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NATIONAL ENERGY EMISSIONS AUDIT

National Energy Emissions Audit Report

March 2020

Providing a comprehensive, up-to-date indication of trends in Australia's energy combustion emissions

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Key points

- **In February 2020, grid renewables supplied 19.7% of all generation supplying the NEM grid.** When rooftop solar is included, the renewable share increases to 24.3% of all generation, including rooftop solar, in the NEM grid.

- **South Australia (SA) has the highest share of rooftop solar in the NEM.** This has meant South Australians are annually reducing their demand for electricity from the grid (when so many are getting it directly from their roofs).

- **The loss of the Heywood interconnector between SA and Victoria on 31 January 2020 meant gas use in SA ramped up**, with nine generating units at Pelican Point, Torrens Island B, Torrens Island A, Osborne, Quarantine and Barker Inlet operating at any particular time, and never fewer than five.

- **Future interruptions to the Heywood interconnector won't need to rely as heavily on gas plants** for grid stability thanks to numerous changes to SA electricity infrastructure and processes.

- **SA is increasing the security and reliability of its electricity grid** through its three battery systems (Hornsdale, Dalrymple North and Tailem Bend), virtual power plants being rolled out in Adelaide, four synchronous condensers currently being installed ahead of Summer, the introduction of Wholesale Demand Response next year, and final approvals in 2021 for a new interconnector with NSW.

- **In SA the relationship between electricity consumption and high temperatures (above 24 degrees C) is quite consistent.** High electricity consumption (driven by increasingly hotter Summers) will continue to be associated with higher gas fired generation, and more emissions, for some years yet in SA, unless clear steps are taken to curb down energy consumption.

- **The SA Government has an opportunity to package stimulus to improve electricity conservation** by ensuring that all air conditioning systems are properly maintained and correctly operated; incentivise heating and cooling improvements to housing stock, particularly the notoriously thermally inefficient private rental properties; and upgrade inspection, certification and enforcement of mandatory minimum energy performance standards for new houses and apartments.

INTRODUCTION

Welcome to the March 2020 issue of the *NEEA Report*, with data updated to the end of February 2019. Data presented covers electricity demand, electricity supply, and electricity generation emissions in the National Electricity Market (NEM), plus electricity demand in the South West Interconnected System (SWIS). The main trends in the mix of generation and the level of demand for electricity have continued as in the past two or three months.

The remainder of this issue focuses specifically on electricity supply and demand in South Australia. It looks at monthly demand for electricity supplied from the grid in the state and the changes in the mix of generation within the state and the balance of imports and exports through the interconnectors to Victoria over the past five years. It then shows exactly the same data, but with the addition to both supply and demand of electricity generated from rooftop and other small solar installations, embedded in the state's distribution network, and not connected to the transmission grid or participating in the wholesale electricity market. As is well known, South Australia has a larger share of supply from rooftop solar, relative to total consumption of electricity. More than any of the other four states in the NEM.

The report then looks in detail at changes in the mix of supply sources in South Australia during January and February 2020, showing the changes in the mix of generation which occurred following the loss of the major Heywood interconnector linking South Australia and Victoria, which occurred on 31 January, when the key transmission line was blown down in western Victoria.

An interesting feature of electricity consumption in South Australia during February 2020 was that it was significantly lower than in February 2019. Careful analysis shows that this was not related to the loss of the connection to Victoria and the rest of the NEM, but was a consequence of weather during February 2020 which was, on average, considerably less hot than in February 2019. This provides an opportunity to examine in detail how extremely sensitive electricity demand in South Australia is to the occurrence of very hot days in summer, and to consider the implications of this sensitivity to the future evolution of electricity supply in the state.

OVERVIEW OF MAIN TRENDS

Update on electricity generation and emissions

Figure 1 shows that trends across the NEM as a whole in electricity consumption, emissions, and emissions intensity of generation were essentially unchanged again during February. Consumption of grid supplied electricity is flat or decreasing very slowly, but is steadily increasing when electricity supplied by rooftop solar is included.

