A Short-Lived Gas Shortfall

A review of AEMO's warning
of gas-supply 'shortfallss', May 2017

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The University of Melbourne

Australian-German Climate & Energy College

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Executive Summary

With the publication of the 9th March 2017 Gas Statement of Opportunities (GSOO), the Australian Energy Market Operator (AEMO) cautioned that within 18 months, "shortfalls" could occur either in the supply of gas, or in the supply of electricity generated by burning gas. AEMO suggested solutions to potential shortfalls that included the construction of new pipelines or Coal Seam Gas (CSG) fields.

AEMO's warning was heard by the Australian Prime Minister who, by late April 2017, had announced plans to implement the "Australian Domestic Gas Security Mechanism". This will allow the government to impose gas-export controls on companies when there is a gas-supply shortfall in the domestic market. The Prime Minister also recognised that eastern-Australian wholesale gas prices are at historically high levels and are now linked to international prices.

Our report investigates AEMO's gas-and-electricity-system modelling results as well as the communications that followed. We explore reasonable alternate conclusions that can be drawn by analysing AEMO's published modelling inputs, assumptions, and results, and by contemplating future real-world events.

We recommend actions that would improve AEMO's scenario modelling, result interpretation, formulation of recommendations, and communication to stakeholders. We also list recommendations for governments, gas consumers, and other stakeholders. These recommendations aim to provide more information to the gas and electricity markets, ease the strain of rising gas and electricity costs, and avoid unnecessary expenditure on gas production and transportation infrastructure.

We find a shortage of 'cheap' gas . . .

Our research finds that although a "gas-price crisis" exists in eastern-Australia, a gas-supply shortfall is very unlikely to occur.

We find that the former gas "buyer's market" that prevailed in eastern-Australia has shifted to become a "seller's market". Where before the wholesale gas price had been nearly the cheapest in the developed world at $3–4 per gigajoule (GJ), today it is now nearly the most expensive, with prices up to $20/GJ now on offer. These high prices are a result of the eastern-Australian gas market being linked to overseas benchmarks, over-building of gas export capacity with contractual export over-commitments, opaque gas market and gas-producer behaviour, and the high costs of producing unconventional CSG (now estimated to be around $7/GJ, excluding pipeline transportation costs).

Given the above, a return to delivered wholesale gas priced below $8/GJ is unlikely.

. . . but no gas-supply 'shortfall'

Our review finds that the size of AEMO's forecast shortfall is very small, amounting to no more than around 0.2% of annual supply (of either gas or electricity).

AEMO's modelled gas-supply gap is a simple annual imbalance between the volume of gas supplied to the eastern-Australian gas system versus forecast gas demand. Importantly, this means that AEMO is ***not*** indicating any short-term or acute gas-supply concern relating to, as an example, gas availability being constrained by pipeline capacity during peak winter-demand times. Because the modelled supply gap is an annual imbalance, over the course of a modelled year, any extra gas supply or demand reduction acts to narrow or even completely close the gap.

AEMO closes the supply gap eleven days after announcing it

The rapid rise in wholesale gas and electricity prices in eastern-Australia is reducing industrial activity. Industrial decline will reduce gas demand by an amount far larger than AEMO's forecast supply gap. Therefore, because of this "demand destruction", we find it very unlikely that gas-supply shortfalls will occur. Indeed, only eleven days after announcing its supply-gap concerns, AEMO essentially closed the gap when it published, on its website, updated (lower) electricity-demand forecasts. AEMO expected the gas shortfall to result in lower gas powered electricity generation and electricity shortfalls, which are eliminated by this reduction in demand.

No need to expand gas-supply infrastructure

Given the above, we find it necessary to challenge AEMO's urgent warning of nearly-imminent gas shortfalls and AEMO's limited array of "potential solutions".

We find that AEMO focussed attention on a very small, very unlikely, and ultimately short-lived gas-supply shortfall concern. Furthermore, AEMO's suggested new pipelines and new (expensive) gas fields appear to be false "solutions". These massive fossil-energy infrastructure investments are not needed to address a supply shortfall that is very unlikely to occur.

Furthermore, these investments will not reduce the wholesale price of domestic gas. New gas sources are expensive to produce, and in any case, in the "seller's market" that now prevails, domestic-wholesale gas prices are linked to international benchmarks.

Ways that consumers and suppliers can respond to high energy prices

The more useful message for energy consumers is that the wholesale price of gas has increased significantly and is unlikely to return to the low prices previously known. Therefore, AEMO and governments should focus on informing Australian energy consumers - ranging from home occupants, to commercial building managers, to large industries - of the cost-effective actions they can take to respond to rising energy costs, including:

- reducing gas and electricity consumption though energy-efficiency measures
- fuel-switching to lower-cost renewable energy options, e.g. electricity via on-site solar PV, heat pumps (often referred to as reverse-cycle air conditioners), or bioenergy
- utilising energy storage
- engaging with demand-side response in the electricity market
- accelerating renewable-energy deployment.

Addressing the opacity of the gas industry is warranted

Recent actions by Australian governments that seek to reduce gas-industry opacity are greatly warranted, particularly around gas reserves, facility production capacity, future development plans, and Liquefied Natural Gas (LNG) export contracts and commitments. Greater industry transparency would help to improve the usefulness of AEMO's planning activities.

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Contents

1 Introduction

With the publication of the 9 March 2017 Gas Statement of Opportunities (GSOO)[1], the Australian Energy Market Operator (AEMO) warned that by December 2018 (around 18 months from now) there could be "shortfalls" either of gas, or of electricity generated by burning gas[2]. AEMO suggested that new pipelines or gas fields were needed to avoid these shortfalls.

This reports critiques the robustness of both AEMO's communicated results and AEMO's recommendations for addressing gas and electricity supply security. Our report investigates gas and electricity system modelling results published in AEMO's Gas Statement of Opportunities[3] and other reports.

This report is structured as follows: we begin by providing an overview of the genesis and response of the widely reported 'gas crisis'. This is followed by a description of the dynamics of and recent disruptions to the gas market in eastern-Australia. From there, we examine AEMO's energy-system modelling methods and results. Following this, we explore reasonable alternate conclusions that can be drawn from AEMO's published modelling inputs, assumptions, and results. We consider alternate results that modelling would produce based on reasonable alternate assumptions and/or future real-world events. Finally, we list recommendations for governments and other stakeholders. These recommendations aim to provide more information to the gas and electricity markets, ease the strain of rising gas and electricity costs, and avoid infrastructure-expansion expenditures.

2 The gas 'shortfall crisis'

In this section of the report we examine the key messages and recommendations conveyed by AEMO, and the response from media and policy makers.

2.1 AEMO warns of "shortfalls"

On 9 March 2017, AEMO's Chief Operating Officer Mike Cleary was reported as saying[4]:

> *"If we do nothing, we're going to see shortfalls in gas, we're going to see shortfalls in electricity. We can either:*
>
> - *redirect some of the LNG from the international markets into the domestic market, assuming that the price allows that to happen*
> - *we can increase production from the existing fields*
> - *we can explore and develop new fields or we can have investment in the pipelines."*

In its GSOO, AEMO described three "potential solutions" to avoid shortfalls[5]:

1. Jemena Northern Gas Pipeline - a new gas pipeline that would link the Northern Territory with the eastern-Australian gas market via a connection at Mt Isa in Queensland[6,7]
2. Santos Narrabri Gas Project, in conjunction with the Queensland Hunter Gas Pipeline (New South Wales)
3. redirection of LNG export gas to the domestic market.

[1] AEMO, *Gas Statement of Opportunities*.
[2] Ibid.
[3] Ibid.
[4] Harmsen, "Homes could lose power as gas shortage looms, operator warns".
[5] AEMO, *Gas Statement of Opportunities*.
[6] Marks, *Second gas pipeline in the Northern Territory 'not viable without fracking'*.
[7] "Construction could get underway in mid-2017"

AEMO did not describe in depth other "potential solutions" such as:

- electricity supply-side options (e.g. faster expansion of renewable energy and storage)
- electricity demand-side options (e.g. accelerated energy efficiency measures, and demand response)
- gas demand-side options (e.g. accelerated energy efficiency and fuel-switching measures)
- non-fossil gas options (e.g. supply of biogas, biomethane, hydrogen)
- maintaining or expanding production from existing fossil-gas fields (e.g. gas producer response to attainable high sales-gas prices)
- other new gas-field developments (e.g. Western Surat, Ruby Project, Shell-Arrow, etc.)

In later sections of our report we explore these other options. We also explore why AEMO does not detail these options in its Gas Statement of Opportunities.

2.2 Media and political response

Given the public concern about energy supplies and cost, the Australian media widely reported AEMO's "shortfall" warning with headlines such as:

- "AEMO warns of blackouts as gas runs out" (The Australian[8])
- "Gas supply shortage will threaten nation's power supplies"(ABC[9])

Australia's Federal Energy Minister Josh Frydenberg responded immediately to AEMO's report by calling for "more gas supply and gas suppliers"[10].

Australia's Prime Minister Malcolm Turnbull responded by arranging to hold "urgent crisis talks" with gas suppliers on 15 March. In a parallel activity, on 20 March, AEMO published on its website updated (reduced) electricity-demand forecasts[11]. These new forecasts reflected news of industrial "demand destruction" caused by high energy prices. These new forecasts meant that AEMO had closed its supply gap only eleven days after announcing it.

On 21 March, the gas-producing company Shell announced it would proceed with Project Ruby[12]. Because this project was not included in AEMO's energy-system modelling, Project Ruby also has the effect of closing AEMO's supply gap.

By 30 March 2017, AEMO downplayed the risk of gas shortages by saying "authorities and companies had begun to address the issue"[13].

Nevertheless, given the acute and ongoing concerns about high gas prices, following another meeting with the gas industry (19 April), the Prime Minister tasked the Australian Competition and Consumer Commission (ACCC) to carry out a new three-year investigation into the gas industry. (This follows just one year after a previous investigation[14]). In this latest investigation and with a first report due October 2017, the ACCC[15]:

> *" ... will use its inquiry powers, including its ability to compulsorily acquire information, to increase transparency and address opaqueness in the gas market. The inquiry will examine how gas suppliers will make more gas available to Australian industry and other domestic gas users, and the effect this has on overall market dynamics. Improved transparency will provide a clear overview of the entire market and help ensure it is operating efficiently and that competition is benefiting all gas users."*

[8] Chambers, *Blackouts warned as gas runs out*.
[9] Harmsen, "Homes could lose power as gas shortage looms, operator warns".
[10] Josh Frydenberg, *'We need more gas and gas suppliers'*.
[11] AEMO, *Update: National Electricity Forecasting Report*.
[12] Shell Australia, *Media release: Shell invests in east coast gas supply*.
[13] Morton, "What we'll do to keep the lights on post Hazelwood".
[14] ACCC, *Inquiry into the east coast gas market*.
[15] ACCC, *ACCC to investigate and report on Australian gas markets and market transparency*.

Other responses reported in the media were suggestions that gas pipelines could be installed from the Northern Territory[16] or Western Australia[17,18] connecting in to South Australia or Queensland.

As the operator of the National Electricity Market (NEM) in Australia, AEMO has been widely criticised over its role in recent electricity-supply disruptions[19]. In addition to its market-operations role, AEMO has certain long-term planning responsibilities for Australian gas and electricity networks and is legislatively required to publish the annual GSOO. Given the responses by the Australian media and government to AEMO's messages about gas "shortfalls", it is clear AEMO's messages had the effect of attracting attention to gas-supply concerns.

In a significant move, on April 27 the Prime Minister declared that there was a shortage of gas supplies for eastern-Australia and that certain restrictions may be placed on gas exports[20]. The gas industry responded by saying that "restricting exports is almost unprecedented for Australia" and that it would need to "carefully consider the details" of the announcement[21].

In more detail, the Prime Minister's announcement said:

> *" . . . the Australian Domestic Gas Security Mechanism will give the government the power to impose export controls on companies when there is a shortfall of gas supply in the domestic market.*
>
> *The Minister for Resources, in consultation with relevant ministers, will impose export controls based on advice from the market operator [Australian Energy Market Operator] and regulator [Australian Energy Regulator]"*

Key to the application of this new Australian Government initiative, therefore, is AEMO's declaration of whether gas-supply shortfalls do or don't exist and the circumstances under which shortfalls might occur. The practicalities of how this mechanism would work were questioned in a Renew Economy article entitled 'The Shortage may be Short-lived'[22]:

> *"Exactly how a physical shortage is defined is not disclosed and in our view it's almost impossible to operationalise it in a fully satisfactory manner. For instance, the 'need' or 'supply' of gas-fired electricity generation is both price and cost elastic. If the gas was cheap enough there would be more demand and vice versa."*

[16] Marks, *Second gas pipeline in the Northern Territory 'not viable without fracking'*.
[17] Flint, *Colin Barnett calls for 'nation-building' gas pipeline*.
[18] The Australian Pipeliner, *Barnett calls for trans-continental pipeline*, reported pipeline from Western Australia "to cost upwards of $5 billion."
[19] Evans, "SA Energy Minister fumes in phone call to AEMO on power cuts".
[20] Prime Minister, *Delivering Affordable Gas for all Australians*.
[21] APPEA, *Media Release: Gas export controls no substitute for genuine reform*.
[22] Leitch, "Gas shortfall may be short-lived, thanks to growing renewables".

3 Context: Disruption to the Australian gas market

This section describes how, over a two-year period, the export of Liquefied Natural Gas (LNG) from Queensland disrupted the gas and electricity markets. High energy costs are leading to domestic "demand destruction", particularly in the industrial sector. It is now uncertain what role gas will play as the eastern-Australian electricity grid evolves and decarbonises. Figure 1 illustrates eastern-Australian gas production and transmission infrastructure.

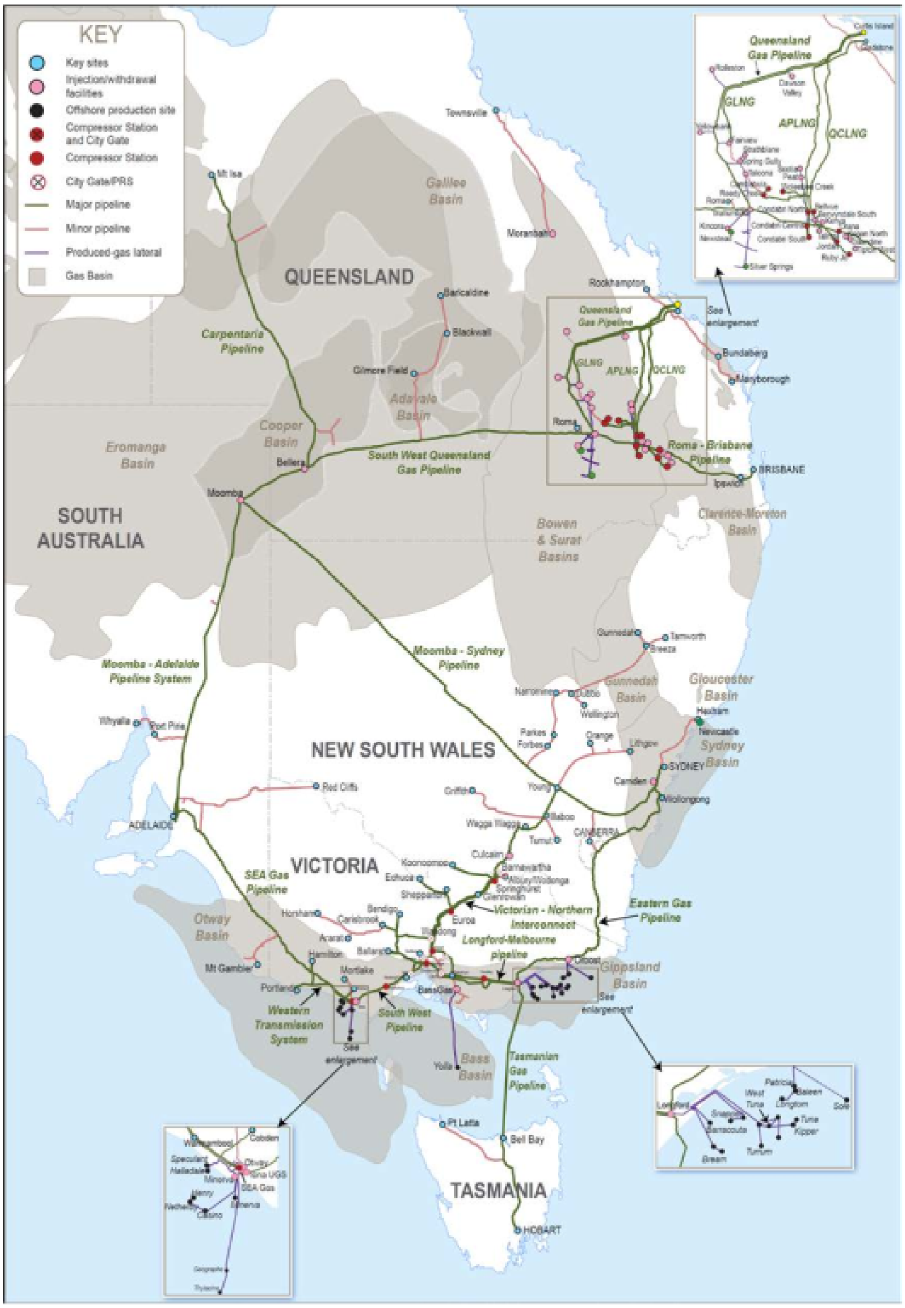

Figure 1: Eastern and south-eastern Australian gas basins and infrastructure [source: AEMO[23]]

[23] AEMO, *Gas Statement of Opportunities*, page 28, Figure 12.

3.1 The creation of the eastern-Australian LNG export industry

The export of LNG from eastern-Australia commenced from Gladstone, Queensland in January 2015. Prior to this event and since the 1970's, eastern-Australian gas had been characterised as a low-value by-product of conventional crude oil exploration and production[24]. In those earlier times, gas in eastern-Australia was some of the cheapest in the developed world.

Local and federal governments encouraged the use of gas in industry, in buildings, and for electricity generation. Encouragement continues even today with programs such as the Victorian Government "Regional Gas Infrastructure Program"[25].

Starting in the late 1990's, gas produced from vast coal seams in Queensland began to enter the eastern-Australian domestic market. As the assessed reserves of this "unconventional" coal seam gas (CSG) grew (see Section 9.3), CSG developers sought and attracted large overseas gas customers.

Figure 2 shows the rapid ramp-up of the CSG - LNG industry from late 2014 to the present. The gas required by this new industry will become nearly three times larger than the, now in-decline, domestic market.

