared to coal generation. Depending on the relative fuel (and carbon prices) the lower investment cost can offset the typically higher fuel costs of gas plants. The cost of combined cycle gas turbine amounts to approximately $1,000 per kilowatt, which is half the cost of high-efficiency supercritical coal plant.

Natural gas demand for industry is also forecast to grow by over 50% mainly due to rising demand for the process heat and steam generation needed to meet the requirements of economic growth.

Gas consumption for residential and commercial buildings is forecast to increase by 50% by 2040. Thirty percent of that growth comes from China alone. With the envisaged expansion of China's gas distribution network, scope for gas to displace coal, oil and the traditional use of biomass is large in the Chinese building sector. Growth opportunities for gas demand in the buildings sector for developed countries are limited as heating demand is largely saturated, energy efficiency of buildings continues to improve and coal and oil have been largely displaced from buildings.

Gas demand for transport is forecast to more than double the current levels. This growth is primarily driven by road transport which accounts for two-thirds of the total growth demand with the remainder being taken up by marine transport where the role of LNG as a bunker fuel rapidly rises. The key uncertainty for the future role of gas in the transport sector continues to be the dilemma around refueling infrastructure.

Figure 3: World gas demand growth by sector in the New Policies Scenario



* Other includes agriculture and any other non-energy use
** Industry includes gas used as petrochemical feedstocks, and energy consumption in coke and blast furnaces

Source: International Energy Agency, World Energy Outlook 2016, Chapter 4.

8 International Energy Agency (2016), World Energy Outlook 2016 – Chapter 4.

Policy settings

Australia's policy settings can strongly shape what Australia will look like in 2030 and 2050. The gas industry's preferred policy settings revolve around:

- Australia contributing fairly to the global reductions of greenhouse gas emissions and pursuing these targets with a technology neutral approach.
- Ensuring security across the energy system by considering renewables, electricity and gas as a single energy system.
- Avoiding unnecessary regulation or placing unwarranted restrictions on the development of industry.
- Allowing markets to work effectively to reduce costs to consumers and increase economic benefit.

Proposed policy settings and their influence on economic outcomes are outlined below.

Table 1: Proposed policy settings and their influence on economic outcomes

Policy settings	**Economic Outcome**			
	Environmental outcomes	Energy Security	Cost Effectiveness	Jobs & Economic Growth
Continue to ensure that gas expansions for new residential and commercial developments are based on economic outcomes.	✓	✓	✓	✓
Ongoing support for research, development and demonstration of a diverse range of low emission technologies.	✓	✓	✓	✓
By mid-2017, achieve COAG agreement to appoint an independent agency to complete an independent assessment of national energy market implications, including power systems security, when developing jurisdiction initiatives on carbon and renewables policy.	✓	✓	✓	
By end 2017, agree and establish an enduring, stable and nationally integrated carbon policy framework based on consensus.	✓		✓	✓
By end 2017, adopt a scientific approach for approving gas exploration instead of regional bans on gas exploration and development.	✓	✓	✓	✓
By 2018, implement an appropriate light vehicle emissions standard policy, supporting COP21 climate goals.	✓	✓	✓	
By 2019, complete a review of the effectiveness of federal and state governments' direct incentive programs that are focused at providing technology specific support beyond 2020.		✓	✓	
By 2019, establish regulatory frameworks that encourage innovation in industry.	✓	✓	✓	✓
By 2021, ensure gas markets are operating to achieve optimal outcomes for domestic gas users and gas exporters without introducing energy market distortions, such as reservation policies.		✓	✓	✓
By 2020, establish a national climate change policy response that delivers greenhouse gas emission reductions at least cost and facilitates broad based investment decisions consistent with an international price on carbon.	✓	✓	✓	✓
By 2022, review Australia's nationally determined contributions to ensure they remain aligned with achieving the long-term objectives of the COP21 Agreement.	✓		✓	✓

