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Coalapse!

The New South Wales winter "energy crisis"

How over 5 gigawatts of New South Wales gas and coal plants being simultaneously offline pushed the state's power supply to the brink and drove high electricity prices.

Discussion paper

Mark Ogge

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Summary

Between June 5 and June 8 2018 during a mild winter week, New South Wales (NSW) experienced a serious and unexpected shortage of its electricity supply which was referred to by some commentators as an “energy crisis”.

This was almost entirely the result of simultaneous outages (some planned, some unplanned) at the state’s gas and coal power plants.

During periods of highest demand and high price events over this period, up to 52 percent (6.4 GW) of the state’s coal and gas power generation capacity was idle or unavailable, including up to 48 percent (4.8 GW) of coal capacity.

This triggered a series of wholesale electricity price spikes during peak demand trading intervals with prices exceeding $2,400 MWh on five occasions over four days.

The primary cause was multiple unplanned outages (breakdowns) at Liddell and Vales Point coal power stations combined with planned outages at a number of other coal plants.

The state’s two newest combined cycle gas power plants, designed to provide dispatchable energy to back up the coal fleet and meet peak demand, remained offline or operated at less than half their capacity during all five high price events.

This shortage of supply led the Australian Energy Market Operator (AEMO) to notify the market of “Lack of Reserve” (LOR) conditions. This culminated in the announcement of its intent to intervene in the market and bring on emergency reserves by activating the Reliability and Emergency Reserve Trader (RERT).

Some commentators have proposed building new “HELE” (supercritical) coal power stations, purportedly to increase reliability and lower electricity prices. However this option would be likely to result in higher electricity prices and a less reliable electricity supply.

Australia’s existing supercritical coal plants currently break down more frequently than the older subcritical plants that they would replace. This year Australia’s newest coal power station, the supercritical coal plant at Kogan Creek in Queensland has broken down four times. Because Kogan Creek is the largest single generating unit in the NEM, its breakdowns are particularly disruptive.

Summer is fast approaching and NSW can expect an increasing number of peak energy demands during extreme heat days. The question should be asked, how will the NSW electricity system cope if it suffers major energy crises during relatively mild winter weeks?

Despite enthuisiam from some politicians and groups, refurbishing old coal power plants is unlikely to be a cost effective or reliable way to improve the reliability of the electricity supply. Refurbishing old plants can require a large investment to achieve a short life extension, and is a band-aid solution to reliability issues.

Fortunately, there are a range of affordable renewable energy, energy storage and demand management solutions that can restore reliability to the New South Wales electricity system and reduce electricity prices.

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Introduction – the NSW winter energy crisis

Between June 5 and June 8 2018, NSW experienced an unexpected shortage of its electricity supply that resulted in series of high wholesale price events and "Lack of Reserve" conditions.

The situation was described as an "energy crisis" by some commentators. Matt Howell, the chief executive of the Tomago aluminium smelter appeared to blame wind and solar for the "crisis".

> "This is not summer with extreme demand. This is the likely future of our energy grid as once reliable baseload generators exit the [NEM] and are mostly replaced with intermittent wind and solar projects with no practical storage to speak of," Mr Howell said.
>
> "Our energy debate should not advocate either renewables or conventional thermal," he said. "As with most things in life, we need a balance and we have reached a point where urgent rebalancing is required."[1]

However, what Matt Howell didn't make clear is that the cause of this "energy crisis" was that up to over half of NSW's gas and coal power plant capacity remained offline when demand was highest over this period.

Gas and coal make up 76 percent of NSW electricity generation capacity[2] and at the height of this "crisis" up to over half of this capacity (6,400 MW) was idle.

In comparison, solar makes up only 1.6 percent of utility scale power generation in NSW and wind 5.1 percent.[3]

In their report on the shortages on June 7, AEMO pointed out that the reduction of solar output over this period as a result of rain and cloud cover was between 115 MW

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[1] Hannam and Latimer (June 2018) *Tomago Aluminum warns of 'energy crisis' as power supply falters*. https://www.smh.com.au/business/markets/tomago-aluminium-warns-of-energy-crisis-as-power-supply-falters-20180608-p4zkbw.html

[2] Ibid.

[3] AEMO (March 2018) *Generation Information Page*, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information

to 254 MW on any given day,[4] a tiny fraction of the 6,400 MW of idle coal and gas capacity during this period.

[4] AEMO (June 10, 2018) *NSW June 7,* https://www.aemo.com.au/Media-Centre/New-South-Wales-7-June

Context

ELECTRICITY GENERATION IN NSW

The National Electricity Market (NEM) is made up of five interconnected markets in Queensland, New South Wales (including the Australian Capital Territory), Victoria, South Australia, and Tasmania.

Each of these markets has a number of “generators”, which are infrastructure that generate electricity at a large “utility” scale. These include fossil fuel power stations (coal, gas and diesel) and renewable energy (wind, solar, hydro and biomass).

A network of high voltage transmission lines carries the electricity from these generators to “substations” located near demand areas. From here a low voltage distribution network distributes electricity to consumers.

These regional markets are designed to match supply to demand in five minute intervals. However, there is also some high voltage transmission lines providing “interconnection” between these markets. NSW for example has interconnection with Queensland and Victoria. When there is a shortage or surplus of electricity in any of these markets, the excess power from one market can be sent to another market as required.

While interconnection adds a level of security to the electricity supply, each market aims to have enough generating capacity to meet its own demand. This is important because interconnection is limited, and often weather conditions will mean that demand is high in several states simultaneously and as such additional supply of electricity from neighbouring states may not always be available.

