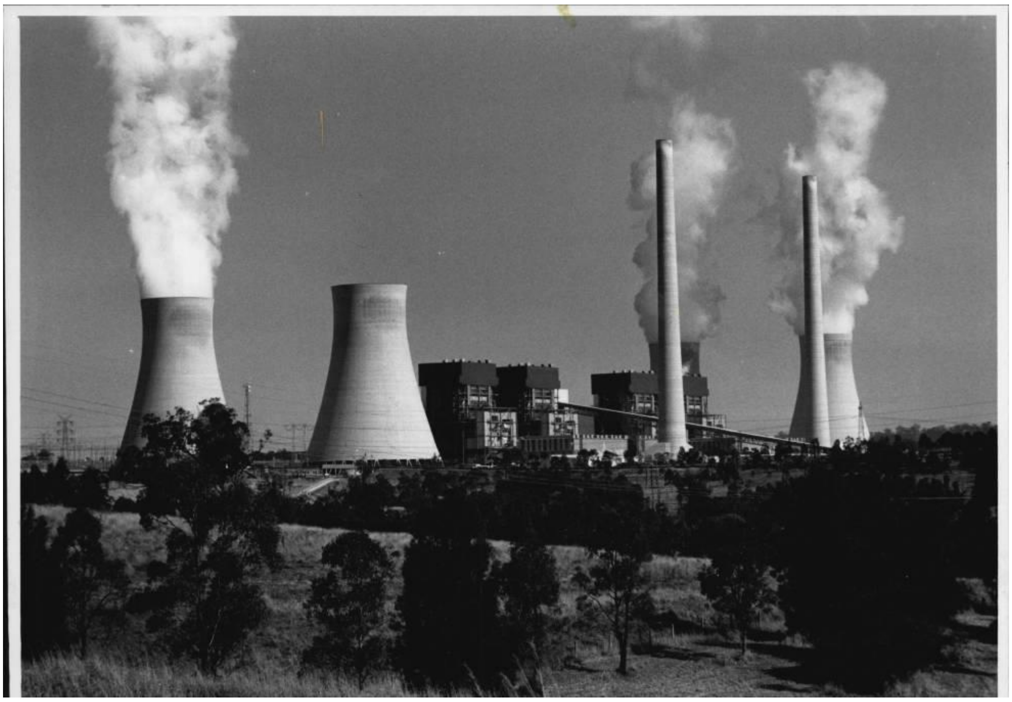

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Can’t stand the heat

The energy security risk of Australia’s reliance on coal and gas generators in an era of increasing heatwaves

Discussion paper

Mark Ogge Hannah Aulby **November 2017**

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Summary

Australia's reliance on an ageing fleet of coal and gas power plants that are unable to cope with increasing temperatures and more frequent heatwaves is the single greatest threat to the energy security of our electricity system.

During the February 2017 heatwave across south eastern Australia, 3,600 MW failed during critical peak demand periods in South Australia, New South Wales and Queensland as a result of faults, largely related to the heat. This is equivalent to 14% of the total capacity of the coal and gas power plants in those states.

Heatwaves like this are inexorably increasing in frequency, intensity and duration in Australia as a result of global warming.

The record-breaking February 2017 heatwave was one of three consecutive heatwaves that summer. Without the impact of global warming a heatwave like this would be considered a one in 500-year event. With current warming, it is now considered a one in 50-year event, and if global temperatures reach 2 degrees above pre-industrial levels, which is considered possible by as early as 2050,[1] summers this hot will become a one in five-year event.[2]

During this heatwave, coal and gas plants failed in NSW, SA and Queensland:

- In South Australia, 17% of gas powered generation (438 MW) was unavailable during the peak demand period that led to the blackouts on the 8th of February.
- In New South Wales, 20% of coal and gas generation (2,438 MW) failed to deliver during the peak demand period on the 10th of February, leading to load shedding at Tomago aluminium smelter.
- In Queensland, 7% of coal and gas generation (787 MW) was withdrawn in the four hours leading to peak demand on the 12th of February due to technical issues, mostly and possibly entirely due to the heat. This led to dispatch prices reaching $13,000 per MWh eleven times within three hours.

In each of these cases rooftop solar significantly reduced underlying demand and avoided far more serious disruptions.

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[1] McSweeney (2015) *Met Office forecasts 2016 to be hottest year on record*, https://www.carbonbrief.org/met-office-forecasts-2016-to-be-hottest-year-on-record
[2] World Weather Attribution (2017) *Extreme Heat: Australia, February 2017,* https://wwa.climatecentral.org/analyses/extreme-heat-australia/

Without rooftop solar, the daily peaks that caused the blackouts, load shedding and high price events would have been exceeded:

- 4 hours 20 minutes earlier on the 8th of February in South Australia.
- 3 hours 25 minutes earlier on the 10th of February in New South Wales
- 5 hours and 10 minutes earlier on the 12th of February in Queensland

There are a range of non-fossil flexible dispatchable energy technologies that do not suffer the reliability issues of coal and gas power plants. These include concentrated solar thermal with storage (CST), pumped hydro with energy storage (PHES), batteries and demand response These technologies are already competitive with, or cheaper than, coal, gas and diesel, and are rapidly reducing in cost as coal and gas costs increase.

This report recommends that under the Reliability Guarantee of the National Energy Guarantee (NEG), retailers be required to hold forward contracts with *"heat safe"* flexible dispatchable resources to cover the risk of unplanned outages in heatwaves.

The reliability standard would be determined by examining the record and condition of particular generating resources. If plants have a record of unplanned outages, including during heatwaves, enough *heat safe* flexible dispatchable resources would need to be contracted to cover such an eventuality. The age and condition of the plant would be relevant considerations.

Heat safe flexible dispatchable resources would not include plants that have a record of unplanned outages including in extreme heat conditions, or are technically vulnerable to extreme heat, for instance water cooled thermal generators.

Given its proven record in delaying and reducing peaks in heatwave conditions, although not flexible dispatchable, solar PV could potentially also be contracted to cover generating assets with an inherent risk of failure in heatwave conditions.

Extreme heat is the greatest threat to the security of the electricity supply in eastern Australia. Our fossil generators are particularly vulnerable to extreme heat. Resilience to extreme heat can only be achieved by reducing this exposure and increasing the amount of generating capacity that is resilient to heat.

Introduction

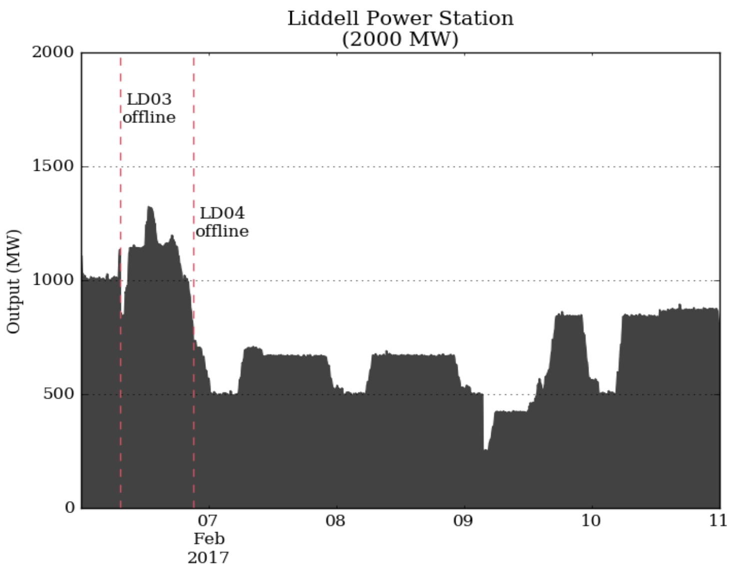
The reason Australia's reliance on coal and gas generators presents such a risk to the security of our electricity supply during heatwaves is partly due to their particular susceptibility to high temperatures, but also due to their size and age.

Heatwaves lead to large increases in electricity demand that often bring us close to the limit of the overall generating capacity of the National Electricity Market (NEM). Individual coal and gas generating units typically have a capacity of hundreds of megawatts. As such, when they break down they can have a significant effect on the overall supply of electricity available.

Power plant faults, even during heatwaves, are not always caused by heat. During the February 2017 heatwave, several large generators were unavailable due to faults and breakdowns unrelated to the heat – dramatically reducing the supply of electricity available during the crucial heatwave demand peaks.

At the Liddell coal power plant in New South Wales plant, two 500 MW units were unexpectedly closed down due to "boiler tube leaks", a common and difficult to fix problem associated with ageing thermal power stations. As a result, they were unavailable at the critical heatwave demand period on the 10th of February. A 120 MW unit at Torrens Island gas plant in South Australia was unavailable for the same reason, as blackouts occurred in that state on the 8th of February.

Figure 1: Liddell power station output on the 6th to 9th of February 2017



Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

Multiple plants, notably the Vales Point coal power plant in New South Wales and several gas generators in Queensland, either failed or had to significantly reduce their capacity due to heat related problems.

It is not only coal plants that proved themselves unreliable in the 2017 heatwave. Gas power plants fared at least as badly. The 600 MW Tallawarra and 400 MW Colongra gas plants in New South Wales are both less than ten years old and both failed at the critical peak demand moment on the 10th of February for unspecified reasons that may or may not have been heat related.

In South Australia, there is no coal generation, and all the 438 MW of outages identified by AEMO on the 8th of February were gas or diesel generation.[3] 165 MW from Pelican Point gas plant failed to operate because it didn't have gas available. The lack of availability of gas due to market conditions is not a result of heatwaves, but is an additional energy security risk peculiar to gas plants in the event of heatwaves.

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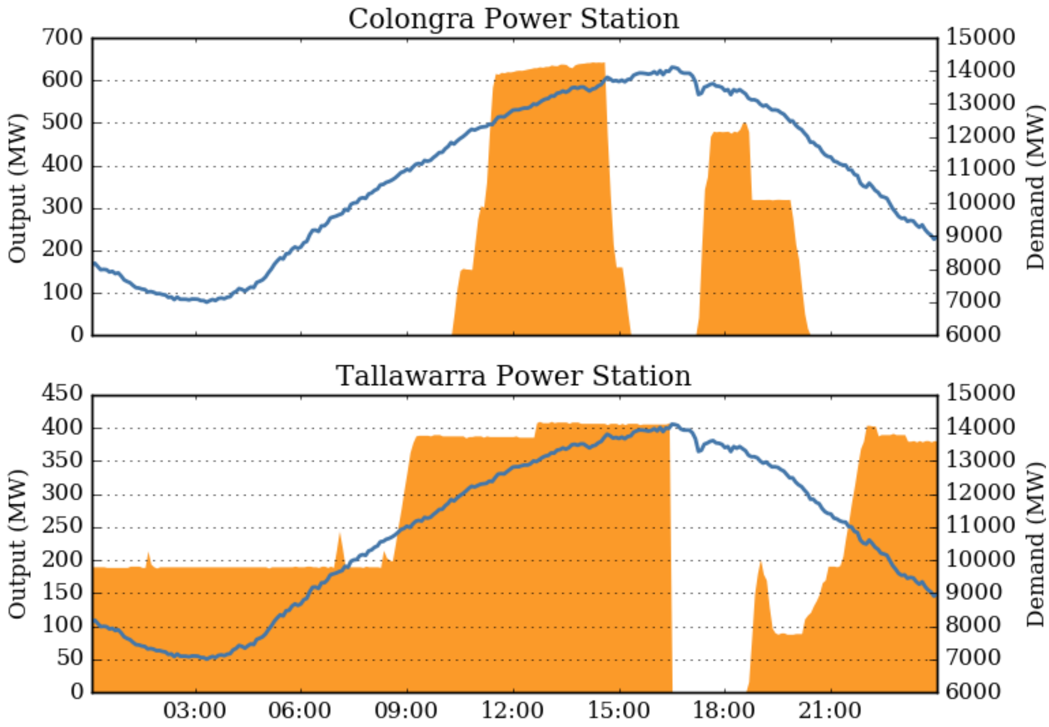
[3] Port Lincoln is a diesel generator and had 73 MW of forced outages on the 8th of February. The remaining outages were gas generators.