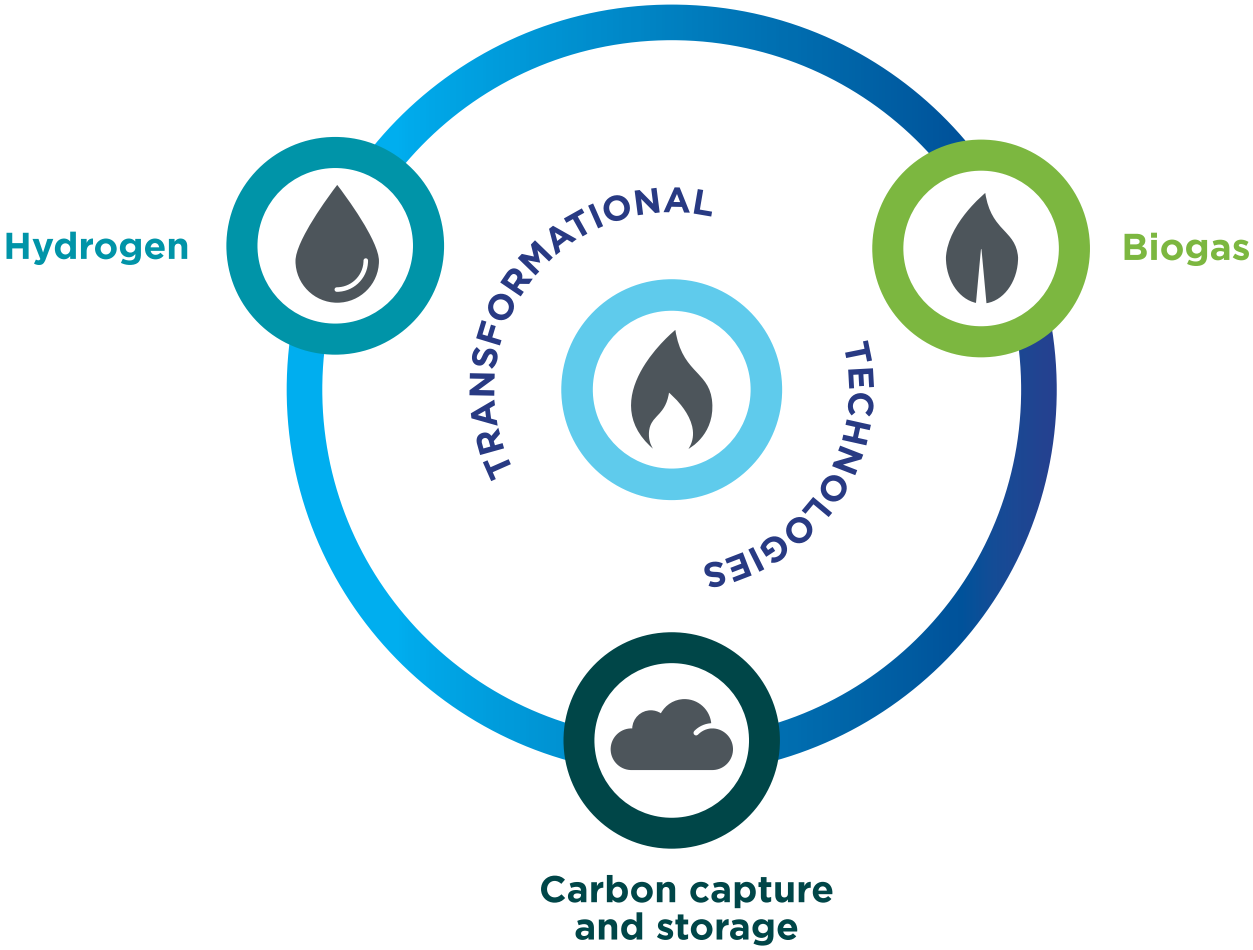
Low emission transformational technologies

The energy sector faces the challenge of cutting greenhouse gas emissions without compromising safety, security and affordability. Innovation will be key to achieving this goal.

Amongst many technology options, three transformational technologies stand out for producing low emissions from the use of gaseous fuels, biogas, carbon capture and storage (CCS), and integration of gas and hydrogen.

These three technologies can be used to slash emissions from gaseous fuels, ensuring that the benefits of gas can continue to be enjoyed in a decarbonising economy beyond 2050.

Figure 4: Integration of low emission transformational technologies with gas



Biogas

Biogas is a term that covers gaseous fuels such as biomethane or biopropane recovered from renewable sources including wastewater, landfill, agricultural or forestry waste. This means there are net-zero emissions from its use. Feedstock sources for biogas are widely available and diverse, so biogas could be produced at many different locations close to users and simply injected into the existing network. ARENA is funding a study[9] to identify and assess the bioenergy sources across Australia. This project will provide reliable nationwide information on biomass feedstocks, which will support the development of bioenergy and biogas projects across Australia.