In order to minimise the risk of a shortfall in supply, there are pre-determined buffers of reserve capacity of additional supply above forecast demand. When the available supply of electricity is lower than these buffers, AEMO has a number of mechanisms to bring on additional supply from the market. These include notifying the market of “Lack of Reserve” conditions when reserves are forecast to fall, or actually do fall below these pre-determined buffers in order to elicit further supply from the market.

AEMO also maintains “strategic reserves” to be activated if the market is unable to supply enough electricity to meet demand.

The total amount of electricity that can be generated at any given time when an electricity generator is operating at its maximum output is known as its "generating capacity*"*. This term can be applied to a single power plant or the system as a whole.

NSW has around 16,000 MW (16 GW) of generating capacity including coal, gas and renewable energy.[5]

As shown in Table 1 below, gas and coal currently make up around 76 percent of NSW generating capacity, with hydro making up the bulk of the remainder (16.6 percent)

Solar power plants make up 1.6 percent of capacity and wind 5.1 percent.

Table 1: Electricity generation capacity in NSW

Type of generation	Total capacity	Percentage of total capacity
Coal	10,160	62.3
Gas	2,206	13.5
Solar (utility)	267	1.6
Wind	840	5.1
Hydro	2,706	16.6
Biomass	131	0.8
Total	16,319	

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Source: AEMO (n.d.) *Generation Information Page, NSW Region*.

Electricity is also generated from rooftop solar in NSW. This electricity is mostly used by the households and businesses with the solar panels, so it is not part of the NEM. Instead it has the effect of reducing demand for electricity that needs to be provided by the NEM. In 2017 there was around 1,200 MW of solar PV capacity in NSW.[6]

Rooftop solar plays an important role in reducing and delaying peak demand on hot high demand days. This is particularly important because the highest demand occurs on these days, and conventional gas and coal power plants are prone to high rates of

[5] AEMO (2018) *Generation Information Page,* https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information

[6] Parkinson (2017) *Australian solar capacity now 6GW, to double again by 2020,* https://reneweconomy.com.au/australian-solar-capacity-now-6gw-to-double-again-by-2020-2020/

breakdowns in the extreme heat. As such, hot days are usually the greatest challenge for our power system.[7]

COAL POWER STATIONS IN NSW

There are five coal power stations in NSW. All use black coal, and the fleet as a whole is relatively old (between 26-47 years old).[8]

Each of these coal power stations consists of a number of individual "generating units" that can operate or cease operating independently of other units in the same power station. For instance, as shown in Table 2 below, the Bayswater coal power station in the Hunter Valley has four individual generating units, each with a generating capacity of 660 MW, for a total "capacity" of 2,640 MW for the power station.

Table 2: NSW coal power stations

Power station	Age (years)	Nameplate capacity (MW)	Generating units
Eraring	34-35	2,880	4 x 720 MW
Bayswater	34-36	2,640	4 x 660 MW
Vales Point	40	1,320	2 x 660 MW
Mt Piper	26	1,400	2 x 700 MW
Liddell	45-47	2,000	4 x 500 MW

Source: AEMO (n.d.) *Current registration and exemptions list.*

[7] Ogge (2018) *Watt on a hot tin roof: How rooftop solar increases reliability and reduces electricity prices,* http://www.tai.org.au/sites/default/files/P527%20Watt%20on%20a%20hot%20tin%20roof%20%5BWEB%5D.pdf

[8] Senate Standing Committees on Environment and Communications (2017) *Retirement of coal fired power stations,* https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Coal_fired_power_stations/Final_Report

COAL "OUTAGES"

When generating units of power plants are not operating, it is referred to as an "outage".

Outages can be planned or unplanned. Planned outages can be for maintenance or due to market conditions. Unplanned outages are breakdowns, and are also referred to as "unit trips".

Individual units of gas and coal power stations have a large generating "capacity", typically hundreds of megawatts. This means that each unit makes up a significant portion of the overall generating capacity of the state. For instance, as shown in Table 2 above, individual generating units at NSW coal plants range between 500-720 MW out of the total 16,000 MW capacity for all types of electricity generation in NSW.

When these units break down the result is a sudden and unexpected loss of that amount of capacity. Because supply and demand need to be matched at all times, the sudden unexpected loss of such large amounts of capacity is problematic.

At times of high demand, the sudden loss of such a large amount capacity can be difficult to replace simply because there are insufficient reserves. When there are several simultaneous outages at times of high demand it can lead to very high electricity prices and load shedding (where customers have their energy supply shut off for the safety of the power system).

The sudden loss of large amounts of capacity can also lead to a loss of frequency which can be disruptive to the stability of the system.

Frequency is kept in balance when supply matches demand. If there is insufficient or too much electricity, and the frequency exceeds a certain range there are a number of risks. These range from damage to equipment (on both the power generation and demand sides), to destablising the system as a whole in extreme cases.

If supply exactly meets demand then the frequency of the power system is 50 Hertz (Hz). Because demand and supply never remain exactly matched, there is a "normal operating frequency band" where frequency fluctuates within an acceptable range. This range is 50 Hz +/- 0.15 Hz (between 49.85 and 50.15 Hz).

Breakdowns at gas and coal plants often cause a sudden large drop in supply, often of several hundred megawatts. This ofeten causes the frequency of the grid to fall below the normal operating frequency (49.85 Hz).

When this happens, new supply needs to be brought on quickly to restore the frequency within the *normal frequency operating band*. This is where the Frequency Control Ancillary Services (FCAS) market are activated to quickly arrest the fall in frequency.

The larger the breakdown the more challenging to maintain frequency and the greater the FCAS costs to maintain operation of the system withing an acceptable range of frequency.

