How National Climate Change response can both benefit and burden the gas industry

Presentation to the 2017 Australian Pipelines and Gas Association (APGA) Convention

19 October 2017 | Dr Gordon Weiss

Executive summary

The recent challenges facing Australia's power supplies have highlighted the difficulties of balancing expectations of cheap, reliable energy with the integration of new, clean energy sources across the generation mix. Solar and wind generation are now competitively priced and their uptake is forecast to increase driven primarily by economics. However, as these new energy sources challenge the effectiveness of traditional modes of transmission and distribution due to the intermittent nature of their supply, there is an opportunity for the gas industry to provide a solution that offers the necessary flexibility and responsiveness.

The case for gas fired power as a complement to renewables is further supported by the outlook for national energy demand. Modelling by Energetics demonstrates that across a range of energy productivity targets and emissions reduction objectives, demand for energy will fall, which has implications for the make-up of Australia's energy generation mix. Across all scenarios modelled, the percentage of renewables in the total energy mix grows through to 2030, with gas fired generation potentially providing a key part of the balance of supply. However, with the current political debate supporting coal based generation, the gas industry must argue the case for gas fired generation as offering far greater advantages for ensuring security of supply and for delivering on Australia's emissions reduction commitments under the Paris Climate Agreement.

This paper also argues that a vision for gas fired power in the energy mix must be presented quickly. The rise of batteries, along with other forms of energy storage, poses a clear threat to gas as the transition fuel.

The gas industry must work with energy users, governments and the renewables industry to enhance the role of gas in a market that delivers both reliable electricity supplies and emissions reductions from power generation.

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1. Introduction

Natural gas has traditionally enjoyed support as an ideal fuel for industrial, commercial and residential heating applications. It is also available as a fuel for thermal power generation, typically in a gas turbine open cycle power plant (OCGT) or a gas turbine combined cycle (CCGT) power plant. The former has the advantage of a short start-up time and a fast response. The latter benefit from high thermal efficiencies compared to other forms of thermal power generation. Also, the greenhouse gas emissions from a gas fired power plant are, in almost all circumstances, lower than emissions from a coal fired power plant[1]. Therefore, in a carbon constrained world, gas for power generation has a natural advantage over coal fired generation. In this paper, we examine these potential advantages in the context of gas as the transition fuel for power generation.

The International Energy Outlook published by the U.S. Energy Information Administration[2] projects that global natural gas consumption will increase from 124 trillion cubic feet (Tcf) in 2015 to 177 Tcf in 2040 (see **Figure** 1). Natural gas accounts for the largest increase in world primary energy consumption, and it remains a key fuel in the electric power sector and the industrial sector. In the power sector, natural gas becomes the attractive choice for new generating plants because of its relative fuel efficiency and low greenhouse gas emissions.

Natural gas and renewables compete to supply the expansion of the global power demand. However, the situation in Australia is not so clear.

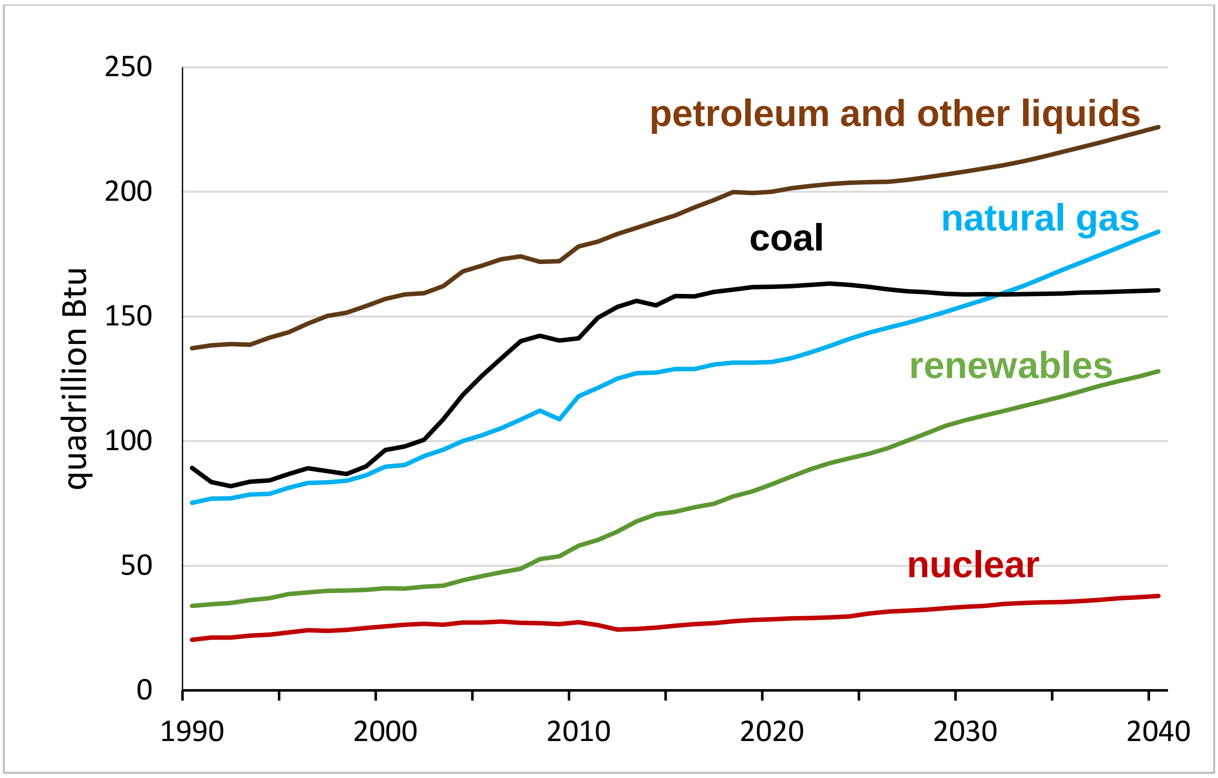

Figure 1: World energy consumption by energy source[2]

[1] Figure 4 compares the emissions of various classes of gas-fired and coal-fired generators.
[2] "International Energy Outlook 2017", U.S. Energy Information Administration, 2017

1.1. The mess that is energy and climate change policy in Australia

"Coal is dead"[3]. This is the view of BlackRock, the largest investor in the world. And Blackrock is not alone. Australian banks are backing away from investment in the coal industry[4,5].