Production of biomethane, which is the same as natural gas, is a well-established process using currently available commercial technologies. It can be mixed with natural gas in transmission and distribution networks with no modifications of user appliances or industrial processes required. Production of biopropane, which is the same as propane in LPG, is becoming established overseas. It can be used as a transportable gaseous fuel in areas where the gas network does not extend. Biogas can be stored in the distribution or transmission networks, or within cylinders, effectively providing renewable energy on demand. Biomethane converted to CNG or LNG or biopropane can also be used as transport fuel.

The potential for biogas is significant. In Canada[10], it is estimated that up to 1,300 billion cubic feet of biogas could be produced annually, representing approximately 50% of domestic gas consumption. In the UK[11], it is estimated that between 30 and 50% of natural gas demand could be met from the production of biogas.

The Clean Energy Council[12] estimates that Australia's bioenergy has the potential to power 10.2 million homes by 2050, although that is mostly focused on using biomass for power generation instead of the production of biogas. Regardless, the potential for biogas is significant.

Converting waste to biogas also benefits our environment through improved waste management and reduced waste.

Producing biogas from biomass uses a commercially available reactor that reduces the biomass to biogas. This gas is then processed prior to being injected into the distribution network. This practice is common in Europe, especially in Norway, Germany and the United Kingdom. Within Australia, the largest biogas reactor is located near Goulburn, New South Wales, and processes 20 percent of Sydney's household waste. This reactor[13] is located at an old mine site. The biogas produced is converted to green electricity, but also provides heat for an aquaculture farm. Another project[14] in Western Australia, uses a specialised process to convert biomass into biogas. This project procured and modified technology from European vendors. Once again, the current setup is focused on generating green electricity but the project could just as easily be configured to produce gas that can be injected into the gas network as renewable gas.

There are no technical obstacles to biogas production. It has been proven on a commercial basis for producing renewable electricity and the produced gas could easily be injected into the distribution network as renewable gas.

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9 ARENA (2016), The Australian biomass for bioenergy assessment project, https://arena.gov.au/project/the-australian-biomass-for-bioenergy-assessment-project/

10 Canadian Gas Association (2014), Renewable natural gas technology roadmap for Canada, December 2014.

11 National Grid (2016), The future of gas – supply of renewable gas, available from http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Gas/

12 Clean Energy Council (2012), Bioenergy fact sheet, available from: https://www.cleanenergycouncil.org.au/cec.html

13 www.veolia.com/anz/our-services/services/municipal-residential/recovering-resources-waste/woodlawn-bioreactor

14 Jandakot project – biogas, available from: https://arena.gov.au/files/2015/11/Jandakot-Bioenergy-Plant.pdf

Carbon capture and storage

Carbon capture and storage (CCS) combines a range of commercially available technologies – used widely by the oil and gas industry – to limit the amount of greenhouse gas emissions reaching the atmosphere.

CCS is comprised of three processes that need to be integrated for effective reduction of greenhouse gases[15].

- Firstly, the carbon dioxide (CO_2) is separated. This is already widely practised in gas processing where the CO_2 needs to be removed from the raw produced gas to meet pipeline specifications. For example, the Sleipner project in Norway has separated CO_2 from natural gas since the early 1990s and has successfully stored 16 million tonnes of CO_2 in the subsurface instead of emitting it to the air. CO_2 separation is also carried out in industrial processes such as hydrogen or fertiliser production. Within the power generation sector, research has been undertaken to modify these capture processes to make them suitable for power generation. The Boundary Dam project in Canada is the world's first demonstration of carbon capture at a commercial coal-fired power station and another three commercial scale CCS projects are expected to commence operation in early 2017 in the power generation sector.
- Secondly, the CO_2 is compressed and transported to the storage site. It is most commonly transported via pipeline, although shipping can also be a viable alternative. Transporting CO_2 in pipelines is common practice, with the United States alone having over 7,600 km of high pressure CO_2 pipelines in operation. These provide naturally occurring CO_2 to oil and gas fields for enhancing oil recovery from those fields.
- Lastly, the CO_2 is injected in suitable geological formations, thereby preventing it from reaching the atmosphere so it does not contribute towards global warming. Geological storage has been widely carried out in enhanced oil recovery operations, although some of that CO_2 is subsequently recovered. Alternate storage sites have no CO_2 recovered. At the end of 2016, 29.5 million tonnes of CO_2 were geologically stored per annum, with a further four projects nearing completion that will inject a further 8.8 million tonnes per annum. One of these projects is Australia's Gorgon project[16] that is separating the reservoir CO_2 and reinjecting that into the surface from its LNG operations. CO_2 injection at this project is expected to come online in the first half of 2017.