The June 2018 coal collapse

DEMAND

It is unusual for energy crises to occur in winter. Usually the challenge for the electricity system is on hot summer days due largely to high demand for air-conditioning combined with higher rates of breakdowns at gas and coal power plants.[9]

Electricity demand over this period was above average for June on three of those days (Tuesday, Wednesday and Friday), reaching 11,029 MW on Wednesday 6.[10]

However, this level of winter demand is not unusual and was lower than the seasonal winter peak demand for NSW for the last 18 years.[11] It was also considerably lower than summer peak demand which reached over 13,000 MW last summer and over 14,000 MW the summer before.[12]

SEQUENCE OF EVENTS

During the June "energy crisis" at least five NSW coal power plant units were simultaneously offline, and at least three of these outages were sudden breakdowns.

Figure 1 below shows the output of all of NSW's coal power stations from June 1-9. The total output of each plant is represented by a different shade of grey. The overall shaded area represents the total output of NSW coal power plants over that period measured in megawatts (MW) corresponding to the Y axis.

The output of each plant is made up of a number of generating units. The individual generating units of each plant are not differentiated in this chart. However the overall contraction of the output of the stations is largely the result of individual generating units of these power stations going offline.

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[9] Ogge (2017) *Can't stand the heat: The energy security risk of Australia's reliance on coal and gas generators in an era of increasing heatwaves,* http://www.tai.org.au/sites/defualt/files/P454%20Can%27t%20stand%20the%20heat%20FINAL%202.31.pdf

[10] AEMO (June 10, 2018) *New South Wales 7 June*, https://www.aemo.com.au/Media-Centre/New-South-Wales-7-June

[11] AER (2018) *Wholesale market Statistics, Seasonal peak demand (region)* https://www.aer.gov.au/wholesale-markets/wholesale-statistics/seasonal-peak-demand-region

[12] Ibid.

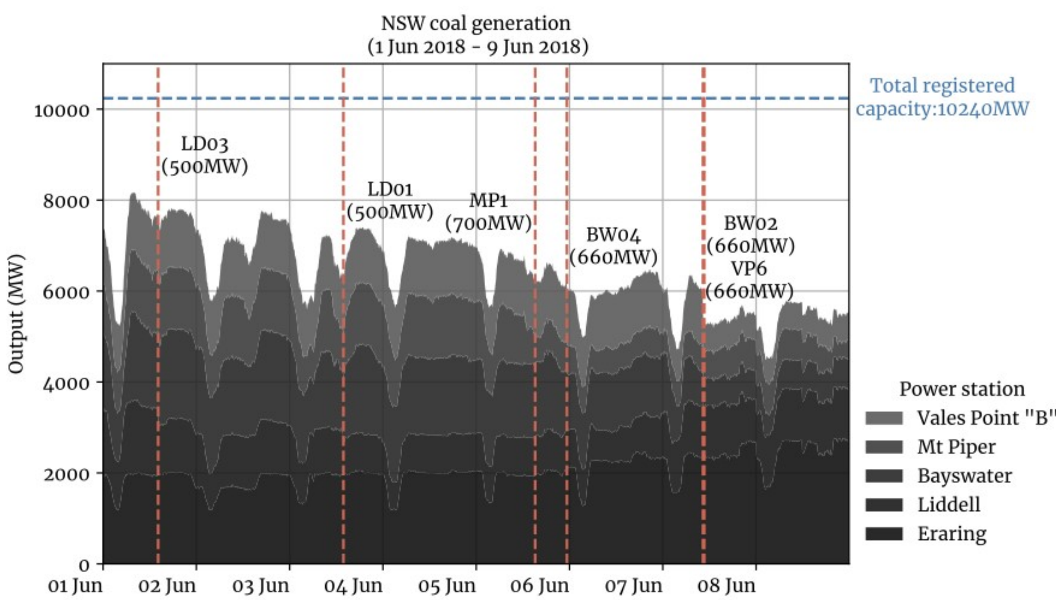
The dotted orange lines show the timing of when particular individual generating units went offline between June 1-9. The labels adjacent to the dotted lines identify the individual generating units. For instance LD03 is Liddell Unit 3, one of four 500 MW generating units at Liddell Power Station.

There were breakdowns at two separate 500 MW generating units at Liddell Power station on June 1 and June 3 (LD03 and LD01) and one 660 MW unit at Vales Point on June 8 (VP6). Over the same period two 660 MW units at Bayswater Power Station (BW04 and BW02) and one 700 MW unit at Mount Piper Power Station (MP1) were also taken offline over this period, presumably for maintenance.

The blue dotted line at the top of the chart shows the total capacity of NSW coal plants if they are all operating at full output (10,240 MW).

Figure 1 shows that at the beginning of this period on June 1, NSW coal plants reached an output of up to around 8,000 MW. This around 80 percent of the total capacity of NSW coal plants (10,240 MW indicated by the dotted blue line). By June 8, following these simultaneous outages, the output had dropped to as low as around 50 percent of total capacity.

Figure 1: NSW coal generation 1 June 2018 - 9 June 2018



Source: OpenNEM

IMPACT ON PRICES

We can identify the times at which the electricity supply was most challenged in meeting demand by looking at electricity prices over this period. This is because wholesale electricity prices are usually highest when the gap between supply and demand is smallest.