Figure 1

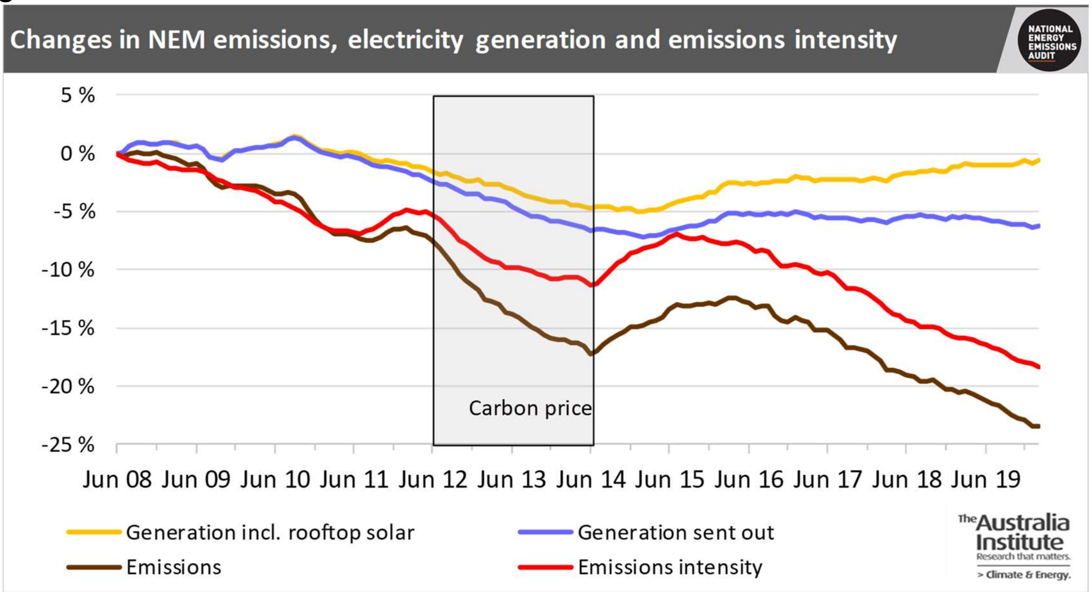


Figure 2

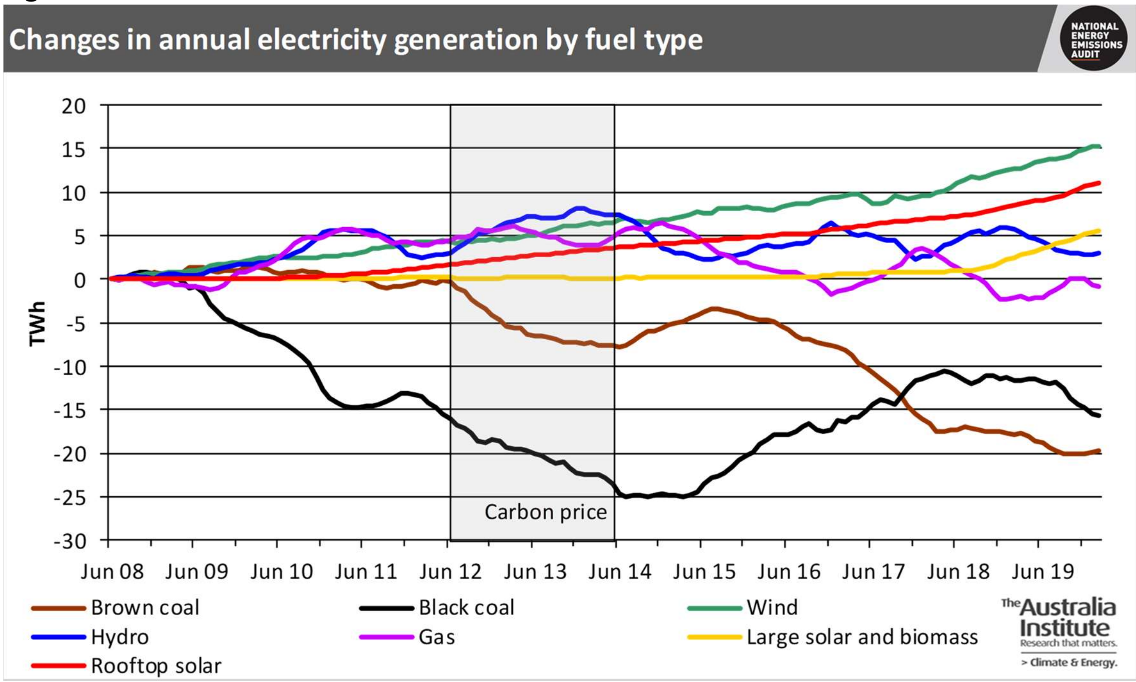


Figure 2 shows that wind and solar