# Watt on a hot tin roof

## How rooftop solar increases reliability and reduces electricity prices

***Rooftop solar generates best on hot sunny days, exactly the conditions that see gas and coal generation at risk of breakdown. This summer rooftop solar reduced demand peaks in the National Electricity Market by over 2000 MW, while a breakdown at a major coal generator contributed to wholesale electricity prices hitting $12,000 MWh.***

Discussion paper

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# Summary

Hot days present the greatest challenge for the National Electricity Market (NEM) to supply our electricity needs. There are two main reasons for this. Firstly, the highest demand for electricity occurs on hot days, due to increased use of air-conditioning. Daily peak demand can more than double - in Melbourne this summer demand on cooler days peaked around 4,000MW, but approached 9,000MW on the hottest days.

Secondly, gas and coal power stations are less efficient and break down more frequently in very hot weather.

Conversely, rooftop solar produces electricity best on hot days, as they are usually very sunny. They can directly contribute to powering air-conditioning (and other uses) reducing the demand for electricity from the grid.

Rooftop solar consistently reduces the size of the crucial summer day demand peaks and delays the timing of the peak to later in the day. This reduces the amount of electricity needed from large-scale generators. As such it increases the reliability and resilience of the grid, providing power when gas and coal plants are most likely to fail, and when the consequences of those breakdowns would be most serious.

January 18, 2018 was very hot. It was the second highest demand day in the NEM over January. On that day, Victoria's Loy Yang B coal power station broke down, reducing NEM capacity by over 500 MW almost instantaneously. Wholesale electricity prices then soared to over $12,000 per MWh.

Fortunately, that day rooftop solar reduced peak demand in the various NEM states by around 1,600 MW overall, three times the amount lost by the Loy Yang B breakdown and 50% greater than the full capacity of Loy Yang B Power Station. Without solar, the consequences of the breakdown would have been far worse.

The next day, January 19, was also over 40 degrees, and the highest demand day in the NEM for all of January. That day solar reduced peak demand in NEM states by a total of over 2000 MW, twice the full capacity of Loy Yang B.

As more people acquire battery storage to store excess electricity from their solar panels, they will be able to use that electricity after the sun goes down, which will have the effect of further reducing and delaying peak grid demand.

If rooftop solar did not delay and reduce peaks in this way, more large power stations would need to be built. These are ultimately paid for via consumers' electricity bills. Providing further incentives to increase rooftop solar in the NEM is one of the most effective ways of increasing the reliability and lowering the cost of electricity.

# Introduction

The greatest challenge for Australia's electricity system is to meet electricity demand in periods of extreme heat. On very hot days, electricity demand is driven to high levels that come close to exceeding the amount of electricity that the NEM can provide. This is largely as a result of increasing demand for air-conditioning.

While there are typically only a few days each summer with these conditions, they are of critical importance, because the electricity system needs to be sized to have adequate generating capacity to supply enough electricity on these days.

Currently around 72 percent of the generation capacity of the NEM is from coal and gas power stations.[1] Coal and gas power stations are particularly vulnerable to these extreme heat conditions. This includes reduced output as a result of lower efficiency and sudden breakdowns, which regularly result in the sudden and unexpected loss of hundreds of megawatts of capacity.

During the February 2017 heatwave for example, multiple coal and gas plants experienced breakdowns or reduced their output as a result of the high temperatures.[2] Over the summer of 2017/18 there were 44 major breakdowns at gas and coal power plants in the National Electricity Market.[3]

This vulnerability will only increase over time. Extreme heat events are steadily increasing Australia wide as a result of global warming.[4] At the same time, as the gas and coal fleet ages, it will become increasingly vulnerable to heat-related breakdowns.

While gas and coal plants become less reliable on hot days, solar can be relied upon to consistently produce electricity on hot days, simply because there is more solar radiation in these conditions.

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[1] AEMO Generation information Page, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information

[2] AEMO (2017) *System event report South Australia, 8 February 2017;* AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*; 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

[3] The Australia Institute Climate & Energy Program (2018) *Gas and Coal Watch,* http://www.tai.org.au/climate-energy-program

[4] AEMO (2018) *AEMO observations: Operational and market challenges to reliability and security in the NEM*, p 5, https://www.aemo.com.au/-/media/Files/Media_Centre/2018/AEMO-observations.pdf

Because the output of rooftop solar panels is either used in situ by consumers or is put into the distribution system and used locally, in total it reduces the quantity of electricity required to be supplied by the NEM grid.

This means that ultimately fewer large-scale power plants are required to meet peak electricity demand by consumers on these critical hot days.