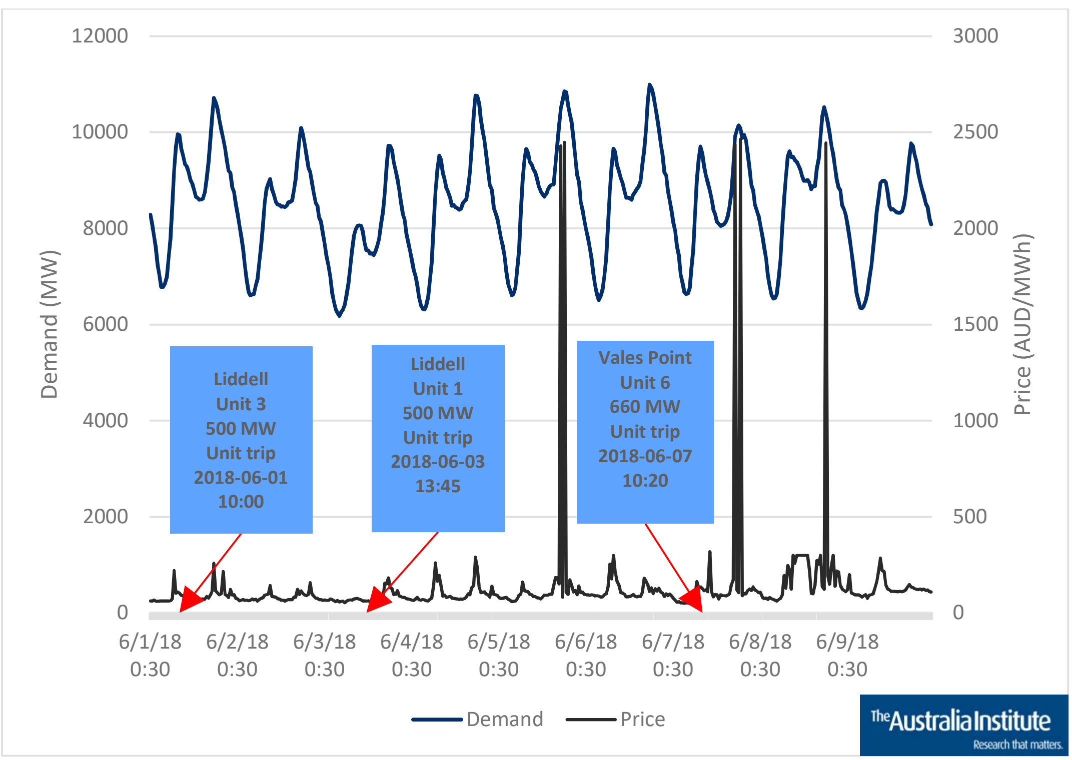
The Australian Energy Market Operator (AEMO) publishes wholesale electricity prices in the various states averaged over half hourly trading intervals.

Usually power prices in NSW range between $60-$300 MWh. Occasionally, when there is a shortage of supply relative to demand, high price events will occur where prices will reach thousands of dollars per megawatt hour (MWh). The wholesale price is capped at $14,200 MWh.

As shown in Figure 2, during the June 2018 "energy crisis" prices reached over $2,400 MWh on five occasions.

During these peak demand price spikes, overall, NSW coal power stations ran between 38-48 percent below capacity (see Table 4 below).

Figure 2: NSW demand, price and coal breakdowns, June 1-6, 2018.



Source: OpenNEM

The chart plots demand for electricity (blue line) against wholesale prices (black line). The timing of the three coal plant breakdowns over this period are also indicated. The loss of electricity generation capacity from these breakdowns would have had a significant impact on the tightness of supply relative to demand.

These high wholesale prices are ultimately passed onto consumers.

COAL OUTPUT DURING PEAK DEMAND JUNE 5-9

To further understand the cause of the shortage of electricity supply, we can examine the output of the various gas and coal generators at the time of those high price events and shortages.

Table 3 below shows the output of all of NSW's large gas and coal power stations during one of the high price events over this period; the trading interval between 7:00-7:30 pm on Thursday June 7.

The table shows the "registered capacity" of the various power plants. This is the amount of electricity they can produce if they are running at full capacity. It also shows the "average output" over this half hour trading period, i.e. the average amount of electricity they were actually producing during this period. The final column shows difference between the two previous columns, i.e. how much below their full capacity the various power stations were operating at during this trading interval.

As the table shows, during this period up to 52 percent (6,399 MW) of the state's coal and gas power stations capacity remained idle, including up to 47 percent (4,828 MW) of coal capacity.

Table 3: Output from NSW gas and coal generators June 7, 2018, 19:00-19:30

Power Station	Technology	Registered Capacity (MW)	Average Output (MW)	Difference (MW)
Bayswater	Black coal	2,640	649.7	1,990
Colongra	Gas OCGT	724	0	724
Eraring	Black coal	2,880	2,370.0	510
Liddell	Black coal	2,000	1,132.5	868
Mt Piper	Black coal	1,400	676.7	723
Smithfield Energy Facility	Gas CCGT	170.9	108.4	63
Tallawarra	Gas CCGT	440	0	440
Uranquinty	Gas OCGT	664	319.8	344
Vales Point "B"	Black coal	1,320	583.1	737

Total (gas)	*Gas*	*1,999*	*428.2*	*1,571*
Total (coal)	*Coal*	*10,240*	*5,412.1*	*4,828*
Total	*All*	*12,239*	*5,840.3*	*6,399*

Source: OpenNEM

Table 4 below shows the percentage of coal capacity that remained idle during each of the five high price trading intervals.

The fact that between 38-48 percent of coal was offline during Lack of Reserve conditions as prices surged undermines the perception of coal as a reliable energy source underpinning the electricity supply in NSW.