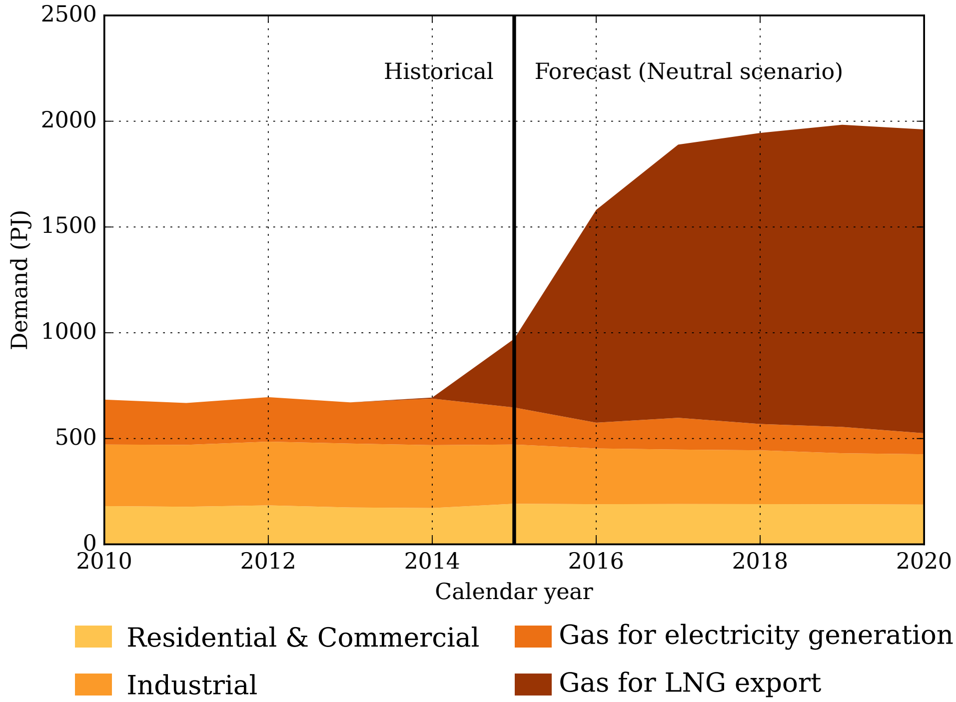

Figure 2: Historic and forecast gas demand for eastern-Australia, showing ramp-up of LNG exports. The 'neutral' scenario from AEMO's *2016 National Gas Forecast Report* is illustrated. Australian gas production has more than doubled from around 700PJ a year from before 2014 to an expected 1900PJ in 2017 [source: AEMO[26]].

[24] Forcey, "Victoria's days of gas dependence are fading".
[25] http://www.rdv.vic.gov.au/regional-projects/regional-gas-infrastructure
[26] Data from AEMO, *National Gas Forecasting Report*, available at `http://forecasting.aemo.com.au/`.

Over 10,000 CSG wells have so far been drilled in Queensland[27] and New South Wales, with further potential to over 40,000 wells. Figure 3 shows before-and-after aerial photos of a small section of the Queensland CSG fields and the placement of 150 wellpads. The spacing between wellpads is 500 to 700 metres.

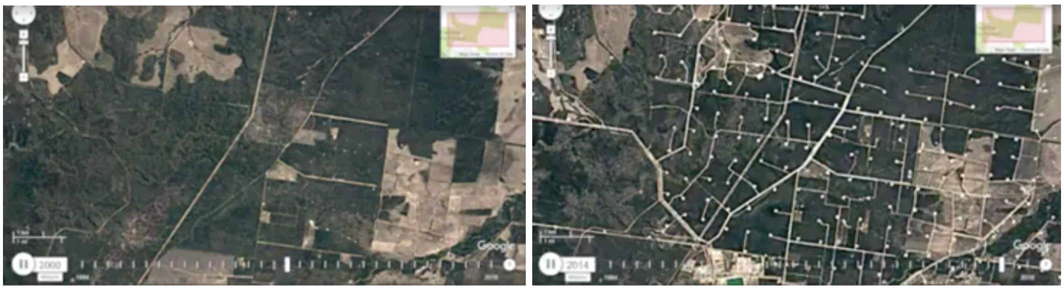

Figure 3: 'Before and after' aerial photographs showing the placement of more than 150 CSG wellpads in Queensland [source: Google earth].

Six LNG "trains" now operating at Gladstone, Queensland (Figure 4) are owned by three separate consortiums known as:

- APLNG - operated by Origin
- GLNG - operated by Santos
- QCLNG - operated by Shell

Beyond the first six LNG trains, given the potential CSG volumes in Queensland and New South Wales, as many as eleven more LNG trains had at one time been envisioned[29]. The most advanced of these additional CSG-LNG projects is the Shell-controlled Arrow project,

Figure 4: The six Gladstone Queensland LNG trains are owned by the consortium's APLNG, GLNG, and QCLNG [source: Stock et al.[28]].

27 Queensland Government, *Queensland Globe*.
28 Stock et al., *Pollution and price: the cost of investing in gas*, page 27.
29 Lewis Grey Advisory, *Projections of Gas and Electricity Used in LNG*.

which received Queensland government approval in September 2013 for an additional four LNG trains[30]. Despite having proven-up substantial gas reserves, Shell placed that project on hold in January 2015. These gas reserves could potentially be directed to the other Gladstone LNG projects or to the domestic market[31].

Although the reserves and resources of CSG throughout Queensland are large, not all of the three operating Gladstone CSG-LNG consortiums are equally endowed with reserves. In particular, Santos-GLNG is reported to have purchased 59% of its export gas from "third-parties", including from suppliers of conventional gas[32].

The Shell-controlled Arrow CSG reserves are one such source of additional gas. Farther afield, in January 2016 gas flow in the large Moomba-to-Sydney pipeline was reversed. For the first time, conventionally-produced gas from the offshore Bass Strait fields was transported over thousands of kilometres from Victoria to Queensland[33].

3.2 Wholesale gas price increases

With the 2015 commencement of LNG-exports, the eastern-Australian gas market was transformed from a captive domestic "buyers" market to an internationally-linked "sellers" market. As was confirmed by the Australian Prime Minister on 27 April 2017, wholesale gas prices are now linked-to and are reported to even exceed international prices[34]. Figure 5, from the Australian Energy Regulator (AER), shows the rapid increase in the wholesale gas price from historical values of around $3 per GJ to present prices as high as $9/GJ. This price escalation occurred as several Gladstone LNG trains began operating.

Gas buyers continue to report difficulties agreeing long-term contracts with gas suppliers quoting wholesale prices of $20/GJ[35] or higher[36].

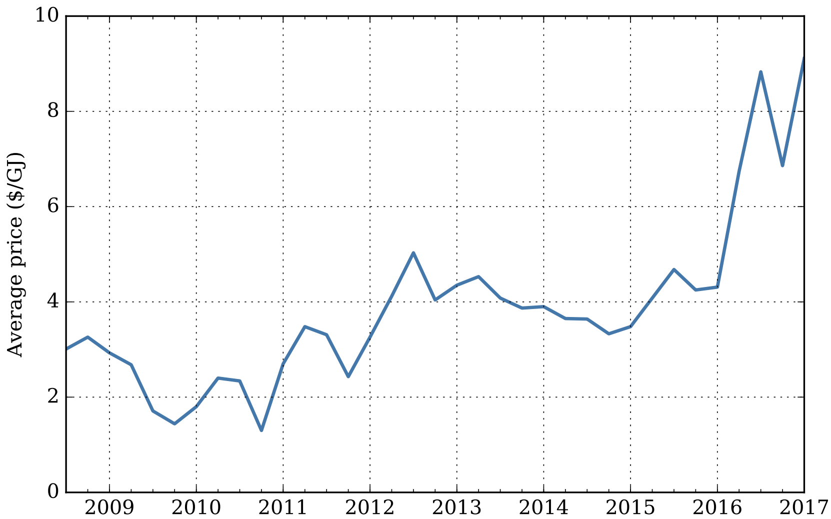

Figure 5: Victorian gas market average-daily-weighted imbalance prices by quarter [source: AER[37]].

[30] Jeff Seeney, *Media statements: $15b Arrow LNG project given approval - The Queensland Cabinet and Ministerial Directory*.

[31] Macdonald-Smith, "Shell shelves plans for Arrow LNG project in Queensland".

[32] Chambers, "Santos taps outsiders for gas".

[33] Forcey, "Heading north: how the export boom is shaking up Australia's gas market".

[34] Karp, "Gas producers attack export controls as industrial users cheer 'bold' changes".

[35] This is higher-cost energy that what can be provided with crude oil of diesel. Currently the energy value of crude oil is $14/GJ ($US 50 per barrel of oil and Australian/US foreign exchange rate of 0.75

[36] Macdonald-Smith, "Gas producers defiant ahead of recall to Canberra".

[37] Data available from the AER: `https://www.aer.gov.au/wholesale-markets/wholesale-statistics/victorian-gas-market-average-daily-weighted-prices-by-quarter`

In April 2016, the ACCC released the findings of an inquiry into the competitiveness of wholesale gas prices in eastern-Australia[38]. The ACCC characterised the gas outlook as "uncertain" and made a number of recommendations in relation to[39]:

- *"Enabling new gas supply to come to market, in particular in south eastern-Australia,*
- *Revisiting the regulatory coverage of pipelines, increasing the ability for pipelines with market power to be regulated; and*
- *The consistency and transparency of the provision of information to the market."*

Notably, the ACCC did not attempt to restrict or influence the behaviours of gas producers.

3.3 Impact of gas prices on electricity prices

Given the role of gas as a marginal energy source in the National Electricity Market, rising wholesale gas costs have contributed to wholesale electricity price increases.

Pressure on electricity prices also occurred as renewable-energy deployment slowed and coal-fired electricity generators retired. Retirements include most recently Victoria's 1,600 MW Hazelwood facility that closed at the end of March 2017.

Figure 6 illustrates the recent, sudden, and large increase in wholesale electricity prices in, for example, New South Wales, where the price tripled over the two-year period March 2015 to March 2017.

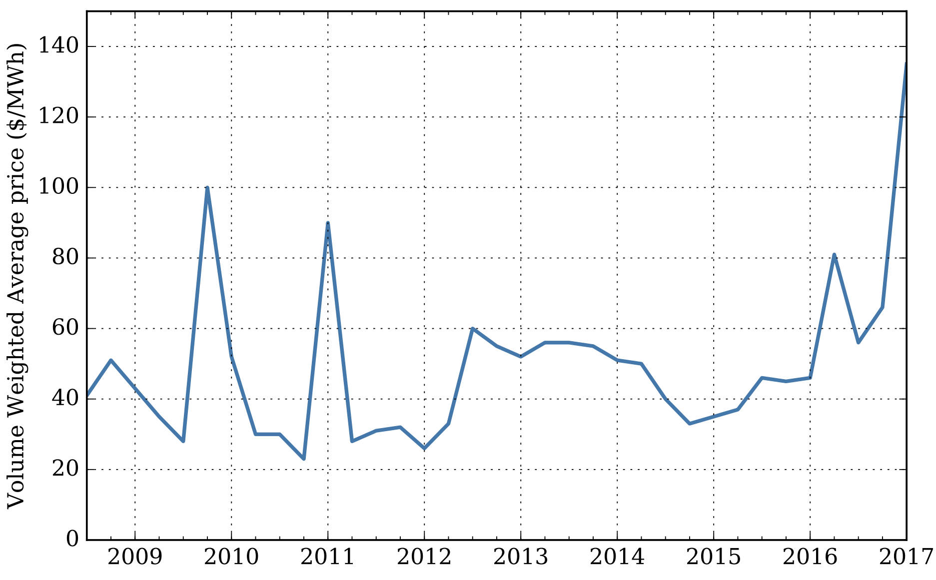

Figure 6: Quarterly volume weighted average electricity spot prices for New South Wales [source: AER[40]].

[38] ACCC, *Inquiry into the east coast gas market*.

[39] ACCC, *Media Releae: Release of East Coast Gas Inquiry report into the increasingly complex and uncertain gas market*.

[40] Data available from the AER: `https://www.aer.gov.au/wholesale-markets/wholesale-statistics/quarterly-volume-weighted-average-spot-prices`

3.3.1 High energy costs & "demand destruction"

Rapidly escalating gas and electricity costs are significantly impacting the profitability of energy-intensive Australian industries and are already driving gas and electricity "demand destruction".

On 20 March 2017, AEMO published an "Update" to its National Electricity Forecasting Report[41]. In this update, AEMO reduced its forecast for grid-supplied electricity by approximately one per cent (1,580 GWh in Financial Year (FY) 2021-22).

AEMO updated its forecast because of "more recent information on electricity usage from Queensland's Boyne Island Smelter and the Liquefied National Gas (LNG) sector". In its "Update", AEMO referenced a news report that the aluminium output of the Boyne Island smelter would be reduced by 14% due to high electricity costs[42].

As MEI reported previously[43], the potential that this series of events - from the creation of gas-export capability, to higher gas and electricity prices, to energy demand destruction - would eventually lead to reduced economic activity was forewarned by the Australian Industry Group in 2013 in its report "Energy shock: the gas crunch is here"[44]. In 2014, a study conducted by Deloitte found a possible $120 billion loss in manufacturing output (net present value) with increased gas prices[45].

[41] AEMO, *Update: National Electricity Forecasting Report*.
[42] Annett, *What 'significant number' of job cuts mean for BSL*.
[43] Forcey and Sandiford, *The dash from gas: Could demand in New South Wales fall to half?*
[44] AIG, *Energy shock: the gas crunch is here*.
[45] Deloitte, *Gas market transformations- Economic consequences for the manufacturing sector*.

4 AEMO's Gas Statement of Opportunities

This section of work details the modelling approach and results of AEMO's 2017 Gas Statement of Opportunities. The sensitivities of AEMO's result to changes in various input assumptions are also highlighted. These sensitivities are explored in further detail in later sections of the report.

4.1 AEMO modelling approach

AEMO's recently-published Gas Statement of Opportunities and media statements are based on AEMO's annual electricity and gas-system modelling. AEMO's modelling results, methodologies, and inputs are described in annual reports such as:

- the Electricity Statement of Opportunities (ESOO)
- the National Electricity Forecasting Report (NEFR)
- the National Transmission Network Development Plan (NTNPD)
- the National Gas Forecasting Report (NGFR)
- the Gas Statement of Opportunities (GSOO)

AEMO's electricity-and-gas-system modelling techniques have evolved over several years and continue to grow in complexity. However, there is limited transparency as to how sensitive AEMO's modelling results are to variations in key assumptions and inputs.

AEMO's modelling depends on information provided by the gas industry. The accuracy and relevance of this information cannot be independently confirmed or cross-checked. There is a concerning level of opacity and uncertainty around Australian gas reserves, gas processing capacity and constraints, and gas supply contracts. A gas industry consultant commented[46]:

> *"Another impediment to investment is the general lack of transparency of the Australian upstream gas market. Any overseas investor is likely to have great difficulty getting the most basic information about reserves, production and drilling results.*
>
> *An executive in a US oil and gas company without interests in Australia recently made the comment: 'Australia is not a very data transparent country. It's not as bad as Malaysia but light-years away from Norway, which has excellent transparency. Thailand is much more transparent than Australia. I suspect that Australia does not view transparency as being in the national interest.'*
>
> *If better information helps attract additional investment it is indeed in the national interest. The worst offender in this regard is the Commonwealth Government, which has jurisdiction over offshore waters beyond the three-mile limit but information on activities in Commonwealth waters is deteriorating, not improving, immersed in a fog of confidentiality.*

At a major gas conference, another gas-industry commentator lamented that "this is no way to run a country" when major gas suppliers such as Esso and BHP Billiton are not required to publish their assessments of gas reserves in the strategic Bass Strait.

Given the opacity of the gas industry and the limited information on which AEMO must base its conclusions, our report illustrates how small changes to AEMO's modelling assumptions can lead to significantly different conclusions and planning messages.

As defined by the National Gas Law[47], the purpose of AEMO's "Gas Statement of Opportunities" report is to:

[46] Bethune, *Where is the east coast domgas development boom?*
[47] Government of South Australia, *National Gas (South Australia) Act*, Part 6, Division 4.

> *"Provide information to assist Registered participants and other persons in making informed decisions about investment in pipeline capacity and other aspects of the natural gas industry."*

In its electricity and gas forecasting and planning, AEMO has tended to over-estimate future demand[48,49]. AEMO has then tended to focus on supply-side solutions (i.e. new gas field and pipeline investments) rather than giving equal weight to demand-side solutions such as economic fuel-switching, energy- efficiency, and demand-response measures.

4.2 Results of the Gas Statement of Opportunities

This section describes the small gas-supply gap (no more than 0.20% of annual supply) that AEMO's modelling indicates could occur in three of the next thirteen years. This section also then describes how this small gap closes with slightly different modelling assumptions or the occurrence of real-word events.

AEMO's modelled gas-supply gap is a simple annual imbalance between the volume of gas input to the eastern-Australian gas system versus the forecast gas volume demanded by consumers. Importantly, this means that AEMO's modelling is not indicating any short-term or acute gas-supply concern relating, for example, to gas availability at peak winter-demand times. Since the modelled supply gap is an annual imbalance, any extra gas input or reduced demand that is considered over the year in question acts to narrow or perhaps completely close the gap.

Further, AEMO has modelled how this gas-supply gap could manifest as a small electricity supply-gap[50]. The largest gap modelled by AEMO (in financial year 2020-21, see Table 1) is equal to only 0.19% of the annual electricity supply, or 363 gigaawatt hour (GWh). In gas-supply terms, this is equivalent to only 0.20% of the annual gas supply, or 3.9 petajoule (PJ).

AEMO's forecast 0.20% gas-supply gap is illustrated by Figure 7.

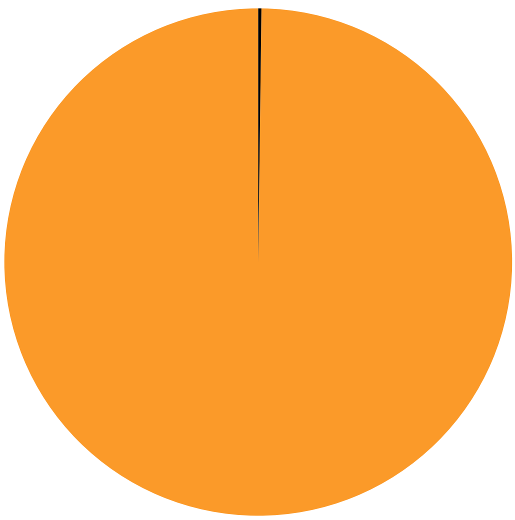

Figure 7: AEMO's modelled gas-supply gap is no more than 0.20% of annual gas supply (shown on the pie chart as a black sliver).

[48]Sandiford et al., "Five Years of Declining Annual Consumption of Grid-Supplied Electricity in Eastern Australia".
[49]Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.
[50]See AEMO, *GSOO methodology*, Figure 6, page 15.

Table 1: AEMO's modelled gas-supply gap

Financial Year (1-July to 30 June)	AEMO electricity supply gap caused by gas supply gap (Figure 8)	Supply gap is what % of annual electricity supply?	Supply gap is how many hours electricity supply?	Equivalent gas supply gap*	Gas supply gap is what % of annual gas supply?	Gas supply gap is what how many hours gas supply?
2016-18	--	--	--	--	--	--
2018-19	80 GWh	0.039%	3.4 hrs/yr	0.086 PJ	0.044%	3.9 hrs/yr
2019-20	--	--	--	--	--	--
2020-21	363 GWh	0.19%	15 hrs/yr	3.9 PJ	0.20%	18 hrs/yr
2021-22	1 GWh	0.001%	0.1 hrs/yr	0.01 PJ	0.001%	0.1 hrs/yr
2022-26	--	--	--	--	--	--

**Conversion efficiency for gas fired elelctricity is assumed to be 33%. For example, 363 GWh * 3.6 TJ/GWh *1 PJ / 1000 TJ / 0.33 = 3.9 PJ*

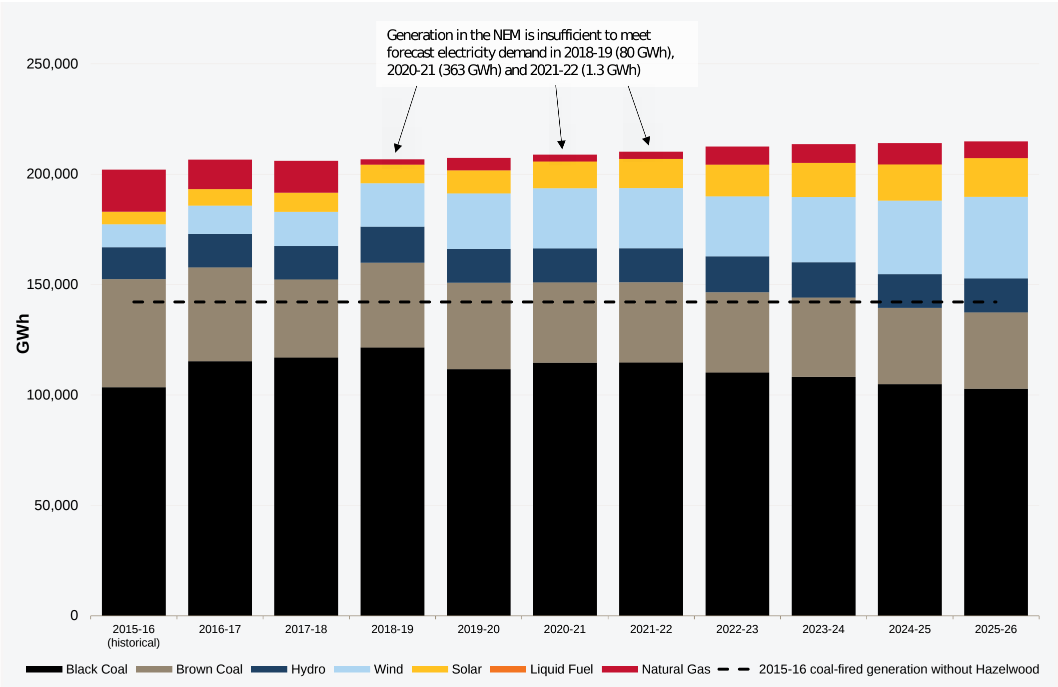

Figure 8: AEMO's forecast electricity generation mix [source: AEMO[51]].