This increases the resilience and reliability of the electricity supply. Every megawatt of reduced demand is a megawatt that doesn't have to be supplied by coal and gas power plants that are unreliable in these extreme conditions. A megawatt of reduced demand cannot break down in the heat.

Without solar additional large-scale power stations would need to be built to supply peak demand on hot days. This it is a cost that would ultimately born by electricity consumers through higher electricity prices.

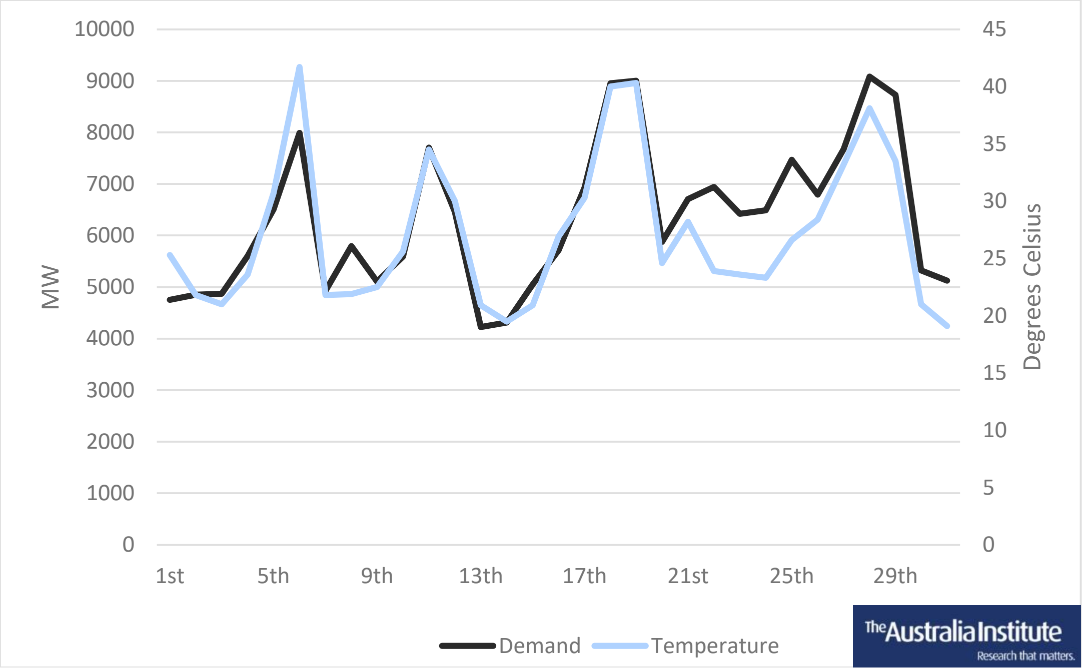
As such, households and businesses with rooftop solar are not only increasing the resilience and reliability of our electricity supply when it is most needed but are also saving all consumers the cost of building additional power plants.

# Extreme heat drives high demand

Hot days result in high demand for electricity largely as a result of people turning on their air-conditioners to cope with the heat.[5]

Figure 1 below shows the strong correlation between hot days and high demand in Victoria with maximum demand reaching little more than 4,000MW on cooler days, but over 8,000 and up to 9,000MW on the hottest days.

**Figure 1: Victorian daily maximum electricity demand compared to Melbourne maximum daily temperature, January 2018**




Source: Bureau of Meteorology (n.d.) *Climate data online*; AEMO (n.d.) *Aggregated price and demand data – historical*

Our electricity network needs to be able to supply enough electricity to meet peak demand. This means that sufficient capacity at our power stations needs to be available to generate enough electricity to meet those peaks.

Because the output of rooftop solar panels is either used in situ by consumers or is put into the distribution system and used locally, in total it reduces the quantity of electricity required to be supplied by the NEM grid. This means that fewer large-scale power plants are required to meet peak electricity demand by consumers on hot days.

[5] SA.gov.au (n.d.) *Air conditioning energy efficiency requirements,* https://www.sa.gov.au/topics/energy-and-environment/energy-efficient-home-design/air-conditioning

# Gas and coal plants break down in the heat

Most gas and coal power plants lose efficiency and generate less power on hot days. They also break down more frequently in these conditions. This is particularly the case with power plants that are water cooled as almost all Australian coal plants and many gas plants are.

Thermal power plants burn coal or gas to heat water in order to create steam. This steam is used to drive a turbine that in turn drives a generator that produces electricity. The steam then needs to be cooled to change back to water and begin the process again. These plants use water run through condensers to absorb the heat from the exhaust steam and cool it enough to return it to a liquid state in order to be re-used. These cooling systems are less effective in very hot weather, which reduces the overall efficiency of the power plants.