Table 4: Coal capacity during high price trading intervals June 5-8 2018

Trading interval	Wholesale electricity price (AUD)	Registered Capacity (MW)	Average Output (MW)	Difference (MW)	Percentage idle
2018-06-05 17:00-17:30	2,429	10,240	6,341	3,899	38%
2018-06-05 18:00-18:30	2,448	10,240	6,585	3,655	36%
2018-06-07 17:30-18:00	2,438	10,240	5,320	4,919	48%
2018-06-07 19:00-19:30	2,465	10,240	5,412	4,828	47%
2018-06-08 18:30-19:00	2,445	10,240	5,333	4,907	47%

Source: OpenNEM

Gas backup: Missing in action

Open cycle gas turbine power stations (OCGT) can be switched on and off quickly but are relatively inefficient and thus produce relatively high cost electricity. As such they are designed to dispatch electricity for short periods of time to meet demand peaks.

Combined cycle gas power stations (CCGT) are more efficient and can be used to provide (relatively expensive) bulk electricity but are also flexible enough to dispatch electricity to meet demand peaks.

NSW has two new combined cycle gas turbine (CCGT) power plants, Tallawarra Power Station and Colongra Power Station. These plants are less than 10 years old and are the newest gas power plants in New South Wales. They are designed to provide over 1,000 MW of dispatchable energy to back up NSW coal power plants and dispatch electricity to meet demand peaks.

As shown in Table 5 below, during these five high demand price peaks Tallawarra did not dispatch any power. Colongra did not dispatch power during three out of these five high price trading intervals and ran at less than half its capacity at the other two.

Table 5: Output of Tallawarra and Colongra power stations during high price events June 5-8, 2018

Trading interval	Wholesale electricity price (AUD)	Tallawarra output (capacity 440 MW)	Colongra output (capacity 724 MW)
2018-06-05 17:00-17:30	2,429	0	0
2018-06-05 18:00-18:30	2,448	0	299
2018-06-07 17:30 - 18:00	2,438	0	0
2018-06-07 19:00-19:30	2,465	0	0
2018-06-08 18:30-19:00	2,444	0	249

Source: OpenNEM

This is not the first occasion that these gas plants have failed to dispatch power when it is most needed. During the February 10 heatwave energy crisis in 2017 that led to load-shedding at the Tomago aluminium smelter, both Tallawarra and Colongra power stations failed immediately prior to peak demand which was a major contributing factor to the shortfall on that day.[13]

Advocates of further investment in gas power plants argue that it is needed to provide "dispatchable energy" at times wind and solar are not producing electricity due to a lack of wind or sunshine. [14]

It is true that variability of wind and solar photovoltaic plants needs to be managed with "dispatchable energy" or demand management. "Dispatchable energy" is electricity that can be dispatched whenever there is a gap between the amount of electricity being produced by variable renewable sources and overall demand.

Fortunately there is now a range of renewable energy storage and demand management measures available can fill this role without resorting to gas. Battery storage, solar thermal power with energy storage, pumped hydro and demand management are all competitive sources of firming power.

The failure of NSW gas plants to deliver power when it is most needed undermines the case for gas powered generation as a source of reliable dispatchable power back up renewable energy or NSW's ageing coal fleet.

[13] Ogge (2017) *Can't stand the heat: The energy security risk of Australia's reliance on coal and gas generators in an era of increasing heatwaves,* http://www.tai.org.au/sites/defualt/files/P454%20Can%27t%20stand%20the%20heat%20FINAL%202.31.pdf

[14] Roberts (2016) *Road to renewable energy goes via the nation's gas fields,* https://www.appea.com.au/2016/12/road-to-renewable-energy-goes-via-gas-fields/

The overall performance of NSW gas and coal plants during the June 2018 winter "energy crisis"

Table 6 below shows the output coal and gas power stations in NSW compared to their registered capacity during the high price trading intervals between June 5-8. These high price events indicate the time of the greatest shortage of electricity supply relative to demand.

Overall, New South Wales coal and gas plants were operating at less than half their full capacity during three out of the five high price peak demand intervals over this period.

Table 6: Output of NSW coal and gas power plants during high price events June 5-8 2018

Trading interval	Wholesale electricity price (AUD)	Registered Capacity (MW)	Average Output (MW)	Difference (MW)	Percentage idle
2018-06-05 17:00-17:30	2,428.77	12,238.9	7,024.4	5,214.5	43%
2018-06-05 18:00-18:30	2,447.89	12,238.9	7,644.8	4,594.1	38%
2018-06-07 17:30-18:00	2,438.00	12,238.9	5,639.9	6,599.0	54%
2018-06-07 19:00-19:30	2,464.52	12,238.9	5,840.3	6,398.6	52%
2018-06-08 18:30-19:00	2,444.49	12,238.9	6,011.0	6,227.9	51%

Source: OpenNEM

NSW gas and coal power stations are highly polluting, emitting 58 million tonnes CO_2e of greenhouse gases – 44 percent of NSW total emissions, and over one quarter of all Australia's greenhouse gas emissions from electricity generation. [15]

[15] Australian Government (February 2018) *State and Territories Greenhouse Gas Inventories 2016,* Appendix 2, Table 11, http://www.environment.gov.au/system/files/resources/a97b89a6-d103-4355-8044-3b1123e8bab6/files/state-territory-inventories-2016.pdf

The continued operation of these power plants is often justified on the basis of being "baseload" or "dispatchable energy" available when it is required. However the actual performance of these power stations in June this year appears to contradict this characterisation.

Energy security impacts

This series of failures of the New South Wales gas and coal fleet compromised the ability of the system to meet electricity demand over this period.

In order to maintain power system reliability, The Australian Energy Market Operator (AEMO) has predetermined levels of reserves to provide a "buffer" over and above the forecast level of electricity demand at any given time.

When supply falls below these reserve levels AEMO issues Lack of Reserve (LOR) notifications.

These notifications are in three tiers: LOR 1, LOR 2 and LOR 3.