generation continue to grow, while coal and, to a somewhat lesser extent, gas generation decrease. The same data are presented in a different format, as shares of total generation, in Figure 3.

Figure 3

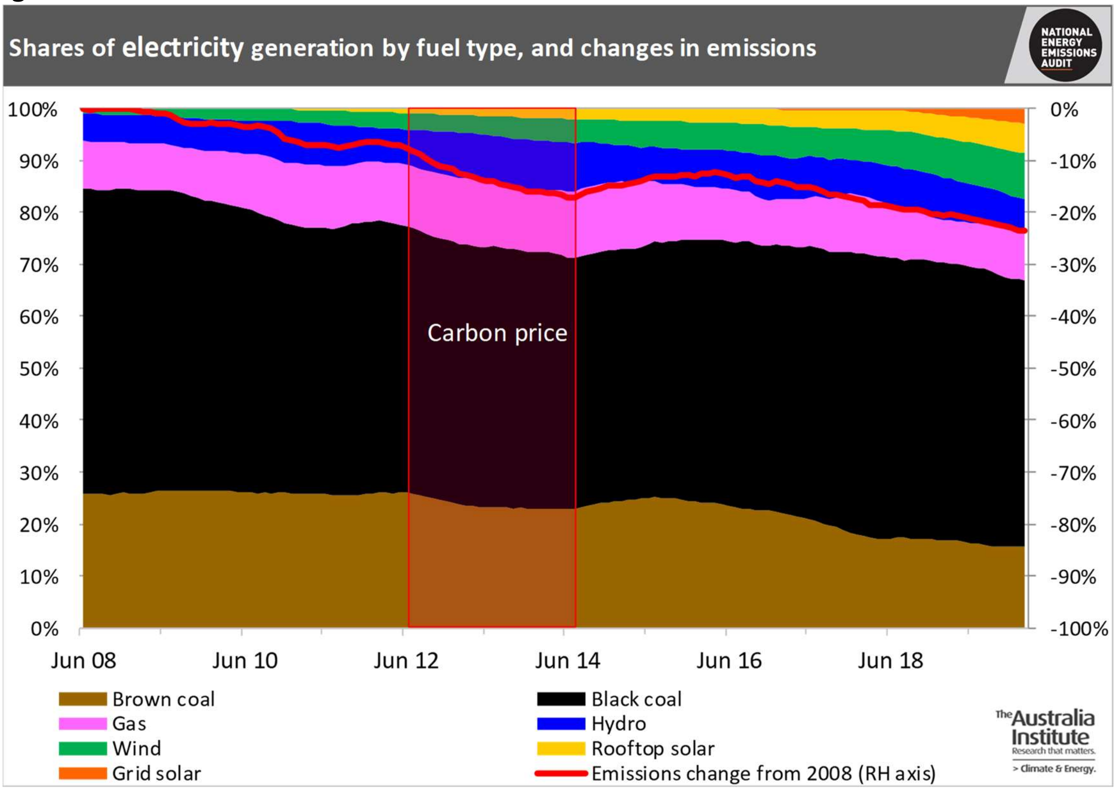
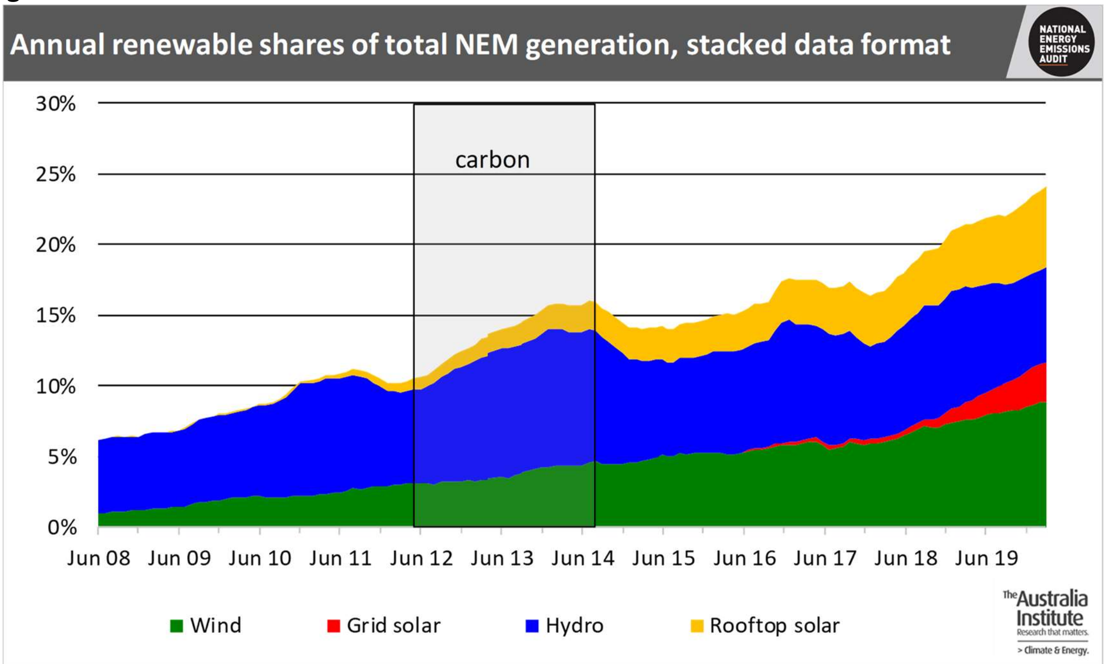