Figure 2: Output of Tallawarra and Colongra gas power plants, 10th of February 2017 (orange, LHS axis) with total NSW demand (blue, RHS axis)



Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

The impact of the heatwaves on the electricity supply in all three states would have been much worse without solar. In all three cases, because rooftop solar was supplying electricity customers, underlying demand was considerably reduced, reducing the amount of electricity that the grid needed to supply, thus delaying and reducing peak demand.

In each case, on the critical days of the 8th, 10th and 12th of February, the level of demand that was ultimately reached at the demand peaks was delayed by several hours. It also significantly reduced the peaks (by up 500 MW in Queensland) when they did eventually occur.

Wind and solar are variable sources of generation whose value is to provide low cost electricity to the grid when they are available. The role coal and gas are meant to play are as dispatchable sources of generation that can be relied on to provide power regardless of weather conditions. However as described above, for reasons including their size, age, susceptibility to heat and the unreliability of their fuel supply, they are increasingly unable to reliably fulfil this role during periods of high demand.

Fortunately, there are several far more reliable non-fossil dispatchable generation alternatives to coal and gas that are competitive, if not cheaper.

Solar thermal power is estimated by Lazard to cost as little as $98 MWh, far lower than the gas peaking plants ($165-223 MWh) that it competes with.[4] The 150 MW Aurora solar thermal power plant recently approved for Port Augusta in South Australia would have alone averted the blackouts in South Australia on the 8th of February if it had already been operating. This plant will have eight hours energy storage at full load and has agreed to supply electricity to the South Australian government for $78 per MWh. It won a competitive tender open to all dispatchable energy generators, including coal and gas, by bidding the cheapest generating price.[5] It is air cooled and designed for arid high temperature conditions so it is unlikely to suffer the reliability issues as coal and gas generators.

Battery storage is becoming increasingly competitive with gas as dispatchable energy storage for short periods, and coming down rapidly in price. It is very quick to install as demonstrated by Tesla's completion of their 100 MW South Australian battery facility ahead of their ambitious 100-day deadline.[6] Pumped hydro with energy storage (PHES) is lower cost than battery storage and able to deliver stored dispatchable energy over longer periods more economically. Both battery storage and PHES are able to store excess wind and solar energy when it is produced, which is an important advantage over gas systems. Figure 4 below shows a comparison or the costs of various dispatchable energy systems.

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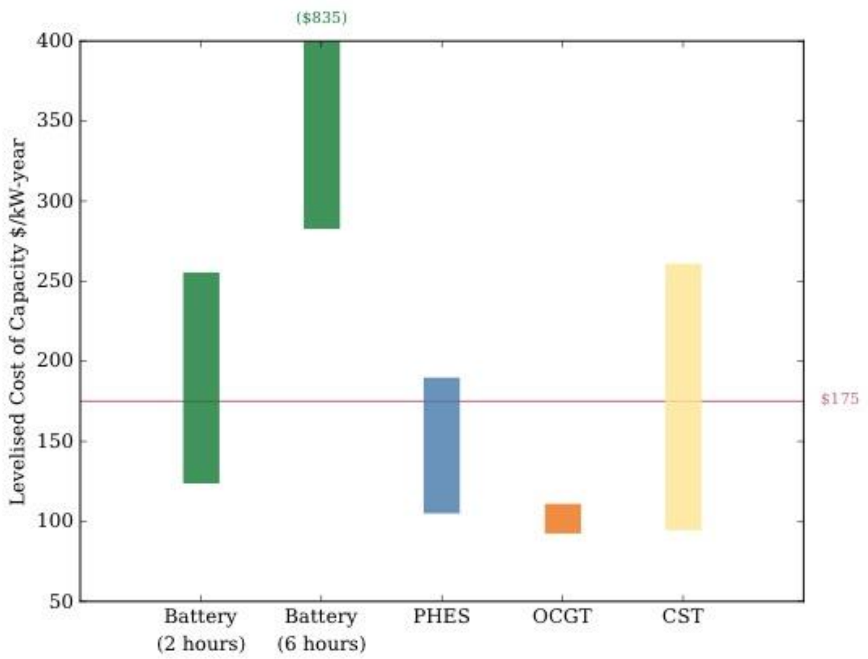
[4] Lazard (2017) *Levelised Costs of Energy Analysis November 2017*

[5] Holmes a Court (2017) *Aurora: What you should know about Port Augusta's solar power-tower*, RenewEconomy

[6] Hamsen (2017) *Elon Musk's giant lithium ion battery completed by Tesla in SA's Mid North*, http://www.abc.net.au/news/2017-11-23/worlds-most-powerful-lithium-ion-battery-finished-in-sa/9183868

Figure 3: Comparison of the Levelised cost of Capacity (LCOC) for various dispatchable technologies



Source: McConnell and Sandiford (2016) *The Winds of Change: An analysis of recent changes in the South Australian Electricity Market*

The cost of each of these systems is falling, while the cost of coal and gas increases. There is an abundance of potential projects for these renewable energy dispatchable systems. The Queensland Government's Energy 400 program has been "swamped" with 6,000 MWs of proposals for energy storage.[7] Even the steel industry, long assumed to be joined at the hip to gas is moving in this direction with the new owners of the Whyalla Steelworks committing to around 1,000 MW, made up of battery storage, solar PV and pumped hydro energy storage.[8]

Unfortunately, the lack of timely investment in these dispatchable systems has meant that high cost polluting diesel generators are being installed as a stopgap measure to prevent summer heatwave blackouts. As noted above, the Lazard Levelised Cost of Energy (LCOE) estimates the levelised cost of solar thermal to be as low as $98 MWh

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[7] Parkinson (2017) *QLD renewables tender swamped by 115 projects, 6,000MW of storage*

[8] Griffiths (2017) *Whyalla steelworks owner GFG Alliance boss Sanjeev Gupta commits to large-scale energy projects in SA,* http://www.couriermail.com.au/news/national/whyalla-steelworks-owner-gfg-alliance-boss-sanjeev-gupta-commits-to-largescale-energy-projects-in-sa/news-story/7bae4f29ba4df01c17ba284599d46a65?csp=64f1fae44ac09f2133f1e776a1b7b549

globally (none has been built in Australia yet), while the cost of diesel generation in Australia can be as high as $358 MWh.[9]

The only policy guaranteed to reduce the reliability of the NEM is to artificially prop up coal and gas power plants and delay the introduction of these non-fossil dispatchable technologies.

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[9] Lazard (2017) *Levelised Costs of Energy Analysis November 2017*

More heatwaves

The duration, frequency and intensity of heatwaves has increased due to global warming, and this trend is worsening. As global average temperatures increase, heatwaves and other impacts of climate change will be exacerbated. One in 20-year extreme hot days are expected to happen every two to five years by mid-century.[10]

Record breaking heat waves are now occurring regularly. In the summer of 2012–13 the record was set for the hottest ever area-averaged temperature across Australia, at 40.3 degrees Celsius. Extreme temperature records were broken in every state and territory during the 2012–13 summer.[11]

In the summer of 2016–17 records were set for the highest monthly mean temperatures for Sydney and Brisbane and the highest daytime temperatures on record for Canberra. New South Wales recorded its overall warmest summer on record, and Queensland had its second-warmest summer on record.[12]

On 8 February, South Australia's area-average maximum temperature was 43.92 °C, the hottest February day on record for South Australia.[13]

The Bureau of Meteorology reported on the 2016–17 summer that:

> The 2017 warm event is the latest in a sequence of prolonged or intense warm spells that have affected Australia roughly every six weeks since the end of 2012 and, overall, the time between heat events is shortening.[14]

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[10] Climate Council (2014) *Heatwaves: longer, hotter, more often*

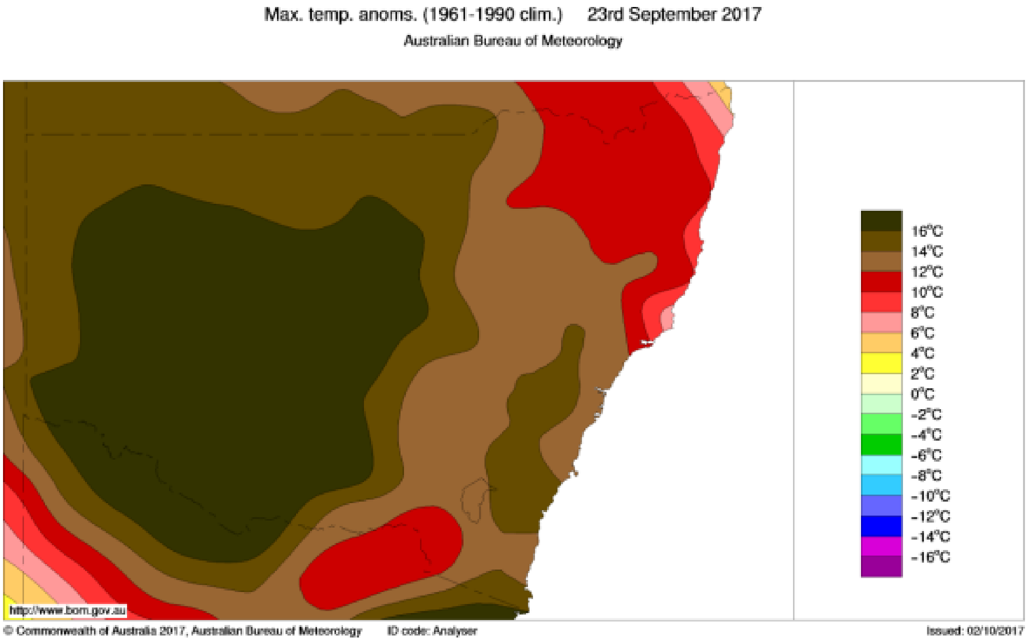
[11] Climate Council (2014) *Heatwaves: longer, hotter, more often*

[12] BOM (2017) *Special Climate Statement 61 - exceptional heat in southeast Australia in early 2017*