While the technology is commercially demonstrated in gas processing, at industrial processes and for power generation around the world, its deployment has been slow. CCS will be required if the level of global emission reductions as agreed at the international negotiations in Paris in 2015 are to be achieved[17]. The International Panel for Climate Change (IPCC) noted in its *Climate Change 2014*[18] report that that the mitigation cost of achieving the Paris targets (450 parts per million CO_2) could be 138% more if CCS is not available.

Australian CCS activity is focused on improved understanding of geological storage sites and conditions. Major projects[19] have been funded to help increase the knowledge of the geology and its potential for carbon storage. Additional research[20] is also being supported to improve the understanding of: subsurface knowledge and mapping; transport infrastructure, technology and methodologies; whole-of-chain integration and cross-cutting issues; and, development of international collaboration. This work is continuing.

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15 Global CCS Institute (2016), *The global status of CCS – 2016*, available from www.globalccsinstitute.com
16 Chevron, Carbon Dioxide Injection Project, www.chevronaustralia.com/docs/default-source/default-document-library/fact-sheet-gorgon-co2-injection-project.pdf?sfvrsn=16
17 United Nations Framework Convention on Climate Change (UNFCCC) 2015 Paris Climate Change Conference
18 IPCC (2014), *Climate Change 2014: Synthesis Report – Summary for Policymakers*, available from http://ipcc.ch/report/ar5/syr/
19 Department of Industry (2016), https://industry.gov.au/resource/LowEmissionsFossilFuelTech/Pages/Carbon-Capture-Storage-Flagships.aspx
20 Department of Industry (2016), https://industry.gov.au/resource/LowEmissionsFossilFuelTech/Pages/Carbon-Capture-and-Storage-Research-Development-Demonstration-Fund.aspx

Integration of gas and hydrogen

Hydrogen is the most abundant chemical element in the universe and the third most abundant element on the Earth's surface.

Hydrogen is a clean burning fuel that only produces water vapour during combustion. Hydrogen can be used as a supplement, or as an alternative, to methane in gas networks or in fuel cells to generate heat or electricity. These in turn can provide energy for vehicles, homes or commercial buildings. Hydrogen is not new as a gaseous fuel. Prior to the introduction of natural gas, town gas – produced from coal - was distributed in towns and cities, and was first used in Australia in 1841. This fuel was made from a variety of raw materials, usually coal, and town gas consisted of 50 to 60% hydrogen. The conversion to natural gas started in Adelaide, Brisbane and Melbourne in 1969 and in Sydney in 1976.

The conversion to hydrogen networks is driven by the need to reduce greenhouse gas emissions. While direct use of natural gas already has one-quarter to one-sixth the emissions of grid based electricity in coal-powered states, in the longer-term, even those emissions may need to reduce. Initially, carbon reductions may be achieved by blending biogas with methane in existing plastic natural gas distribution networks. Further emissions reductions could occur by increasing the proportion of biogas or blending with hydrogen in networks resulting in a mixture of natural gas, biogas and hydrogen.

Hydrogen volumes of up to 10% are already injected in the network in Germany without modifications to the network or appliances. If required for greenhouse gas emission reductions, entire networks may be converted to pure hydrogen or mixtures of hydrogen and biogas in the long-term. This may require some modifications to existing gas appliances but a suitable transformation program could be developed to minimise the cost and impacts on consumers.

Currently, hydrogen is commonly produced from natural gas. Cities around the country have natural gas delivered via long distance transport of gas (e.g. transmission pipelines or potentially LNG tankers), so adding production facilities at cities' edges to produce hydrogen, and injecting the hydrogen into the distribution system, is easily achievable. Any CO_2 by-product could be stored securely through CCS or used in the production of other materials. These innovations create the potential for clean, dispatchable energy resulting in zero emissions while using existing infrastructure. Preliminary planning and feasibility studies of a project like this have been completed for the city of Leeds[21], UK. The intention of that project is to convert 264,000 households and business from natural gas to hydrogen by 2030.

An alternative is to produce hydrogen using electrolysis powered by excess renewable energy. With generation from renewables unlikely to coincide with demand from energy users, efficient storage solutions are essential. Unused energy generated by renewables could be converted to hydrogen through power-to-gas technology.