The notifications are defined by AEMO as follows:

> LOR 1 - Signals a reduction in pre-determined electricity reserve levels. This notification simply provides an indication to the market to encourage more generation. At this level, there is **no impact** to power system security or reliability.
>
> LOR 2 - Signals a tightening of electricity supply reserves and provides an indication to the market to encourage more generation. At this level, there is still **no impact** to power system security, however AEMO will bring in available additional resources, such as demand response and support generation (such as diesels if required).
>
> LOR 3 - Signals a deficit in the supply/demand balance, with no market response controlled load shedding may be required. AEMO views load shedding as an absolute last resort to securely manage the wider power system.

As can be seen in these definitions, LOR 2 is the highest Level of Reserve notice short of an actual deficit in supply, and at this level AEMO will intervene to bring in additional available resources such as demand response and support generation ensure supply.[16]

[16] AEMO (2017) *AEMO Market Notifications explained- What does "Lack of Reserve Mean?* https://www.aemo.com.au/Media-Centre/AEMO-market-notifications-explained

LOR 3, the highest level of alert, indicates that the balance is so tight that load shedding is imminent or has begun.[17]

AEMO issues "forecast" LOR notices when supply is forecast to fall below pre-determined reserve levels, and "actual" LOR notices when supply actually falls below these levels.

If AEMO forecasts that reliability and security is "outside the relevant NEM standard" and there is "no market resolution to it", in order to avoid load shedding AEMO can resort to activating the Reliability and Emergency Reserve Energy Trader (RERT).

This allows AEMO to maintain power system reliability and security by drawing on emergency generation or demand management measures.

As shown in Table 7 below, between Tuesday June 5 and Friday June 8 AEMO issued nine actual LOR notices, including four actual LOR 2 notices, which as previously mentioned are "the highest level of reserve notice short of an actual deficit in supply".

Table 7: Actual Lack of Reserve (LOR) and RERT notifications June 5-8, 2018

Date	Time	Notice	Contingency capacity reserve requirement	Minimum reserve available
5/6/18	1600-1830	Actual LOR1	1,560	1,305
4/6/18	1730-1900	Actual LOR 1	1,560	1,339
5/6/18	1820-1900	Actual LOR 2	867	538
6/6/18	1700-1900	Actual LOR 1	1,550	1,349
7/6/18	1530-1900	Actual LOR 2	844	490
7/6/18	1700-1900	Actual LOR 1	1,537	1,192
7/6/18	1730-1900	Actual LOR 2	844	490
8/6/18	1700-2100	Actual LOR 1	1,553	1,400
8/6/18	1730-1830	Actual LOR 2	855	670
8/6/18	1730-1800	AEMO notice of Intention to implement RERT		

Source: AEMO Market Notices.

[17] AEMO (2017) *Summer operations 2017-18*, P 11, http://www.aemo.com.au/-/media/Files/Media_Centre/2017/AEMO_Summer-operations-2017-18-report_FINAL.pdf

At 5:14 pm AEMO then issued a notice of its intention to bring on emergency supplies by activating the RERT to "maintain the power system in a reliable operating state".[18] The notice was subsequently withdrawn before the RERT was actually activated.

This series of measures shows the seriousness of the problems caused by the unavailability of such a large proportion of New South Wales's coal and gas power stations.

[18] AEMO (2018) *INTENTION TO IMPLEMENT an AEMO INTERVENTION EVENT WITH RERT*, https://www.aemo.com.au/Market-Notices?page=9&currentFilter=&sortOrder=&catFilter=&searchString=

Why building new coal plants is not the solution

Some commentators and politicians have advocated building newer supercritical coal power plants to replace the ageing and problematic coal fleet.[19]

If the aim is to provide greater reliability and affordable power, this is unlikely to provide an adequate solution as it would almost certainly make New South Wales' electricity supply less reliable and more expensive.

Australia has four supercritical coal plants, all in Queensland:

- Kogan Creek
- Callide C (also known as "Callide Power Plant")
- Tarong North
- Millmerran

These plants are sometimes described as High Efficiency, Low Emissions (HELE) plants because they are typically more efficient than subcritical coal plants. However, they are less efficient and have worse emissions than competing power generation like gas and renewables.

Over the summer of 2017/18 supercritical coal power plants in the NEM broke down more often than subcritical black coal plants. Subcritical black coal power plants experienced 39 percent of coal plant breakdowns but make up 56 percent of all coal plants. Supercritical plants make up only 25 percent of coal plants but experienced 19 percent of all breakdowns.

Kogan Creek Power Station is a supercritical coal power plant. It is only 11 years old and the newest coal plant in the NEM. Despite this it is plagued by regular breakdowns.

During June Kogan Creek Power Station broke down twice, losing 750 MW instantaneously and without warning each time. Because it is such a large single