[13] BOM (2017) *Special Climate Statement 61 - exceptional heat in southeast Australia in early 2017*

[14] BOM (2017) *Special Climate Statement 61 - exceptional heat in southeast Australia in early 2017*, p 25

Figure 4: Maximum temperature difference from the long-term average (1961-1990) for the 23rd of September 2017 – New South Wales overall warmest September day on record (since 1911)



Source: BOM (2017) *Special Climate Statement 62—exceptional September heat in eastern Australia*

World Weather Attribution has found that global warming has made the extreme heat event in NSW in the of summer 2016–17 (see Figure 4 above) fifty times more likely to occur than prior to global warming. Expressed another way, a summer as hot as 2016–17 was previously a one in 500-year event. It is currently a one in 50-year event. If global temperatures reach 2 degrees above pre-industrial levels, which is possible by as early as 2050, summers this hot will become a one in 5-year event.[15]

Since then south-eastern Australia has experienced record temperatures in September,[16] and Victoria has experienced the longest November heatwave since records began.[17]

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[15] World Weather Attribution (2017) *Extreme Heat: Australia, February 2017,* https://wwa.climatecentral.org/analyses/extreme-heat-australia/

[16] BOM (2017) *Special Climate Statement 62—exceptional September heat in eastern Australia,* http://www.bom.gov.au/climate/current/statements/scs62.pdf

[17] Cunningham (2017) *Melbourne to swelter through longest November heatwave in 150 years,* http://www.theage.com.au/victoria/melbourne-to-swelter-through-longest-november-heatwave-in-150-years-20171121-gzpwu1.html

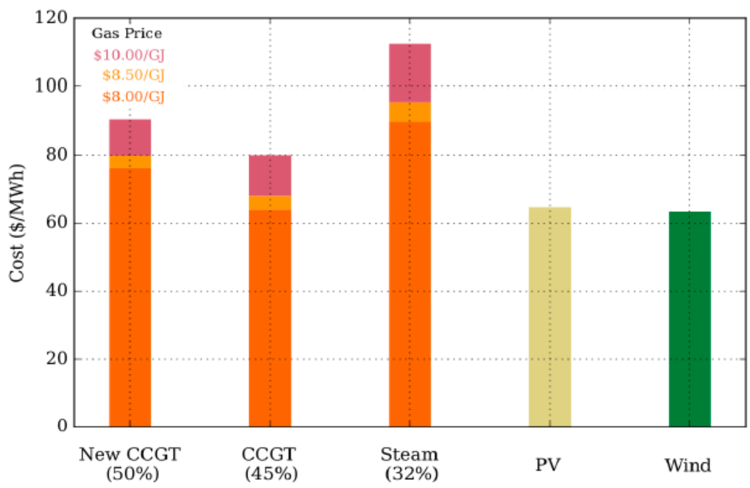
Dispatchable energy

The electricity system requires supply and demand to be matched at all times. This is done cost efficiently with a mix of different technologies. Different energy technologies play different roles in meeting demand. To cost efficiently meet demand, as much supply as possible should come from low cost sources as long as overall reliability is not compromised.

Traditionally low-cost energy was produced by technologies such as coal, and combined cycle gas turbines. Over recent years, these have become problematic for a number of reasons. These include concerns over greenhouse gas emissions, but also the increasing cost of gas, and the reduced reliability of an ageing fleet coal and gas plants, particularly in heatwave conditions.

At the same time, as shown in Figure 5 below, the cost of wind and solar PV have dramatically fallen, to the point where – even including the cost of building solar and wind farms – they provide electricity cheaper than existing gas plants would.

Figure 5: Comparison of costs of providing bulk energy with gas and renewable technologies



Source: Forcey and McConnell (2017) *A short lived gas shortfall. A review of AEMO's warning of gas "shortfalls"*

Note: New CCGT, PV and wind all include the capital costs. CCGT and steam represent the cost of producing electricity from existing plants.

With traditional systems that use coal and combined cycle gas as the source of low cost bulk electricity, flexible technologies such as open cycle gas turbines and hydro power were used to provide peak demand. These also balance the system ensuring supply and demand are matched. These technologies are both dispatchable and synchronous technologies and could provide various grid services (including Frequency Control Ancillary Service, inertia and others).

With the falling cost of wind and solar, we are seeing the emergence of new energy systems where low-cost energy is increasingly being provided by solar PV and wind power. These technologies play a similar role as coal, providing low cost bulk energy.

Coal can be described as “dispatchable” energy in that it can be turned on and off to meet demand. However, it is inflexible, in that it is slow and expensive to turn on and off. Wind and solar are “variable” sources, as they follow the weather.

There are advantages and disadvantages to both as a source of bulk energy.

Wind and solar fluctuate and are not always available. However, their availability can be forecast with a high degree of accuracy, and when they reduce their supply they reduce over time (as distinct from instantaneously).

Coal on the other hand is not dependent on the weather. However individual coal generating units are usually large, and when they break down they can (and do) cause unexpected and instantaneous losses of hundreds of megawatts which can be very disruptive. It is of course also the most emissions intensive source of energy and has a range of other serious environmental health impacts that are significant external costs ultimately borne by the community.

Whether coal or renewables supply bulk electricity, ***flexible dispatchable*** capacity is required to fill the gap between low cost bulk electricity supply and fluctuating demand. Flexible forms of energy generation are usually more expensive than variable renewable energy or dispatchable but inflexible coal.

Technologies including battery storage, solar thermal (CST), pumped hydro with energy storage (PHES) and demand response can provide a balancing role, ensuring supply and demand is met. These dispatchable technologies can also provide grid services. Some technologies (for example CST and pumped hydro) inherently provide inertia. Other technologies (such as wind and solar PV farms, and batteries) can also provide synthetic inertia, or Fast Frequency Response)

These technologies play a similar role to and compete with open cycle gas peaking plants (OCGT) and hydro. The solar thermal power plant at Port Augusta, for instance, won a completive tender for dispatchable energy outbidding all other technologies including coal and gas. These technologies are considered in more detail below. The question is which flexible dispatchable technologies are most effective and appropriate to ensure a reliable and cost-efficient electricity supply.

Vulnerabilities of coal and gas generators to heatwaves

VUNERABILITY TO EXTREME HEAT

Thermal electricity generation, including thermal coal and combined cycle gas, require cooling in order to function. 65 per cent of generating capacity in Australia's National Electricity Market depends on water for cooling.[18] In heatwaves, cooling becomes difficult and many power stations fail to produce at their full capacity.

Coal power stations burn coal to heat water, creating steam which is used to turn turbines that generate electricity. Once the steam has passed through the turbine it must be cooled and condensed back into water so it can be reused in the steam cycle. It is often cooled by cold water that is pumped from the cooling tower, and is sometimes referred to as a re-circulating system. During periods of extreme heat coal power stations can fail if the water from the cooling tower is too warm, if access to water is limited in a drought, or if the discharged water being pumped out of the cooling tower is too hot.[19]

If the water being pumped from the cooling tower is too warm, it cannot effectively cool the steam from the turbines back into water. In this case, power stations must curtail production because there is not enough water in the system to continue to create steam and turn the turbines. The efficiency of a power station is reduced if the water from the cooling tower is too warm. This because the thermodynamic efficiency of a power station is determined by the temperature difference between the high temperature steam in the boiler and the low temperature steam exhausting the turbine.[20]

If access to water is limited due to a drought, power stations will not have enough water to condense steam to turn turbines, or to supply the cooling tower with cold water.

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[18] Smart and Aspinall (2009) *Water and the electricity generation industry*

[19] Union of Concerned Scientists (2011) *Energy and Water in a Warming World: Freshwater Use by US power plants*, http://www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/freshwater-use-by-us-power-plants.html#.WfEcCohx3IU

[20] Smart and Aspinall (2009) *Water and the electricity generation industry*

Power stations that use a once-through cooling system discharge water back into the ocean, river or lake once it has passed through the cooling process. If the discharge water being pumped into rivers and lakes is too hot it can harm aquatic ecosystems. Environmental regulations require the power station to cut production once a high temperature threshold has been reached.[21]

Combined-cycle gas turbine (CCGT) power plants use both gas and steam turbines. Hot exhaust gas from the gas turbine is passed through a heat recovery steam generator to produce steam to power the steam turbine. Steam that is ejected from the steam turbine is condensed in the cooling system and recycled to the steam generator.[22] The same problems with cooling apply to the gas thermoelectric turbines as steam is still required to be cooled back into water. Gas combustion engines do not use steam and therefore do not require the same cooling systems, though gas combustion turbines are less efficient in extreme heat.

The water usage of cooling thermoelectric power stations is significant. In the United States, it is the single biggest use of freshwater resources, demanding 41% of water use.[23] In Australia a typical 1,000 MW subcritical power station using recirculated cooling consumes 17 gigalitres of water a year.[24] As climate change worsens, and periods of heatwaves and droughts become more frequent and intense, the collision of water needs will become a major issue in Australia.

AGE AND SIZE MATTER

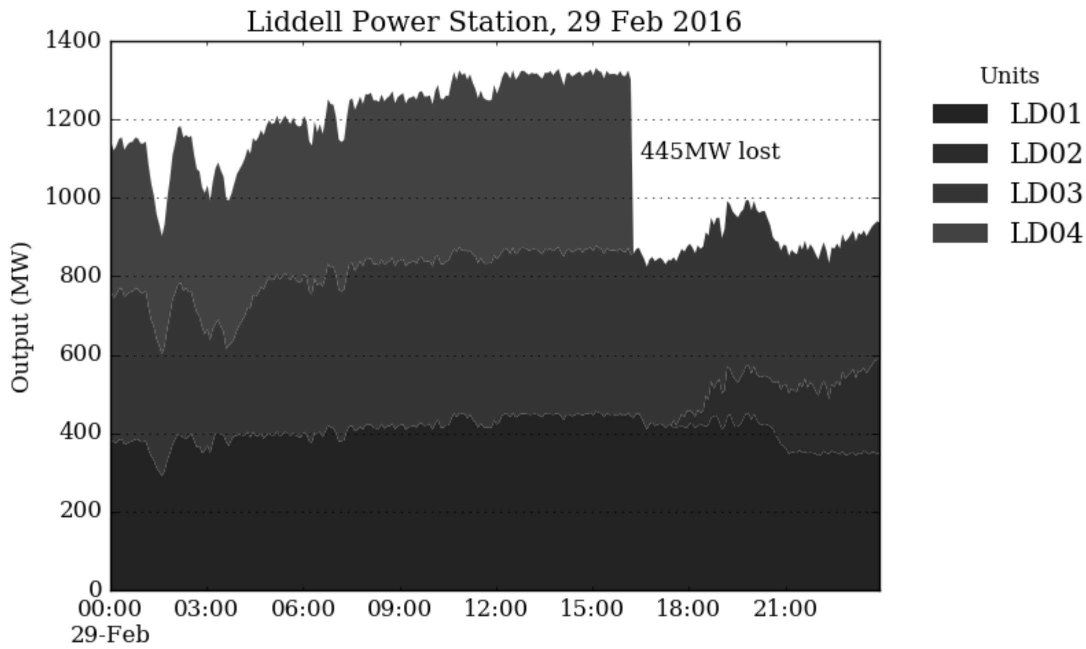
The age and size of coal and gas generators also contribute to their unreliability. Coal and gas power plants in Australia are typically made up of individual generating units of hundreds of megawatts each. This means that the outage of a single generating unit during a period of high demand can have serious implications for the ability of electricity market to meet demand. Figures 6 and 7 show examples of generating units at New South Wales coal power plants that failed, leading to the unexpected and instantaneous loss of large amounts of capacity to the grid.