This water is usually supplied by rivers, and sometimes the ocean. When the temperature of this water is higher as a result of high ambient temperatures, it increases the condenser pressure, which reduces the efficiency of the plant. The reduced efficiency of the plant results in lower output.[6]

This impact was particularly demonstrated during the February 2017 heatwave for example, when multiple coal and gas plants reduced their output as a result of the high temperatures.[7] The vulnerability of gas and coal power plants to breaking down in hot weather was also vividly demonstrated during the February 2017 heatwave[8], and the experience this summer (2017/18) with 44 major breakdowns at gas and coal power stations over the summer period.[9]

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[6] IEA, Coal Industry Advisory Board (2010), Power Generation from Coal Measuring and Reporting Efficiency Performance and CO2 Emissions, https://www.iea.org/ciab/papers/power_generation_from_coal.pdf

[7] AEMO (2017) *System event report South Australia, 8 February 2017;* AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*; 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

[8] Ogge and Aulby (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

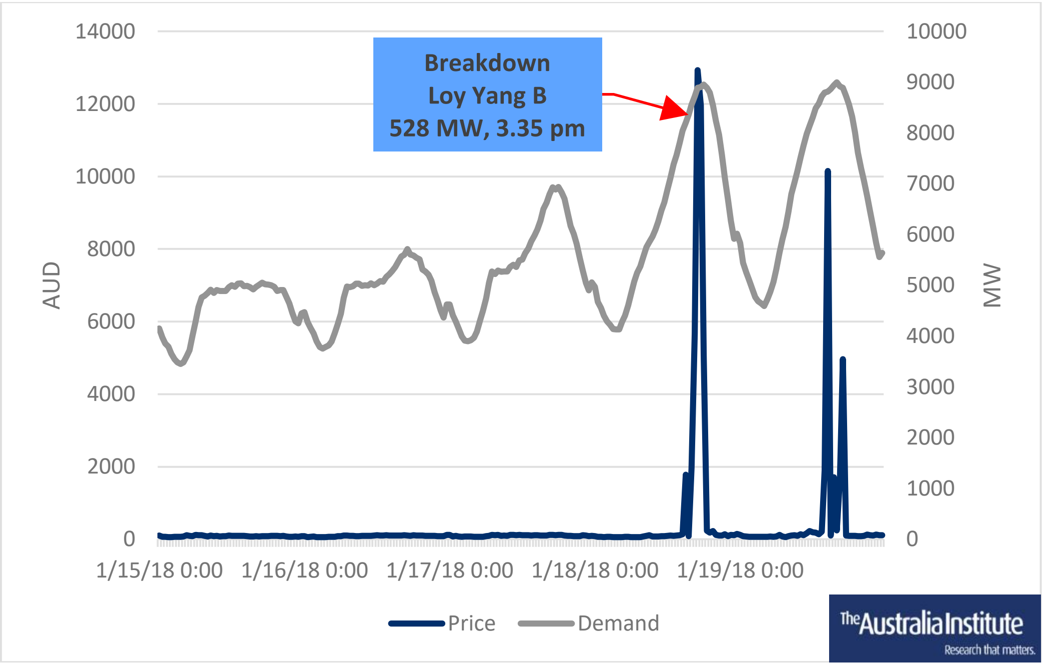
[9] The Australia Institute, Climate and Energy Program (2018) Gas and Coal Watch, http://www.tai.org.au/gas-coal-watch

One of these breakdowns was at Loy Yang B brown coal power station in Victoria on 18 January this year.  18 January was a very hot day (reaching 40 degrees Celsius) with very high electricity demand. The following day also reached 40 degrees.

That day Victorian electricity demand reached 8,989 MW at 6.30 pm,[10] very close to the highest summer demand of 9,159 MW.[11]

As shown in 2 below at 3:35 PM, just as demand reached very high levels, Unit 1 of Loy Yang B power station tripped, reducing the grid's capacity by 528 MW immediately and without warning. By 5.30 pm, the wholesale electricity price had soared to over $12,000 MWh.