However, the recent challenges to energy cost and reliability in Australia are seen by many supporters of the coal industry as a way of extending the role of coal in Australia's generation mix. Many of the reasons cited by the supporters of coal are not supported by the evidence. Some of this evidence – the average cost of power from various types of generators – is included in this paper.

One consequence of the recent focus on energy security and on proposals from members of the Government for procuring coal fired power stations is a reduced focus on climate change policy. This is unfortunate. Emissions reductions, which are tied to the national and global response to climate change, cannot be ignored. The majority of the scientific and engineering community, the majority of policy makers, the majority of business leaders and the majority of Australian accept the evidence that human activities are influencing the global climate. Personal views about the merits or otherwise of the current state of climate science by some politicians and opinion leaders, is not a robust basis for setting national policy. Further, the genuine challenges of high energy prices and uncertain supply that Australia faces due to the mismanagement of energy policy should not be used as an excuse to abandon Australia's contribution to global efforts to address human induced climate change.

This paper discusses the emissions reduction challenge that Australia has, and touches on the role of various types of generation in the context of the evolution of the generation fleet from being based on fossil fuels to being based on low cost renewable generation. This leads to the need for a flexible, efficient transition fuel that can balance intermittent supply, and which can be deployed quickly given the current, urgent need to address energy cost and security concerns.

Finally, we examine the trends which may impact the demand for gas and options the industry may have to position natural gas as a solution in the transition to a renewables-led generation mix.

2. Transition to what?

At the 2015 Paris Climate Change Conference, Australia committed to both a short term national emissions reduction target of 28 per cent below 2005 levels by 2030, and a broader objective of contributing to a '2-degree world', that is limiting the global average temperature increase to well below 2 degrees above pre-industrial levels.

Figure 2 shows the challenges that these objectives pose. The figure displays Australia's past and projected emissions, and our national targets. The 2030 target is the short-term commitment and falls well short of the commitment to the 2-degree world. Emissions are forecast to rise to just over

600 Mt CO_2-e, well above even the short term target.

[3] ***http://www.afr.com/business/mining/coal/blackrock-says-coal-is-dead-as-it-eyes-renewable-power-splurge-20170524-gwbuu6***
[4] "The future of Australian coal: an unbankable deposit", The Conversation, May 3, 2017
[5] "ANZ turns a coal shoulder on Liddell power station", The Australian, September 8, 2017

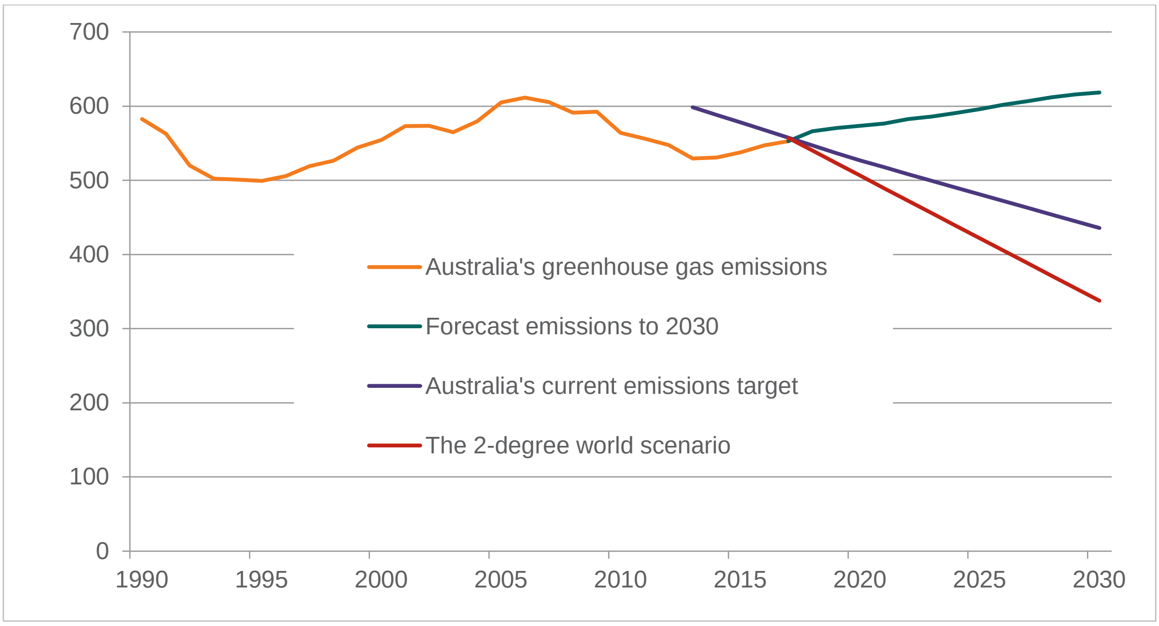

Figure 2: Australia's greenhouse emissions and targets[6]

A substantial gap exists between our international commitment to reduce emissions and the expected rise in emissions in the absence of action. The Australian Government and the state and territory governments are developing a range of policies to address this gap. A look at the sources of Australia's emissions helps to focus attention on the areas where the reductions in emissions must come from.