Coal and gas power plants in Australia are also old, with some over their technical operating lifespan, meaning they are more susceptible to breaking down. The current median age of existing coal plants is 30 years, though as shown by Figure 8 the coal

[21] Smart and Aspinall (2009) *Water and the electricity generation industry*
[22] Smart and Aspinall (2009) *Water and the electricity generation industry*
[23] Union of Concerned Scientists (2011) *Energy and Water in a Warming World: Freshwater Use by US power plants*
[24] Smart and Aspinall (2009) *Water and the electricity generation industry*

plants with the largest capacity are much older. Liddell power station has a capacity of 2,100 MW and is 45 years old, and Eraring and Bayswater are 34 years old and have capacities of 2,693 MW and 2,780 MW respectively.[25]

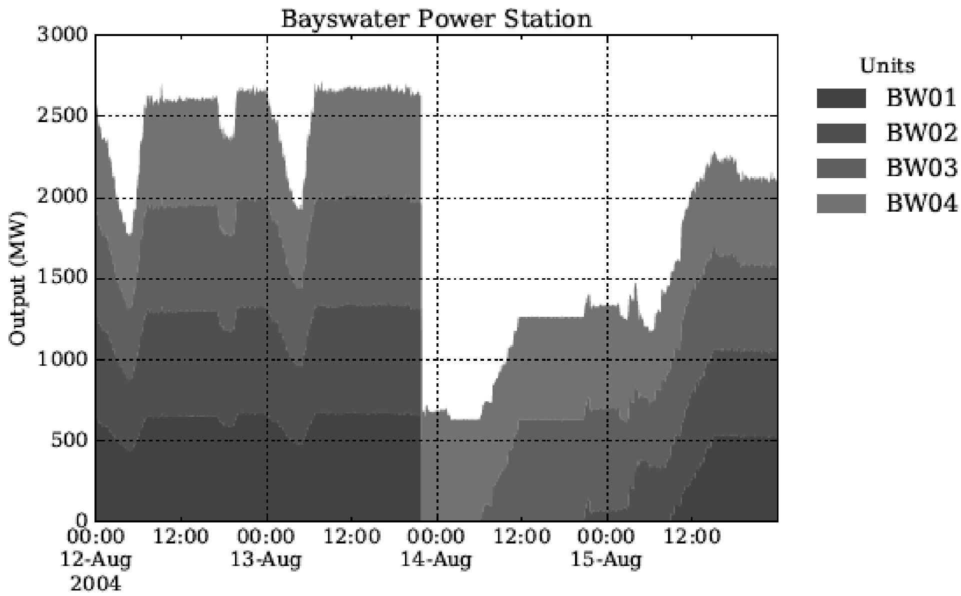
Figure 6: Output of Liddell Power Station, 29th of February 2016



Source: McConnell (2016) *Submission to the senate inquiry into Retirement of coal fired power stations*

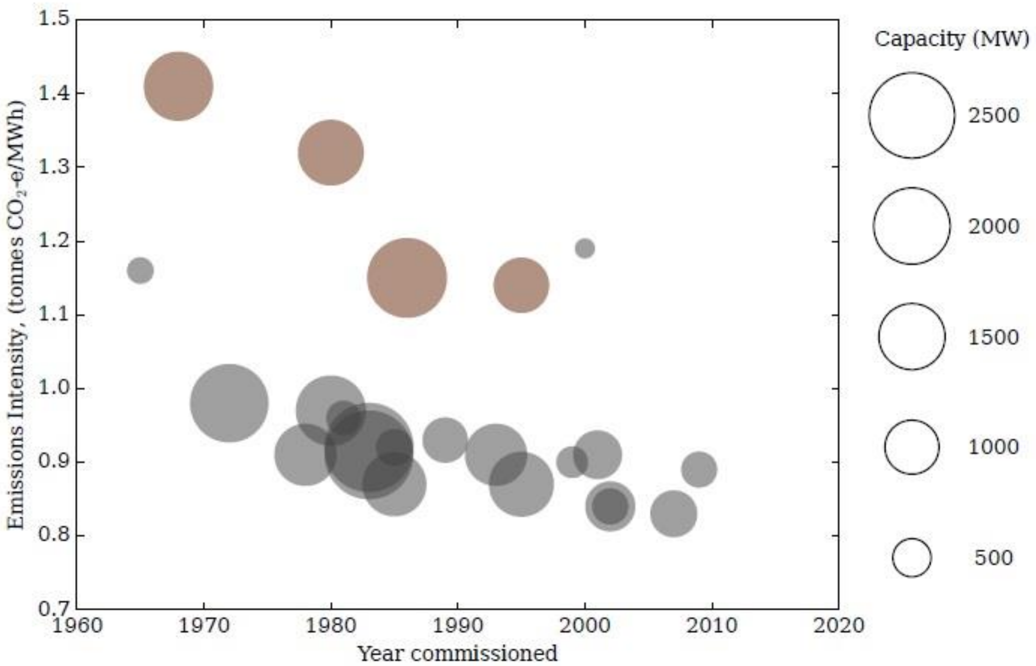
[25] McConnell (2016) *Submission to the senate inquiry into Retirement of coal fired power stations*

Figure 7: Output of Bayswater power plant on the 13th of August 2004 – Units 1, 2 and 3 all tripped automatically leading to the instantaneous loss of 1,971 MW



Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

Figure 8: Age, size and emissions intensity of coal generation in Australia



Source: McConnell (2016) *Submission to the senate inquiry into Retirement of coal fired power stations*

February 2017 heatwave timeline

As the second heatwave of summer 2017 moved across south eastern Australia, it led to very high electricity demand. This coincided with 3,600 MW of coal and gas generation (14% of total coal and gas generation in the NEM) becoming unavailable at the critical peak demand intervals over three days in South Australia, New South Wales and Queensland. These outages led to blackouts in South Australia, load shedding in New South Wales and multiple high price events in Queensland.

These unscheduled outages and reduced capacity were due to a number of factors, including the high temperatures, and highlighted the vulnerability of our electricity supply to heatwaves as a result of our reliance on coal and gas generators.

SOUTH AUSTRALIA, 8TH OF FEBRUARY 2017

In South Australia on 8th February, 17% of gas and diesel powered generation (438 MW) was unavailable during the peak demand period that led to the blackouts experienced on that day.

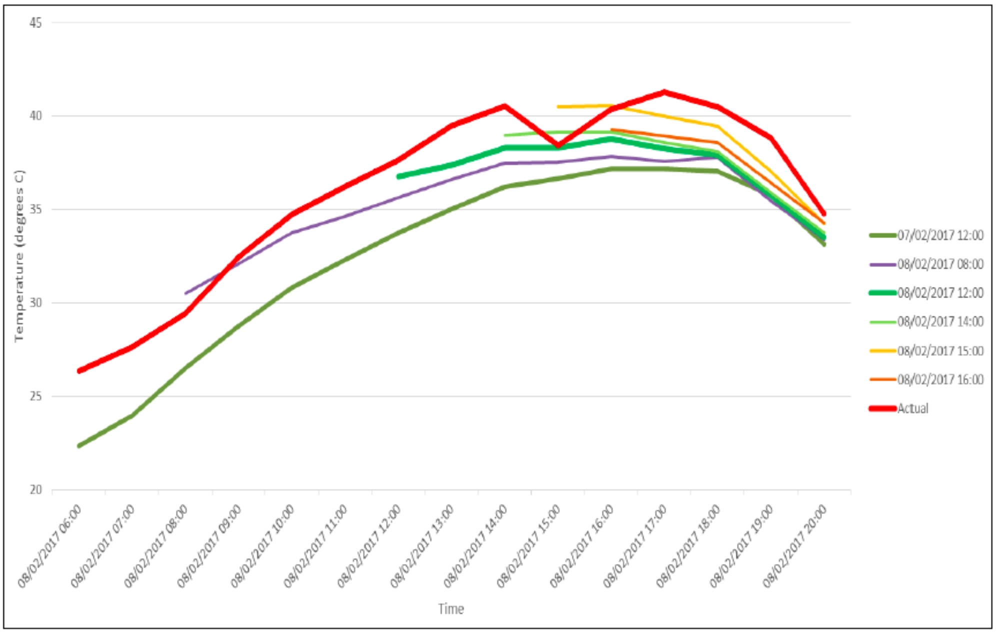
In a special climate statement, the Bureau of Meteorology wrote:

> On 8 February, South Australia's area-average maximum temperature was 43.92 °C, the hottest February day on record for South Australia as a whole—previous hottest was 43.60 °C on 16 February 1983.[26]

High temperatures lead people to increase their use of cooling, which increases demand for electricity. As shown in Figure 9 below, the temperatures in South Australia that day were consistently above forecasts, even those forecasts made on an hourly basis during the day.[27]

[26] BOM (2017) *Special Climate Statement 61—exceptional heat in southeast Australia in early 2017,* p 19
[27] AEMO (2017) *System event report South Australia, 8 February 2017*

Figure 9: Forecast and actual South Australian temperatures during the 8th of February 2017

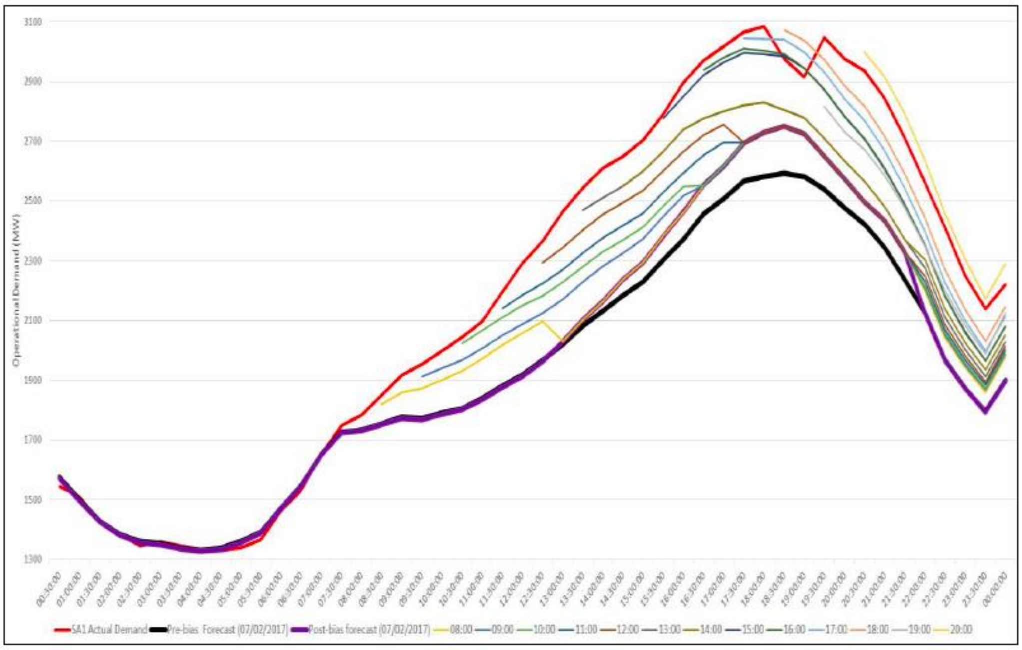


*Actual temperatures illustrated are the average of temperatures at the Adelaide and Adelaide Airport weather stations.