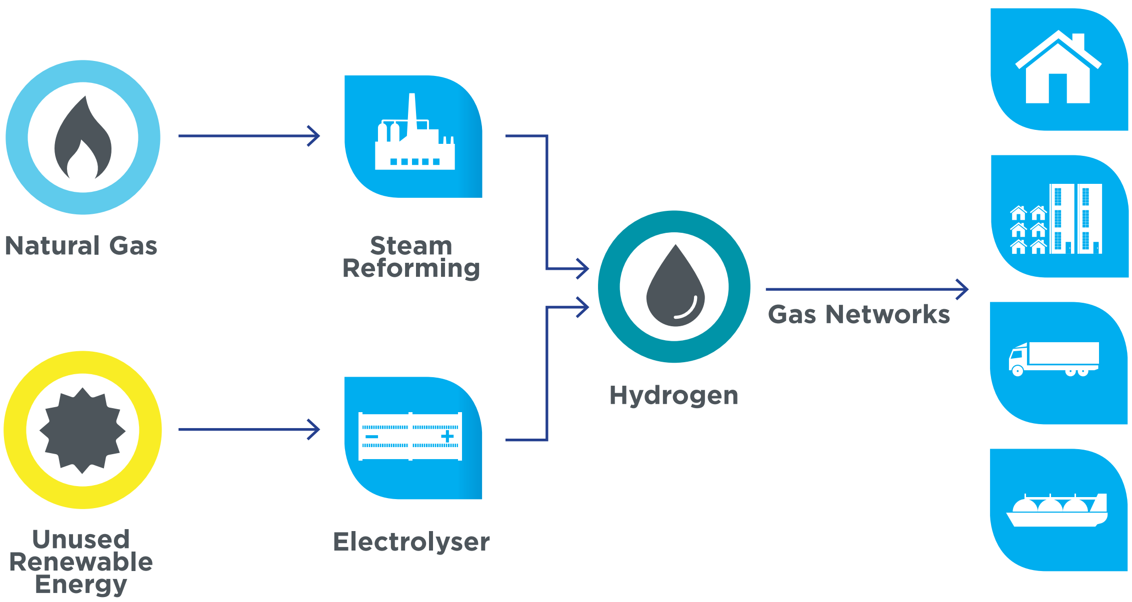
21 Northern Gas Networks (2016), *H21 Leeds City Gate project*, accessed from: www.northerngasnetworks.co.uk/archives/document/h21-leeds-city-gate

The hydrogen could then be stored in the gas network. In these systems, which are already in use today (for example, the 2MW power-to-gas demonstration plant in Falkenhagen, Germany), surplus renewable energy can be used to electrolyse water. This then releases pure hydrogen, which can be injected and stored in existing networks thereby avoiding expensive new batteries.

Hydrogen can be stored in the gas pipeline network or in underground storage. These integrated solutions help to address the intermittency of renewable energy sources and enable a secure transformation to a net-zero emissions energy system. The storage of hydrogen provides short term supply of gas as well as inter-seasonal supply of gas.

Exporting hydrogen from Australia from either natural gas with CCS or excess renewable energy, provides a significant economic opportunity. For example, Japan has developed a roadmap[22] for hydrogen and Japanese businesses[23] are looking at Australian natural energy resources to supply that hydrogen.

Figure 5: Hydrogen Pathways



22 METI (2014), *Summary of the Strategic Road Map for Hydrogen and Fuel Cells*, accessed from: www.meti.go.jp/english/press/2014/pdf/0624_04a.pdf

23 Kawasaki (2017), *Kawasaki Hydrogen* Roadmap, accessed from http://global.kawasaki.com/en/stories/hydrogen/

Technology mix

Ongoing research, development and demonstration of the three transformational technologies will be required to meet the global 2050 carbon reduction goal. All technologies described in this *Vision* have been demonstrated but additional work will be required to further improve the efficiencies and reduce their costs, as well as customising the technologies to Australian conditions.

It is expected that these and other energy technologies, such as energy storage and advanced solar photovoltaics, will all contribute towards the energy mix. The three transformational technologies will allow the benefits of natural gas to continue to be enjoyed in a net-zero emissions economy. Natural gas can continue to be used for industry and power generation where its emissions can be captured and stored using CCS. Or natural gas can be used to produce hydrogen which can then be injected into networks along with biogas and renewable hydrogen to provide zero emissions energy to households and cities.

The correct policy settings will encourage all technologies with an opportunity to contribute to the energy mix of 2050 and the optimal energy mix to meet the energy market requirements and account for energy security, cost-effectiveness and environmental outcomes.