**Figure 2 Electricity demand and price January 15-19 with Loy Yang B breakdown**



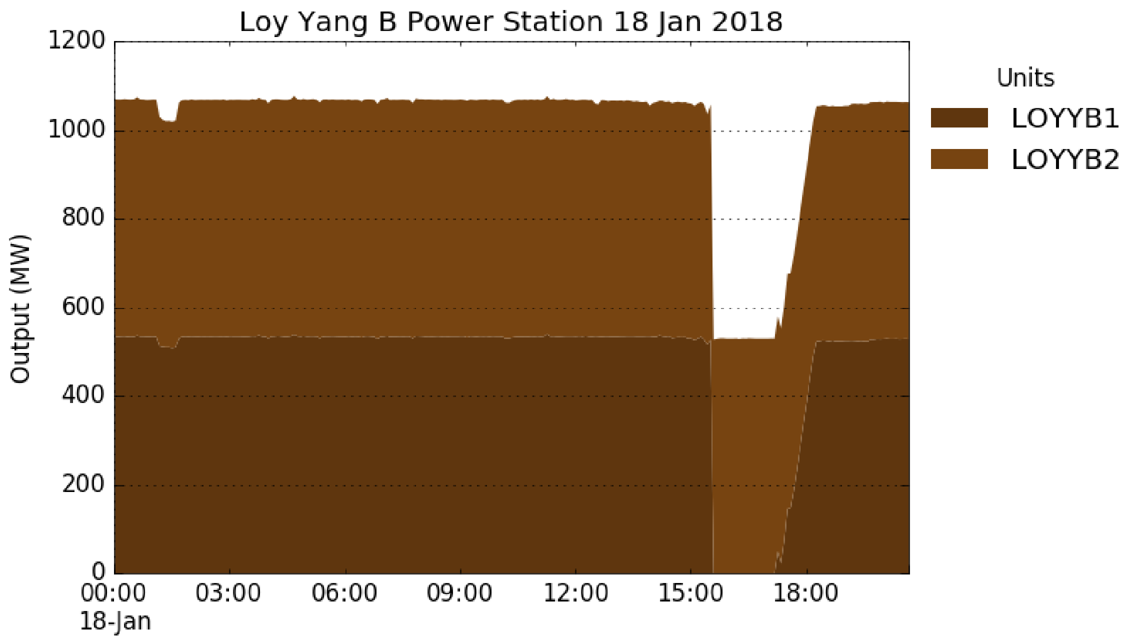

Source: OpenNEM (2018), AEMO 2018.

Figure 3 below shows the output Loy Yang B Power Station at the time of the breakdown. Loy Yang B has two generating units that each have a capacity of around 500 MW.  The darker shaded area at the bottom is the output of the chart is Unit 1 (LOYB1).  At the time of the breakdown, Unit 1 was operating at 528 MW, near its peak capacity. We can see that at 5.35 pm, the unit broke down completely dropping zero output unexpectedly and almost instantaneously, remaining out for over two hours as demand peaked, and the electricity was needed most.

[10] AEMO (2018) *Aggregated price and demand - historical*, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Data-dashboard#aggregated-data

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

**Figure 3 Unit trip Loy Yang B Power Station 18 January 2018**




Source: OpenNEM (2018)

# Solar delivers on hot days

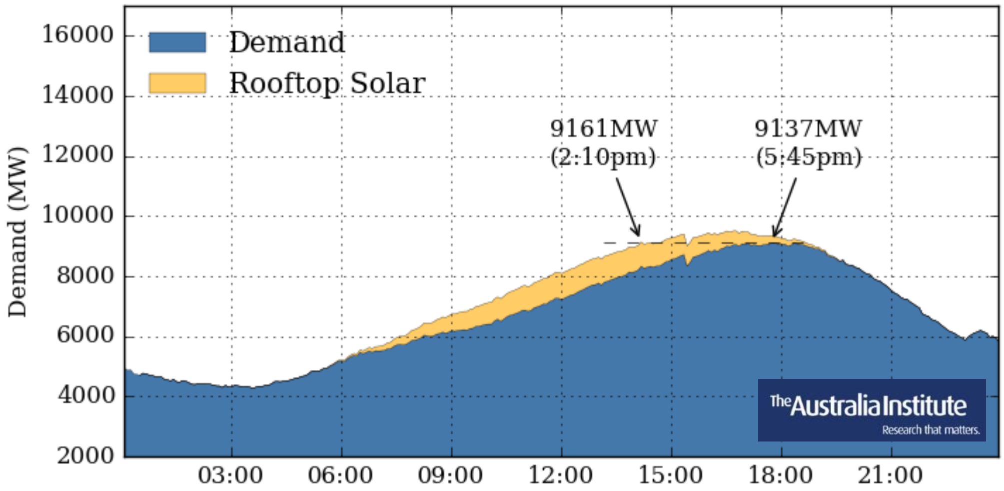
Because rooftop solar produces energy reliably on hot days due to ample sunshine, it reduces demand on the grid, as well as delaying and reducing demand peaks.