Source: AEMO (2017) *System event report South Australia, 8 February 2017*

This led to demand being significantly underestimated even during updated forecasts throughout the day. Peak demand was around 500 MW higher than estimated the previous day.

Figure 10: South Australia operational demand forecast and actual during the 8th of February 2017



Source: AEMO (2017) *System event report South Australia, 8 February 2017*

A difficult situation was then made much worse by the failure of three gas, and two diesel generators to deliver power to meet peak demand, and the reduced capacity of two others due to "high ambient temperatures" (see figures 11 and 12 below).[28]

Overall, 438 MW of gas generation was unavailable during the peak demand episode that led to the blackouts of the 8th of February.[29] This is very significant in the context of a total peak demand of around 3,000 MW.

The 120 MW Torrens Island A1 generator was unavailable due to a boiler tube leak, and the B1 and B4 generators at the same plant were operating at 60 MW reduced capacity due to the heat.[30]

At 4.06pm, Engie notified AEMO that 73 MW of supply from their Port Lincoln diesel fuelled gas turbine power plant was unavailable due to a control signal fault.[31]

But the critical moment came at 5.39pm. Just as the system was reaching the operational peak demand, Engie informed AEMO that its 165 MW Pelican Point gas

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[28] AEMO (2017) *System event report South Australia, 8 February 2017*

[29] AEMO (2017) *System event report South Australia, 8 February 2017*

[30] AEMO (2017) *System event report South Australia, 8 February 2017*

[31] AEMO (2017) *System event report South Australia, 8 February 2017*

power station, “one of Australia's most advanced, efficient and environmentally friendly power stations”,[32] was not able to operate because it did “not have sufficient gas to run and if the gas were available, there would be a four-hour minimum run up time”.[33]

Figure 11: South Australian thermal generation – outages pre-existing the 8th of February 2017

Generating unit	Normal capacity	Actual capacity	Bid status	Reason
Torrens Island A1	120 MW	0 MW	Declared unavailable ahead of the day	Long term outage: boiler tube leak.
Pelican Point Gas turbine 12	165 MW	0 MW	Unavailable	Market participant bid as unavailable; confirmed unavailable at 1739 hrs with minimum start time of four hours.
Total capacity unavailable = 285 MW				

Source: AEMO (2017) *System event report South Australia, 8 February 2017*

Figure 12: South Australian thermal generation – forced outages on the 8th of February 2017

Generating unit	Normal capacity	Actual capacity	Bid status	Reason
Torrens Island B1	200 MW	150 MW	Available	Market participant reduced capacity bid at 1742 hrs 8 February due to high ambient temperatures
Torrens Island B4	200 MW	190 MW	Available	
Quarantine 4	20 MW	0 MW	Available	Market participant bid unavailable at 1718 hrs 8 February
Port Lincoln 1	50 MW	0 MW	Unavailable	Market participant bid unavailable 1607 hrs 8 February as a result of a control signal fault, caused by failure of electronics in the communications system.
Port Lincoln 3	23 MW	0 MW	Unavailable	
Total capacity reduction after 1600 hrs on 8 February = 153 MW				

Source: AEMO (2017) *System event report South Australia, 8 February 2017*

This coincided with a period of low wind generation which was higher than forecast the previous day, but lower than updated forecasts during the day.[34]

This led to a shortfall, meaning that more electricity had to be imported from Victoria over the Murraylink and Heywood interconnectors. However, the amount of electricity

[32] Engie (n.d.) *Pelican Point Power Station,* http://www.gdfsuezau.com/about-us/asset/Pelican-Point-Power-Station

[33] AEMO (2017) *Electricity Pricing Event Report - Wednesday 8 February 2017,* https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Pricing-Event-Reports/Feb-2017/08-February-2017---High-energy-price-SA.pdf

[34] AEMO (2017) *System event report South Australia, 8 February 2017*

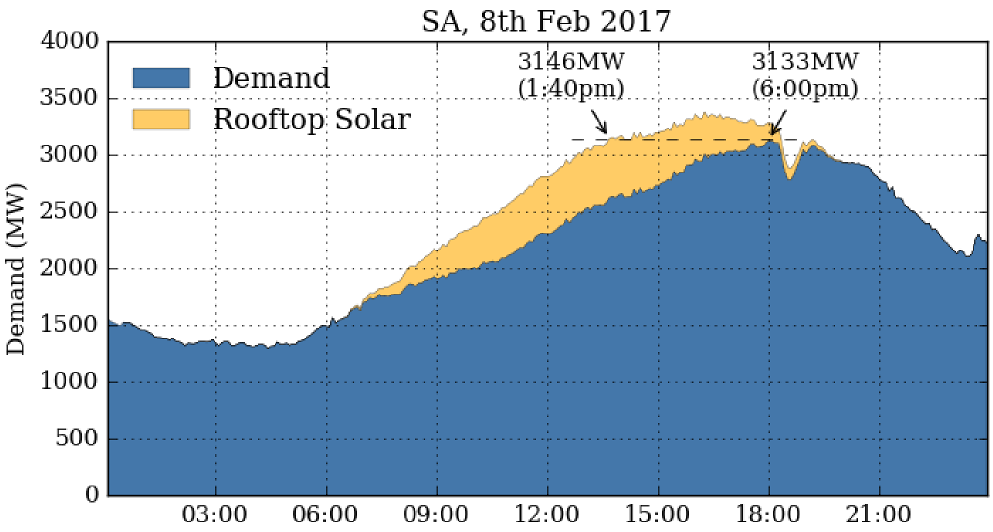
being imported over the Murraylink interconnector was above the safe limit meaning the power system was “not in a secure operating state”.[35]

Because there was no additional supply available in South Australia, with 438 MW of gas power and diesel capacity unavailable, AEMO required around 100 MW of load to be shed to bring the system back to a secure operating state. In fact, around 300 MW of load was shed. As a result, some customers had their electricity cut off for around half an hour.[36]

Solar PV delays and reduces peak demand

The crunch would have come much earlier had it not been for rooftop solar reducing demand. As shown in Figure 13 below, the level of demand of the operational demand peak of 3085 MW that occurred at 6pm would have been reached ***four hours and twenty minutes earlier*** at 1.40pm without the reduction in demand from rooftop solar. Demand would have then continued to ***rise a further 250 MW***. Without solar PV delaying and reducing peak demand, the consequences would have been far worse.

Figure 13: Total South Australian demand and rooftop solar generation on the 8th of February 2017



Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

[35] AEMO (2017) *System event report South Australia, 8 February 2017*

[36] AEMO (2017) *System event report South Australia, 8 February 2017*

Table 1: The impact rooftop solar on demand peak South Australia, 8th of February 2017

Peak Deferral (hours)	Peak deferral	Peak reduction (MW)	Peak Contribution (MW)	Peak Contribution (%)
SA 8th Feb	01:45	251.5	156.5	4.76%

Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

Since that time, a 150 MW solar thermal power plant with 8 hours energy storage has been approved for Port Augusta. The plant will be able to produce 135 MW in full sun and be able to dispatch the same output at full load for 8 hours.[37]

Had the plant already been operational, it would have been able to supply 135 MW over this period. Solar thermal power plants are designed for high temperature environments and as such are much less susceptible to problems with heat than thermal coal and gas plants.

NSW, 10TH OF FEBRUARY 2017

Two days later, on Friday the 10th of February, the same record-breaking heatwave hovered over New South Wales. That day the state hit an average of 42.4 degrees, and over 44 degrees on the Saturday. Before that Friday, the state as a whole had never had a February day of average temperatures above 42 degrees.[38]

The high temperature resulted in high energy demand of 14,181 MW, below the record of 14,744 MW[39] reached in a previous record-breaking heatwave in 2011.[40]

At the time of peak demand, several major coal and gas generators either failed completely or were operating at reduced capacity due to the heat. Overall, an extraordinary 2,438 MW of dispatchable fossil fuel generation failed to deliver during the peak demand period.[41]

[37] SolarReserve (2017) *Aurora,* http://www.solarreserve.com/en/global-projects/csp/aurora

[38] Hannam (2017) *Red hot: NSW smashes February state wide heat records two days in a row*

[39] AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*

[40] Scwartzkiff (2011) *Finally some relief after the hottest night in history*, http://www.smh.com.au/environment/weather/finally-some-relief-after-hottest-night-in-history-20110206-1aif4.html

[41] AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*

Two 500 MW units at Liddell coal power station were out of action due to faulty boiler tubes.[42]

At 11.05am that day the Eraring coal power plant, the largest coal power plant in Australia, notified the grid operator that all of its four 720 MW generating units would be operating well below capacity, three due to "plant temperature issues" and one due to a "minor boiler tube leak". At 1.55pm Origin Energy notified AEMO that Eraring's capacity would be reduced by a further 55 MW due to "a change in their license agreement". [43]

In total, this meant Eraring's output would be 19% or 540 MW below its capacity. Later, Eraring advised AEMO that the unit with the "minor boiler leak" would be able to "come on slowly" to 550 MW, meaning that overall Earing would operate at 390 MW,[44] 13% below capacity.

At 4.06pm Delta Energy notified AEMO that its Vales Point coal power plant was "within one degree of its absolute outlet temperature limit" and could only supply full output of 660 MW from each of its two units for the next 1.5 hours, then down to 600 MW each, a loss of 120 MW around the crucial 5.30pm period. [45]

Then, at the crucial moment between 4 and 5pm, as electricity demand was reaching its peak, two gas fired power plants, designed specifically to generate electricity at exactly these circumstances of high demand, each failed, wiping a further 1,000 MW from the energy available to the grid.

At 4.22pm the 435 MW Tallawarra combined cycle plant at Wollongong suddenly went offline completely due to a fault in the gas turbine, and stayed offline until 6.30pm, after the ensuing crisis.[46]

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[42] AGL (2017) *AGL injecting $2 billion to improve energy affordability and reliability,* https://www.agl.com.au/about-agl/media-centre/asx-and-media-releases/2017/september/agl-injecting-%242-billion-to-improve-energy-affordability-and-reliability

[43] AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*

[44] AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*

[45] AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*

[46] AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*

At 4.50pm all four units of the 600 MW Colangra gas power plant failed to start and weren't able to come back online until 5.15pm, too late to prevent load shedding to the Tomago aluminium plant.[47]

The three interconnectors to New South Wales were above their limits from approximately 4.30pm to cover the gap left by the Tallawarra gas plant failure. This meant the power system was insecure, and when Colangra also failed to start, AEMO ordered Transgrid to shed 290 MW of load to the Tomago Aluminium smelter.[48]

Thus, at the critical operational peak demand at 5pm on 10th of February, around 2,438 MW of fossil fuel capacity was unavailable due to faults, largely related to the heat.