Energetics' modelling[7] shows that the majority of the emissions reductions opportunities through to 2030 are to be found within Australia's energy sector – electricity, stationary energy and transport - with electricity generation contributing half. The clear conclusion is that the energy sector needs to be the focus of efforts to reduce emissions. In the absence of decarbonising energy generation and driving down the demand for energy, Australia will struggle meet our 2030 target and will lack the ability to deepen emissions reductions in line with the 2 degree world and the 1.5 degree aspirational target.

Our modelling has shown that coal fired generation must be systematically replaced with lower carbon energy. This can be achieved by using a number of tools. For instance, increasing Australia's energy productivity[8] by 40% by 2030, replacing all coal fired generation with gas fired generation and lowering the emissions intensity of stationary energy applications would see the country meet its current 28% emissions reduction objective. Under this scenario gas fired generation increases by 250%.

The fundamental argument for gas as a transition fuel - the fact that burning gas in a power station tends to produce lower greenhouse gas emissions than burning coal, for the same quantity of electricity produced – supports a growth in demand for gas during the transition from today's

[6] Sources: Australian Government, Energetics analysis
[7] http://www.environment.gov.au/submissions/climate-change/review-climate-change-policies-2017/energetics.docx
[8] Energy productivity measures the ratio between GDP and energy consumed. The current national energy productivity target is a 40% increase by 2030.

energy mix to the alternative, low or zero emissions energy sources such a renewables and potentially modern nuclear power[9]. However, this advantage is threatened in several ways.

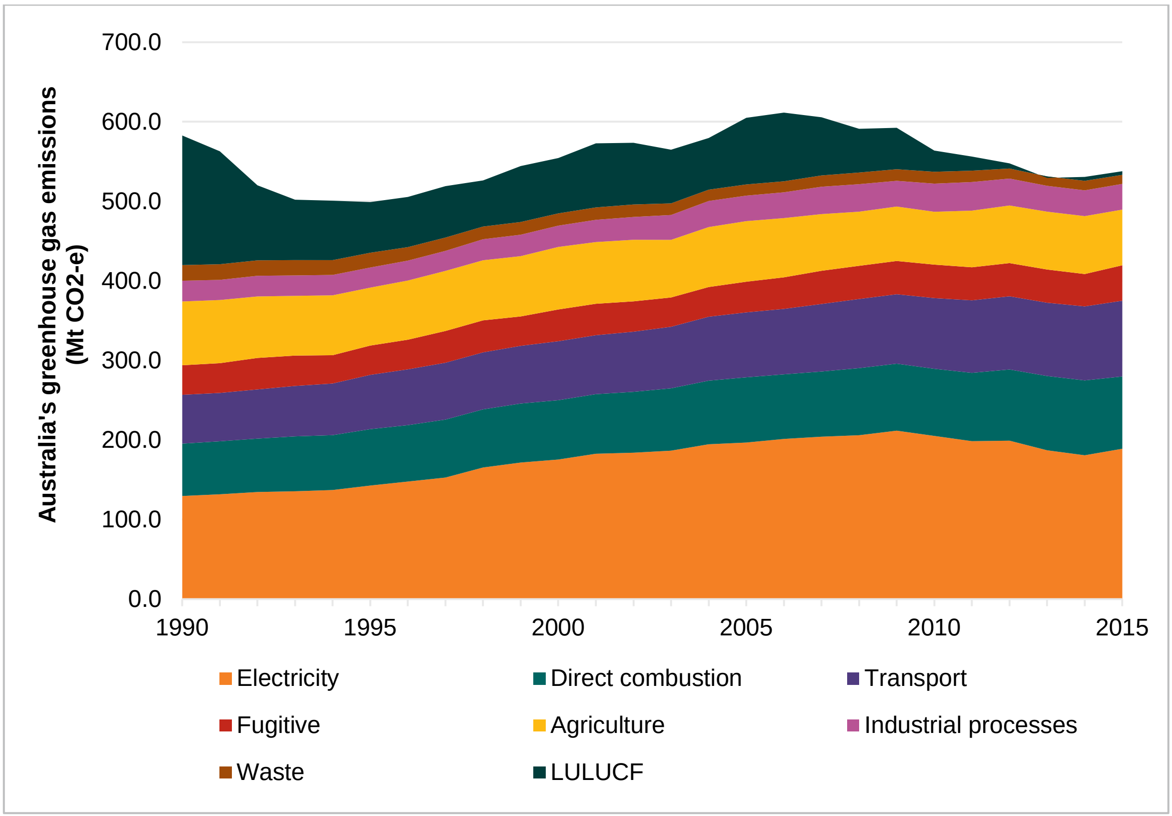

Figure 3: Australia's greenhouse gas emissions since 1990[10]

3. The threats to 'transition' gas

The 2-degree world scenario essentially requires global emissions to be zero by the middle of this century. Any emissions due to the burning of fossil fuels such as natural gas, or emissions from other sources such as agriculture will require offsetting through biological or geological sequestration. While offsetting is feasible, pressure will be on the sources of emissions to reduce. This places bounds on the long term future of natural gas as a fuel. The viability of gas as the transition fuel is being potentially compromised in a number of ways. These include:

- Gas is not so clean (in some circumstances)
- Gas is not so cheap (in Australia at least)
- The gap to be filled by the 'transition fuel' is disappearing

These are now examined in more detail.

[9] See "New to Nuclear Countries: Considerations for Adoption of Small Modular Reactors – A Guide to Future Adopters", Adi Paterson, Mark Ho, Greg Storr, 19th Pacific Basin Nuclear Conference (PBNC 2014), August, 2014. Available from *http://www.nuclearaustralia.org.au/wp-content/uploads/2015/04/PBNC2014-Paterson-et-al.-paper.pdf* (accessed September, 2017)

[10] Source: 'Australia's emissions projections 2016', Commonwealth of Australia, 2016

3.1. Gas is not so clean

While the actual combustion of gas results in less emissions than the combustion of coal, the emissions associated with the production and distribution of gas are greater than those of coal. However, on a full lifecycle basis, one must also consider emissions associated with gas production, including fugitive methane emissions, and also (if applicable) emissions associated with converting gas into liquefied natural gas (LNG), transporting and regasifying it.