This has the effect of reducing our reliance on vulnerable coal and gas plants, thus increasing the resilience of our power system.

On 18 January, the day of the breakdown previously mentioned at Victoria's Loy Yang B Power Station, rooftop solar generated up to 10.7% of Victoria's electricity. At the time of the Loy Yang B breakdown, rooftop solar in Victoria was producing around 650 MW,[12] more than the amount of capacity lost as a result of the coal outage.

As shown in figure 4 below, without rooftop solar the peak level of grid demand reached at 5.45 pm would have been reached three and a half hours earlier at 2.10 pm. It would then have continued to increase by a further 394 MW to a peak of 9,350 MW 4.45 pm.

**Figure 4: Solar demand reduction & total demand in Victoria (18 January 2018)**




Source: OpenNEM (2018)

This longer and higher period of peak demand that would have occurred without solar is very significant because in a situation where fossil generators are already operating at reduced capacity and are more likely to break down in the heat, a longer period of this high level of demand would result in significantly higher risk of breakdowns and load- shedding.

On January 19 solar effectively offset the requirement for almost 400 MW of additional capacity (the equivalent to a large gas plant). For example, this is

[12] The Australia Institute Climate & Energy Program (2018) *Gas and Coal Watch*

considerably larger than the new 252 MW gas power plant announced by AGL in New South Wales at the cost of $400 million.[13] The capital cost of a gas plant is only part of the overall cost of generating electricity from gas. Fuel costs make up a large additional cost, often more than the cost of building the plant[14]. This additional capacity would ultimately be paid for by electricity consumers.

Total demand across the NEM that day was also very high, exceeding 30,000 MW. This was the second highest demand peak reached in January, exceeded only on the following day.[15]

The reduction in demand from rooftop solar was even larger in other states on 18 January 2018.

As shown in Table 1 below, rooftop solar reduced peak demand that day in the various states of the National Electricity Market by 1,627 MW. This is the equivalent to a large coal power station. State peaks occur at different times, so the total of state peaks is not equivalent to the total peak reduction from rooftop solar for the NEM.

**Table 1: Rooftop solar generation, peak delay and reduction (18 January 2018)**

| State | Peak reduction (MW) | Maximum solar (MW) | Maximum solar (% total generation) | Period of time above actual operational peak that would have occurred without solar (hours) |
|---|---|---|---|---|
| **Victoria** | 393.7 | 868.0 | 10.72 | 3:35 |
| **NSW** | 454.7 | 1,072.8 | 11.28 | 2:45 |
| **Queensland** | 567 | 1,347.1 | 16.60 | 8:10 |
| **SA** | 186.5 | 604.1 | 20.44 | 6:25 |
| **Tasmania** | 25.2 | 84.1 | 6.58 | 1:55 |
| ***Total*** | *1,627* | | | |

Source: The Australia Institute Climate and Energy Program (2018) *Gas and Coal Watch;* OpenNEM (2018)

The following day, January 19, demand in the NEM reached 30,831 MW, its highest level for the whole of January.[16] On that day, as shown below in Table 2, rooftop solar

[13] AGL (2018) *AGL commits to new gas-fired power station in NSW*, https://www.agl.com.au/about-agl/media-centre/asx-and-media-releases/2018/april/new-gas-fired-power-station-in-nsw
[14] Finkel (2017) *Independent review into the future security of the national electricity market*
[15] AEMO (2018) *Aggregated price and demand – historical,* https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Data-dashboard#aggregated-data
[16] AEMO (2018) *Aggregated price and demand - historical*, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Data-dashboard#aggregated-data

reduced peaks in the five NEM states by over 2,000 MW in total. It also significantly delayed peak demand.

**Table 2: Rooftop solar production, peak delay and reduction (19 January 2018)**

| State | Peak reduction (MW) | Maximum solar (MW) | Maximum solar (% total generation) | Period of time above actual operational peak that would have occurred without solar (hours) |
|---|---|---|---|---|
| **Victoria** | 393.7 | 868.0 | 10.72 | 3:35 |
| **NSW** | 687.2 | 1,053.3 | 9.87 | 3:15 |
| **Queensland** | 632.3 | 1,363.7 | 16.69 | 6:25 |
| **SA** | 358.6 | 575.6 | 18.85 | 8:10 |
| **Tasmania** | 42.1 | 70.8 | 5.24 | NA |
| ***Total*** | *2,113.9* | | | |

Source: The Australia Institute Climate and Energy Program (2018) Gas and Coal Watch; OpenNEM (2018)

Besides reducing peak demand, rooftop solar also plays an important role in delaying and narrowing peaks. If demand increases earlier in the day and the system is already struggling to maintain enough power, having several additional hours of sustained high demand make the system very vulnerable to the impact of power station breakdowns.