[51] AEMO, *Gas Statement of Opportunities*, Figure 6, page 15.

4.3 Impact of modelling assumptions

Given that the gas-supply gap modelled by AEMO is so small (no more than 0.20% of annual supply in any year) the gap closes entirely with slightly-changed modelling assumptions. Table 2 illustrate some of the key sensitivities of AEMO's result to changes in various input assumptions. These are explored in further detail in the following sections of the report.

Table 2: Change required to close the AEMO supply gap

Electricity demand	In FY 2020-21, AEMO forecasts that the demand for grid-supplied electricity in eastern-Australia will be around 187,000 GWh. AEMO's FY 2020-21 electricity-supply gap (363 GWh shortfall caused by lack of gas supply) would be closed if electricity demand were 0.19% less than AEMO forecasts. See Section 5 for more discussion.
Electricity supply	As shown in AEMO's 2017 GSOO Figure 6, AEMO forecasts that in, for example FY 2020-21, electricity will be generated in eastern-Australia by a mixture of energy sources including coal, hydro, solar, wind, and gas. To close the 363 GWh electricity-supply gap listed in Table 1, electricity generated by wind and solar would have to be 0.9% greater than AEMO's forecasts for those sources. Alternatively, electricity generated from coal would have to be 0.2% greater than AEMO forecasts. See Section 6.
Diversion of gas from LNG	In its 9 March 2017 announcement, AEMO pointed out that diverting a small amount of gas from LNG export to the domestic market would close the gas-supply gap. As shown in Table 1, the largest gas-supply gap modelled is 3.9 PJ in the financial year (FY) 2020-21. For that year, AEMO's forecasts that the volume of gas used for LNG export is around 1,430 PJ. Therefore, a diversion of only 0.3% of the gas used for export LNG would be required. See Section 7.
Domestic gas demand	In FY 2020-21, AEMO forecasts that the demand for gas consumed within eastern-Australia (i.e. not exported) will be around 530 PJ. AEMO's FY 2020-21 gas-supply gap (3.9 PJ) would be closed if gas demand were 0.7% less than AEMO forecasts. See Section 8.
Gas supply capacity	AEMO bases its gas-system modelling on information provided by the gas industry. Prior to any Final Investment Decisions (FID) for a new gas project, the gas industry often does not provide AEMO with information such as start-up dates or facility capacities. As indicated in Table 1, the largest supply gap occurring in FY 2020-21 can be closed if the capacity of gas supply facilities available in FY 2020-21 is increased by 0.2%. See Section 9.

5 Declining electricity demand

This section describes how high energy costs are impacting eastern-Australian electricity users.

This section also shows that AEMO's forecast FY 2020-21 electricity-supply gap is only 0.19% of the total amount of electricity that is forecast to be required that year. This gap is readily closed by small changes in demand-forecast assumptions, (declining gas demand is discussed in Section 8).

AEMO's electricity-demand forecasts were published in its 2016 National Electricity Forecasting Report or NEFR[52]. That forecast indicates that the demand for grid-supplied electricity will remain relatively flat for the next 20 years ("2016 - Neutral" scenario shown in Figure 9, despite projected 30% population growth and growth of the Australian economy[53].

Two factors restraining demand for grid-supplied electricity are:

- the continuing deployment of "behind-the-meter" rooftop solar photovoltaic (PV).
- continually increasing electrical appliance efficiency.

AEMO's forecast electricity-supply gap of 363 GWh (FY 2020-21) is only 0.19% of forecast demand for that year (187,000 GWh).

Figure 9: AEMO electricity-demand forecasts (published in 2015 and in 2016). AEMO's small forecast supply gap (363 GWh in FY 2020-21) would not be visible on this chart [source: AEMO[54]].

[52] AEMO, *National Electricity Forecasting Report*.
[53] Ibid., page 3.
[54] Ibid., page 22, Figure 5

AEMO also published electricity-demand forecasts for “Strong” and “Weak” scenarios which were characterised by stronger or weaker Australian economic conditions.

In FY 2021-22 (as an example year), the difference between AEMO’s “Neutral” scenario versus the “Strong” and “Weak” scenarios is about +/- 5%, or +/ 8,500 GWh. This range highlights the uncertainty of electricity forecasts and is far greater than the 363 GWh supply gap described by AEMO in its 9 March 2017 announcement. A 363 GWh electricity-supply gap is only 0.19% of the total electricity demand forecast for that year (187,000 GWh).

As also shown in Figure 9, AEMO’s electricity-demand forecasts published in the previous year’s 2015 NEFR featured an even broader range from the “High” to the “Low” scenario: +/-12% (+/ 23,000 GWh).

AEMO has a track-record of reducing electricity-demand forecasts from year to year[55]. From the 2015 NEFR to the 2016 NEFR, AEMO reduced its electricity demand forecast for FY 2020-21 (for example) by approximately 2%.

As described in the next section, it is becoming clear that eastern-Australian electricity demand will trend below AEMO’s “Neutral” scenario given the outlook for continuing high gas and electricity prices and the impact of these higher energy costs on industrial consumers[56].

5.1 Update to the National Electricity Forecast Report

Just eleven days after the 9 March 2017 supply-gap warning, AEMO published updated electricity-demand forecasts in a “NEFR Update”[57].

In the NEFR Update, AEMO reduced its forecast NEM electricity demand by approximately 1% (1,580 GWh in FY 2021-22). This update was necessary because of “more recent information on electricity usage from Queensland’s Boyne Island Smelter and the Liquefied National Gas (LNG) sector”. In its NEFR Update, AEMO referenced a news report that the aluminium output from that smelter would be reduced by 14% due to high electricity costs[58]. The revised forecast published in the NEFR Update easily closes the 363 GWh electricity-supply gap.

As was highlighted by industrial gas buyers at an AEMO-led industry consultation forum held in Melbourne on 11 April, electricity and gas ‘demand destruction’ is likely to result from high energy costs. Industrial gas users characterised the impact of increasing energy costs with comments such as:

- “frightening from an end-user perspective”
- “no major gas users can afford this gas”
- “there will be a significant loss of industrial activity”
- “it is inevitable that high energy prices will reduce gas and electricity demand”.

[55] Sandiford et al., “Five Years of Declining Annual Consumption of Grid-Supplied Electricity in Eastern Australia”.
[56] AIG, *Energy Shock: No gas, no power, no future?*
[57] AEMO, *Update: National Electricity Forecasting Report*.
[58] Annett, *What 'significant number' of job cuts mean for BSL.*

6 Demand response & other electricity sources

This section describes how AEMO's forecast gas-supply related electricity-supply gap (363 GWh, or just 0.19% of electricity demand in FY 2020-21) can be closed by small increases in the use of renewable energy or coal. Energy storage and demand response will also have a role to play in ensuring reliable electricity supply.

As described in AEMO's 2017 GSOO (and as reproduced in Figure 10 below), AEMO forecasts that in the coming decade and beyond, grid-supplied electricity in eastern-Australia's NEM will be generated by a mixture of energy sources including coal, liquid fuel (e.g. diesel), hydro, solar, wind, and gas.

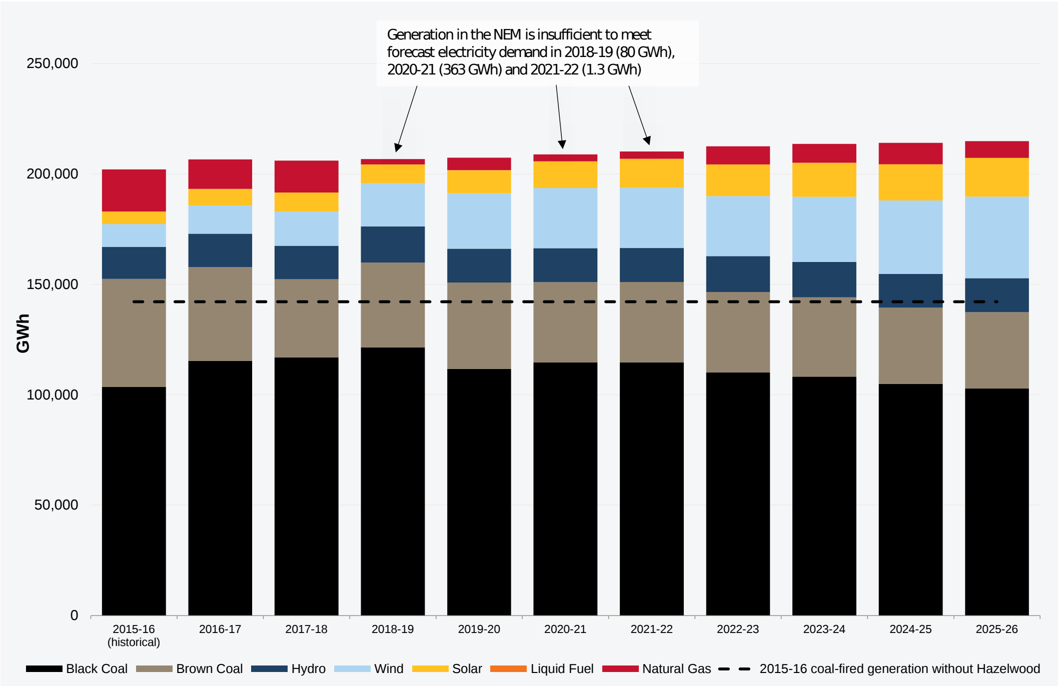

Figure 10: AEMO's forecast electricity generation mix [source: AEMO[59]].

[59] AEMO, *Gas Statement of Opportunities*, Figure 6, page 15.

In Figure 11, AEMO's small FY 2020-21 supply gap (363 GWh) is compared with the amount of electricity that AEMO forecasts will be generated in that year by a range of energy sources.

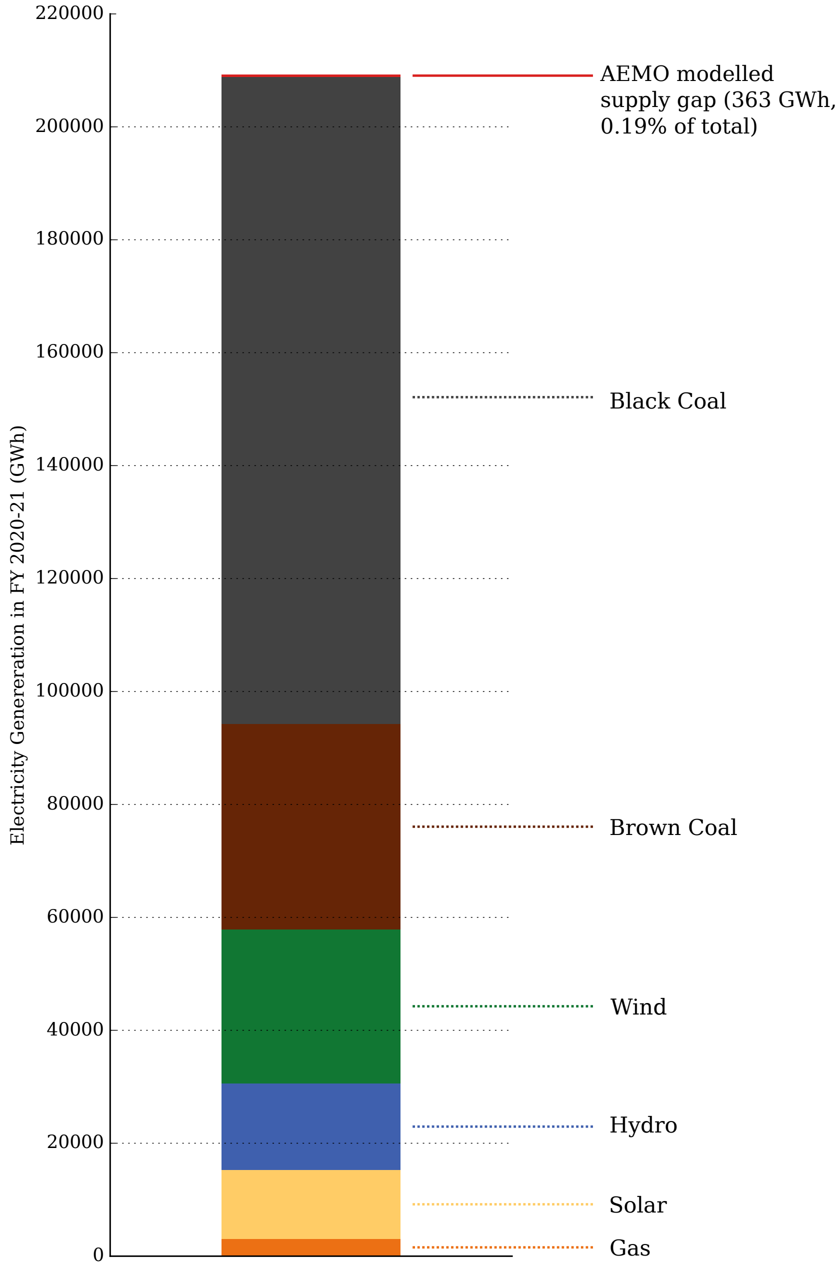

Figure 11: AEMO forecast electricity generated by fuel source in FY 2020-21, showing AEMO's small forecast supply gap as a thin red line at the top of the stack [source: AEMO[60]]

[60]AEMO, *Gas Statement of Opportunities*.

6.1 Renewable generation

As shown in Figure 10, AEMO forecasts that the use of wind and solar to supply grid electricity increases from an actual amount of 16,000 GWh in FY 2015-16 to a forecast amount of 54,000 GWh in 2025-26, an increase of 240%. This increase is driven by renewable energy deployment and greenhouse-gas emission-reduction requirements.

In Figure 11, AEMO's small forecast supply gap (shown as a thin red line) is compared with wind and solar electricity generation expected in FY 2020-21. To close the key 363 GWh electricity-supply gap that AEMO describe for FY 2020-21, the amount of electricity generated from wind and solar would have to be only 0.9% greater than AEMO's modelling forecasts for that year. (Table 1) Assuming a 25% capacity factor, a solar or wind generation facility of approximately 170 megawatt (MW) would produce 363 GWh of electricity in one year.

AEMO includes in its modelling the federally-mandated Large-scale Renewable Energy Target (LRET) and the Victorian Renewable Energy Target (VRET). AEMO does not intend to include in its modelling consideration of the following state-based targets, which AEMO refers to as "aspirational", until mechanisms to achieve these targets are confirmed[61]:

- South Australia – 50% renewable energy by 2025
- Queensland – 50% renewable energy by 2030
- New South Wales – net zero emissions by 2050.
- Victoria – net zero emissions by 2050[62].

Regarding the rate at which renewables-based electricity generation is being installed in eastern-Australia and the impact of this activity on AEMO's forecast supply shortfall, an article published by Renew Economy (28 April 2017) entitled "The shortage may be short-lived" claimed[63]:

> *"AEMO forecasts will likely be revised. There is much more renewable generation being built than is generally acknowledged, something like 5 megawatt (GW) of power and over 11.5 terawatt hour (TWh) of energy. We expect still more projects will be confirmed. In short, the [AEMO forecast gas-supply] shortfall may largely disappear."*

6.2 Thermal generation

For the years shown in Figure 10, AEMO forecasts that the use of coal for electricity generation reaches a maximum level in FY 2018-19. For the following year, AEMO forecasts that coal-use falls significantly by around 6% and then remains at approximately that level for the years after that. During an industry consultation meeting held on 11 April 2017, AEMO stated that this modelling outcome is driven by greenhouse-gas emissions reduction requirements and modelling parameters relating to coal plant flexibility, reliability and availability.

To close the 363 GWh electricity-supply gap that AEMO describe for FY 2020-21, the amount of electricity generated from coal would have to be only 0.2% greater than what AEMO forecasts. (Table 1)

6.3 Energy storage

Energy storage will play a key role in future electricity supply and in closing electricity-supply gaps that might occur for example in AEMO's critical FY 2020-21.

Storing energy with chemical batteries, pumped hydro, or molten salt has been a topic of great discussion in Australia over recent months.

[61] AEMO, *Gas Statement of Opportunities*.
[62] Government of Victoria, *Climate Change Act 2017*.
[63] Leitch, "Gas shortfall may be short-lived, thanks to growing renewables".

In February 2017, Australia's Prime Minister announced a study into the feasibility of incorporating a very large pumped hydro-energy storage scheme into the existing Snowy Mountains Hydro Scheme. This new scheme (known as "Snowy 2.0") might have the capacity to store the equivalent of nearly 400 GWh of electricity in a single weekly charge and discharge at a rate of 2 GW. However, this concept would be unlikely to be built before 2022[64]. Similar concepts have also recently been described where Tasmania becomes "the nation's battery"[65].

For more immediate installation, the state of Victoria has tendered for 100 MW of energy storage, likely to be in the form of chemical batteries. Similarly, South Australia has tendered for 100 MW / 100 megawatt hour (MWh) of battery storage[66]. These facilities could be in place by 2018. 200 MWh of energy storage, used throughout the year, would provide 73 GWh of energy.

Of course because of system losses, any form of stored energy requires a charge of energy that is greater than what the device will supply during subsequent hours or days.

Large-scale energy storage is yet to feature in AEMO's annual planning documents such as the Electricity Statement of Opportunities (ESOO[67]) or the National Transmission Network Development Plan (NTNDP[68]).

6.4 Demand response

The most critical time for the reliability of an electricity grid is during times of high demand. In eastern-Australia, high electricity demand occurs during the evenings following hot summer days when air conditioners are in widespread use. Electricity consumers (ranging from home occupants to very large industries) can be incentivised during critical times to reduce electricity demand. This activity is referred to as Demand Response (DR) or Demand-Side Participation (DSP).

According to the incoming Chief Executive Officer of AEMO Audrey Zibelman[69]::

> *"You don't have to invest in generation that you are only going to use a few hours a year, because you can use the load itself as a balancing resource. It is that signal that says [to peaking power plants]: "Hey there, we don't really need you" that is going to help moderate [wholesale electricity] prices. It's pure economics applying to them and making demand a much more active portion of the grid".*

According to the demand-response vendor Enernoc[70]:

> *"Relative to global peer market, the NEM has exceedingly low levels of demand response participation in its wholesale markets. However, this can be rectified with relatively simple improvements to the NEM's market design."*

In eastern-Australia, AEMO has described demand response activities such as:

- centralised control of appliances, for example air conditioners and hot water heaters
- interruptible commercial and industrial loads / load shedding
- behavioural (incentivised) residential-consumer response
- Distributed Energy Resource (DER) – small generators (including diesel-fuelled) that can be activated at critical times[71].