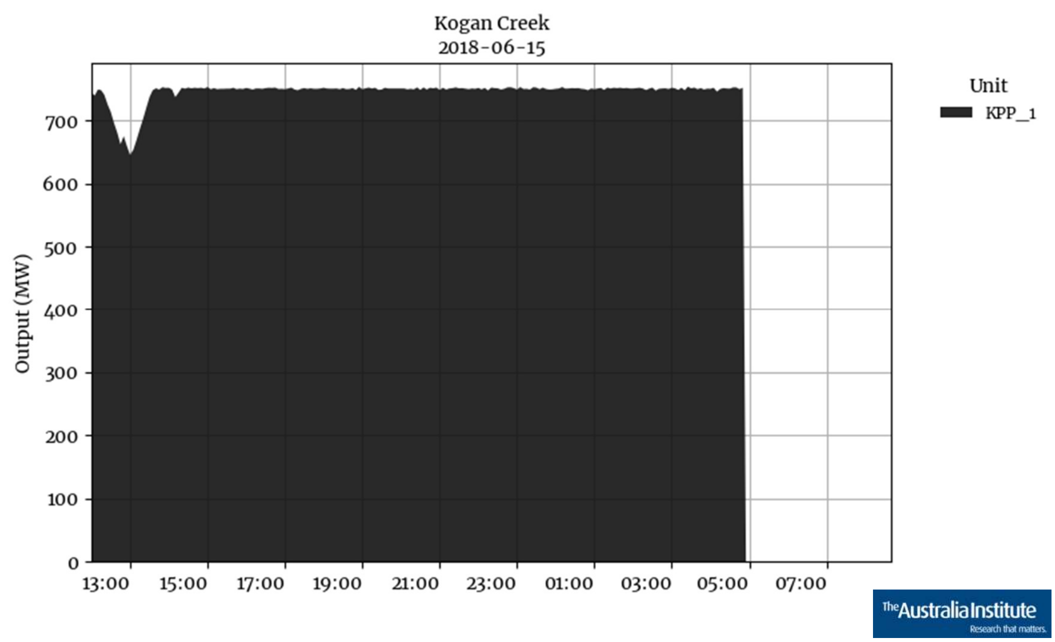
[19] Kelly and Benson (June 2018) *$5bn fund at top of Nationals' demands for Turnbull on energy,* https://www.theaustralian.com.au/national-affairs/5bn-fund-at-top-ofnationals-demands-for-turnbull-on-energy/news-story/9748f24a8b6670a116dc6f52a32a4735?csp=a97c1a7795b6821e8c990f4eab2c4ae8

generating unit, these breakdowns mean it has been responsible for the two largest breakdowns in the NEM to date this year.

Figures 3 and 4 below show the output of Kogan Creek Power Station over the period of time leading up to, and immediately after, these breakdowns. The dark shaded area of the charts represents the output of the plant remaining fairly constant at around 750 MW for four hours up to each breakdown when output dropped to zero almost instantaneously (time is shown on the horizontal axis).

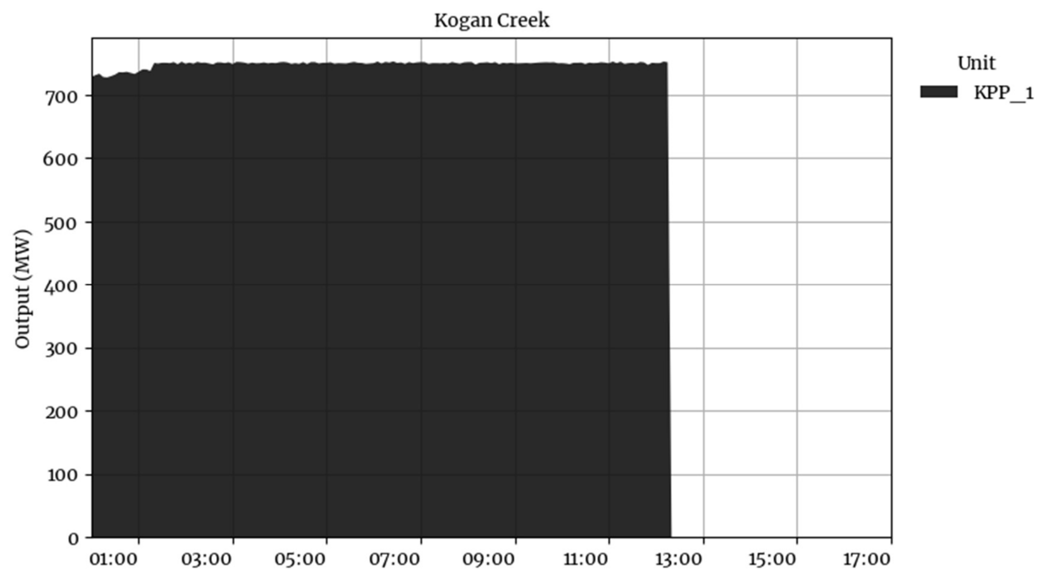
The charts illustrate the scale and suddenness of these breakdowns. As discussed above, the larger and more sudden the loss of electricity supply to the grid, the more serious and disruptive that loss is to the system as a whole.

Figure 3: Kogan Creek Power Station output June 13, 2018



Source: OpenNEM

Figure 4: Kogan Creep Power Station output June 5 2018



Source: OpenNEM

Supercritical coal plants are not only unreliable, they are expensive.

Bloomberg New Energy Finance (BNEF) estimate the Levelised Cost of Energy (LCOE) of new build ultra-supercritical coal plants in Australia is $134-203 MWh. For comparison the LCOE of new build wind is $61-118, solar $74-90 MWh and combined cycle gas $74-80 MWh.[20]

As a result, BNEF suggest

> that if new coal were to be built in Australia, electricity prices would be substantially higher than with a combination of wind, solar and gas – provided gas markets operate efficiently.[21]

[20] BNEF (February 2018) *Australia Insight, Turnbull's new coal: expensive inflexible and by no means clean*

[21] Ibid, p 1.

Why refurbishing old coal power stations is not the solution

Like old cars, coal power plants develop problems over time that make them less reliable and more expensive to maintain.

As with an old car, coal power plants can be repaired to extend their life. However, both car owners and those responsible for managing energy markets need to evaluate whether the cost of keeping an old piece of machinery running for a limited amount of time is more effective than investing in new technology that will operate more reliably and for a much longer period.