During the February 2017 heatwave, sustained high demand combined with multiple breakdowns at coal and gas power plants resulted in blackouts, load shedding and very high wholesale prices.[17] The consequences would have been much worse had rooftop solar not significantly reduced peak demand and delayed it by several hours in all the effected states that day.[18]

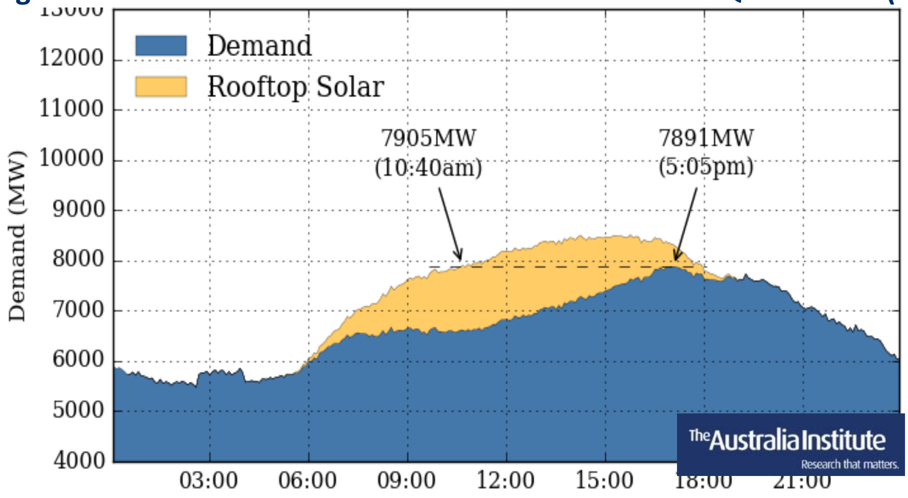
As shown in the figures 5-8 below, on 19 January this year (the highest demand day in January for the NEM) rooftop solar significantly delayed and reduced peak demand in all the mainland states of the NEM.

[17] AEMO (2017) *System event report South Australia, 8 February 2017;* AEMO (2017) *System event report NSW, 10th February 2017, Reviewable operating incident report for the National Electricity Market*; 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

[18] Ogge and Aulby (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

In Queensland, as shown below in Figure 5, the level of peak demand that was ultimately reached at 5.05 pm on January 19 would have been reached over six hours earlier at 10.40 am and risen a further 687 MW without rooftop solar.

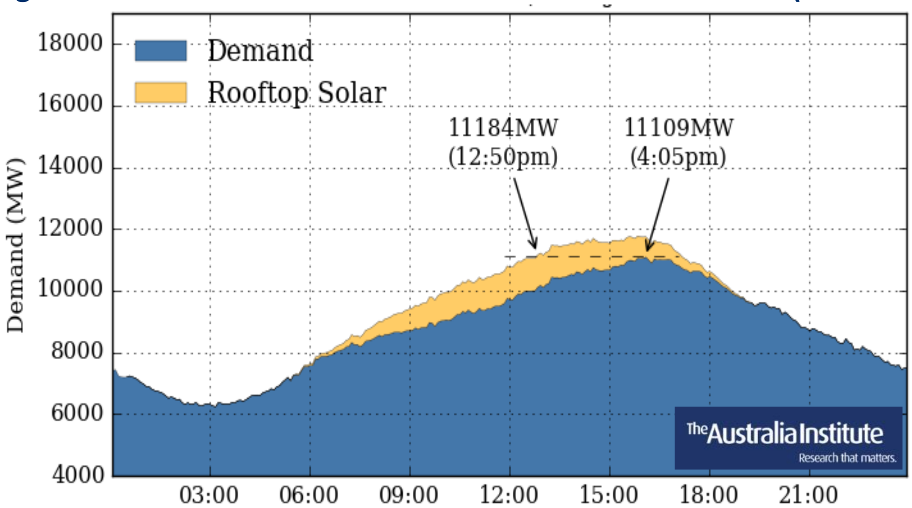
**Figure 5: Solar demand reduction and total demand in Queensland (19 January 2018)**




Source: OpenNEM (2018)

In New South Wales, as shown below in Figure 6, the level of peak demand that was ultimately reached at 4.05 pm on January 19 would have been reached over three hours earlier at 12.50 pm and risen a further 687 MW without rooftop solar.