"The correct policy settings should be technology neutral."

Gas Vision 2050

Reliable, secure energy and cost-effective carbon reduction

This *Gas Vision 2050* (‘*Vision*’) describes an aspirational and attainable future for gas across Australia’s economy. With our population forecast to almost double to 40 million by 2050, Australia’s need for energy, food and materials will only rise.

The *Vision* highlights how gas and renewables can support each other to achieve a near zero carbon energy sector by 2050, including a decarbonisation pathway for gas beyond 2050.

Gas will continue to benefit the economy and provide the following outcomes:

- environmental
- energy security
- cost-effectiveness
- jobs and economic growth

“With a forecast population of 40 million by 2050, Australia will need new sources of energy, food and materials.”

The *Vision* describes major changes to Australia’s energy mix and to the role of gas in this mix. The *Vision* is not an economic analysis or a price forecast. Rather, it seeks to extrapolate from today’s technologies and trends, a future which meets the international aspiration of zero emissions beyond 2050, while delivering energy security, affordability, and jobs in Australia.

The following pages provide a conceptual framework of gas across the economy in 2050. It is the starting point of our journey and will be refined and further developed as the role of gas in the Australian energy mix continues to evolve.

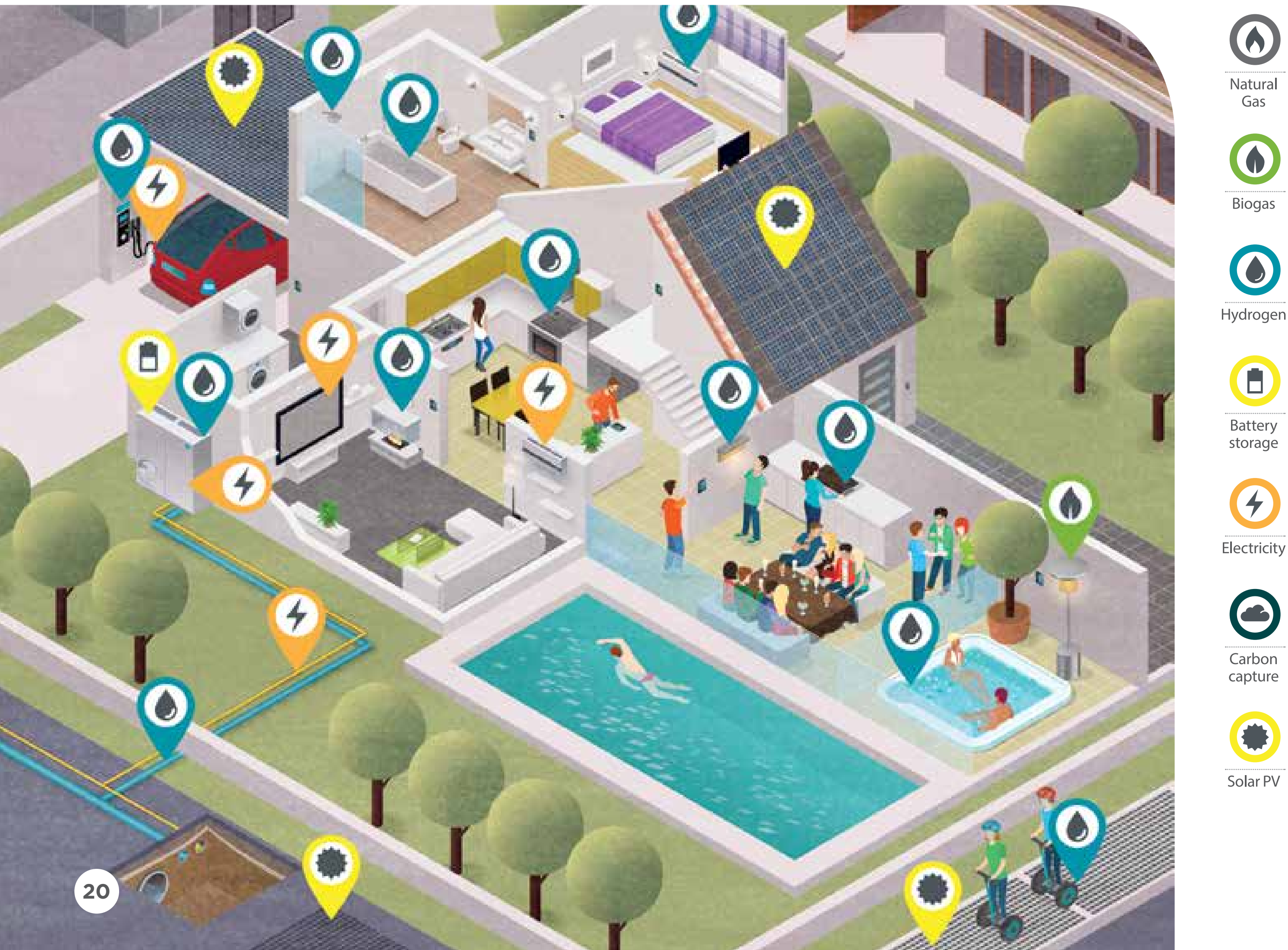
Gas in the 2050 home

It is a Sunday afternoon in April 2050 and an Australian family is having friends around for a barbecue.

The guests arrive in shared driverless electric or hydrogen fuel-cell vehicles or drones, except for one family. They're going camping the next morning and have driven their hydrogen powered 4WD - which still has a steering wheel – to the barbecue. They are also taking a cylinder of biogas so they can cook and enjoy hot water while travelling.

Smart solar PV materials in the 'skin' of the house produce most of the family's electricity during the day. The home battery system is integrated into the family's electric vehicle and connects to the electricity grid. Zero emission hydrogen gas – via the distribution network from the local hydrogen production facility – provides the home with fuel flexibility and powers the family's hydrogen vehicles. Hydrogen is also used in fuel cells to generate electricity and complements the home battery system. It can also be used directly for hot water, heating or cooking where a range of coloured flames can be produced.

At night time, the outdoor entertainment area is heated using hydrogen space heaters. Away from the house, additional heating is provided using biogas in portable heaters.