Such demand-side options may provide more economical ways to deal with critical periods for the electricity grid than using high-cost gas-fuelled electricity generation.

[64] Aston, "Snowy Hydro 2.0 could hasten death of fossil fuel-generated electricity".
[65] Burgess, "Turnbull outlines vision for Tasmania to become 'battery of Australia"'.
[66] Giles Parkinson, "Storage boom".
[67] AEMO, *Update: Electricity Statement Of Opportunities*.
[68] AEMO, *National Transmission Network Development Plan*.
[69] Parkinson, "South Australia should dump diesel plan and think smarter".
[70] Ibid.
[71] AEMO, *National Transmission Network Development Plan*.

7 Diverting LNG

In its 9 March 2017 announcement[72], AEMO pointed out that diverting a small amount of gas from LNG export to the domestic market would close the gas-supply gap.

As shown in Table 1 the largest gas-supply gap modelled is 3.9 PJ in FY 2020-21. For that year, AEMO's expected volume of gas used for export LNG is around 1,430 PJ. Therefore, in that year, a diversion to the domestic gas market of only 0.3% of the gas used for export LNG would be sufficient to close AEMO's forecast supply gap.

Likewise, a small change to AEMO's forecast of the volume of LNG exported closes the supply gap.

AEMO's most recent LNG-export forecasts were published in the 2016 National Gas Forecasting Report (NGFR)[73]. AEMO's forecast methodology is described in AEMO's NGFR methodology report[74] and in a report by Lewis-Grey Advisory[75]. In short[76]:

> *"LNG forecasts were developed undertaking modelling, using a range of public data and the outcomes of technical engagement with producers".*

Following AEMO's 9 March 2017 announcement and actions taken by Australia's Prime Minister (as described in Section 2), gas-industry spokespeople were reported to be critical of AEMO's LNG export forecasts, saying that AEMO over-estimated the volume of LNG sales and therefore the volume of gas that would be required by the LNG industry[77]. Judging from this, gas industry sources are implying there is no gas-supply gap.

In the 2016 NGFR, AEMO offers a range of LNG-export forecasts. As shown by Figure 12, in the year 2021 the "Strong" and "Weak" scenarios vary from the "Neutral" scenario by approximately +/- 15% (+/- 200 PJ). This range of uncertainty is much larger than the 3.9 PJ supply gap described above.

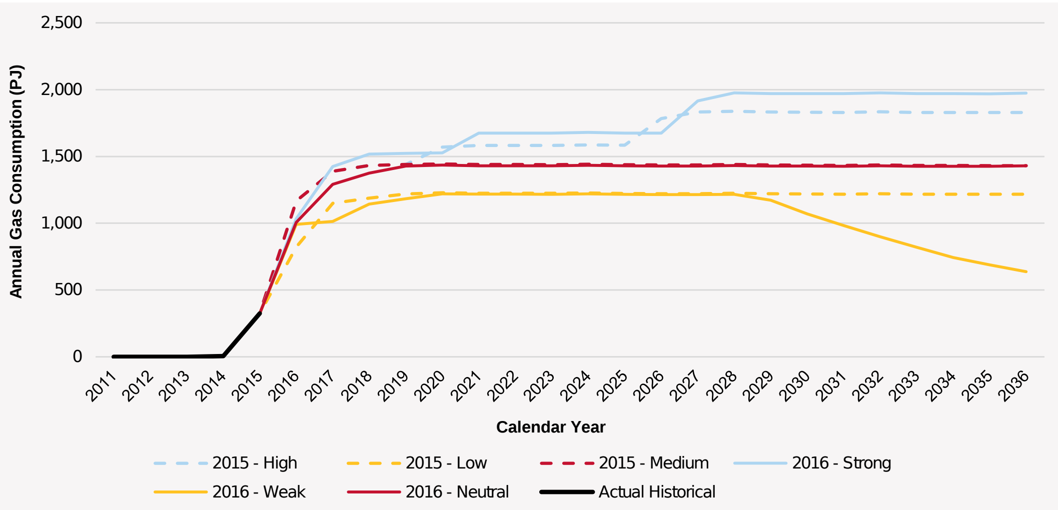

Figure 12: AEMO eastern-Australian gas demand forecast showing ramp-up of LNG exports [source: AEMO[78]].

[72] AEMO, *Media statement: Gas development required To meet future energy demand*.
[73] AEMO, *National Gas Forecasting Report*.
[74] AEMO, *Forecasting Methodology Information Paper*.
[75] Lewis Grey Advisory, *Projections of Gas and Electricity Used in LNG*.
[76] AEMO, *Forecasting Methodology Information Paper*.
[77] Macdonald-Smith, "Gas producers defiant ahead of recall to Canberra".
[78] AEMO, *National Gas Forecasting Report*, page 19, Figure 2.

8 Declining domestic gas demand

This section describes the impact of high energy costs on eastern-Australian energy users, and how gas users might respond. This section also describes how a small change to forecast domestic-gas demand closes AEMO's small forecast supply gap.

Figure 13 shows that domestic-gas demand (excludes gas used for LNG export) peaked in 2012 at 713 PJ[79], and by 2016 had fallen 16% to 589 PJ.

Domestic-gas demand has declined in all sectors: gas used by industry, gas used to generate electricity, and gas used in buildings.

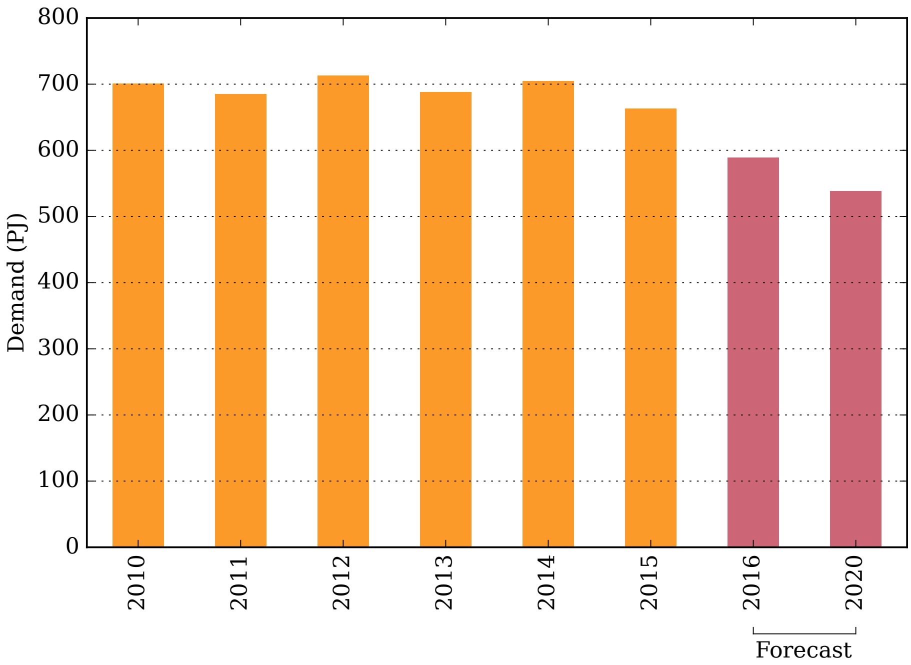

Figure 13: Actual and forecast eastern-Australian gas demand (petajoules). The forecast are taken from the 'neutral' scenario from AEMO's *2016 National Gas Forecasting Report* [source: AEMO[80]].

[79] As described in Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.

[80] Data from AEMO, *National Gas Forecasting Report*, available at `http://forecasting.aemo.com.au/`

8.1 Gas demand continues to fall

AEMO published its most recent gas-demand forecasts in the December 2016 National Gas Forecasting Report[81]. AEMO forecasts that domestic-gas demand will decline by another 9% over the period 2016 to 2020 to reach a level just 74% of the 2012 peak at 525 PJ (Figure 14).

AEMO forecasts that gas demand will continue to decline in all sectors. The greatest per cent decline is in the gas-for-electricity generation sector (19% decline), followed by gas for industry (10% decline), and then residential and commercial (only a 1% decline).

AEMO forecast that the largest gas-supply gap (3.9 PJ, see Table 4) could occur in FY 2020-21. For that same year, AEMO forecast that eastern-Australian domestic-gas demand will be around 530 PJ. Therefore, AEMO's FY 2020-21 gas-supply gap would be closed if domestic gas demand were just 0.7% less than what AEMO has forecast.

As was described in Section 5.1, on 20 March 2017 AEMO revised down its electricity demand forecasts to reflect reduced industry activity. AEMO's most recent gas demand forecasts do not reflect the continuing escalation of wholesale gas prices seen so far in 2017 and the impact of this price escalation on gas-consuming industries. We judge that in the coming months AEMO will also further revise down its gas demand forecasts.

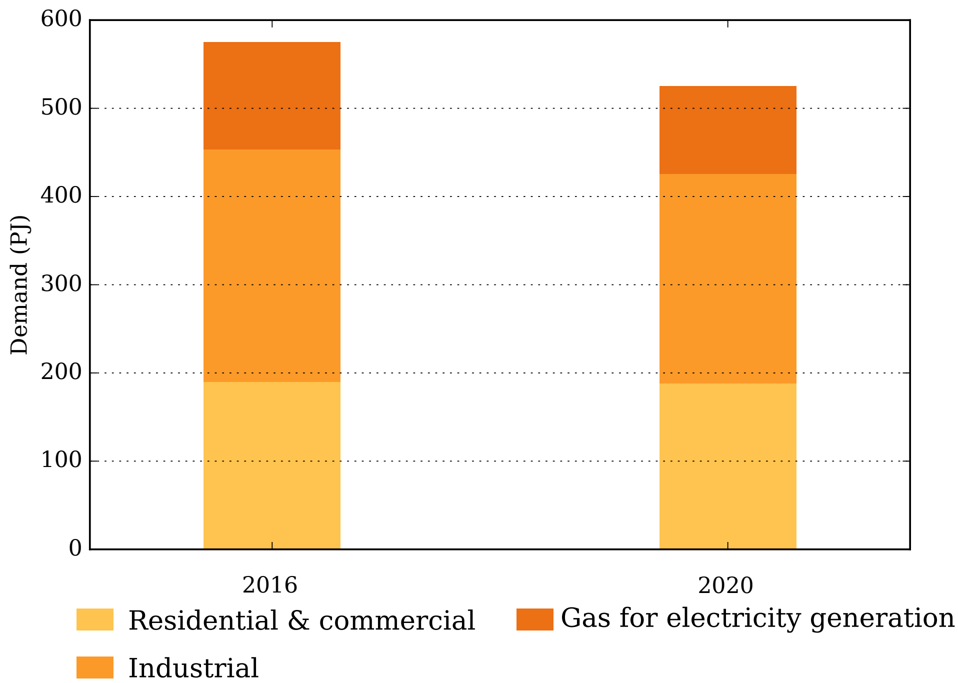

Figure 14: Domestic gas demand forecast for 2020 compared with 2016. The 'neutral' forecast scenario from AEMO's *2016 National Gas Forecasting Report* is illustrated [source: AEMO[82]].

[81] AEMO, *National Gas Forecasting Report*.
[82] Ibid., data available at `http://forecasting.aemo.com.au/`

8.2 Industrial gas demand

This section describes in more detail how industrial gas demand is declining in eastern-Australia. It also describes options and opportunities for existing and new industries in this new expensive-gas world.

As described in Sections 3.3 and 5, high energy costs are already causing electricity and gas "demand destruction" in eastern-Australia, particularly in the industrial sector.

As shown in Figure 15, AEMO forecasts that eastern-Australian industrial gas demand will continue to decline. In the "Weak" scenario, industrial gas demand in the year 2026 falls to only two-thirds of the 2013 peak (204 PJ vs 302 PJ). In the 'Neutral" scenario, demand falls to three-quarters of the 2013 peak.

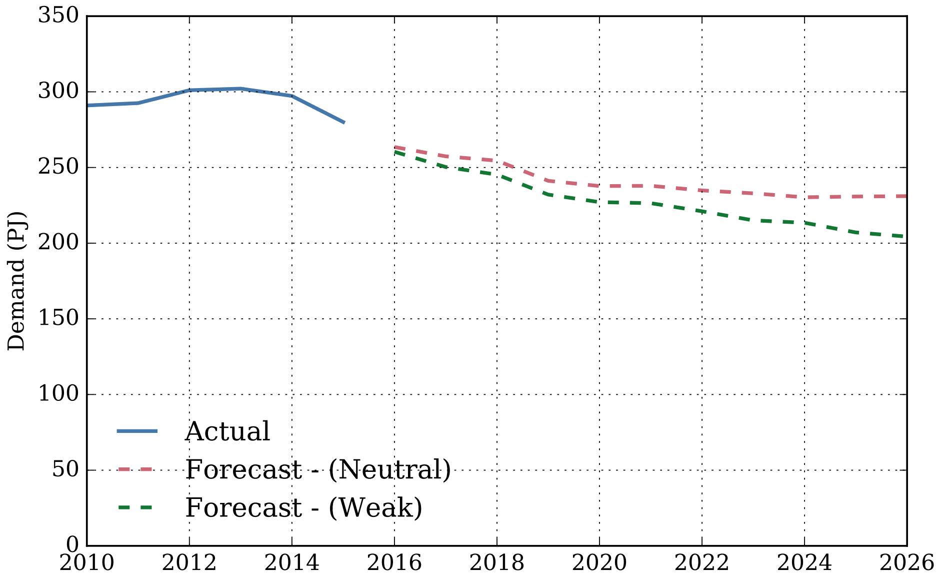

Figure 15: Actual and forecast industrial gas demand in eastern-Australia. The 'neutral' and 'weak' scenarios from AEMO's *2016 National Gas Forecasting Report* are illustrated [source: AEMO[83]].

[83]Data from AEMO, *National Gas Forecasting Report*, available at `http://forecasting.aemo.com.au/`.

8.2.1 Fuel switching

In response to high energy costs, industry may employ the energy-efficiency and fuel-switching measures we described in 2015[84,85].

For example in a study for the Australian Renewable Energy Agency (ARENA), IT Power quantified the amount of gas-derived energy used at various temperature levels and potential renewable energy alternatives[86]. Figure 3 shows that some of these technologies can achieve very high process temperatures.

Electricity-based technologies can be powered by renewable or non-renewable energy sources. These include:

- heat pumps
- electric-induction heating
- electric-resistive heating
- electric-arc heating

Process heat level used in manufacturing	**Less than 250°C**	**250°C to 1300°C**	**Greater than 1300°C**
Share of total process heat requirement (33)	9%	45%	47%
Applicable renewable energy technologies for process heat generation			
Electric heat pump – air source	yes		
Electric heat pump – ground source (geothermal)	yes		
Geothermal - direct	yes		
Biomass combustion	yes	yes	
Biogas combustion	yes	yes	yes
Solar thermal - direct	yes	yes	yes

Table 3: Renewable energy alternatives for process heat [source: MEI[87]]

[84] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.
[85] Forcey and Sandiford, *The dash from gas: Could demand in New South Wales fall to half?*
[86] ITP, Pitt & Sherry, and ISF, *Renewable Energy Options for Australian Industrial Gas Users*.
[87] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*, page 18, table 2

8.2.2 Biogas and biomethane

As the price of fossil gas rises and the preference for lower-carbon sources of energy and chemical feedstock increases, the distributed production of renewable biogas and biomethane will become increasingly economic in eastern-Australia. Renewable biogas / biomethane is gas derived from biomass sources and municipal waste[88].

Bioenergy and gas from waste[89] is proving to be a significant resource in countries such as Denmark and Germany[90].

In 2013, the City of Sydney identified that up to 50 PJ/yr of gas[91] could be produced from sources located around Sydney[92,93]. As an example, Sydney Water reports that up to 5 PJ/yr of gas could be created from their own waste sources[94].

In 2012, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) completed work for AEMO's "100% Renewable Energy Study" for eastern-Australia that identified recoverable biogas resource of more than 200 PJ/yr[95].

In 2015 in a report for the ARENA, IT Power described how biogas can displace fossil gas in industrial applications[96].

The above gas volumes can be compared with small gas-supply shortfall of 3.9 PJ/yr that AEMO forecast will occur in FY 2020-21.

8.2.3 Renewable hydrogen

Renewable hydrogen, manufactured via renewable-energy-powered electrolysis, may become the basis for new Australian domestic and export industries[97].

The South Australian government is developing a hydrogen "road map"[98], and in March 2017 commissioned an exploratory "Green Hydrogen Study". That study "is intended to assess the technical and commercial feasibility of producing green hydrogen in South Australia as a central piece of quantitative input to underpin the roadmap." South Australia's aim is to capitalise on their "abundance of renewable resources to become the green hydrogen capital of Australia"[99].

In the Australian Capital Territory (ACT) the feasibility of adding hydrogen to the gas distribution network is also being investigated[100].

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[88] This section adapted from 'Switching off gas – An examination of declining gas demand in eastern-Australia' Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.

[89] IEA, *IEA Bioenergy Annual Report 2013*.

[90] IEA Bioenergy Task 37, *Country Reports Summary 2015*.

[91] Note that the City of Sydney study does not utilise timber plantations or native forest timber. The study included a small amount of bioenergy (0.4 PJ/yr) from pine wood processing residues.

[92] City of Sydney, *Decentralised energy masterplan*.

[93] Pigneri Attilio, *Renewable Gases Supply Infrastructure*.

[94] Anders, Peter, *New energy paradigm, better energy better business*.

[95] James and Hayward, *AEMO 100% Renewable Energy Study: Energy Storage*.

[96] ITP, Pitt & Sherry, and ISF, *Renewable Energy Options for Australian Industrial Gas Users*.

[97] Forcey, "Meeting the future needs of Australia's energy customers with renewable energy chemicals".

[98] Government of South Australia, *Our Energy Plan South Australian power for South Australians*.

[99] Dunis, "Could South Australia be the nation's hydrogen state, too?"

[100] ACT Government, *Media Release: ACT Government brings hydrogen energy storage to Canberra*.

8.3 Options for homeowners and building managers - fuel switching

In 2015, we described how home owners and building managers can reduce gas use as well as energy-use overall by implementing energy-efficiency measures and "fuel-switching" from gas-fired appliances to heat pumps[101,102,103].

In 2016, ClimateWorks Australia, in a report for the Australian Sustainable Built Environment Council (ASBEC), also described a scenario where[104] "emissions from gas combustion in buildings can be largely eliminated through a switch to electric alternatives."

For home space-heating, Figure 16 illustrates how a modern heat pump (known as "reverse-cycle air conditioner", RCAC, on mainland Australia) can use just 1/13th of the energy used by a gas-fired system to deliver the same amount of useful heat.

In the diagram on the left, a ducted gas-fired system consumes 33 megajoule (MJ) of gas energy (plus 0.6 MJ of electrical energy) to produce 10 MJ of useful space-heating.

In the diagram on the right, a reverse-cycle air conditioner (or air-source heat pump) uses only 2.5 MJ of electrical energy to produce the same amount of useful heat. This is possible because in space-heating applications, heat pumps recover free renewable-ambient heat from the air surrounding a building. Air-source heat pumps can be said to harvest solar energy because it is the sun that warms the Earth's atmosphere.

Heat pumps can also be used in a similar way to heat water. In Australia, the act of installing a hot-water heat pump can earn renewable energy certificates[105].