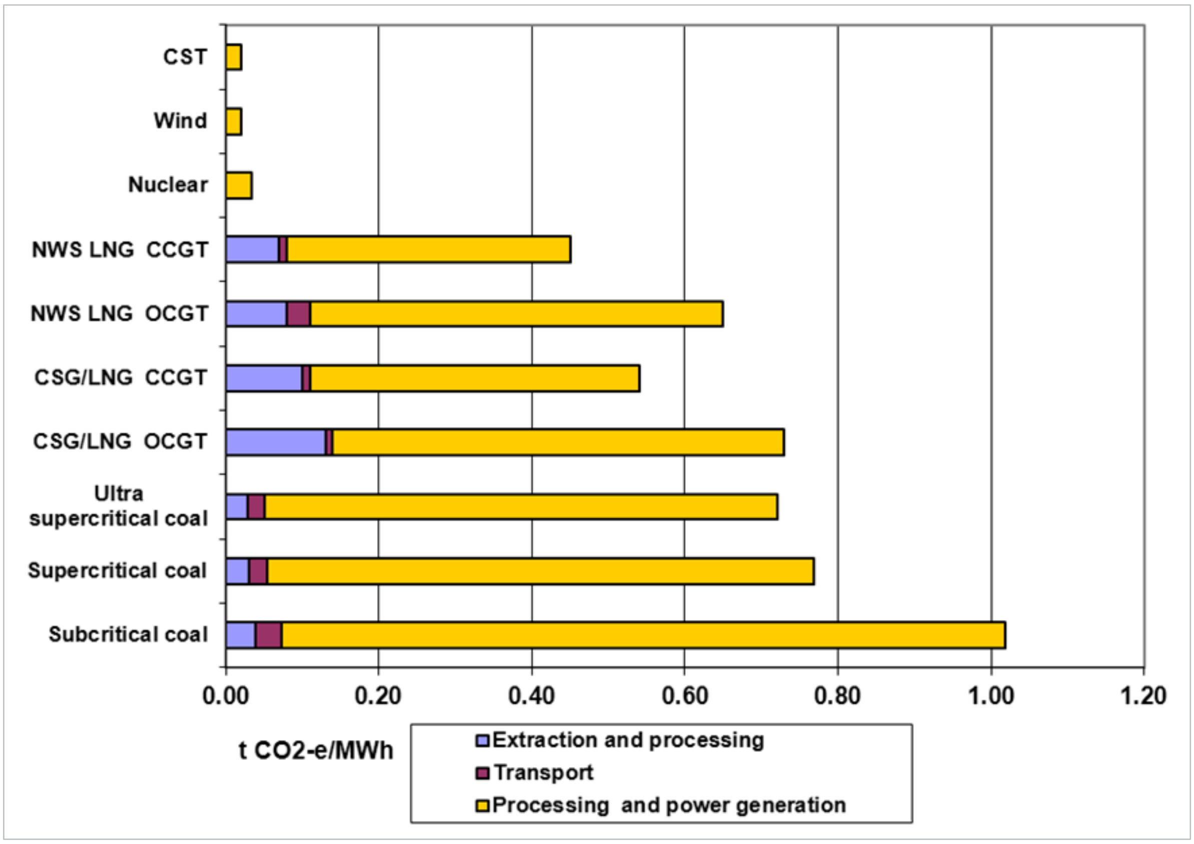

Figure 4: Lifecycle GHG emissions intensities for Australian fossil fuel exports, and selected renewables and nuclear[11]

Many lifecycle comparisons of gas and coal for power generation have been reported, and all show that even after accounting for emissions along the supply chain, gas is still the better fuel. **Error! Reference source not found.** shows that electricity from LNG from various sources generally has a lower greenhouse footprint than electricity from coal, but the gap is not great. Other studies reveal more about the features of the emissions footprint of gas that may offer guidance to the industry.

In **Figure** 5, the lifecycle emissions associated with electricity from conventional and non-conventional gas are compared to those for electricity from coal in the US. The results in **Figure** 5 differ from those in **Error! Reference source not found.** in two key ways. First, **Figure** 5 considers pipeline gas rather than LNG and so does not include emissions due to the liquefaction and regasification of gas. Emissions due to extraction and processing reported in **Error! Reference source not found.** are likely to be dominated by the contribution of liquefaction and regasifaction. Second, **Figure** 5 disaggregates the emissions into carbon dioxide and methane.

[11] Source: "Life Cycle Greenhouse Gas Emissions from Electricity Generation: A Comparative Analysis of Australian Energy Sources", Paul E. Hardisty, Tom S. Clark and Robert G. Hynes, Energies, v5, p872-897, 2012