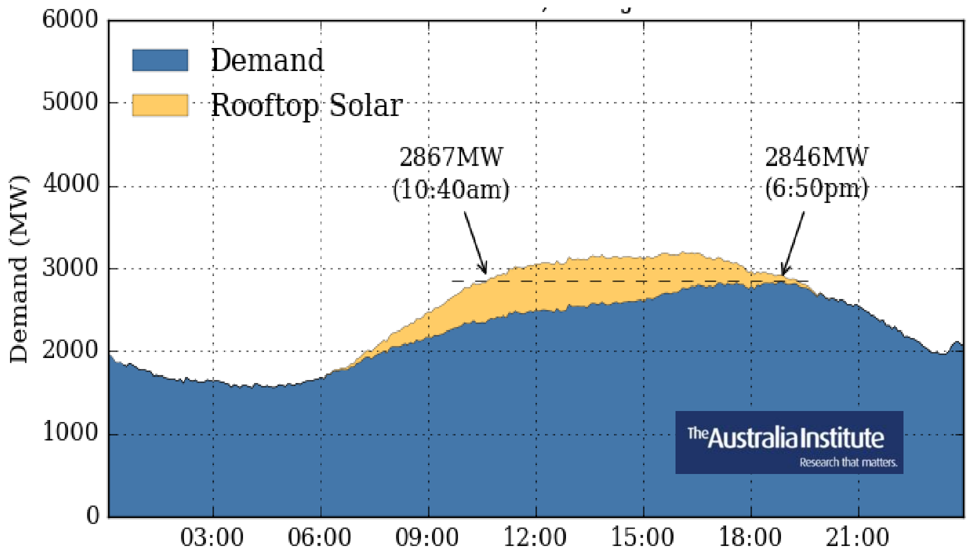
**Figure 6: Solar demand reduction and total demand in NSW (19 January 2018)**




Source: OpenNEM (2018)

In South Australia, as shown below in Figure 7, the level of peak demand that was ultimately reached at 6.50 pm on January 19 would have been reached over eight hours earlier at 10.40 am and risen a further 359 MW without rooftop solar.

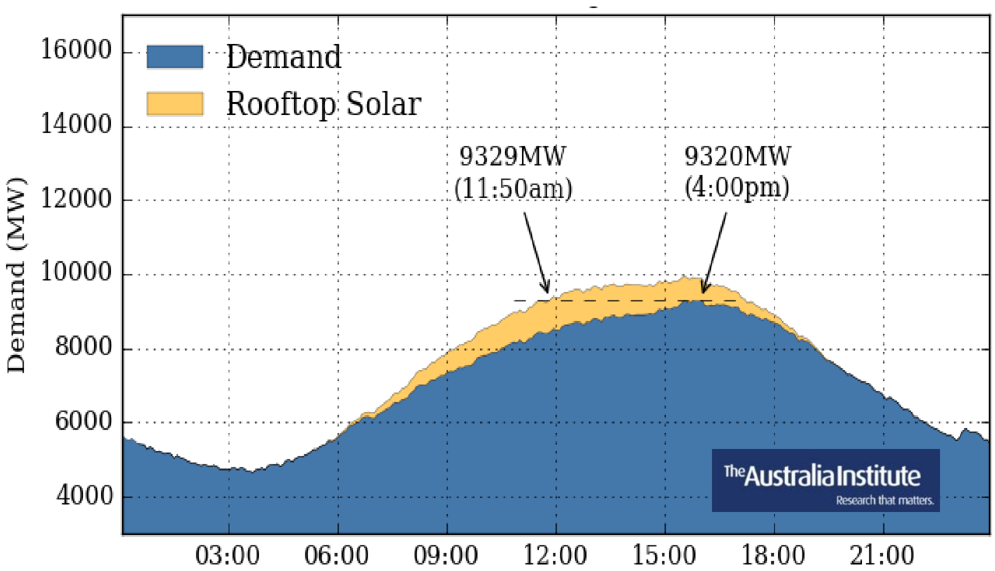
### Figure 7: Solar demand reduction and total demand in SA (19 January 2018)




Source: OpenNEM (2018)

In Victoria, as shown below in Figure 8, the level of peak demand that was ultimately reached at 4 pm on January 19 would have been reached over four hours earlier at 11.50 am and risen a further 394 MW without rooftop solar.

### Figure 8: Solar demand reduction and total demand in Victoria (19 January 2018)




Source: OpenNEM (2018)

# Battery uptake will further reduce peak demand

When rooftop solar systems are combined with battery storage, excess energy can be stored and used in the evening. Currently rooftop solar consistently delays and reduces peak demand. The delayed and reduced peak demand now usually occurs in the early evening of hot days.  The addition of batteries will further erode that peak.