In the case of the Liddell Power Station, energy company AGL commissioned advice from the engineering services company Worley Parsons on the cost of extending the life of Liddell Power Station for a further 5 years after 2022,[22] as urged by the Commonwealth Government.[23]

The cost of the five-year life extension as advised by Worley Parsons was $920 million dollars. AGL then compared this to the cost of its planned $1.36 billion investment in replacing Liddell. This consisted of a combination of new renewable and gas generation, a far smaller upgrade of Bayswater Power Station and demand management measures.

Although the replacement option is more expensive, it provides power over a much longer period – resulting in lower cost electricity overall. The Levelised Cost of Electricity (LCOE) of the replacement plan ($83 MWh), significantly lower than the cost of the 5-year life extension ($106 MWh).[24]

The replacement also has reliability advantages. The combination includes a significant amount of demand management and flexible dispatchable generation including

[22] AGL (2017) *NSW Generation Plan* https://www.agl.com.au/-/media/agl/about-agl/documents/media-center/asx-and-media-releases/2017/171209nswgenerationplandecember2017.pdf?la=en&hash=529E1A89370A33DA8F378

[23] McDonald Smith (March 2018) *Josh Frydenberg at odds with energy industry leaders over Liddell demands*, https://www.afr.com/brand/business-summit/josh-frydenberg-at-odds-with-energy-industry-leaders-over-liddell-demands-20180306-h0x3mk

[24] Ibid. "A carbon emissions cost has been included as per AEMO's "Moderate" 2015 scenario. 2. Removal of the cost of carbon from the LCOE has the effect of reducing the Liddell Replacement portfolio to $82/MWh and the Liddell lifetime extension portfolio to $92/MWh"

battery storage, gas peaking plants and potentially pumped hydro. This means the replacement will be more suited to supplying power on critical peak demand days than Liddell which is old inflexible “baseload” generation.

Because the new capacity is mostly up to date modern technology it is likely to be far more reliable than the old legacy coal plant that is so subject to breakdowns in peak demand periods.

The diversity of generation sources also increases reliability. A single breakdown at a coal generator (refurbished or not) usually results in the loss of hundreds of megawatts of capacity. A diverse range of smaller generators means that problems with any single generator have far less consequence.

However, the most important reason not to extend the life of new coal power plants is their greenhouse gas emissions.

Australia is already suffering severe impacts of global warming with increasing extreme heat events and natural disasters including storms, drought, floods and bushfires. These have an enormous cost to the Australian community and economy.

NSW’s ageing coal fleet is very emissions intensive. In 2017 its coal power plants emitted almost 50 million tonnes of greenhouse gas.[25] This is a significant contribution to the heat events that have such a detrimental effect on the people of NSW.

[25] AER (2017) *Electricity sector emissions and generation data 2016–17*, http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/electricity-sector-emissions-and-generation-data/electricity-sector-emissions-and-generation-data-2016-17

Real solutions to more reliable and lower cost electricity for New South Wales

There are several commercially available and cost effective options to replace or remove the need for New South Wales ageing fossil generators. These include:

- Solar thermal with storage
- Pumped hydro
- Battery storage
- Demand management

A more reliable and lower cost renewable grid will employ a combination of these.

Wind and solar already provide lower cost electricity than coal for new build infrastructure.[26] Even when the capital costs of constructing new wind or solar plants are included, they can still provide lower cost electricity than from the suite of existing gas plants.[27]

These trends will almost certainly continue as gas and coal prices continue to rise over time due to climate policy and renewable energy costs continue to fall due to economies of scale.

Wind and solar are variable sources of electricity and require "firming power" to ensure they can reliably provide electricity when it is needed.

The Finkel Review noted that wind is cheaper than coal and gas plants, and utility scale solar is cheaper than gas, even with the additional cost of dispatchable firming capacity that accounts for variability.

> AGL recently outlined its estimates for the cost of different fuels. AGL considers that a new wind farm supported by gas peaking generation (through the 'firming cost') to now be cheaper than new CCGT at a $8/GJ price. A new solar

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[26] BNEF (February 2018) *Turnbull's new coal: expensive, inflexible and by no means "clean"*

[27] Forcey and McConnell (2017) *A Short-Lived Gas Shortfall: A review of AEMO's warning of gas-supply 'shortfalls'*, p 45

farm supported by gas peaking generation would also be cheaper than new CCGT at a gas price of $12/GJ.[28]

[28] Finkel (2017) *Independent review into the future security of the national electricity market* (based on AGL analysis)

Conclusion

Australia's ageing fleet of coal power stations is becoming increasingly unreliable. The recent winter "energy crisis" is emblematic of the issues created by the unreliability of these plants.

The failure of almost half the capacity of New South Wales coal fleet during a sustained period of Lack of Reserve conditions and multiple high price events confirms reliance on coal generation as the central reliability weakness in the New South Wales electricity system. If the system struggled under relatively mild conditions in winter – how will it cope over increasingly hot and demanding summer days.

There are also serious problems with gas power plants that are designed to back up the coal fleet and meet peak demand. The repeated failure of New South Wales's newest combined cycle gas plants at Colongra and Tallawarra to operate when they are most required highlights this problem.

Supercritical coal plants are expensive and recent experience has shown that even the newest supercritical plants are likely to be even less reliable than the older subcritical power plants. As such, building new coal power plants is likely to result in a more expensive and less reliable electricity supply.

Refurbishing old power plants is also unlikely to be an effective means of dealing with the problem. The large investment required to keep old plants operating for a relatively short period of time is likely to be higher over time than the cost of replacing them with new more up to date technology that will operate far longer.

The solution lies in a range of affordable renewable energy, energy storage and demand management solutions that can restore reliability to the New South Wales electricity system and ultimately reduce electricity prices. Fortunatley, most new electricity generation on the NEM is renewable and hopefully continue.