Table 2: Outages and reduced capacity from fossil fuel generators in New South Wales during peak demand at 4.30pm on 10th of February 2017

Power station	Fuel	Capacity lost due to faults (MW)	Cause
Liddell	Coal	1,000	Boiler tube faults
Eraring	Coal	340	Boiler tube leak in Unit 3 and heat issues with units 1,2 and 4
Vales Point	Gas	90	Heat issues
Tallawarra	Gas	408	Outage due to turbine fault
Colongra	Gas	600	Unable to start due to low gas pressure in the fuel supply lines
Total		*2,438*	

Source: AEMO (2017) *System event report New South Wales, 10 February 2017*

Solar PV delays and reduces peak demand

As bad as this was, it could have been a lot worse without renewables. At the 5pm peak, large-scale wind and solar provided a combined 416 MW, and solar PV reduced

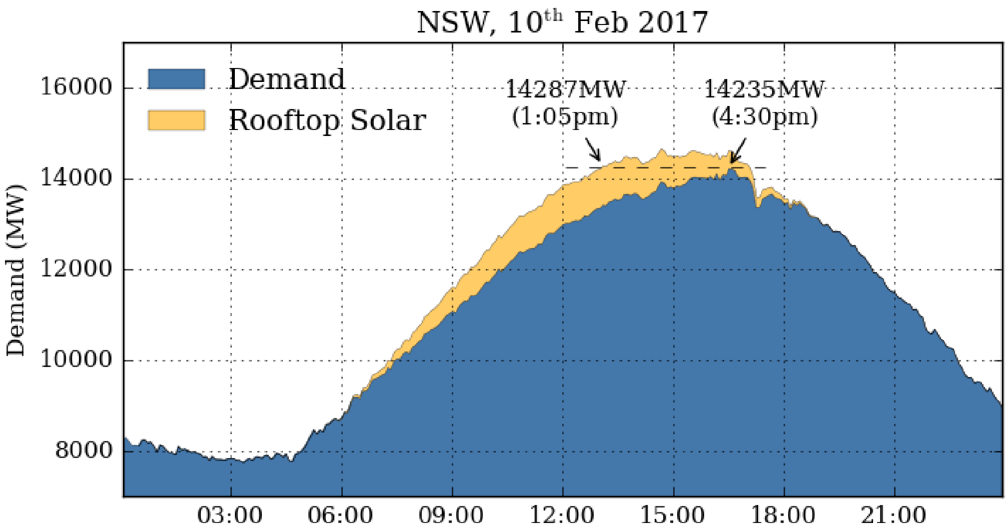
[47] AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*

[48] AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*

underlying demand by an estimated 433 MW, bringing the total contribution to 849 MW.

As with the situation in South Australia, rooftop solar significantly reduced and delayed peak demand. As shown in Figure 14 below, the level of demand reached at the operational demand peak (14,235 MW) at 4.30pm would have been reached almost ***three hours and a half hours earlier,*** at 1.05pm, if small scale solar had not reduced underlying demand. Demand would have then continued to climb an additional 433 MW, resulting in considerably more load shedding and possibly blackouts.

Figure 14: Total New South Wales demand and rooftop solar generation, 10th of February 2017



Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

Table 3: The impact rooftop solar on demand peak New South Wales, 10th of February 2017

	Peak deferral (hours)	Peak reduction (MW)	Peak contribution (MW)	Peak Contribution (%)
NSW 10th Feb	01:50	432.9	394.8	2.70%

Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

As Giles Parkinson put it:

> It is now clear that solar (rooftop and large scale) was contributing more than 1GW to the grid during much of the day, and around 500MW in the late

afternoon on Friday when the Australian Energy Market Operator had flagged the possibility of rolling blackouts.[49]

It was also reported that analysis from by Energy Synapse found that over three days of the February 2017 heatwave, the reduction in demand from small scale solar reduced wholesale electricity prices by over the $888 million.[50]

QUEENSLAND, 12TH OF FEBRUARY 2017

By Sunday the 12th of February, the impacts of the heatwave began to seriously affect Queensland's electricity generation. That day, Queensland was experiencing record temperatures. Brisbane reached 37.6 degrees, almost eight degrees above the February average maximum, following on from 37 degrees the previous day.[51]

These extreme temperatures led to record electricity demand of 9,369 MW at 5.30pm.[52]

In the four hours period prior to the 5.30 trading interval, 787 MW of coal and gas generation was withdrawn due to technical failures, mostly (and possibly entirely) due to the heat (see Figure 16 below).[53]

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[49] Parkinson (2017) *Record solar, wind "save" NSW consumers as coal, gas went missing*, http://reneweconomy.com.au/record-solar-wind-save-nsw-consumers-as-coal-gas-went-missing-79390/

[50] Parkinson (2017) *Record solar, wind "save" NSW consumers as coal, gas went missing*, http://reneweconomy.com.au/record-solar-wind-save-nsw-consumers-as-coal-gas-went-missing-79390/

[51] AER (May 2017) *Electricity spot prices above $5000/MWh Queensland,* https://www.aer.gov.au/system/files/Prices%20above%20%245000MWh%20-%2012%20February%202017%20%28QLD%29.docx_0.pdf

[52] AER (May 2017) *Electricity spot prices above $5000/MWh Queensland,* https://www.aer.gov.au/system/files/Prices%20above%20%245000MWh%20-%2012%20February%202017%20%28QLD%29.docx_0.pdf

[53] AER (May 2017) *Electricity spot prices above $5000/MWh Queensland,* https://www.aer.gov.au/system/files/Prices%20above%20%245000MWh%20-%2012%20February%202017%20%28QLD%29.docx_0.pdf

Figure 15: Queensland Capacity withdrawn within four hours of the 5.30pm trading interval on the 12th of February 2017

Participant	Capacity priced below $5000/MWh (MW)	Capacity priced at or above $5000/MWh (MW)	Rebid Reasons	Total MW
CS Energy	85	10	Over nine rebids, technical issues and condenser limits	95
Origin	28		Over four rebids, change in ambient conditions and backpressure limitation	28
Millmerran	60		Over two rebids, condensate polisher inlet temperature	60
Arrow Energy	148		Over one rebid, delayed return to service	148
Stanwell	315	141	Over 11 rebids, emissions and condenser vacuum limits	456
Total	**636**	**151**		**787**

Source: AER (May 2017) *Electricity spot prices above $5000/MWh Queensland*

Most of this capacity, 636 MW, was "low-priced capacity", at prices at under $5000 MWh. According to the Australian Energy Regulator, the withdrawal of this low-priced capacity was one of the main reasons for the high price events of the day.[54]

Due to constraints on the interconnectors between Queensland and NSW, very little electricity could be imported from New South Wales meaning that almost all generation had to come from Queensland.

Dispatch prices reached $13,000 MWh eleven times between 4.30pm and 7.30pm, contrasting with forecasts of prices of just $290 MWh made just four hours previously, before the heat affected gas plants withdrew their capacity.[55] Sundays are usually a time of relatively low demand given many businesses and industrial users are closed.

[54] AER (May 2017) *Electricity spot prices above $5000/MWh Queensland,* https://www.aer.gov.au/system/files/Prices%20above%20%245000MWh%20-%2012%20February%202017%20%28QLD%29.docx_0.pdf

[55] Ibid.

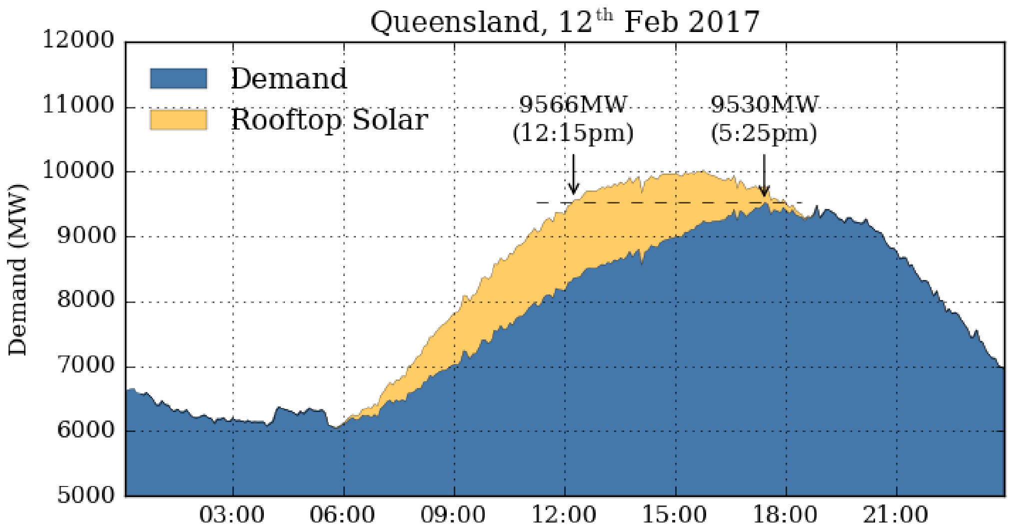
Solar PV delays and reduces peak demand

As with South Australia and New South Wales, rooftop solar significantly delayed and reduced peak demand almost certainly avoiding much more serious consequences.

As shown in Figure 16 below, the level of demand reached at the operational demand peak (9,530 MW) at 5.25pm would have been reached five hours and fifteen minutes earlier at 12.15pm if small scale solar had not reduced underlying demand.

Demand would have then continued to climb an additional 502 MW, almost certainly resulting in load shedding and potentially blackouts.

Figure 16: Total Queensland demand and rooftop solar generation, 12th of February



Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

Table 4: The impact rooftop solar on demand peak Queensland February 12th, 2017

	Peak Deferral (hours)	Peak reduction (MW)	Peak Contribution (MW)	Peak Contribution (%)
QLD 12th Feb	01:40	502.5	259.0	2.65%

Source: Provided by Dylan McConnell, German-Australian Climate and Energy College, University of Melbourne

Unfortunately, Queensland has virtually no large scale solar or wind that would further mitigate these kinds of events, although the Queensland Government has introduced a 50 per cent by 2030 renewable energy target, including an energy storage component which will increase Queensland's energy security.