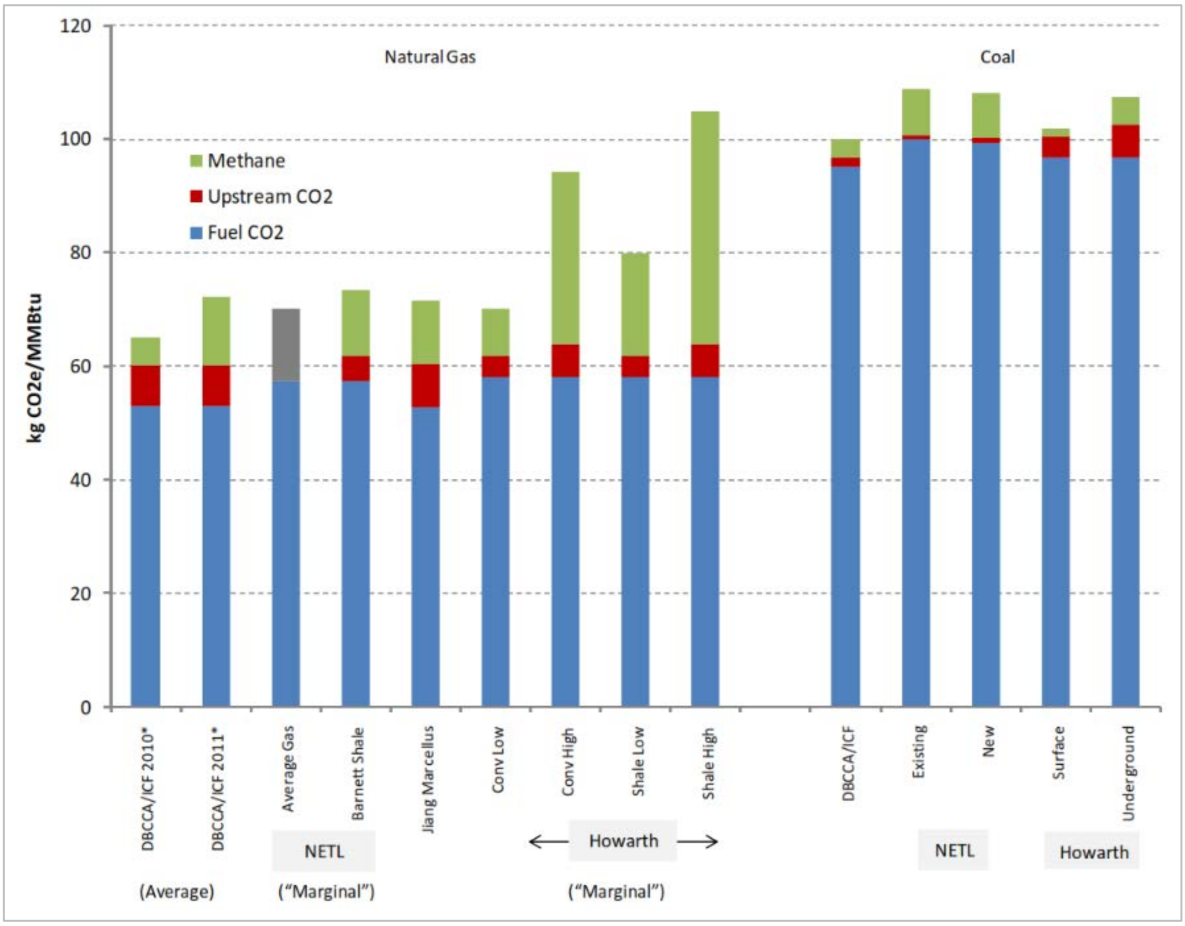

Figure 5: Comparison of US based lifecycle assessments[12]

Methane is a potent greenhouse gas, with around 30 times the impact of carbon dioxide. The high levels of emissions due to methane shown in **Figure** 5 are due to fugitive emissions at the production wells and along the supply chains. Methane lost to the atmosphere during the production and transportation of fossil fuels (ie fugitive emissions) can greatly impact the lifecycle greenhouse emissions estimates for power generation. The US Department of Energy currently estimates a fugitive emissions rate (FER) of around 1% in natural gas systems. A number of academic studies estimate rates in the range of 2%-4%.[13] At these higher FERs the lifecycle emissions of natural gas fired power stations may be comparable to coal fired power stations[14].

That is the situation with unconventional gas in the USA. The situation in Australia may be better, with work by the CSIRO[15] suggesting that, while most coal seam gas wells leak, the emissions rates are very low especially when compared to the volume of gas produced from the wells.

3.2. Gas is not so cheap

A useful way of comparing the cost of various power generation technologies is to determine their levelised cost, which is the average cost of electricity generated over the life of the asset. In this

[12] Source: Comparing Life-Cycle Greenhouse Gas Emissions from Natural Gas and Coal, Deutsche Bank, 2011
[13] "Life-Cycle Greenhouse Gas Assessment of Coal and Natural Gas in the Power Sector", Richard K. Lattanzio, Congressional Research Service, June 26, 2015
[14] ib id
[15] "Field Measurements of Fugitive Emissions from Equipment and Well Casings in Australian Coal Seam Gas Production Facilities", Day, S.,Dell'Amico, Fry, R.,Javanmard Tousi, H., CSIRO, Australia, 2014

way, technologies such OCGT, with its relatively low capital costs and high operating costs, complements wind turbines which have high capital costs and very low operating costs.

The following chart shows the relationship between the price of gas and the levelised cost of electricity from new efficient combined cycle gas generators. It also indicates the recent anecdotal gas prices offered to industrial users, and these prices align with Energetics' own observations. Current wholesale electricity prices are generally below $100/MWh.