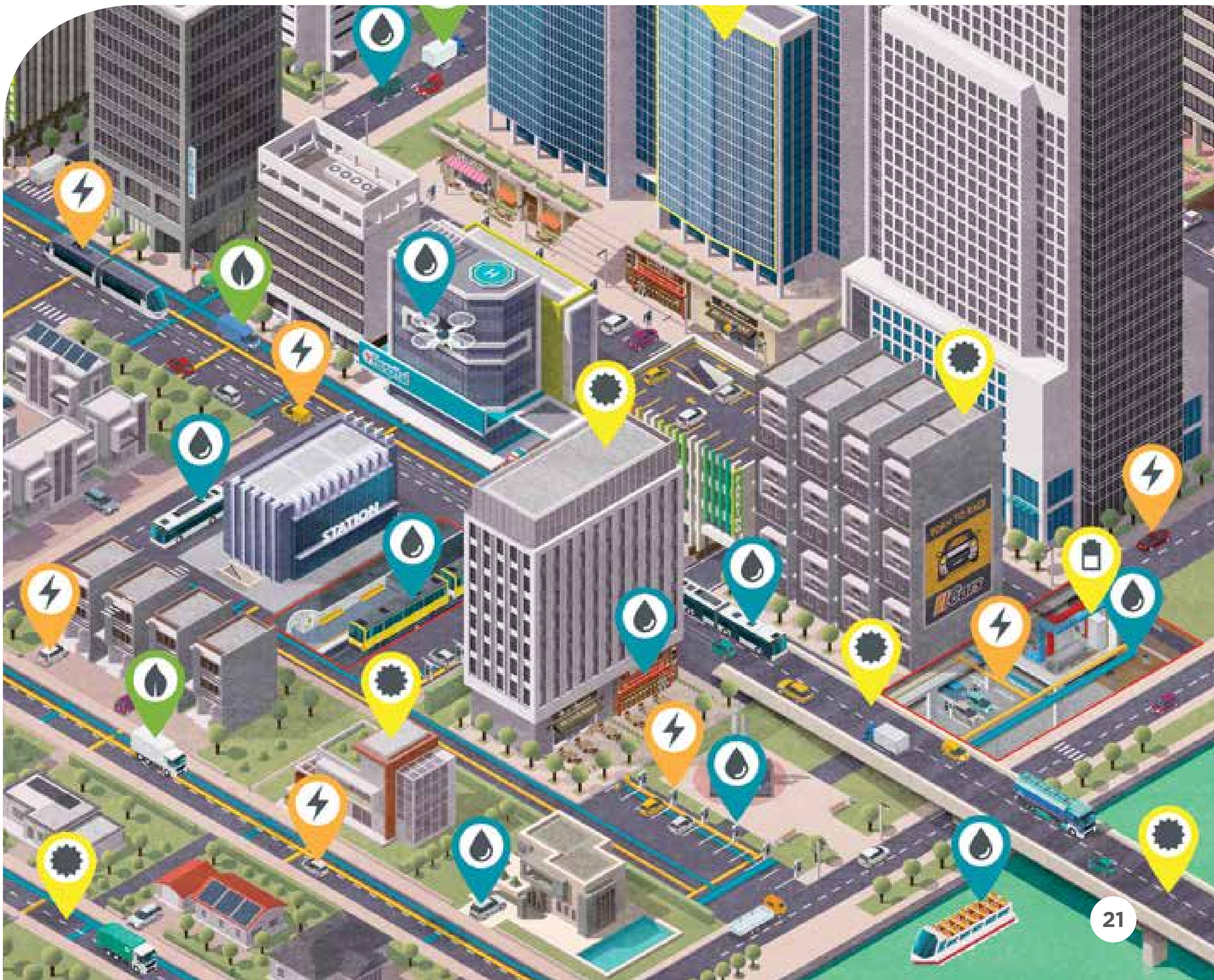
Gas in cities in 2050

The city block of 2050 is an integrated energy system. Smog is a thing of the past as only clean fuels are used in the city.

During daytime, the city generates much of its electricity from integrated solar PV materials within the buildings' material. At times, the city can generate more power than it requires. This can either be stored in utility-scale batteries, exported through the transformed electricity grid and used elsewhere in the system, or converted to hydrogen and injected into the gas network for storage. As people park their vehicles they are automatically connected to the grid. Smart systems ensure that individual vehicles are charged at the right time – using either electricity or hydrogen – so the overall energy demands of the city are met. The grid also connects the city to low carbon power generation to ensure that the total electricity demand is securely met.

Hydrogen gas is produced at the edge of the city and injected into the gas network to meet additional energy requirements. This hydrogen can be used in tri-generation units to provide a range of cooling, heating and electrical services to buildings. Public transport within the city is largely powered using hydrogen in trains, ferries, driverless cars or drones. Goods delivery in the city is made possible through biogas fuelled trucks that are quieter and produce no pollution. The hydrogen is also used to refuel the hydrogen fuel cells of the cars from residents and visitors to the city.

Entertainment and dining in the city relies on hydrogen to provide control over cooking in restaurants. Hydrogen is also used to provide heating to outdoor dining areas and sporting venues.



Gas in industry in 2050

On a typical day in 2050, natural gas produced from onshore and offshore reservoirs is sold at the gas hub where contracts for export and domestic use of gas are met.

This gas is processed prior to sale. The CO_2 is removed and injected into the ground resulting in a clean gas. It is then exported or pipelined to cities and industrial precincts around the country.