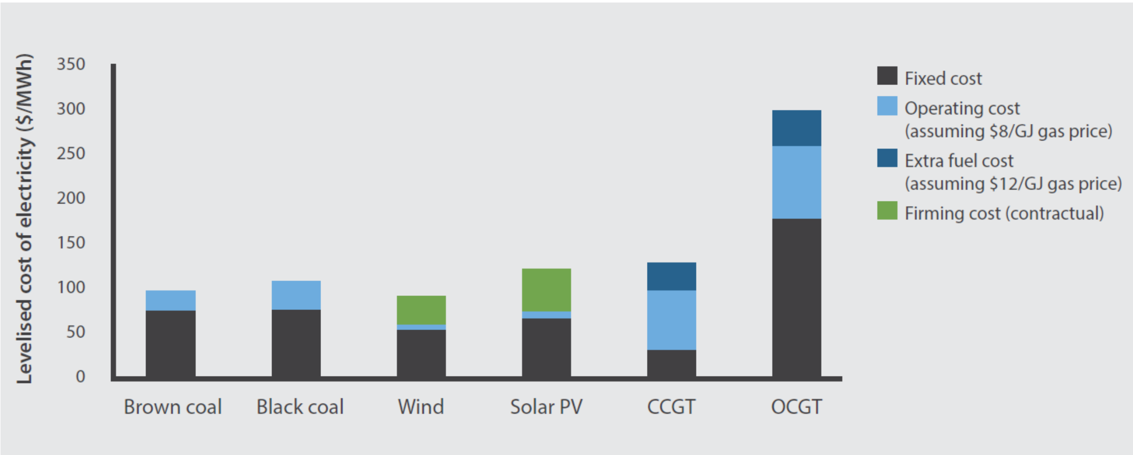
Renewable energy dispatchable solutions

Wind and solar PV are far less susceptible to large scale outages than coal and gas plants, as individual wind turbines and solar panels are the actual generating units, and are usually a few megawatts at most. A breakdown of a 2 MW wind turbine is of less consequence than the breakdown of a 500 MW turbine at Liddell.

However, wind is not a dispatchable generation source unless it is paired with firming power. This firming power could be one of a number of technologies including, pumped hydro with energy storage (PHES), open cycle gas turbine or battery storage as Tesla is building at Hornsdale Wind Farm in South Australia.

The value of wind and solar PV is that they generate low cost electricity that is dispatched to the grid when they are available to reduce the need for higher cost dispatchable energy sources. As shown in Figure 17, the cost of wind and solar are now so low that it is far cheaper to build a new solar or wind farms than provide the electricity from existing combined cycle gas plants.

Figure 17: Implied cost of new generation.



Source: Finkel (2017) *Independent Review into the Future Energy Security of the National Electricity Market Final Report*. Adapted from AGL (2017) *A future of storable renewable energy*, p 6

While renewable sources can usually provide the bulk of electricity required, they need to be supplemented by power plants that can dispatch electricity on demand to fill gaps when wind and solar PV output is low.

The key issue is whether this dispatchable power should be provided by coal and gas generators or sources that do not rely on coal and gas as fuel sources.

In Figure 17 above, AGL assumes the “firming costs” in green are provided by gas peaking generation. However, there are several commercially available options that do not do not have the reliability drawbacks of gas power plants, including solar thermal, pumped hydro, battery storage and demand response. All are able to dispatch electricity to the grid quickly and reliably and at affordable prices.

COMPARING THE COSTS OF DISPATCHABLE ENERGY SOLUTIONS

One measure of the relative costs of different electricity generation technologies is the Levelised Cost of Energy (LCOE). This measures the average cost of producing electricity from a particular technology over its life.

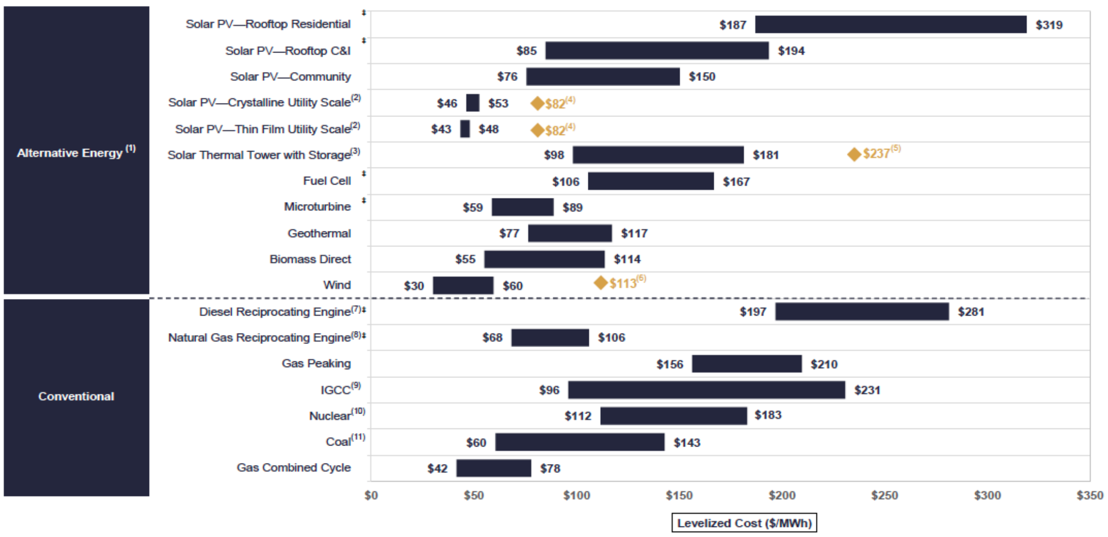
The two key flexible dispatchable energy systems are solar thermal power with storage and open cycle gas turbines (OCGT), or “Gas Peaking” as it is represented in the Lazard table below. These technologies provide very similar services, providing energy almost instantaneously to the grid to meet fluctuating demand.

Globally, electricity from solar thermal with storage is considered far lower cost than from gas peaking plants. As shown in Figure 18 below, the unsubsidised cost of solar thermal power with storage is considered to be as low cost as $98 MW (USD), while gas peaking plants have a range of $156-210 MWh (USD)

In Australia, no solar thermal power plants have yet been completed, so the cost is more uncertain, however Lazard do have an Australian specific cost for gas peaking plants, which is higher again at $165–223 MWh (USD).[56]

[56] Lazard (2017) *Levelised Cost of Energy Analysis, Version 11.0*, p 8.

Figure 18: Unsubsidized Levelised Cost of Energy Comparison



Source: Lazard (2017) *Levelised Cost of Energy Analysis, Version 11.0*

However, the LCOE doesn't take into account value of flexibility and dispatchability by technologies with energy storage. For example, open cycle gas peaking plants (OCGT) are still built despite being up to 300–500% higher than the volume weighted wholesale price of electricity on the NEM.[57]

When meeting demand peaks is a challenge due to either high levels of variable power supply or the susceptibility of generators to outages, the availability of additional capacity is valued. A measure of the cost of supplying this additional capacity (as distinct from supplying energy) for various technologies is the Levelised Cost of Capacity (LCOC).

University of Melbourne researchers have estimated the LCOC enables us to compare the costs of various other technologies such as battery, PHES and CCGT, as shown in Figure 19 below. The wide range of costs largely reflects the uncertainty in the capital cost for the technologies.

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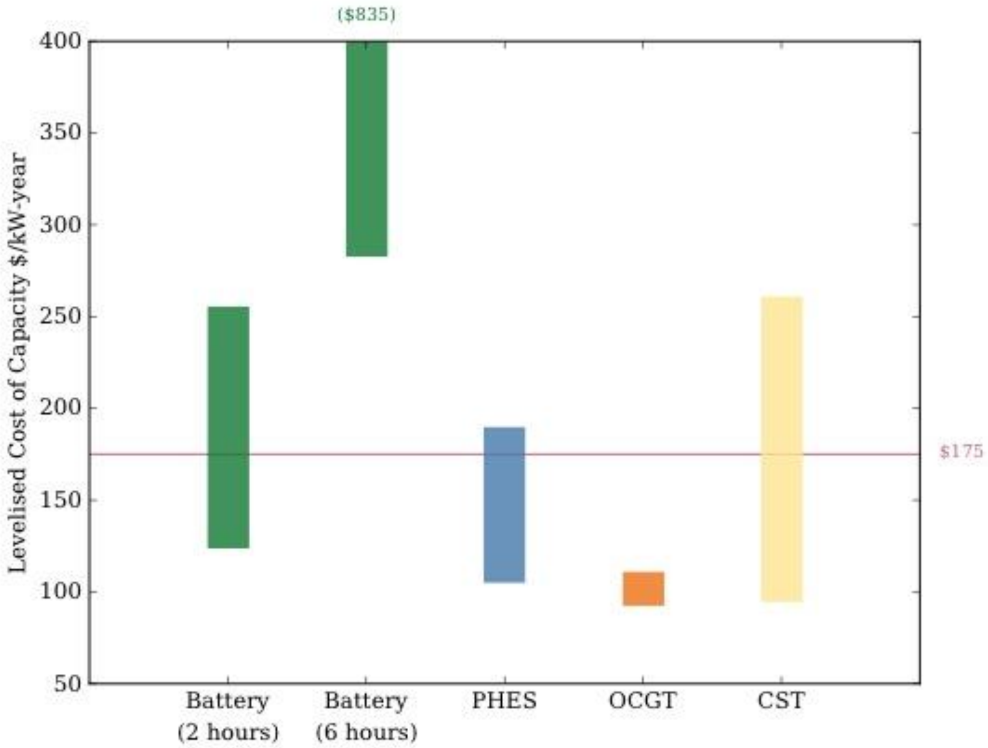
[57] McConnell and Sandiford (2016) *Winds of change: An analysis of recent changes in the South Australian electricity market*

Figure 19: Comparison of the Levelised cost of Capacity (LCOC) for various dispatchable technologies



Source: McConnell and Sandiford (2016) *The Winds of Change: An analysis of recent changes in the South Australian Electricity Market*

Note: Aurora solar thermal PPA inserted by The Australia Institute.

SOLAR THERMAL (CST)

Solar thermal power plants use mirrors to focus the sun's energy to heat molten salt, which is stored and used to create steam that can be used to drive the same type of steam turbine found in a coal plant. Molten salt stored in hot tanks can be dispatched on demand to create steam, drive the turbine and generate electricity.

Solar thermal power plants, such as the one being built in Port Augusta in South Australia, can have eight hours of storage at full power. They are far cheaper than battery storage, particularly over multiple hours of storage, and are competitive with gas power plants.

They also generate electricity during the day, unlike battery and pumped hydro which store energy from other sources rather than generate renewable energy themselves.

The Solar Reserve Aurora solar thermal plant won a competitive tender open to all dispatchable energy generators, including coal and gas, by bidding the cheapest generating price of $78 MWh.[58]

As discussed above, LCOE of solar thermal is considered to be between $96–181 MWh (USD), far lower than gas peaking. The Levelised Cost of Capacity (LCOC) estimates by the University of Melbourne show a similar range.

It is worth noting that in both the LCOE and LCOC comparisons above, the analysis does not take into account that solar thermal has the important advantage of also being able to dispatch significant amounts of additional energy when the storage tanks are sufficiently charged and the sun is shining. This reduces overall wholesale prices and adds supply during heatwave conditions. Open cycle gas plants only dispatch at times of high prices, and as such do not have this option of supplying additional bulk energy.