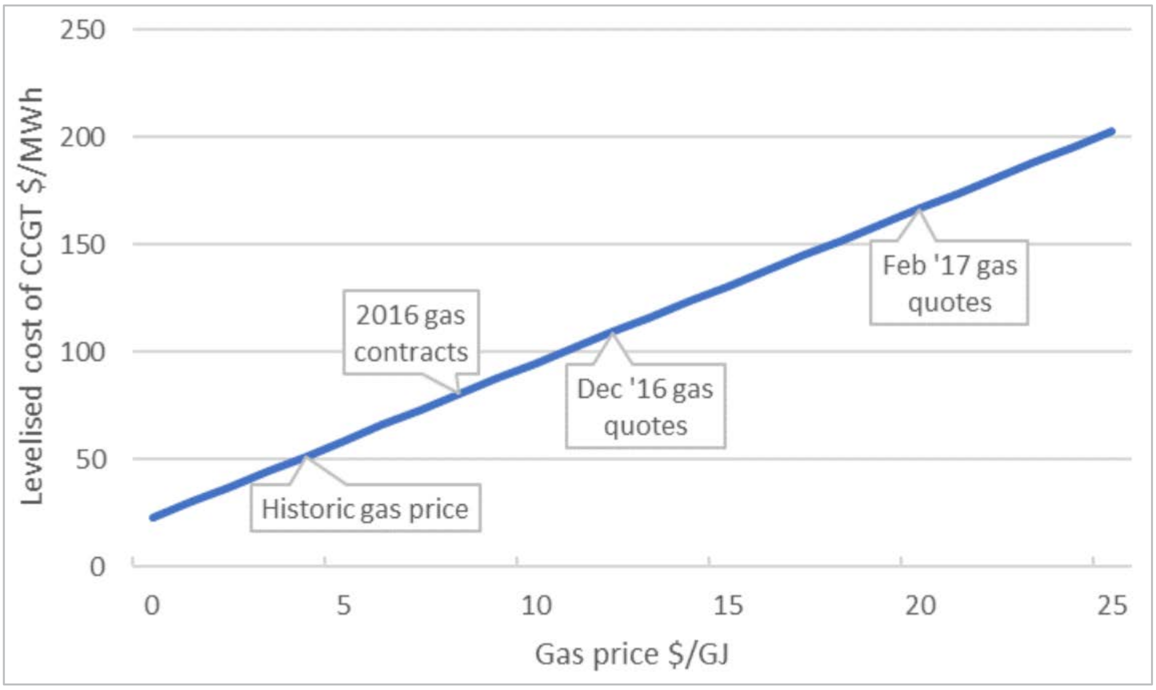

Figure 6: Relationship between the gas price and the levelised cost of gas fired generation[16]

The figure shows how gas struggles to be economic as a fuel for baseload generation. It is an expensive option for supplying peak power. The wholesale price for power in the National Electricity Market is set by the price of the most expensive generator, and this is often an OCGT, which explains why the current high price of gas significantly affects the wholesale price of electricity.

The high prices for gas that are currently being experienced in Australia are due to a range of factors, with some consensus emerging that a lack of domestic supply especially in the light of the volume of gas exported from Gladstone, is pushing up prices. For instance, ACCC chairman Rod Sims has said that domestic users in the south face very high gas prices largely as a result of the expected supply shortfall and lack of competition among southern gas suppliers. He is of the view that prices could be significantly reduced if additional sources of supply are developed to increase the amount of gas and diversity of suppliers.[17]

[16] Source: 'Energy Shock: No Gas, No Power, No Future?", The Australian Industry Group, February 2017
[17] "Why Australia's not cooking with gas", The Australian, 30 September 2017

3.3. The gap to be filled by the 'transition fuels' is disappearing

In 2017, wind and solar are the cheapest sources of electricity from new power stations. Some examples demonstrating include:

- In October 2017, Saudi Arabia received offers to supply solar electricity for the cheapest prices ever recorded – US1.79c/kWh or AU$23/MWh.[18]
- Tucson Electric Power will buy solar energy from a new 100MW array for less than US3c/kWh[19].[20]
- The Kauai Island Electric Cooperative and AES Corp. plan to combine a 28 MW solar array with a 20 MW, 100 MWh battery system to deliver dispatchable renewable generation to the Hawaiian island. KIUC will pay $0.11/kWh[21] for power delivered from the solar-plus-storage system, below the cost of oil-fired power that comprises the island's current baseload generation.[22]
- Spain has allocated 3 GW of new onshore wind power capacity at a price of €43/MWh[23].
- ReGen Power Tech Company had bid for Re3.42/kWh[24] per unit for a capacity of 200MW in Tamil Nadu in India.
- Origin Energy committed to a long-term power purchase agreement of below $60/MWh for the 530MW Stockyard Hill Wind Farm in Victoria.[25]

The next figure provides a comparison between coal and gas fired generation with wind and solar coupled bit batteries for firming capacity. In this case, a gas peaking plant provides the firming capacity, and this increases the levelised costs of $65/MWh for wind and $75/MWh for solar to about $100/MWh and $125/MWh respectively. The figure shows how wind or solar coupled with firming from a gas peaking plant has a levelised cost that is at or below the cost of electricity from a new coal fired power plant, and below the cost of power from a CCGT power plant. This has clear implications for the gas industry as the demand for gas for an OCGT power stations used to firm the capacity of wind or solar farms is much less than the demand for a CCGT 'baseload' power station.

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[18] ***https://www.bloomberg.com/news/articles/2017-10-03/saudi-arabia-gets-cheapest-ever-bids-for-solar-power-in-auction***
[19] $AU37.50/MWh
[20] "TEP to Power 21,000 Homes with New Solar Array for Historically Low Price", Tucson Electric Power, May 2017. Available from ***https://www.tep.com/news/tep-to-power-21000-homes-with-new-solar-array-for-historically-low-price/*** (accessed Sept 2017)
[21] $AU137.50/MWh
[22] Source: ***http://www.utilitydive.com/news/hawaii-co-op-signs-deal-for-solarstorage-project-at-11kwh/433744/***
[23] $AU64.25/MWh
[24] $AU65/MWh
[25] "Origin stuns industry with record low price for 530MW wind farm", reneweconomy, 8 May 2017. Available from ***http://reneweconomy.com.au/origin-stuns-industry-with-record-low-price-for-530mw-wind-farm-70946/*** (Accessed September 2017)