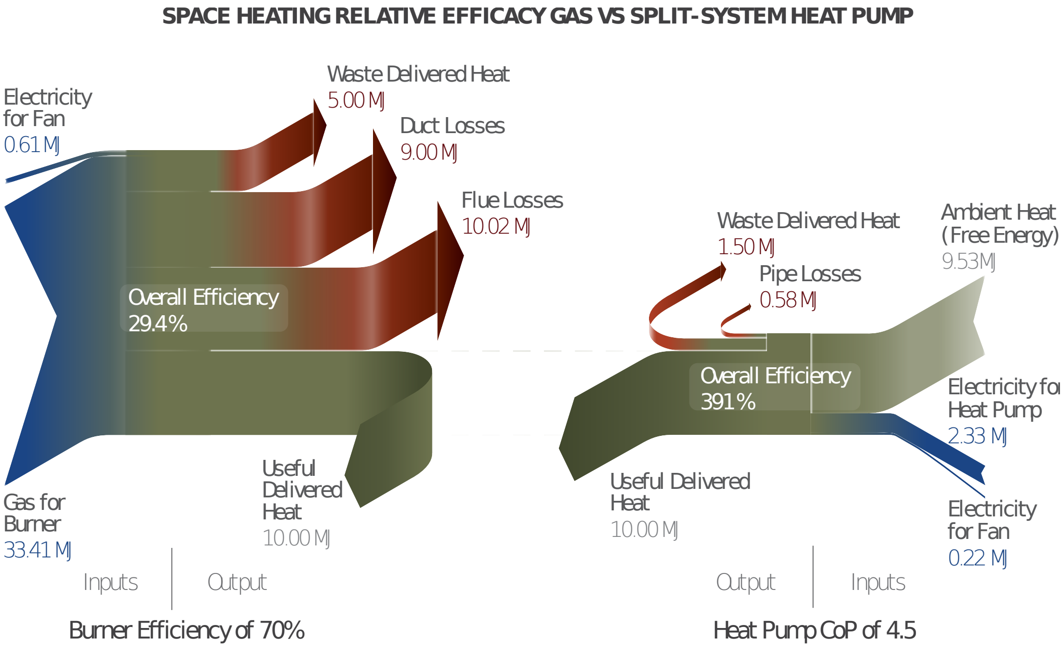

Figure 16: A heat pump space heater (aka reverse-cycle air conditioner) can use just 1/13th the energy of a gas-fired heating system while delivering the same amount of heat to living spaces [source: BZE[106]].

[101] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.
[102] Forcey and Sandiford, *The dash from gas: Could demand in New South Wales fall to half?*
[103] Arup, "Heat pump' tech could save Victorian homes up to $658 a year on gas".
[104] Climate Works, *How buildings can make a major contribution to Australia's emissions and productivity goals*.
[105] Hot water heat pumps are classified grouped with "solar" water heaters at this Clean Energy Regulator
[106] BZE, *Buildings Plan*, page 85, Figure 3.20.

Table 4 highlights the operating-cost savings possible when using an air-source heat pump (aka reversecycle air conditioner or RCAC) for home space-heating. Savings of $1,733 per year are possible for a large home in Canberra[107].

Location	Home type	Gas space-heating costs (energy- only, excludes fixed supply charges)	RCAC space-heating costs (energy- only, excludes fixed supply charges)	Heating cost savings with RCAC	% savings with RCAC
		($/year)	($/year)	($/year)	(%)
Canberra, ACT	large	$2,255	$522	$1,733	77%
Melbourne, VIC	large	$1,049	$391	$658	63%
Orange, NSW	medium	$1,370	$949	$421	31%
South NSW	small	$599	$415	$184	31%
Adelaide, SA	small	$180	$124	$56	31%
This table lists only five of the 156 region/zone and dwelling-type combinations examined by the ATA.					

Table 4: Annual savings possible by heating with heat pump (reverse-cycle air conditioner or RCAC) [source: MEI[108]]

Figure 17 further emphasises that heat pumps harvest renewable energy. In Australia, where heat pumps are particularly well-suited in our relatively mild climate zones, RCACs recover more renewable energy than is recovered by roof-top solar panels[109]. The amount of energy recovered by RCACs will grow significantly as more Australians learn of their value.

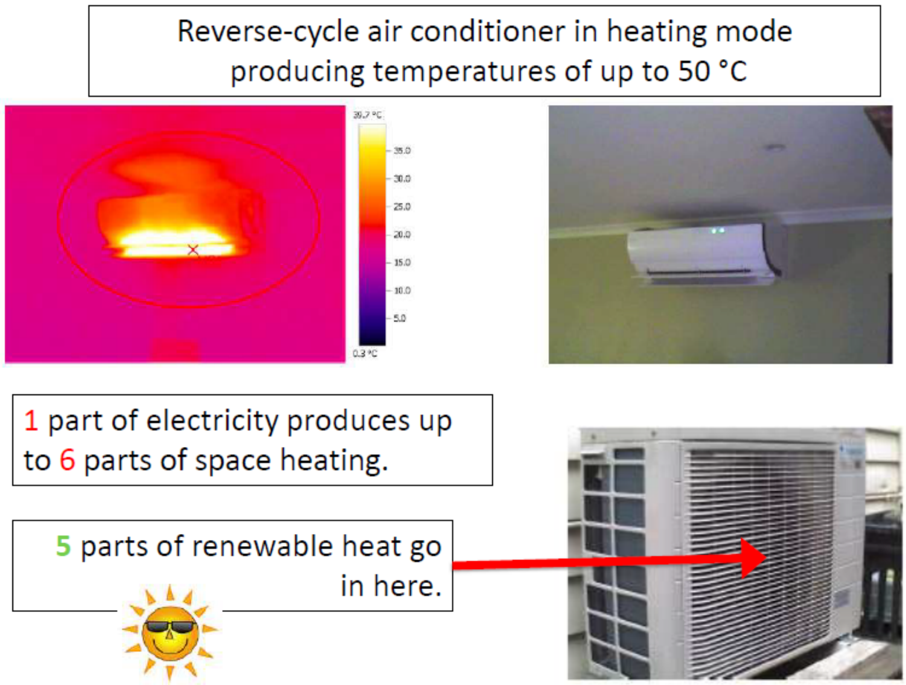

Figure 17: - A reverse-cycle air conditioner in heating mode harvests renewable-ambient heat [source: Tim Forcey[110]].

[107] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.
[108] ibid., page 24, table 7
[109] Forcey, "The cheapest way to heat your home with renewable energy - just flick a switch".
[110] Forcey, *Reverse-cycle Air Conditioners: Australian Renewable Energy Giants*.

Given the effectiveness of using air-source heat pumps in Australian buildings, the Alternative Technology Association (ATA) found that there is no economic reason for any new home or suburb to be connected to the gas-distribution system[111].

Previously we described how reducing the uneconomic use of gas in Australian buildings can "free-up" significant volumes of gas for other uses[112]. Figure 18 illustrates how the amount of gas that can be saved annually in eastern-Australian buildings (versus today's consumption) approaches a forecast level of industrial gas demand.

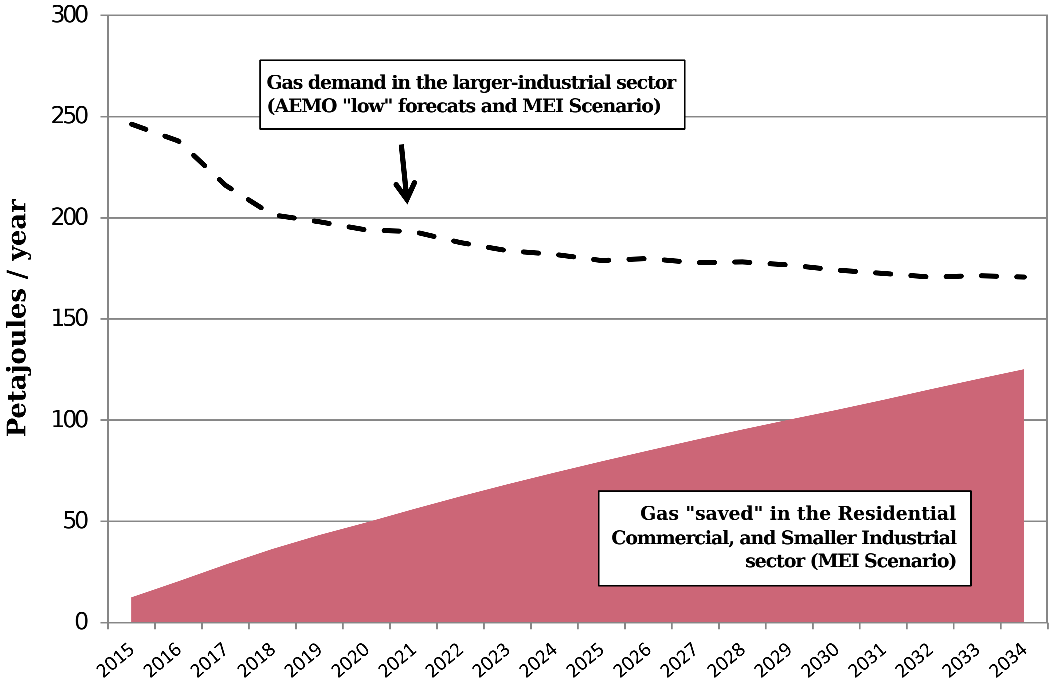

Figure 18: Industrial gas demand (forecast) vs potential for saving gas in building [source: MEI[113]].

[111] ATA, *Are we still Cooking with Gas?*
[112] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.
[113] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*, page 40, Figure 20.

9 Existing gas supply

This section describes how the volume of eastern-Australia's gas reserves and resources is significantly in excess to what is required for both domestic use and LNG export. Therefore, it is not a shortage of gas reserves that leads to AEMO's modelled gas-supply gap. Rather, as will be described in Section 9.3, it is AEMO's assumptions and modelling inputs around gas-production-facility capacity that leads to the forecast supply gap.

This section also discusses the high cost of producing certain eastern-Australian gas reserves.

9.1 Current reserves & resources

According to the AEMO report "GSOO Methodology"[114], AEMO obtains information about gas reserves and resources from the consultants Core Energy Group and gas-producing companies.

Shown in Figure 19 and Table 5 are AEMO's forecasts for cumulative gas production over the next 20 years (to 2036), and also an indication from which gas reserve or resource category the produced gas is derived (proved and probable, contingent resources, or prospective resources).

As shown in Table 19, AEMO forecasts that the total amount of gas to be produced over the next 20 years in eastern-Australia is 39,460 PJ (average production of approximately 2,000 PJ/yr). Subtracting that amount from the total reserves and resources of 257,613 PJ leaves a potential-remaining volume of recoverable gas of 218,153 PJ, a volume 5.5 times larger than what will be produced in eastern-Australia over the next 20 years.

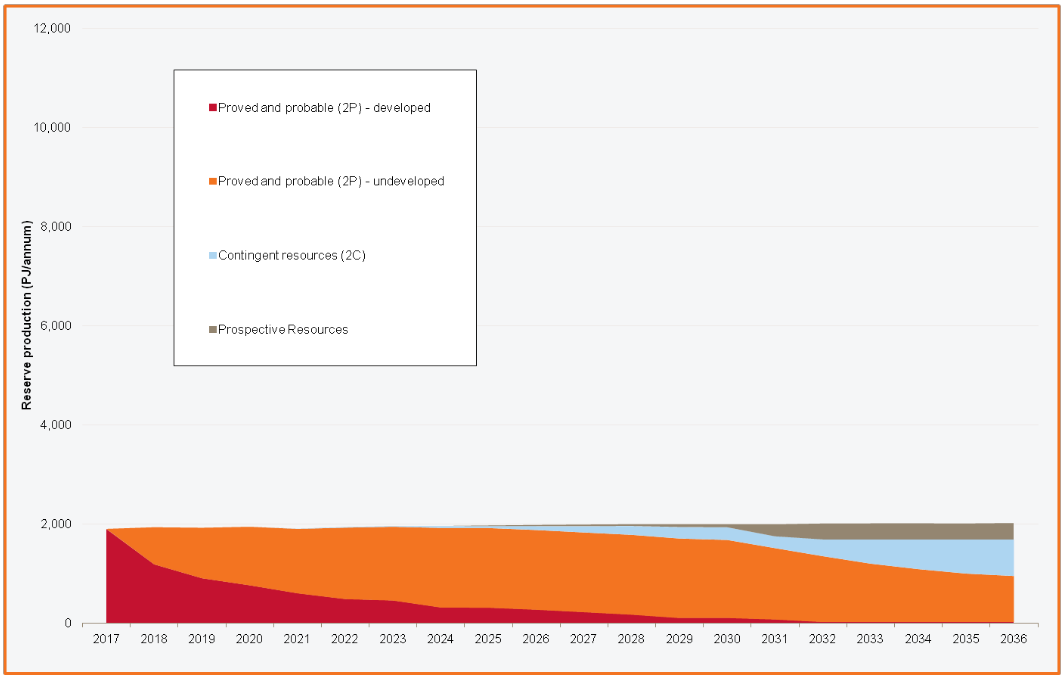

Figure 19: Eastern-Australian 20-year outlook for gas production and use of reserves and resources [source: derived from AEMO[115]].

[114] AEMO, *GSOO methodology*.
[115] AEMO, *Gas Statement of Opportunities*, derived from figure 3.

Table 5: Eastern-Australian gas reserves and resources

Reserve or resource category	Reserves & resources as at 31/12/16 (PJ)	Forecast gas production remaining 2017-2036 (PJ)	Reserves & resources remaining 2036 (PJ)	Reserves & resources remaining 2036 (%)
Proved and probable (2P) reserves	49,316	33,352	15,964	32%
Contingent resources (2C)	56,429	4,052	52,377	93%
Prospective resources	151,867	2.057	149,810	99%
Total	**257,613**	**39,460**	**218,153**	**85%**

Figure 20 reproduces the data shown in Figure 19, but then also shows, for comparison purposes, the remaining 218,153 PJ of gas reserves and resources as if that volume of gas were produced over the 20-year period beyond the year 2036. Figure 20 illustrates that the volume of gas remaining in the ground in eastern-Australia in the year 2036 will far exceed (by 5.5 times) what was produced over the preceding 20 years. This illustrates that the cause of the AEMO-modelled gas supply gap is not a lack of gas reserves and resources.

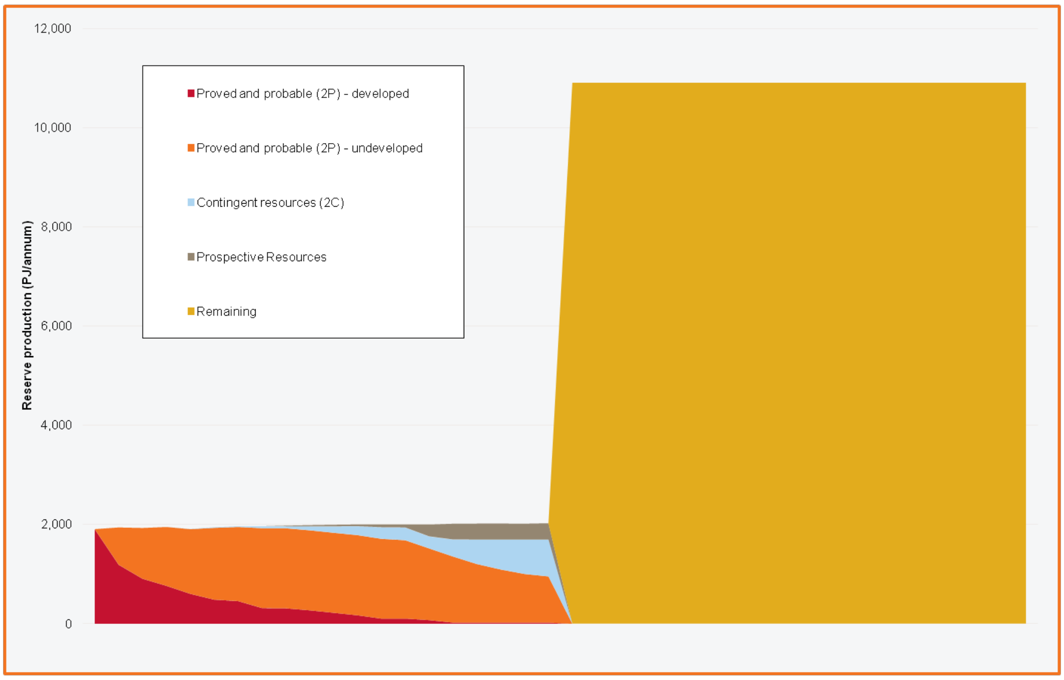

Figure 20: Eastern-Australian gas reserves and resources remaining after 2036 are 5.5 times larger than the volume of gas that will be produced over the 20-year period 2017-2036 [Source: data from AEMO[116]].

[116] AEMO, *Gas Statement of Opportunities*.

Figure 21 illustrates the assessed gas reserves and resources of eastern-Australia's larger gas fields. The reserves and resources directly associated with the three LNG-export projects are shown: Shell-operated QCLNG, the Origin-operated APLNG, and the Santos-operated GLNG.

Of the LNG projects, GLNG has the least amount of proved and probable reserves (shown in orange in Figure 21) and is reported to be purchasing "3rd party" gas to meet its contractual LNG-export commitments made to overseas buyers[117].

The reserves and resources shown below can be compared with the approximately 10,000 PJ forecast to be enough to supply all of eastern-Australian domestic gas needs for the next 20 years.

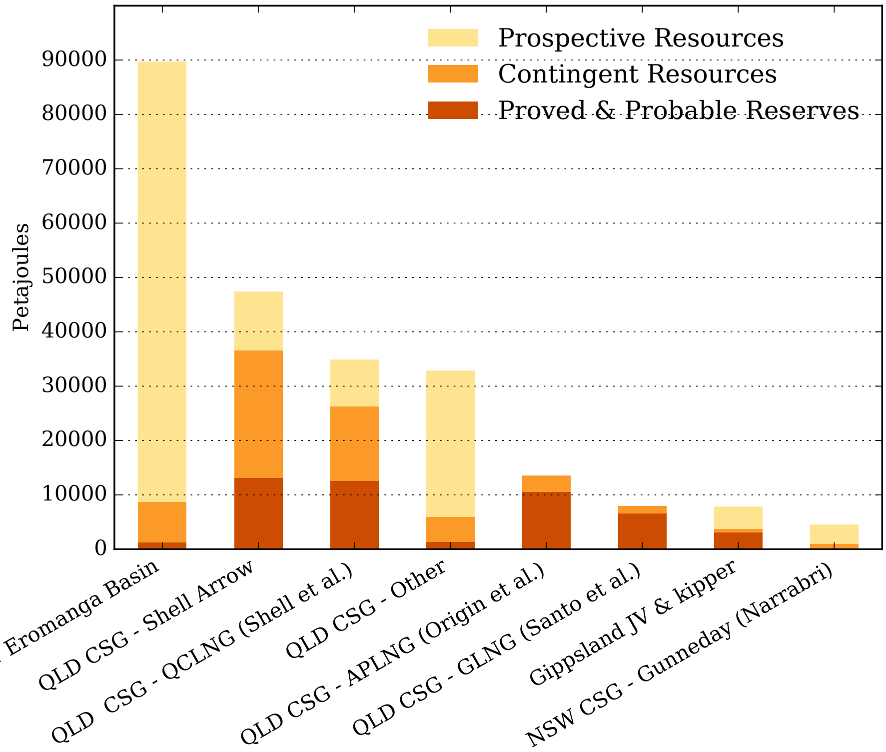

Figure 21: Certain significant eastern-Australian gas reserves and resources by field and project [source: AEMO[118]].

[117] Stevens, "GLNG partners clash over domestic gas plan".