Another shipment of natural gas – such as LNG - leaves the harbour, taking cleaner Australian energy to our neighbours in Asia. While renewable electricity generation in Asia has grown, large amounts of natural gas are still imported to support manufacturing and industry. On the horizon, another ship is waiting to dock and be loaded with Australian minerals and agricultural products.

The waste materials from the agricultural and forestry sector are processed to produce biogas and 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. Heavy transport relies on this biogas to move materials around the country.

Natural gas remains 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. At the edge of cities, hydrogen is produced from natural gas, which is then injected into the gas network supporting that city.

Carbon capture and storage is used to ensure that the CO_2 from industry is not emitted into the atmosphere. Alternatively, the CO_2 is used to manufacture specialty chemicals and materials, resulting in zero emissions from industry.

Gas power generation in 2050

On a hot summer day in December 2050 the power generation sector is supporting the electricity demands of Australian households, businesses, cities and industry. Power blackouts on days like today are a distant memory.

Power generation is decarbonised and widely distributed using a wide range of technologies. While houses and cities generate their own power, and use carbon-free hydrogen for thermal loads, the electricity grid provides additional resilience and connects the electrical demand of the cities with power generation including large scale hydro, wind, solar thermal, and gas generation.

Very high levels of renewables penetration has created large storage requirements. These are met through both grid scale batteries and traditional energy storage such as pumped hydro. Electrolysis produces hydrogen which can be stored underground and in the gas networks for later use or during the colder winter months.

Biogas is produced in regional Australia and this is combined with hydrogen in gas turbines to manage peak demand.

Natural gas generation with carbon capture and storage supports intermittent generation and provides ancillary services such as frequency support.

These technologies combine to provide secure, lowest cost and low emissions electricity for use across the economy.

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