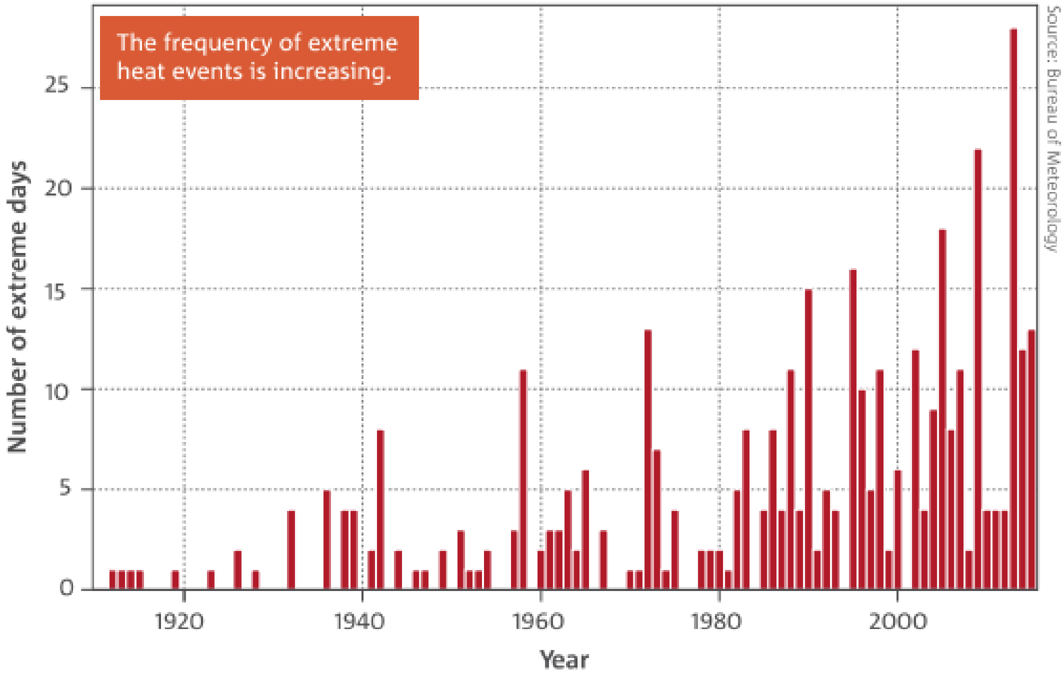
Residential battery storage in Australia tripled in 2017. Uptake will be further boosted by the new South Australian Government’s scheme to create a $100 million household battery fund which would provide means-tested grants averaging $2,500 to 40,000 homes to help them buy batteries.[19]

[19] Hamsen and Dayman (October 2017) *SA power: State Opposition releases $100m home battery plan to 'reduce energy costs',* http://www.abc.net.au/news/2017-10-10/sa-opposition-releases-$100m-home-battery-plan/9032900

# Extreme heat events are increasing

Extreme heat events in Australia are increasing in duration, intensity and frequency.[20] Figure 9 below shows the increase in extreme heat events in Australia since 1900.

**Figure 9: Increase in extreme heat events in Australia (1900-2016)**




Source: Bureau of Meteorology (2016) *State of the Climate*

The Australian Energy Market Operator (AEMO) has acknowledged that heatwaves and extreme heat events are increasing impact of increasing as a result of global warming and that this impacts the reliability and resilience of the electricity grid.[21]

This means that incentivising further uptake of household solar, particularly coupled with battery storage is an important way to increase the resilience and reliability of our electricity supply.

[20] Steffen et al (2014) *Heatwave: Hotter, longer, more often*. https://www.climatecouncil.org.au/uploads/9901f6614a2cac7b2b888f55b4dff9cc.pdf

[21] AEMO (2018) *AEMO observations: Operational and market challenges to reliability and security in the NEM*, p 5, https://www.aemo.com.au/-/media/Files/Media_Centre/2018/AEMO-observations.pdf

# Conclusion

In an era of ever increasing heatwaves, which drive high demand peaks and cause breakdowns at gas and coal power plants, rooftop solar reduces and delays peak demand, and increases the resilience and reliability of the electricity system.

By reducing demand on the grid, including peak demand, rooftop solar also offsets the need for further investment in expensive utility scale power generation capacity, the cost of which would ultimately be passed onto electricity consumers.

Providing further incentives to increase the amount of rooftop solar in the NEM is one of the most effective ways of increasing the reliability and lower the cost of electricity.