[118] Data from AEMO, *Gas Statement of Opportunities* input data files, available at `https://www.aemo.com.au/-/media/Files/Gas/National_Planning_and_Forecasting/GSOO/2017/2017-Gas-Statement-of-Opportunities-input-data-files.zip`.

As was shown by (Table 5), AEMO's modelling indicates that 32% of the gas reserves currently classified as proved and probable will still remain in the ground after 2036. A large part of this "un-produced" 2P-classified gas is controlled by the gas company Shell. The Shell- Arrow Queensland CSG-LNG project has received all regulatory development approvals; however, in early 2015 Shell announced it would defer development[119]. In March 2017, the energy industry consultants Energy Quest commented on the large Shell-controlled eastern-Australian gas reserves[120]:

> *"Sitting quietly in the background on the east coast is a large undeveloped resource of 9,000 petajoules of coal seam gas in Surat and Bowen Basins in Queensland, owned equally by Shell and PetroChina following their takeover of Arrow Energy. These reserves would be enough to supply east coast demand for 15 years at current levels of demand. They were originally earmarked for a fourth LNG project in Queensland but the high costs of development put an end to that.*
>
> *Shell and PetroChina have been silent on development of these reserves, but would be closely monitoring the domestic gas prices and working out the best way to play their hand. It has not worked out well so far. They have spent billions of dollars and all they have to show is lots of feasibility studies but only modest levels of gas and electricity production. Should they throw more good money after bad or just get out"*

AEMO's modelling assumes this Shell-controlled gas is not produced over the next 20 years. However, on 21 March 2017, Shell announced that they would proceed with the 161-well Project Ruby (See also Section 9.3).

Figure 21 also shows the large reserves and resources of the Cooper Eromanga Basin, and those described as "QLD CSG - Other". The smaller gas volumes of the Gunnedah (Narrabri) CSG field, currently under environmental review[121], are also shown.

[119] The Observer, "Shell takes Arrow LNG project off the table —".
[120] Bethune, *Where is the east coast domgas development boom?*
[121] https://narrabrigasproject.com.au/about/environment/

9.2 Gas production costs

This section describes how the costs of producing newer sources of eastern-Australian gas, in particular coal seam gas (CSG), are at a level where it is unlikely that "cheap" gas prices seen decades ago will return.

AEMO's forecast eastern-Australian gas-production costs are only marginally higher than AEMO and its supporting consultants had forecast a few years ago (for example in August 2012[122]). This as-forecast result is contrary to statements made by gas-industry commentators (including AEMO[123]) about sudden and unexpectedly-high gas production costs related to poorly-understood geology, poor weather conditions, community obstruction, or other reasons.

Figure 22 shows the eastern-Australian gas supply-cost curve. AEMO indicates that at the low-cost end, gas-production costs of around $2/GJ still apply for some proved and probable developed CSG and conventional gas reserves. Figure 22 also shows that 40,000 PJ of gas (i.e. the forecast volume required for 20 years of domestic and LNG-export supply) is available at production costs of less than $5.50/GJ with an average or approximately $4.25/GJ.

This forecast average production cost of $4.25/GJ is only $0.62/GJ higher (17%) than the forecast average of $3.63/GJ published in 2012 (2012 dollars). This result is nearly in-line

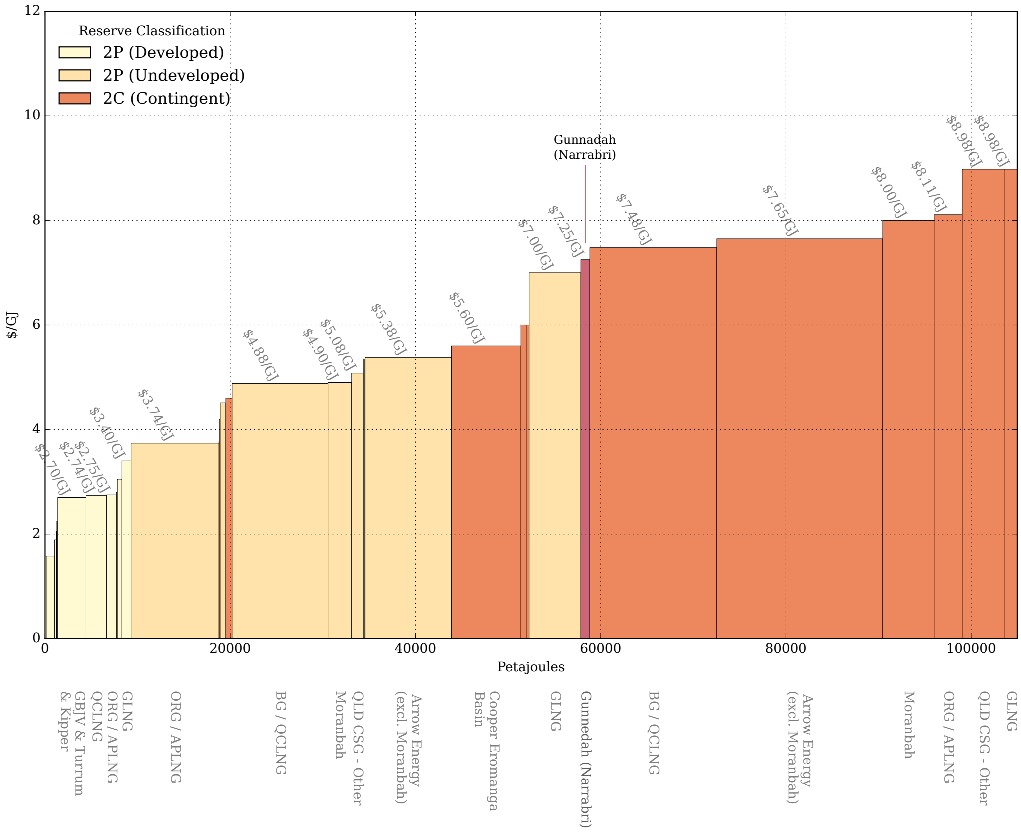

Figure 22: Supply cost curve for eastern-Australian proved and probable gas reserves and contingent resources. Prospective resources with production costs assumed to be greater than $10/GJ are not shown on this figure. Gunnedah (Narrabri) contingent resources are highlighted in red (971 PJ with $7.25 production costs) [source: AEMO[124]].

[122] Core Energy Group, *Gas Production Costs*.

[123] AEMO, *Gas Statement of Opportunities*, See Section 2.1, "Rising production costs and prices",

[124] Ibid. Input data files, data from available at `https://www.aemo.com.au/-/media/Files/Gas/National_Planning_and_Forecasting/GSOO/2017/2017-Gas-Statement-of-Opportunities-input-data-files.zip`.

with inflation[125]. Nevertheless, considering production costs alone (ignoring international market-price linkages), it is unlikely that low-cost gas, which was available to wholesale gas buyers years ago at only $3 to $4/GJ, will ever return.

Figure 22 shows that production costs as high as $7/GJ apply for some proved-and-probable undeveloped CSG reserves. Some contingent resources may cost around $9/GJ to produce.

Not shown on Figure 22 are 150,000 PJ of prospective resources that are estimated to cost more than $10/GJ to produce. Some offshore gas and some unconventional gas (CSG, shale, tight sandstone) is included in this category of gas resources. Also not shown on this figure is Northern Territory gas. AEMO judges the production costs of that gas to be no less than $6.50/GJ.

As shown on Figure 22, the production costs of Gunnedah (Narrabri, NSW) CSG graded as contingent resources are estimated by AEMO and its consultants to cost no less than $7.25/GJ to produce. In other words, this gas is estimated to be more expensive to produce than 58,000 PJ of other eastern-Australian gas reserves and resources, a volume of gas equivalent to approximately 30 years of domestic and LNG-export supply at current extraction rates. Included amongst these cheaper-than-Gunnedah gas resources are the Shell-Arrow CSG and Cooper-Eromanga basin resources.

The costs of transporting gas by pipeline must be added to all sources of gas supply. Pipeline transmission costs vary between regions[126]. We estimate that transmission adds $2 to cost of delivering gas from the Gunnedah (Narrabri, NSW) development, bring total delivered costs to $9.25. The cost of Northern Territory gas when delivered to east coast market is expected to be above $12-$13[127].

[125] Core Energy Group, *Gas Production Costs*.
[126] Core Energy Group, *Gas Price Consultancy*, see table 3.3, page 13.
[127] Anthony Barich, "NEGI Economics Based On Hope: Wood Mac".

9.3 Increased production at existing facilities

This section describes the gas-production-facility capacity assumptions used by AEMO in its modelling of the eastern-Australian gas-supply system. This section also describes how small changes to AEMO's modelling input assumptions readily close the small forecast gas-supply gap.

As described in its Gas Statement of Opportunities[128]:

> *"AEMO surveyed gas industry participants to obtain detailed gas information including:*
>
> - *processing facility capacities, and potential or committed future expansions.*
> - *pipeline capacities, and potential or committed future expansions.*
> - *LNG facility capacities, and potential or committed future expansions.*
> - *gas project developments (including reserves).*
> - *storage facility capacities and potential or committed future developments.*
>
> *This information is up to date as of 31 December 2016, although AEMO has endeavoured to incorporate more recent information where practical. Collated results from the survey of gas industry participants are available on AEMO's website."*

AEMO then uses the information received from the gas industry as input to its modelling processes. Unfortunately, AEMO has limited powers or capability to confirm, cross-check or assess the accuracy of information provided by the gas industry. For example, discussing the limited information available about gas controlled by Shell, AEMO stated that[129]:

> *"Information relating to the probably timing, production profile, and target market(s) of this gas is not publicly available."*

Therefore, in its modelling, AEMO assumes this Shell-controlled gas is never developed and no gas production capacity is ever built to produce this gas.

Due to the lack of information about gas industry plans, AEMO models certain other gas supplies in a similar way. AEMO highlighted the lack of transparency around other potential gas supplies[130]:

> *"Producers have advised that, under market conditions that incentivise increased production, there may be some scope for supply from existing fields to exceed current projections. The size of this potential increase is unknown."*

As described in Section 4, AEMO's forecast supply gap is only 0.20% of annual gas supply (3.9 PJ/yr). Therefore, if any gas supplier increases supply capacity, beyond what they reported to AEMO, by just 3.9 PJ/yr, the supply gap closes.

Indeed, on 21 March 2017, just days after AEMO announced its gas-supply concerns, Shell announced that it would proceed with the 161-well "Project Ruby"[131]. In its GSOO modelling input datafiles, AEMO shows no information about Project Ruby[132].

[128] AEMO, *GSOO methodology*.
[129] AEMO, *Gas Statement of Opportunities*.
[130] Ibid.
[131] Shell Australia, *Media release: Shell invests in east coast gas supply*.
[132] AEMO, *Gas Statement of Opportunities*.

10 The longer term: Alternatives to gas in the electricity sector

In this section of the report, we look alternatives to gas generation in the power sector in the longer term. We first look at the current role gas plays in the National Electricity Market (NEM), and then consider alternative options for providing this service. Finally, we discuss the long term role of gas in power sector in the context of the *'Paris Agreement'*[133], and limiting dangerous anthropogenic climate change.

10.1 Generation in the National Electricity Market

Electricity is a unique commodity that requires the real-time balance of supply and demand. As electricity demand fluctuates over seasonal, daily, hourly and second scales, the electricity supply system has to be sufficiently flexible to ensure the system remain in balance and demand is met, at all times.

No single technology is currently able to provide this capability at low cost. For example, some generators have the ability to quickly change output levels, but have high operating costs or other limitations. Other technologies have low operating costs, but are less flexible. By combining a range of technologies with differing characteristics and technical capabilities, flexible supply at low cost is provided. It is the responsibility of the AEMO to schedule the differing technologies to ensure demand is met, at lowest cost to consumers.

Brown and black coal have historically provided low cost bulk electricity in Australia. With many power stations built at the mine mouth, the fuel costs have been low. However, a coal generator requires two to three days to start up[134], and the start-up and shutdown cost can be high. As such, coal plants tend to run relatively continuously. This is reflected in Figure 23, with coal providing the majority of energy supplied in then NEM.

Hydro and gas have historically provided flexible supply. These generators have the ability to quickly change output levels and have much smaller shut down and start up times and cost. However, gas generation have higher operating costs, and hydro power is limited by other factors such as rainfall, reservoir size and competing use[135].

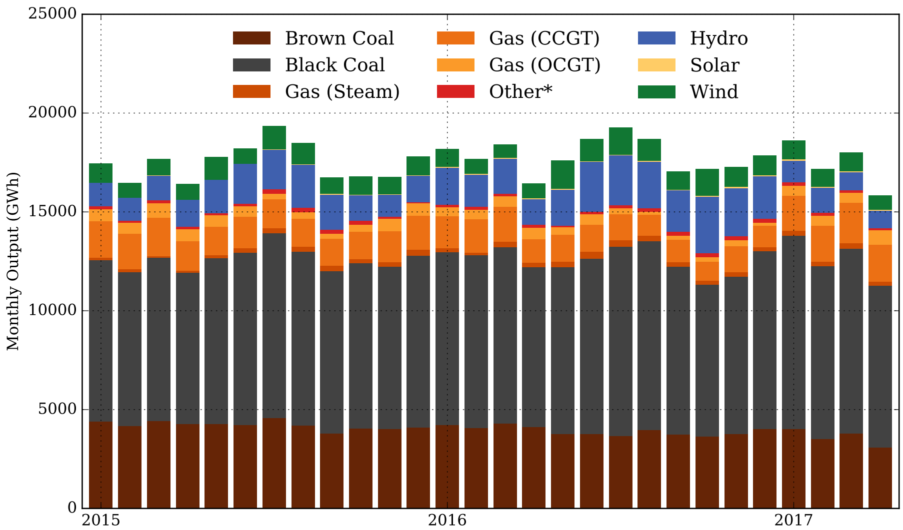

Figure 23: Monthly generation in the National Electricity Market by technology type. Other includes reciprocating engines (both distillate and gas power) as well as biomass. Data from AEMO; own analysis.

[133] United Nations, *Paris Agreement*.
[134] AER, *State of the energy market 2015*, page 27.
[135] For example irrigation, environmental or recreational use

Role of gas

There are several generation technologies available for converting gas to electricity, each with its own characteristics. In the NEM, three[136] main technology types provide the majority of gas power generation, which are briefly described below.

Steam cycle turbines: These turbines are based on the Rankine Cycle. In this cycle, a source of energy is typical used to heat water and run a steam turbine. This is the cycle that is employed in coal fired power stations.

This generation technology is not particularly flexible. It cannot rapidly start-up and shut-down and tends to operate more continuously. Currently, only some older power stations use this technology[137]. These plants have relatively low thermodynamic efficiency (~30%), which represents the amount of thermal energy that is converted to electricity.

Open Cycle Gas Turbine (OCGT)): these are based on the Brayton thermodynamic cycle. The turbines are similar to jet engines, with the gas mixing with air and burning to produce a high temperature and pressure gradient which drives a turbine.

OCGT's are very flexible and can both start-up and shut-down quickly, as well as ramp production up and down quickly. These are sometime described as *'peakers'*, able to rapidly respond during peaks in demand, and are typically not utilised much of year. The amount of time they are used varies from a couple of full load hours per year for some plants (capacity factor of <1%), to above 2,500 full load hours for others (capacity factor above 30%).

The thermal efficiency of an OCGT is also relatively low, at around 30%. This results in OCGT's having a relatively high emissions intensity, at 580 to 670 g-CO_2e per kWh of electricity produced[138].

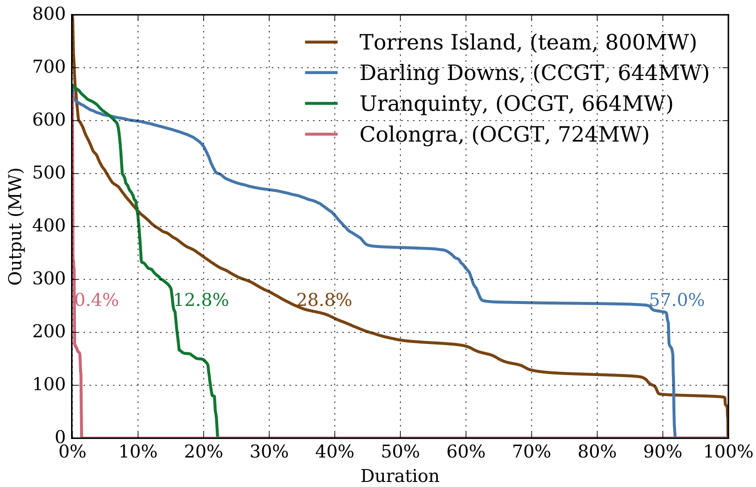

Figure 24: This figure illustrates the *output duration curves* for four different gas generators in the NEM in 2016. In this figure, the output of the generators is ranked in descending order, illustrating the proportion of time that output exceeds a certain level. The percentage figure refers to the capacity factor over the course of the year. While the three plants are roughly similar size, they are operated very differently. Data from AEMO; own analysis.

[136] There is a fourth type: reciprocating engines. This are similar to diesel generators, and have low thermodynamic efficiency

[137] Torrens Island A & B in South Australia, and Newport Power Station in Victoria

[138] Combustion emission only. Does not include upstream emissions or methane emissions

Combined Cycle Gas Turbine (CCGT):

The other type of gas power generator is known as a Combined Cycle Gas Turbine (CCGT). These are based on both the Brayton cycle *and* the Rankine Cycle , hence the name combined cycle. With the CCGT's, heat from the output from a Brayton cycle (e.g. jet engine) is recovered through a steam cycle. As a result, CCGT's are more efficient and able to extract 50% of energy from the gas. As a result, their emissions intensity is lower, approximately 400 g/kWh.

This technology is not as flexible as an OCGT. It cannot start-up and shut-down as easily as an OCGT, and tends to operate more continuously to provide bulk energy, like coal generators. These stations are typically utilised much more than OCGT's. The superior thermal efficiency of these plants means they have super-seeded the gas generators with a steam cycle only.

Figure 24 provides one illustration of the different technologies are used over the course of the year. Four different generators are shown; one steam generator, one CCGT and two OCGT's (a high capacity factor OCGT and a low capacity factor OCGT). As can be seen, the OCGT spend most of their time idle, where as the steam generator is never off. The CCGT is also operating most of the time, and has a high capacity factor (57%).

Figure 25 provides another illustration of different gas generators operating in the NEM. As can be seen, the average output of OCGT's vary considerably more over the course of the day, reflecting the flexibility of the technology. The peaks in average output between 8am and 10am and 4pm and 8pm for OCGT's refelect their role in meeting peak demand. While, CCGT's and steam generators are flexible they have a more steady profile.