Solar thermal plants use dry cooling systems to cool the steam back to water for reuse in the steam turbine. Some coal plants use dry cooling but almost all are water cooled.[59] With dry cooling, steam from the turbines is cooled in an air-cooled condenser. This dry cooling system uses 90% less water than the water based cooling systems, such as recirculating or once-through systems, that are used in almost all thermal coal and gas power plants.[60]

Given the failure of Tallawarra and Colangra Power plants in New South Wales at the critical heatwave peak demand moments on the 10th of February, solar thermal is also likely to be a more reliable flexible dispatchable power option in these circumstances than open cycle gas turbines

PUMPED HYDRO WITH ENERGY STORAGE

Pumped hydro with energy storage uses excess electricity available in periods of low demand to pump water uphill to a high reservoir or dam, where it can be stored. In periods of high demand the water can be released downhill to generate electricity through a hydro powered generator, and stored at a low reservoir or dam. This process

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[58] Holmes a Court (2017) *Aurora: What you should know about Port Augusta's solar power tower,* http://reneweconomy.com.au/aurora-what-you-should-know-about-port-augustas-solar-power-tower-86715/

[59] Only the Kogan Creek and Millmerran power stations in Queensland are dry cooled.

[60] Smart and Aspinall (2009) *Water and the electricity generation industry*

recovers most but not all of the original incoming electricity, as some energy is used in the process of pumping the water uphill.[61]

Pumped hydro does not add any additional energy to the grid, but provides storage capacity that can complement wind and solar PV generation in low demand times. It can store excess energy from wind and solar PV produced in peak times, and dispatch it as needed. Powered by wind and solar PV, pumped hydro would be a reliable option for electricity generation in heatwaves as wind turbines and hydro turbines do not require any cooling to operate. In addition, pumped hydro is competitive in cost compared to building new open cycle gas plants, and does not present the same energy security risk.

BATTERY STORAGE

Batteries can be used to store energy both at a household level and at a large-scale level.

The widespread introduction of lithium-ion batteries in 2016 dramatically cut the cost of installing batteries and costs continue to fall. Responding to this fall in price, batteries are being installed at records rates to store the energy produced from household and commercial solar PV systems, and wind and solar PV farms.[62]

Battery storage is competitive with gas as dispatchable energy storage for short periods, and coming down rapidly in price. It is very quick to install as demonstrated by Tesla's 100 MW Hornsdale battery project that will be delivered in 100 days in South Australia.[63] This project will store energy from the Hornsdale Wind Farm and release it on demand as well as providing ancillary services to the grid.[64]

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[61] Blakers et al (2017) *An atlas of pumped hydro energy storage,* http://re100.eng.anu.edu.au/research/phes/

[62] ABC (2017) *Solar batteries 'exploding' in popularity with uptake tipped to triple in 2017, audit finds,* http://www.abc.net.au/news/2017-02-14/solar-batteries-like-tesla-exploding-in-popularity/8259830

[63] Potter (2017) *Elon Musk's Tesla jumps gun on 100 day SA battery bet*, http://www.afr.com/news/elon-musks-tesla-jumps-gun-on-100-day-sa-battery-bet-20170928-gyqub8#ixzz4xLN3Coil

[64] Parkinson (2017) *Explainer: What the Tesla big batter can and cannot do,* http://reneweconomy.com.au/explainer-what-the-tesla-big-battery-can-and-cannot-do-42387/

DEMAND RESPONSE

In contrast to the solutions above that increase supply and energy storage, demand side management is an energy security solution that does not require new expensive infrastructure. Aggregated demand response is the management of consumer demand to match supply in the electricity market. It encourages consumers to reduce their demand during periods of low supply, by offering lower tariffs to consumers that use aggregated demand response devices.

Aggregated demand response devices turn down or turn off appliances during periods of peak demand, for example by turning down the refrigerator in a cool room during a heat wave, ensuring that the temperature still stays below the 5 degrees required for food storage. By managing the demand of appliances in a centralised way, aggregated demand response can save hundreds of megawatts of demand and help avoid blackouts.[65]

SOLAR PV

Solar PV becomes a dispatchable energy source with battery storage installed. One in five Australians have solar PV on their roof, and battery installations are increasing rapidly. Solar PV with battery storage has the potential to dramatically cut peak demand.

Even without battery storage, however, solar PV brings down peak demand and increases energy security.

Solar PV (without battery storage) meant that peak demand in South Australia, Queensland and New South Wales during the February 2017 heatwave was delayed by several hours in each case. Without solar PV, the ensuing crisis would have been far more serious.

Modelling was undertaken in NSW by Energy Synapse in 2017 looking at the effect of rooftop solar on energy prices and the duration of peak demand in New South Wales.[66]

This study found that despite making up only 2 percent of electricity generation in the state, rooftop solar reduced the wholesale cost of electricity in New South Wales over

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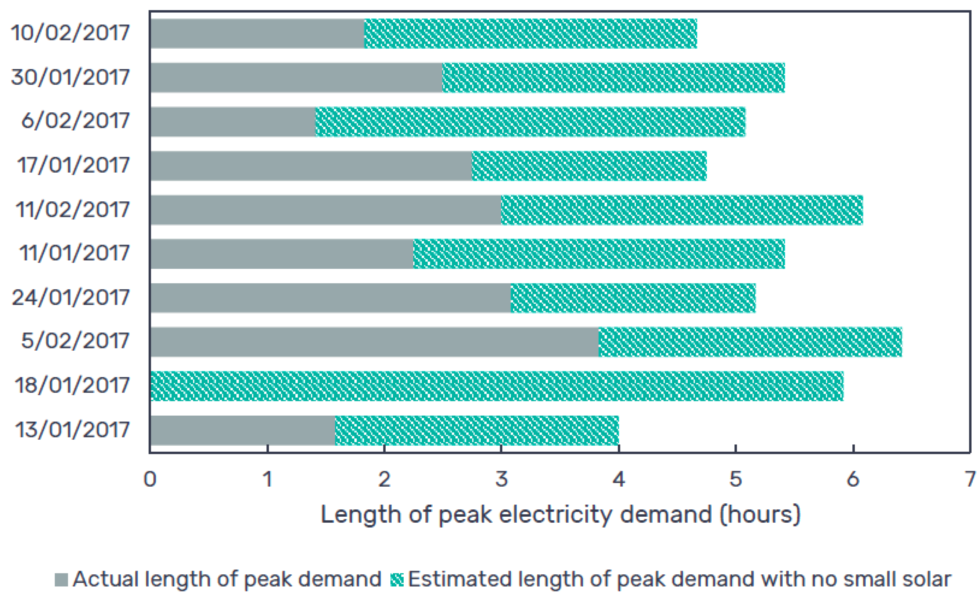
[65] Cass (2017) *Saving mega bucks with negawatts,* http://www.tai.org.au/content/report-saving-mega-bucks-negawatts

[66] Energy Synapse (2017) *Impact of small solar PV on the NSW wholesale electricity market*

twelve months by 33-50%. This represented a saving of $2.2-3.3 billion dollars shared by all New South Wales consumers, whether or not they had solar panels.

The study also found that over the top ten demand days on January and February this year (2017), solar reduced peak demand by an average of 432 MW, and the length of peak demand by 58 percent from 5.3 to 2.2 hours (see Figure 20 below).

Figure 20: Comparison of the length of peak demand across the top 10 demand days in New South Wales over January and February 2017.



Source: Energy Synapse (2017) *Impact of small solar PV on the NSW wholesale electricity market*

Recommendations

Under the Reliability Guarantee of the National Energy Guarantee (NEG) recommendations of the Energy Security Board (ESB), retailers would be required "to hold forward contracts with dispatchable resources that cover a predetermined percentage of their forecast peak load. The amount and type contracted would be based on the system wide reliability standard as determined by the Reliability Panel at the AEMC"[67]

To "cover a predetermined percentage of their forecast peak load" does not appear to take into account that the dispatchable resources contracted may themselves be unreliable, including in heatwave conditions.

Given heatwaves conditions are the greatest challenge to the reliability of the NEM, we recommend that the Reliability Standard applies to these "dispatchable resources"

If a "dispatchable resource" has have a history of unplanned outages (including in heatwave conditions), or is vulnerable to conditions of extreme heat due to age, condition or reliance on water cooling, it should require "heat safe" flexible disptchable capacity to be contracted to cover the risk of the types of outages experienced in the February 2017 heatwaves.

"Heat safe" generating assets would include flexible disptchable systems that are designed for hot conditions and not considered vulnerable to extreme heat, like (air cooled) solar thermal with storage, battery storage and potentially pumped hydro with storage depending on water availability.

This could also include solar PV due to its proven ability to reduce underlying demand and delay and reduce peak demand in heatwave conditions. The addition of battery storage to solar PV would enhance its ability to mitigate heatwave impacts by allowing power to be dispatched into the evenings of hot days while demand remains high.

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[67] Energy Security Board (2017) *Energy Security Board (SEB) advice on retailer reliability, emissions guarantee and affordability*

Conclusion

Climatic conditions in Australia are changing dramatically as a result of global warming. We are entering an era of more frequent, more intense and longer heat waves. Events like the February 2017 heatwave described above that were previously considered extremely rare “one in 500 year events” are likely to occur every few years by mid-century.

Not only do these heatwaves dramatically increase demand for electricity, but our electricity system is not designed to cope with these conditions. Coal and gas generators rely on cooling systems that make them significantly less efficient in hot weather, and increase the risk of breakdowns.

This problem is amplified by the size and age of these power plants.

The age of power plants also affects the risk of faults and outages. The National Electricity Market relies on an ageing fleet of coal and gas power plants. The median age of our coal plants is 30 years, beyond their design life. Some of the largest plants are well over that age.

Each fossil fuel power stations is mostly made up of a few large generating units. This means that when they do break down large amounts of supply can be lost instantaneously and without warning.

The February 2017 heat wave has demonstrated the vulnerability of the fossil fuel fleet to heatwave conditions and the resulting risk to energy security.

However, it has also demonstrated the value of solar in particular in delaying and reducing demand peaks during heatwaves. Solar PV significantly reduced demand peaks on these critical days and delayed them by several hours. The impacts of the heatwave events would undoubtedly have been far worse without solar.

Fortunately, there are also several new dispatchable energy technologies that do not have the vulnerabilities of coal and gas power plants, and are already competitive with coal and power plants, and in some cases cheaper.

These include solar thermal with storage (CST), pumped hydro with energy storage (PHES) and lithium-ion battery storage. Battery storage and PHES can store electricity produced by variable wind and solar PV.

There is an abundance of proponents for these systems, and the shift is already under way. Solar thermal, PHES and utility scale battery projects underway in South Australia. The Queensland government's Renewables 400 project receiving over 4,000 MW of renewable energy storage proposals.

The failure to replace ageing and vulnerable fossil generators with these dispatchable solutions in a timely manner has also led to a reliance on very expensive and polluting diesel generation and reopening gas peaking plants that are more expensive and less reliable than non-fossil alternatives.

The only real danger to the reliability of the NEM is misguided government policy propping up vulnerable coal and plants and delaying the inevitable rollout of this new generation of dispatchable generation technology.