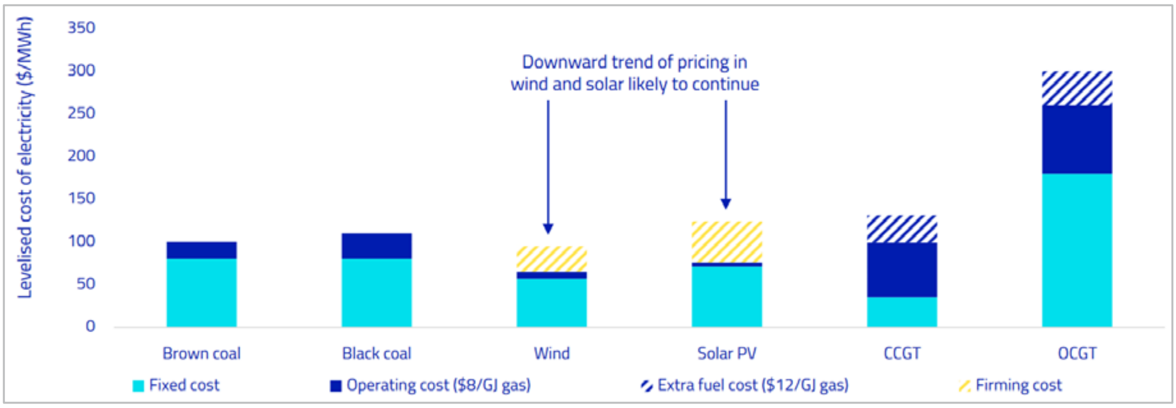

Figure 7: Implied cost of new generation[26]

Several industry players support this view. In their most recent new energy outlook[27], Bloomberg New Energy Finance stated that:

"Gas is a transition fuel, but not in the way most people think. Gas fired capacity increases 16% by 2040 but gas plants will increasingly act more as a source of flexible generation needed to meet peaks and provide system stability rather than as a replacement for 'baseload' coal. In North America, however, where gas is plentiful and cheap, it plays a more central role, especially in the near term."

The figure below shows a possible evolution of the generation mix, driven by the economics of power generation. The charts are for Germany, and they show how the role of gas fired generation will change along with other types of baseload generation. Importantly, the charts show the role of gas fired generation in firming the output of low cost renewable generations.

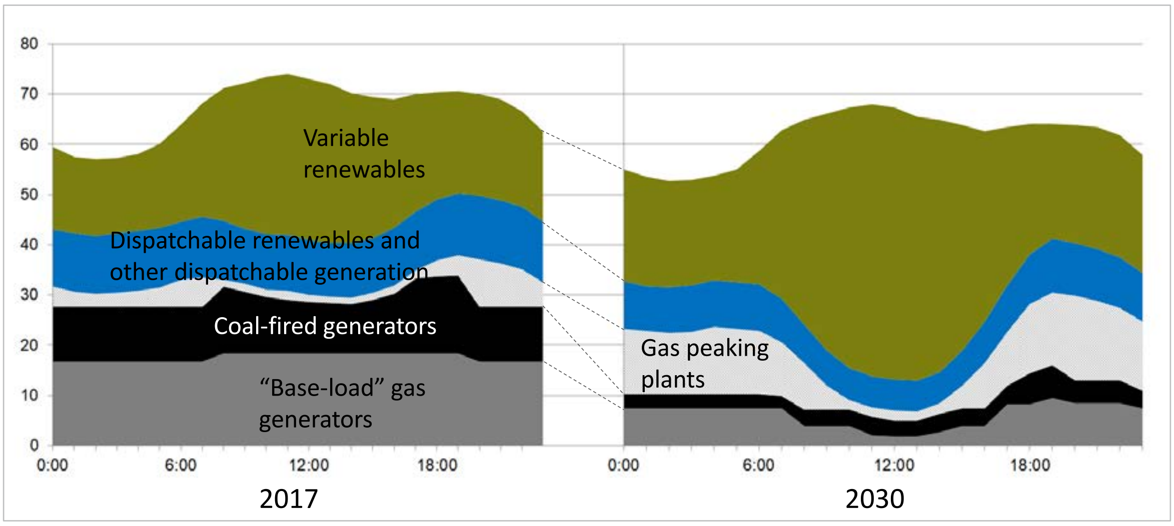

Figure 8: Hourly dispatch of generation by type in Germany[28]

Neither CCGT nor gas fired Rankine cycle generators nor coal fired generations can compete against low-cost renewables firmed with OCGT units (gas peaking plants in **Figure 8**).

[26] AGL Energy, Presentation to Macquarie Australia Conference 2017, 2 May 2017. Assumes capacity factors of 40% for wind, 25% for solar, 75% for CCGT and 10% for OCGT; heat rates of 8 for CCGT and 10 for OCGT.
[27] 2017 New Energy Outlook (NEO), Bloomberg New Energy Finance, June 2017
[28] Source: Bloomberg New Energy Finance

However, OCGTs are not the only source of firming capacity. The recent report by the Australian Energy Market Operator that looked at electricity supply in South Australia[29] shows that battery storage is now competitive with other large-scale solutions for energy balancing. AEMO quoted the following levelised costs for firming capacity:

- Gas peaking plants $218/MWh
- Pumped hydro (subject to size and location) $161/MWh
- Lithium Ion batteries $216/MWh.

Batteries are flagged as already comparable in cost to OCGT peaking plants. However, it should be noted that the levelised cost of storage is highly dependent on the quantity of energy stored, and while batteries or other storage devices may be cost effective for storing one hour of energy, they are less likely to be cost effective for storing one day's worth of energy. That said, none of the other technologies have a learning rate anywhere near that of battery storage. **Figure 9** shows actual and forecast prices for battery packs for electric vehicles.