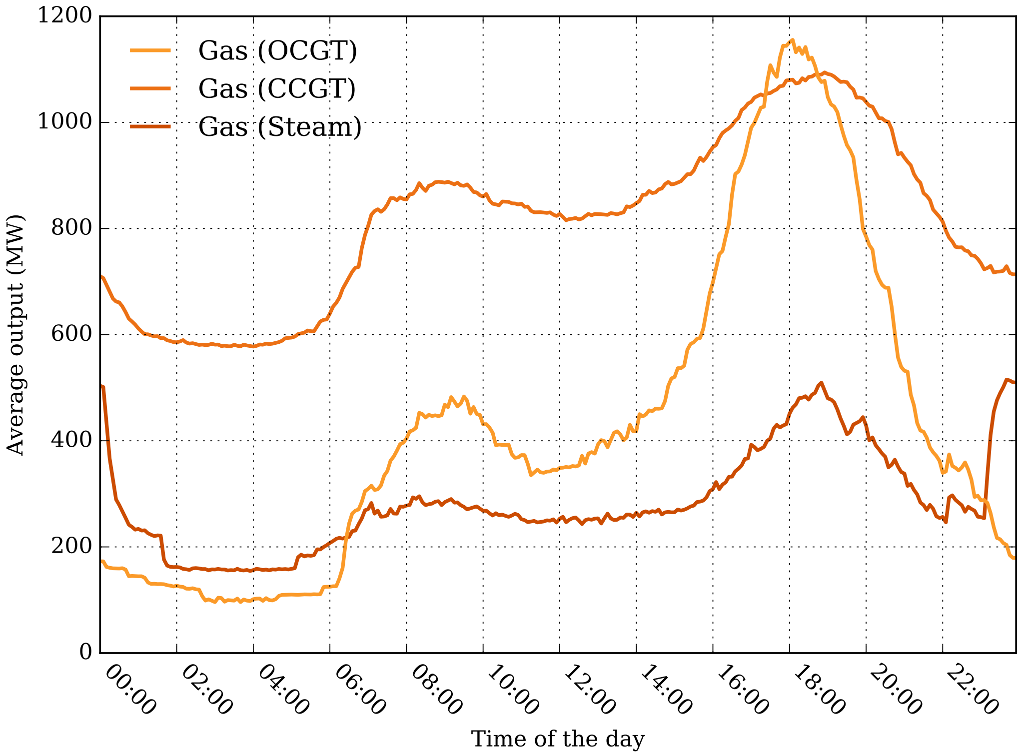

Figure 25: Average output of gas generators by time of day for the 2016 calendar year. The figure illustrates that Open Cycle Gas Turbines mainly operate between 7am and 10pm. Both the Combined Cycle Turbines and the Steam power generators have a more stable output over the day. Data from AEMO; own analysis.

Price formation in the NEM

AEMO schedules different generation technologies to ensure demand is met, at lowest cost to consumers. Conceptually, generators offer their capacity to the market and AEMO dispatches them in order of price (in merit order) to ensure demand is met, subject to a variety of constraints. The last generator dispatched to meet demand sets the clearing price for all generators in the system. This generator is known as the 'price setter', and this process occurs on a five minute basis[139].

The prices that generators offer their capacity to the market is often informed by their marginal cost of production. This the marginal cost of producing an additional unit of power in the short term, and is usually dominated by fuel costs. For renewable energy the fuel cost is $0, and as such the marginal cost of production is zero, or close to zero. Fuel costs for coal are in vicinity of $5–$20 per MWh, and gas is higher again. Some representative marginal fuel costs are presented in Table 6 below.

Gas is increasingly the price setter in the NEM (see Figure 26). Increases in gas prices thus flow through to electricity prices. This has two related implications when considering alternative options to gas generation. As gas is the marginal generator, new lower cost energy generation is likely to displace gas, thus reducing both gas consumption and prices in the NEM.

Table 6: Indicative marginal fuel costs

Technology	Thermal Efficiency (%)	Fuel Cost ($/GJ)	Marginal Fuel Cost ($/Mwh)
Wind	-	$0.0	$0
Brown coal	23%	$0.5	$8
Black coal	36%	$1.5	$15
Gas	45%	$9.0	$72
Gas (peak)	30%	$10.0	$120

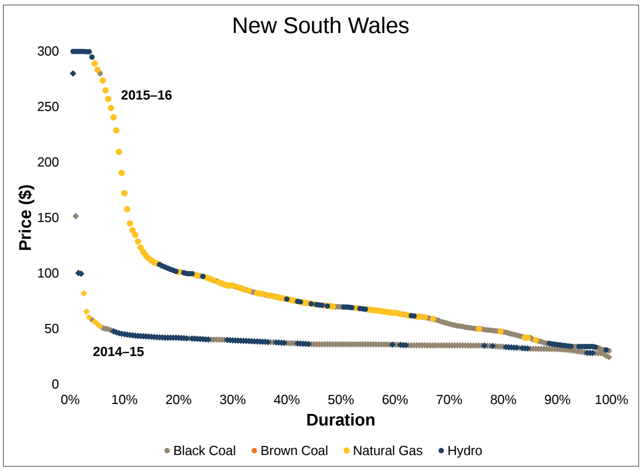

Figure 26: This figure shows the price duration curve for the mainland NEM jurisdictions across two separate years (FY15 and FY16). The fuel type responsible for setting the price indicated by color. As can be seen, prices across FY16 are higher than those in the previous year, and natural gas is setting the price most often [source: AEMO[140]].

[139] Imbalances in supply in demand at sub-5 minute time scales are correct with the Frequency Control and Ancillary Services market

[140] AEMO, *Update: Electricity Statement Of Opportunities*, page 23, Figure 8.

10.2 Providing bulk energy

As discussed in Section 10.1 coal fired generation and some gas generation technology has historically provided low cost bulk energy. Over the past seven years, the cost of wind has dropped over 50%, while solar PV costs have dropped over 80%. The fall in the cost of renewable energy continues to exceed expectations[141]. Reductions in the cost of solar and wind technologies in recent years mean that in the future, these technologies will be providing low cost bulk energy.

Solar PV and wind have very low operating costs, which is similar to some coal plants[142]. Where coal has limitations with flexibility, and high start-up and shut down cost, variable renewable generation such as wind and solar PV are limited to operation when weather conditions are favourable. However, and similar to coal, combining these technologies with other forms of generation allows demand to be reliably met at lowest cost to consumers.

In this section, we compare the cost of providing bulk energy from variable renewable sources with bulk energy from gas generation. Specifically, the cost of bulk energy from new build solar PV and wind is compared with sourcing the same energy from both new gas generation and existing gas generation. A *Levelised Cost Of Energy* (LCOE) analysis is performed for new build generation. The LCOE represents the average cost of producing electricity from a particular technology over its life, given assumptions about how the power station will operate. For existing generation, the cost is assumed to be the cost of fuel only (marginal fuel cost), and does not include capital or other costs. The assumptions used in both calculations can be found in Appendix A.

As can be seen in Figure 27 the cost of new build solar PV and wind generation compares favourably with both the cost of new build CCGT *and* existing gas generation. Wind and

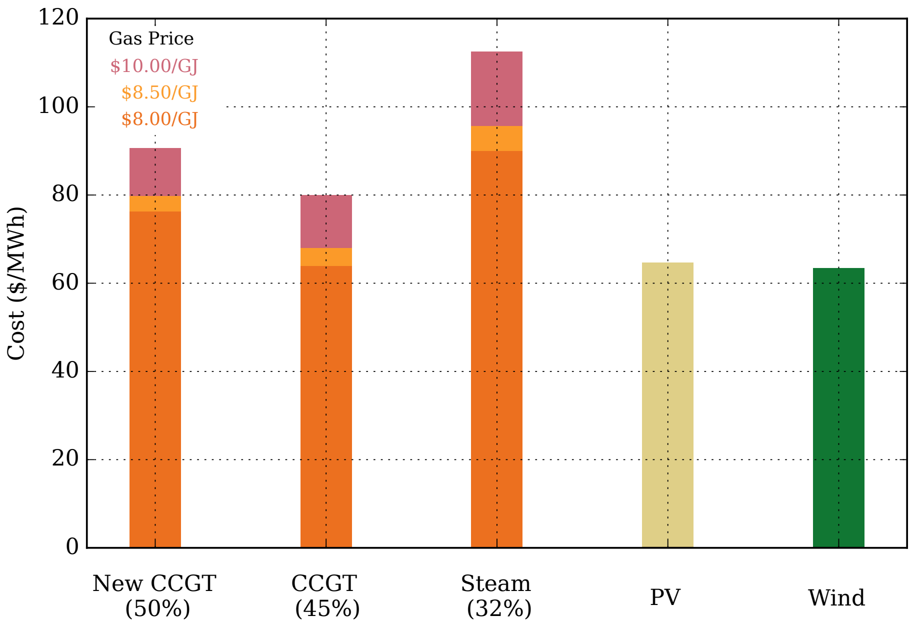

Figure 27: This figure compares the cost of providing bulk energy with gas and renewable technologies. The 'new CCGT', PV and wind cost represent the LCOE (see Appendix A for more details). The other two gas generation costs illustrated ('OCGT' and 'Steam') represent the marginal fuel costs at the respective thermal efficiencies. The steam thermal efficiency is similar to that of an OCGT. The range of gas costs reflects different gas price assumptions. The range of solar and wind costs reflect different capital cost assumptions.

[141] Finkel, *Preliminary Report of the Independent Review into the Future Security of the National Electricity Market*, page 19.

[142] Brown coal plants have particularly low fuel and operating costs

solar PV are actually cheaper than new build CCGT, and in same cases cheaper than gas generators that are already built. These are similar findings to analysis recently presented by AGL[143] (see Figure 28).

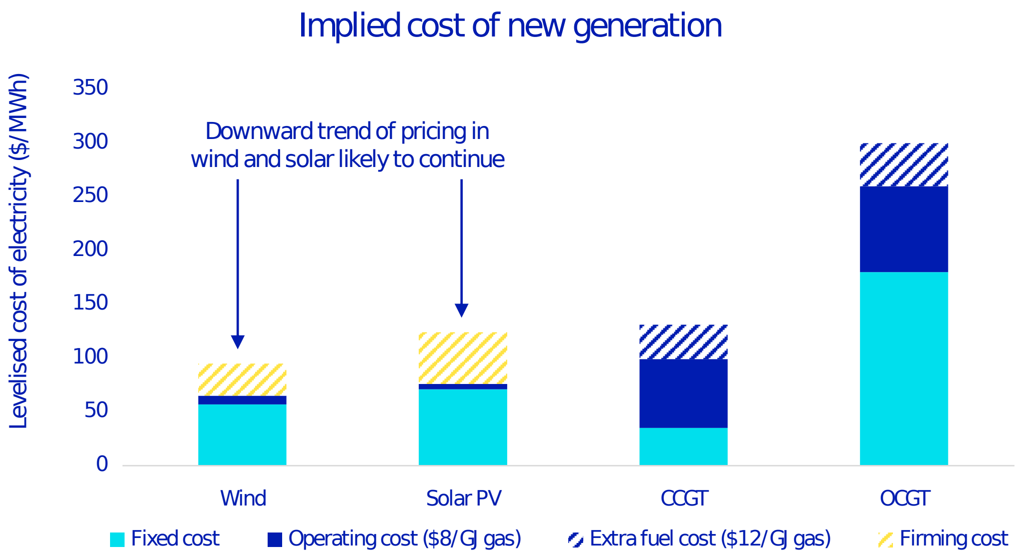

Figure 28: Adapted from AGL. Implied costs of new generation, based on AGL estimates [source: AGL[144]].

10.3 Capacity and flexibility

Historically, hydro power and OCGT's have been the primary provider of capacity and flexible supply in the NEM (as discussed Section 10.1).

The LCOE metric does not provide a good representation of the *value* of energy provided, or the value of flexible *capacity*. OCGT's provide a good example of the limitations of using the LCOE metric. According to the recent Australian Power Generation Technology Study, the LCOE of OCGT is reported to be in the range of $158-$269[145], with further exposure to rising gas prices. This is a high LCOE relative to other technologies (including wind, solar, gas and coal), and higher than historic wholesale prices. However, OCGT stations have been built in recent history[146], since their primary value is providing *capacity* and flexible supply, not bulk energy.

In this section, we compare the cost of capacity of a range of different technologies. We use a modified LCOE calculation to determine the Levelised Cost of Capacity (LCOC) based on the long-run marginal cost of supplying additional capacity (rather than energy). The LCOC represents the price of capacity required for a project to have a net present value of zero. There are many studies that analyse the LCOC[147].

For this analysis, we assume that storage technologies derive additional revenue from providing arbitrage as well as capacity[148]. This is an additional revenue stream that is not available to an OCGT gas *peaker*. Figure 29 compares the cost of providing flexible capacity between gas and storage technologies. Two storage technologies are analysis, battery storage and Pumped Hydro Energy Storage (PHES). As can be seen, storage technologies can provide flexible capacity at similar or lower costs to OCGT technology.

[143] Brett Redman, *A future of storable renewable energy*, page 6.
[144] Brett Redman, *A future of storable renewable energy*, page 6.
[145] Bongers, *Australian Power Generation Technology Report*, page 131 in.
[146] For example, the 550MW Mortlake OCGT was completed in 2012
[147] see McConnell, Forcey, and Sandiford, "Estimating the value of electricity storage in an energy-only wholesale market", for a study that specifically looked at the value of storage in the South Australian electricity market.
[148] We assumie storage technologies have sold cap contracts at $300/MWh. For prices at and above $300, the technology only receives $300/MWh in exchange for cap contract revenue

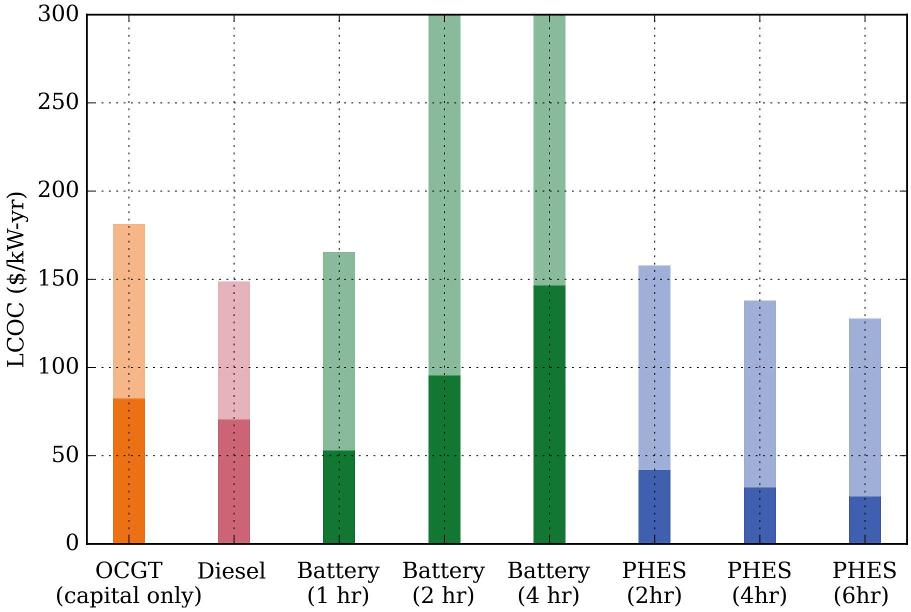

Figure 29: This figure compares the cost of providing flexible capacity between gas and storage technologies. The assumptions used in the *levelised cost of capacity* (LCOC) can be found in Appendix B. For OCGT, the low bound represents the cost of a frame OCGT and the upper bound represents the cost of an aero derivative OCGT. For the storage technologies and diesel, the upper and lower bound represent capital cost ranges. As can be seen, storage technologies can compete with OCGT in providing flexible capacity depending on technology and capital cost.

In this analysis, we consider an OCGT that predominantly provides capacity. This would be similar to the operation of the Colongra plant as illustrated in Figure 24. In this case, fuel costs are not a material factor in determining economic viability.

Whilst OCGT can't derive additional revenue from arbitrage, they can also provide energy. This might result in an operating profile more like Uranquinty, as illustrated in Figure 24. However, as previously discussed, OCGT's do not have a high thermal efficiency, and would incur high operating costs for fuel consumption. Providing bulk energy from an OCGT is even more expensive than CCGT and alternative options (as discussed in Section 10.2).

10.4 Gas powered generation and climate change

In December 2015, a historic global climate agreement was agreed under the United Nations Framework Convention on Climate Change at the 21st Conference of the Parties in Paris. This agreement included a global goal to hold average temperature increase to well below 2°C and pursue efforts to keep warming below 1.5°C above pre-industrial levels. This *'Paris Agreement'* entered into force on the 4th November 2016, after the required ratification conditions were met. On November the 10th, the Federal Government reaffirmed Australia's strong commitment to effective global action on climate change with the ratification of the Paris Agreement[149].

In order to meet the objectives of Paris Agreement, analysis from the International Panel on Climate Change (IPCC) illustrate *'large-scale global changes in the energy supply sector (robust evidence, high agreement)'*[150]. In scenarios where the 2°C objective is achieved, emissions from the energy supply sector are projected to decline by 90% or more below 2010 levels between 2040 and 2070 on global level. Emissions in many of these scenarios are projected to decline to below zero from them onwards.

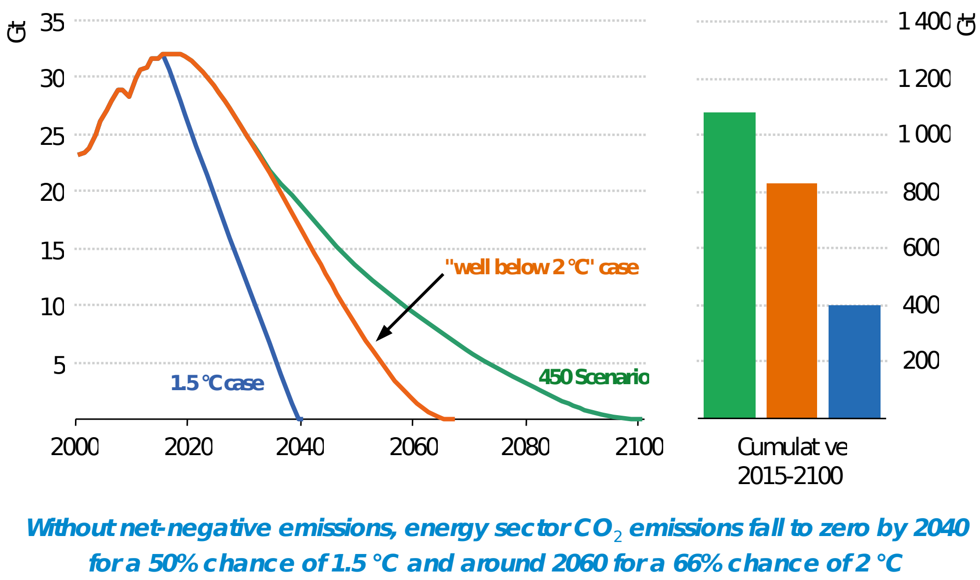

Figure 30: Indicative global energy sector emissions budgets and trajectories for different decarbonisation pathways [source: IEA[151]].

Figure 30 illustrates the direct emissions of CO_2 in the power sector in mitigation scenarios that maintain emissions consistent with a 2°C pathway with out assuming "net negative" emissions. According to the International Energy Agency (IEA), for *"likely"*[152] case of being below two degrees, the global emissions intensity in the power section must fall to 0.065 t-CO_2e/MWh by 2040[153]. By 2050, the average CO_2 intensity of electricity in OECD countries needs to fall from 0.411 t-CO_2e/MWh in 2015 to 0.015 t-CO_2e/MWh to meet this the goal[154].

149 Prime Minister, Minister for Foreign Affairs, and Minister for the Environment and Energy, *Ratification of the Paris Agreement on climate change and the DOHA amendment to the Kyoto Protocol — Prime Minister of Australia*.
150 IPCC Climate Change, "Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change".
151 International Energy Agency and Organisation for Economic Co-operation and Development, *World energy outlook 2016*, 75, Figure 2.9.
152 66% chance of staying below 2°C.
153 International Energy Agency and Organisation for Economic Co-operation and Development, *World energy outlook 2016*, page 75.
154 IEA, *Re-powering Markets*.

Based on current NEM generation, emissions intensity would currently be approximately three times greater than this 15 g-CO_2e/kWh value if all coal generation was to closed today. About 70% *less* gas must be burnt to stay within this emission intensity range at current demand levels.

Figure 31 shows the registered capacity, emissions intensity and age of gas power stations in the NEM [155]. As can be seen both existing and new build gas generation are well below the threshold IEA figure of 15 g-CO_2e/kWh.

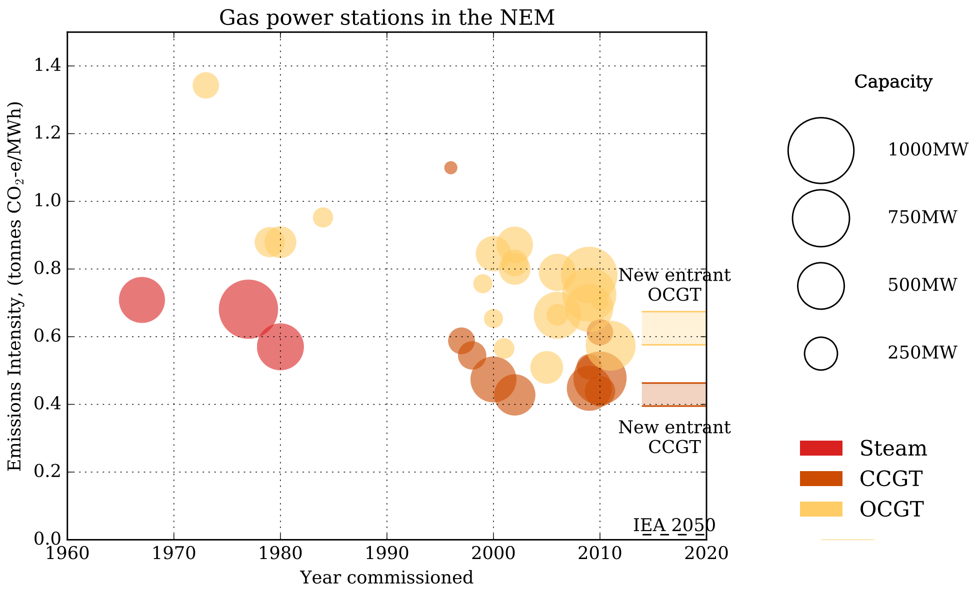

Figure 31: This figure illustrates the emissions intensity, capacity and age of gas power stations in the National Electricity Market (NEM). Generators capacity is illustrated by the size of bubbles, while age is represented on the horizontal axis and emissions intensity on the vertical axis. The different generation technologies include Open Cycle Gas Turbines (OCGT), Combined Cycle Gas Turbines (CCGT) and steam plants and are represented by different colours. The ranges of emissions intensity for both new entrant OCGT and new entrant CCGT are also shown to the right of the figure. The emissions intensity includes both scope 1 and scope 3 emissions[156]. Data from AEMO; own analysis.

[155] This figure only includes generators with publicly available emissions intensity data

[156] Scope 1 greenhouse gas emissions are the emissions released to the atmosphere as a direct result of an activity, for example the combustion of gas. Scope 3 emissions relate to indirect emissions associated with the extraction, production and transport of fuel to the power station, including for example, methane emissions.

Summary points

- Gas technologies currently provide both bulk energy (CCGT & steam generators) and flexible capacity (OCGT)
- Wind and solar PV are cheaper forms of bulk energy than CCGT.
- In some cases, the cost of new-build renewable energy is cheaper than generating electricity at existing gas power stations.
- Alternative options such as renewable energy and storage can place a downward pressure on electricity prices.
- Storage technologies are competitive with OCGT's in providing flexible capacity.
- OCGT's with low capacity factors don't use much gas in any case.
- Increasing gas combustion in the power sector is inconsistent with Australia's commitment to the *Paris Agreement* objective.

Gas has often been characterised as a 'transition fuel', on the pathway to a zero-emissions power system. The falling costs of renewable energy and storage technologies, the increasing gas cost, and climate change objective suggest this transition is no longer necessary, and indeed a detour. This is a sentiment increasingly reflected by industry, most recently by AGL:

> *'...the National Electricity Market or NEM here in Australia could transition directly from being dominated by coal-fired baseload to being dominated by storable renewables.'*
>
> *"...the energy transition we have all been anticipating will skip big baseload gas as a major component of the NEM's base-load generation and instead largely be a case of moving from big coal to big renewable".*

11 Conclusion: AEMO shortfall was short-lived

Our review finds that the former gas "buyer's market" that prevailed in eastern-Australia has shifted to become a "sellers market". Where formerly, the wholesale gas price had been nearly the cheapest in the developed world at 3 to 4 $/GJ, today it is now nearly the most expensive - with prices up to $20/GJ on offer. As was recently confirmed by Australia's Prime Minister, like crude oil, the price of eastern-Australian gas is now linked to international benchmarks.

Given the high cost of marginal gas production in eastern-Australia (now estimated to be around $7/GJ excluding pipeline transportation costs) as well as the international price-linkages, a return to delivered-wholesale gas priced below $8/GJ is unlikely.

On 9 March 2017 with the publication of its Gas Statement of Opportunities, AEMO warned of a small gas-supply shortfall that might impact electricity supply 18 months from now (December 2018). As potential solutions to this shortfall, AEMO suggested new gas pipelines (i.e. from the Northern Territory) and/or new gas fields (i.e. Gunnedah / Narrabri in NSW).

Our review finds that AEMO's forecast shortfall is very small, amounting to no more than around 0.2% of annual supply (of either gas or electricity). The rapid rise in wholesale gas and electricity prices is and will cause "demand destruction" that is far larger than AEMO's forecast supply gap. Therefore, we find it unlikely that gas-supply shortfalls will occur as AEMO has described. Indeed, eleven days after announcing its supply-gap concerns, AEMO closed the supply gap when it published updated (lower) electricity-demand forecasts on its website.

We find that AEMO focussed attention on a very small forecast gas-supply shortfall, that is well within the range of uncertainties of the forecast. A more useful message for to gas consumers is that the price of eastern-Australian wholesale gas has increased significantly and is unlikely to return to the low prices previously known. AEMO should also inform energy consumers of the impact that high gas prices have on electricity prices.

Furthermore, our analysis suggests that new pipelines and new (expensive) gas fields might be false "solutions". These massive fossil-energy infrastructure investments are not needed to address a supply shortfall that is unlikely to occur. Neither will such investments reduce the wholesale gas price.

Given this analysis, it seems pertinent that AEMO and governments inform Australian energy consumers (ranging from home occupants, to commercial building managers, to large industries) of the effective actions they can take to respond to rising energy costs, including:

- reducing gas and electricity consumption though energy-efficiency measures
- fuel-switching to lower-cost renewable energy options, including for example electricity via on-site solar PV, heat pumps (in space-heating applications often referred to as reverse-cycle air conditioners), or bioenergy
- utilising energy storage
- demand-side participation in the electricity market.

Recent actions by Australian governments that seek to reduce gas-industry opacity are greatly warranted, particularly information about gas reserves, facility production capacity, future development plans, and LNG-export contracts and commitments. Greater industry transparency would also improve the usefulness of AEMO's planning activities.

12 Recommendations

This section describes recommendations that would increase the value of AEMO's planning activities for many stakeholders.

Absent, unclear, and changing government policies challenge AEMO

Over the last decade, the energy policies of Australian federal and state governments have often been short-lived, unclear, or absent. This policy landscape makes it difficult for AEMO to effectively fulfil its planning responsibilities and to anticipate, model, and communicate all reasonable future outcomes. More consistent and clear government energy policies would allow AEMO to more thoroughly investigate a range of relevant future scenarios.

AEMO's modelling is of little value if gas-industry input data is opaque

As described in this report, AEMO lacks information about gas reserves, gas production facility capabilities, and the short and long-term plans of gas producers. Were AEMO able to access better gas-industry information, AEMO's modelling activities would be more robust and have greater value. The Australian Government has directed the ACCC to again scrutinise the gas industry. AEMO should work with the ACCC to obtain the gas-industry information it needs to produce useful energy-system modelling results.

Developing an Integrated Resource Plan (IRP)

In 2015, MEI described that eastern-Australia needs an Integrated Resource Plan (IRP). This should consider not only gas-supply options but also gas demand-management options such as economic fuel-switching and energy-efficiency measures. As fuel-switching from gas to electricity occurs, the demand for electricity may increase. Therefore, consideration of electricity generation and distribution must also be part of the Integrated Resource Plan[157].

With its 2017 GSOO, AEMO now recognises the need to investigate and model gas and electricity in an integrated way, stating that "gas and electricity markets cannot be viewed in isolation"[158]. However, it is less clear that AEMO has recognised a responsibility to investigate demand-side opportunities with vigour equal to its investigation of supply-side opportunities.

As MEI wrote in 2015[159]:

> *AEMO publishes the Gas Statement of Opportunities (GSOO) in accordance with Section 91DA of the National Gas Law. A stated aim of the GSOO is to '...provide industry participants, investors, and policy-makers with transparent information to support decision-making to ensure gas – a key resource – is managed in Australia's long-term interests.'*
>
> *Regarding that stated aim, the often inefficient and wasteful use of gas, particularly in the buildings sector, is not in Australia's long-term interests. AEMO and other relevant authorities should develop an Integrated Resource Plan that, in addition to supply-side opportunities, also identifies and recommends economic opportunities for fuel-switching from gas to electricity and energy-efficiency measures. Such a plan is likely to identify that large and economic gas "discoveries" can be found in industry and in the buildings of eastern-Australia.*

[157] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.
[158] AEMO, *Gas Statement of Opportunities*.
[159] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.

AEMO should model all reasonable alternatives

Assuming, as per the above recommendations, that AEMO is able to access useful gas-industry data, and develops the capability to model and analyse gas and electricity demand-side and supply-side opportunities and interactions, then AEMO should model the full range of reasonable alternatives.

Often AEMO has restricted its modelling to describe established government policies. Alternative policies of great interest to stakeholders within Australian society should also be modelled and communicated. As one example, with the exception of the 2013 federal government-mandated '100 Per Cent Renewable Energy'[160], AEMO has not modelled scenarios that involve very strong climate policies aimed at minimising the impacts of climate change.

Communicating modelling results and potential consequences

Governments should work with AEMO to understand, test, and critique AEMO's modelling results. In the past, governments have interpreted AEMO's narrow messages as "gospel"[161]. When, in future, AEMO models and communicates all reasonable alternatives, there will be no single gospel. AEMO should then work with stakeholders to identify what possible future impacts are indicated by the range of modelled scenarios.

Helping large and small consumers to deal with high gas prices

As MEI suggested in 2015[162], in this era of sustained high gas and electricity prices, governments, AEMO, and consumer-assistance bodies can help small and large gas consumers to deal with high gas prices by:

- communicating what opportunities exist for energy efficiency and fuel-switching measures
- removing subsidies that encourage uneconomic use of gas
- removing subsidies that encourage uneconomic expansion of the gas grid
- strengthening the regulatory oversight of the marketing of gas and gas appliances - which are often claimed to be cheaper, more efficient, and more environmentally benign than all electrically-powered appliances
- facilitating the identification and financing of economic fuel-switching and energy efficiency projects
- reducing infrastructure costs by rationalising the gas grid where economic.

[160] AEMO, *100 Percent Renewables Study: Draft Full Report*.
[161] NSW Legislative Council., *Supply and cost of gas and liquid fuels in New South Wales*.
[162] Forcey, *Switching off gas: An examination of declining gas demand in Eastern Australia*.

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Appendix A Levelised Cost of Energy

Economic assumptions

The following assumptions were used across LCOE calculations for all technology. Real 2015 dollars are used, in order to directly use costs from the 2015 *Australian Power Generation Technology Report*[163]. Inflation is only used to de-escalate recent (2017) costs where necessary.

Table 7: Economic assumptions

WACC (real)	5%
Economic life	20 years
Inflation	2.5%

Capital costs

These costs are all from a range of sources. For CCGT and the 'high' range of renewable capital costs, data from the *Australian Power Generation Technology Report* from 2015[164] is used. Since cost reductions in renewable technology have continued to decline since this report was prepared, 'low' range estimates from media reports are also included[165,166].

Table 8: Capital Costs ($/kW installed)

Technology	Capital cost ($/kW)	Source
Wind (High)	$2,450	Bongers et al. (2015)
Wind (Low)	$2,100	Vorath (2017)
Solar PV (High)	$1,570	Macdonald-smith (2017)
Solar PV (Low)	$1,780	Macdonald-smith (2017
CCGT	$1,450	Bongers et al. (2015)

Operating & maintenance costs

These costs are all taken from the *Australian Power Generation Technology Report* from 2015[167].

Table 9: Operating & Maintenance Costs

Technology	Fixed O&M ($/kW-year)	Variable O&M ($/MWh)
Wind	$25	-
Solar	$55	-
CCGT	$20	$1.5

163 Bongers, *Australian Power Generation Technology Report*.
164 Ibid.
165 Vorath, *ERM Power signs PPA for 212MW wind farm in Port Augusta*.
166 Macdonald-Smith, "Solar closing cost gap with wind, conventional power".
167 Bongers, *Australian Power Generation Technology Report*.

Fuel prices

Gas prices were drawn from Core Energy Group's most recent report to AEMO, the *NGFR gas price assessment: final report*[168]. Core Energy presents three different gas price scenarios (Neutral, Weak, and Strong), which form the basis of the three gas prices sensitivities explored in this analysis, which are shown in Table 10. The price projections for the neutral scenario are illustrated in Figure 32.

Table 10: Gas price assumptions

Sensitivity	Gas Price ($/GJ)
Low	$8.00
Mid	$8.50
High	$10.00

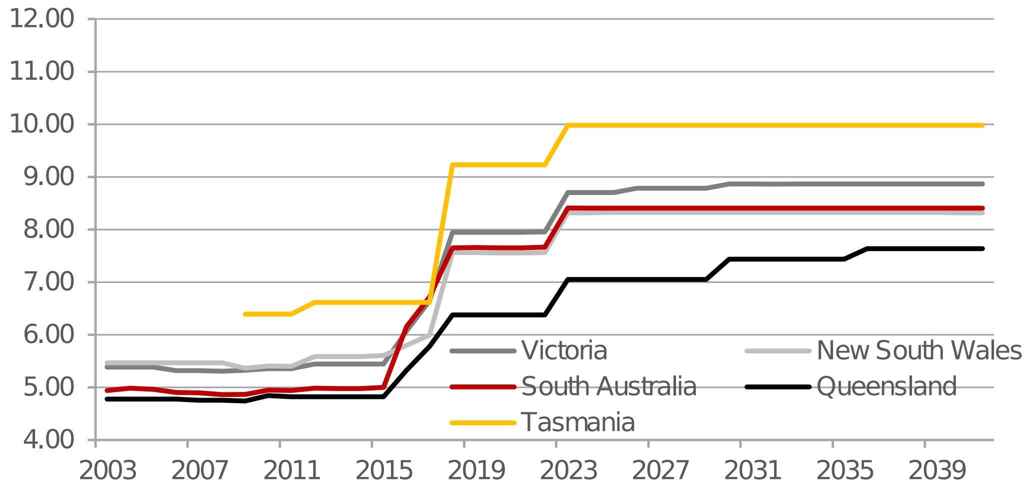

Figure 32: Projection of average gas powered generation gas prices for each NEM state, at transmission pipeline delivery point for the neutral scenario [source: Core Energy Group[169]].

Capacity factors

Capacity factor assumptions were also drawn from the *Australian Power Generation Technology Report*[170]. For wind, a mid point of the range reported was used.

Table 11: Capacity factor assumptions

Technology	Capacity Factor
Wind	38%
Solar	25%
CCGT	85%

[168] Core Energy Group, *NGFR gas price assessment*.
[169] Core Energy Group, *NGFR gas price assessment*.
[170] Bongers, *Australian Power Generation Technology Report*.

Appendix B Levelised Cost of Capacity

The Levelised Cost of Capacity analysis is based on the approach used in *Estimating the value of electricity storage in an energy-only wholesale market*[171]. See this paper for more details.

Economic assumptions

That same economic following assumptions were used across LCOC calculations for all technology as in the LCOE calculations (see Appendix A and Table 7).

Capital cost asssumptions

These costs are all from a range of sources. For CCGT and diesel, the high and low cost ranges were taken from the *Australian Power Generation Technology Report* from 2015[172]. Capital cost estimate for the range of battery storage options analysed where taken from *Lazard's Levelized Cost of Storage Analysis*[173]. The capital cost range for PHES was taken from *Estimating the value of electricity storage in an energy-only wholesale market*[174].

Table 12: Capital costs, ($/kW installed).

Technology	High	Low	Source
OCGT	$1,000	$1,200	Bongers et al (2015)
Diesel	$1,050	$950	Bongers et al (2015)
Battery (1h)	$758	$1,508	Lazards (2015)
Battery (2h)	$1,430	$3,276	Lazards (2015)
Battery (4h)	$2,052	$5,052	Lazards (2015)
PHES	$1,000	$2,000	McConnell (2015)

Annual fixed operation and maintenance costs where also considered for OCGT's ($8-$10 per kW-year[175]) and PHES ($7.5/kw-year[176]).

Replacement capital cost asssumptions

Replacement costs were also taken into account for battery storage (10 year replacement costs from *Lazard's Levelized Cost of Storage Analysis*[177]), summarised below.

Table 13: 10 year replacement costs for battery storage technologies ($/kW installed).

Battery Size	Low	High
Battery (1h)	$964	$1,344
Battery (2h)	$640	$884
Battery (4h)	$360	$455

[171] McConnell, Forcey, and Sandiford, "Estimating the value of electricity storage in an energy-only wholesale market".
[172] Bongers, *Australian Power Generation Technology Report*.
[173] Lazard, *Lazard's Levelized Cost of Storage Analysis*.
[174] McConnell, Forcey, and Sandiford, "Estimating the value of electricity storage in an energy-only wholesale market", see supplementary material.
[175] Bongers, *Australian Power Generation Technology Report*, see page 125.
[176] McConnell, Forcey, and Sandiford, "Estimating the value of electricity storage in an energy-only wholesale market", see supplementary material.
[177] Lazard, *Lazard's Levelized Cost of Storage Analysis*.

Arbitrage value

The arbitrage value of storage is taken into account in this calculation. To do this, the additional revenue from arbitrage when prices are less than ¡$300 are considered as an additional revenue stream. The additional arbitrage value for different amounts (hours) of storage is shown below in Table 14.

Table 14: Arbitrage value for energy storage technologies

Hours Storage	**<$300 Arbitrage value ($/kW-year)**
1	$40
2	$50
4	$60

Acronyms and abbreviations

ACCC Australian Competition and Consumer Commission.
ACT Australian Capital Territory.
AEMO Australian Energy Market Operator.
AER Australian Energy Regulator.
APLNG Australia Pacific LNG.
ARENA Australian Renewable Energy Agency.

CCGT Combined Cycle Gas Turbine.
CSG Coal Seam Gas.
CSIRO Commonwealth Scientific and Industrial Research Organisation.

DER Distributed Energy Resource.
DR Demand Response.
DSP Demand-Side Participation.

ESOO Electricity Statement of Opportunities.

FY Financial Year.

GJ gigajoule.
GLNG Gladstone LNG.
GSOO Gas Statement of Opportunities.
GW megawatt.
GWh gigaawatt hour.

IEA International Energy Agency.

LCOC Levelised Cost of Capacity.
LCOE Levelised Cost of Energy.
LNG Liquefied Natural Gas.
LRET Large-scale Renewable Energy Target.

MEI Melbourne Energy Institute.
MJ megajoule.
MW megawatt.
MWh megawatt hour.

NEFR National Electricity Forecasting Report.
NEM National Electricity Market.
NGFR National Gas Forecasting Report.
NTNPD National Transmission Network Development Plan.

OCGT Open Cycle Gas Turbine.

PHES Pumped Hydro Energy Storage.
PJ petajoule.
PV photovoltaic.

QCLNG Queensland Curtis LNG.

RCAC Reverse-Cycle Air Conditioner.

TWh terawatt hour.

VRET Victorian Renewable Energy Target.