The rapid decline in prices is evident and the developments that underpin the decline in prices for EV batteries will also drive down the cost of utility scale batteries. This in turn will reduce the levelised cost of battery storage. Renewables with energy storage are therefore likely to surpass gas as the cheapest source of new flexible power in Australia, with analysis indicating these sources may alleviate system pressure by providing load-following and peaking generation services.[30]

The consequence of ever more cost-effective battery storage is that they are now competing against gas fired OCGT generators for the firming market.

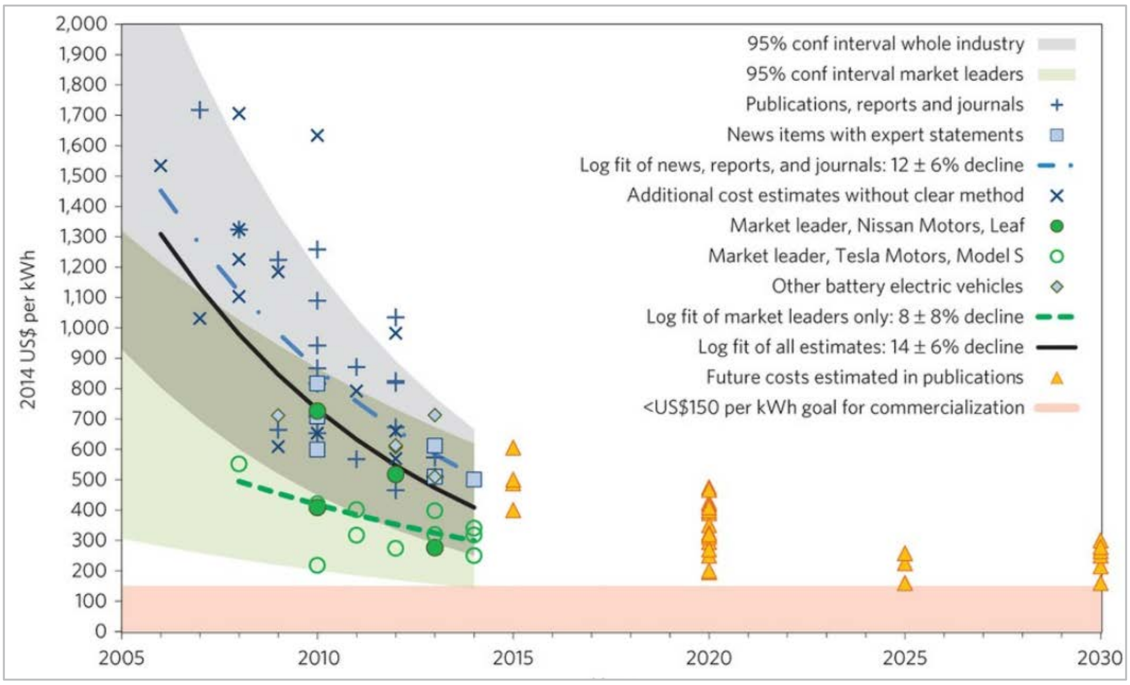

Figure 9: Trend in prices for electric vehicle battery packs[31]

[29] "South Australian Fuel and Technology Report", Australian Energy Market Operator, March 2017
[30] http://reneweconomy.com.au/why-grid-based-battery-storage-is-already-a-no-brainer-in-australia-85967/
[31] "Rapidly falling costs of battery packs for electric vehicles", Bjorn Nykvist & Mans Nilsson, Nature Climate Change, 5, 329–332, (2015)

4. The future of gas in a carbon constrained world

The analysis presented above demonstrates that gas still has a role to play as a 'transition fuel' in Australia. This role is unlikely to be as a replacement for coal to fuel base load power stations but rather as the fuel for the generators that provides firming capacity for lower cost variable renewable generators. We see this played out in the proposed approach of AGL to the replacement of the Liddell Power Station:

"The 1000MW of firm capacity that AEMO is concerned about will mostly be covered by 750MW from a new gas fired plant at Liddell, Newcastle or other sites in NSW. On top of this, Bayswater can be expanded by 100MW and a 250MW battery at Liddell — which would be the world's biggest — could provide up to 50MW of firm capacity during peak demand.

Up to 100MW of capacity could be met by "demand response", or getting users to lower consumption. "Based on the analysis we've done already, we think the (non-coal) investment will meet our necessary hurdle rates," [New AGL chairman Graeme] Hunt said."[32]

While the media attention is on the 250MW of battery storage, the heavy lifting will be done by the 750MW of new gas fired generation.

Gas Vision 2050 outlined a route to zero emissions gas through the enabling technologies of biogas production, carbon capture and storage, and hydrogen. It also outlined an illustrative decarbonisation pathway for gas spanning electricity, industrial and residential applications, and transport.

Gas remains a highly flexible energy source but this does not need to be natural gas, which is why *Gas Vision 2050* outlined the role of Australia's gas infrastructure in the transmission of other gases such as biomethane and hydrogen.

While Energetics does not see a robust future in the production of hydrogen from steam reforming, hydrogen sourced from electrolysis of water using surplus renewable electricity and hydrogen sourced from photo-catalysts[33] may offer a pathway that enables gas to continue to be used as an energy source in a carbon constrained world.

In this paper, the aspects of the electricity pathway have been explored. Gas remains very much part of the transition to a low emissions future. It does however face challenges to its role in the transition. This is certainly case for the provision of the bulk of baseload power, although a hybrid of wind/solar/batteries with gas peaking units to provide mid to longer term firming capacity offers a viable option.

Expanding the demand for gas so that it provides more of the baseload power during the transition will require the industry to clearly demonstrate that gas is a clean fuel, and that gas for power generation can be sold at a competitive price.

[32] "New AGL chairman Graeme Hunt digs in over Liddell closure", The Australian, September 28, 2017
[33] See ***https://phys.org/news/2016-07-strategy-hydrogen-generating-molecular-photocatalysts.html***

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