Figure 4



The steady growth of "new" renewable generation (wind and solar) is shown in Figure 4. For the year ending February 2020, grid renewables, i.e. excluding rooftop solar, supplied 19.7% of all generation supplying the NEM grid. When rooftop solar is included, the renewable share increases to 24.3% of all generation, including rooftop solar, in the NEM grid, as seen in Figure 4.

Update on demand for electricity

Figures 5 and 6 show, respectively, absolute and relative changes in demand for electricity supplied through the NEM grid in each state and in the NEM as a whole. It can be seen that grid demand is flat or gradually declining, with the fastest decline since 2016 in the NEM states occurring in South Australia and Victoria. However, when supply from rooftop solar is added, as in Figure 7, it can be seen that total demand for electrical energy has been increasing strongly in Queensland, and more slowly in New South Wales and Victoria.

Figure 5

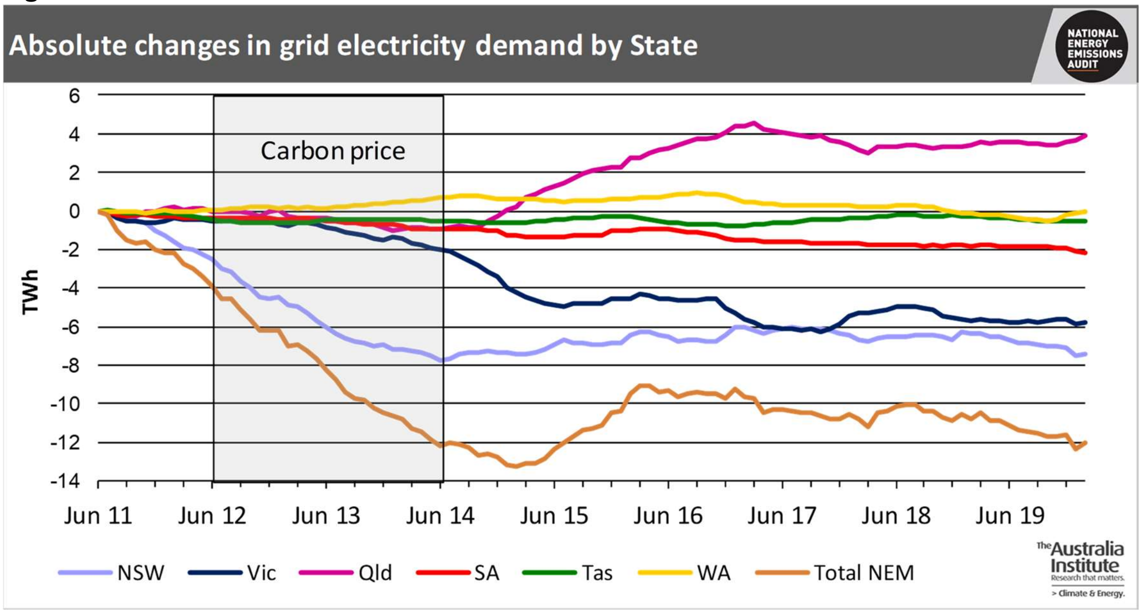


Figure 6

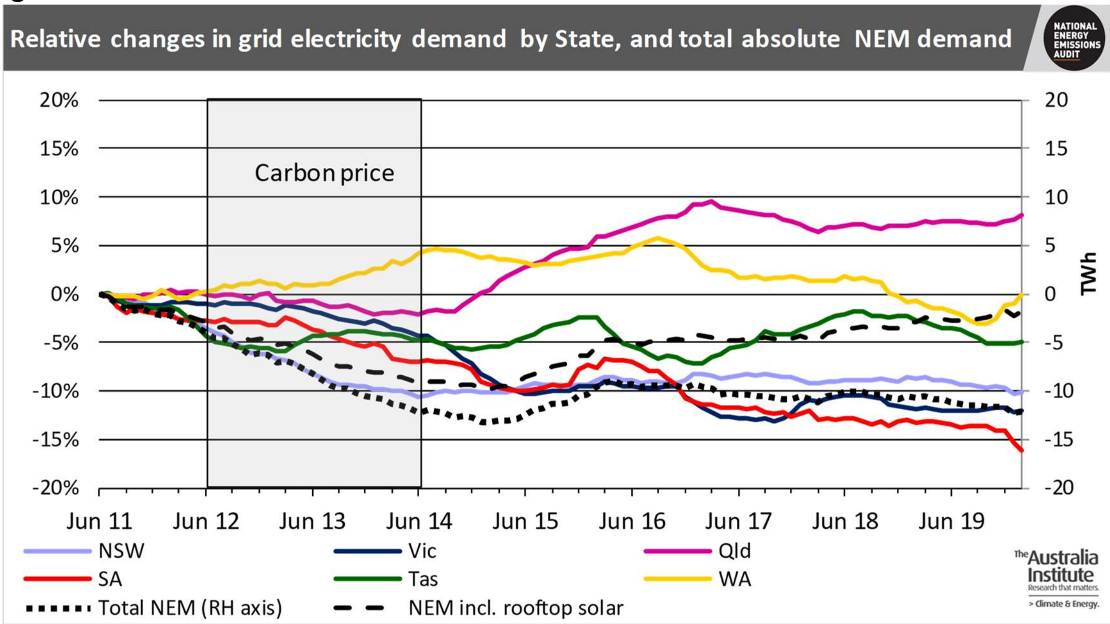
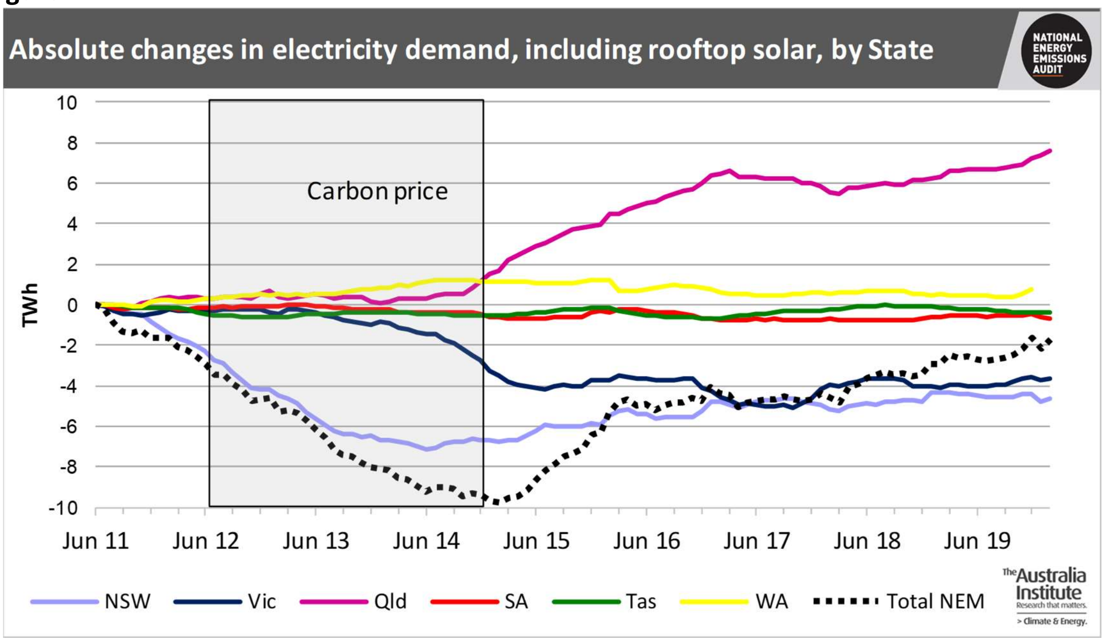


Figure 7



Looking closely at the lines for South Australia in each figure, it can be seen that there was a distinct decline in demand, even including supply from rooftop solar, in the two most recent months, i.e. January and February 2020. The first half of February was the period when the South Australia was separated from the rest of the NEM because of the collapse of the interconnector transmission line in western Victoria. The rest of this month's *NEEA Report* examines electricity demand and supply in South Australia during these two months.

ELECTRICITY SUPPLY AND DEMAND IN SOUTH AUSTRALIA

Overview

As is well known, South Australia now obtains a large share of its electricity supply from wind and solar generation, including a large quantity of rooftop solar and a small, but growing volume of grid scale solar farms. Figure 8, which is an update of a graph included in previous *NEEA Reports*, shows the changing mix of supply since 2015, by month, and total generation in the state, which has been growing steadily, in the process transforming South Australia from being a net importer of electrical energy, to a net exporter. Exports and imports are represented by the gap between total generation and total consumption in Figure 8. The immediate cause of the sudden shift from net imports to net exports in mid-2017 was the closure of Hazelwood power station, in Victoria, which eliminated spare generation capacity in that state and caused a sharp increase in wholesale prices. However, it was the growth in wind and solar generation within the state that made it possible for South Australia to respond by ending its consistent reliance on imports from Victoria.

Figure 8

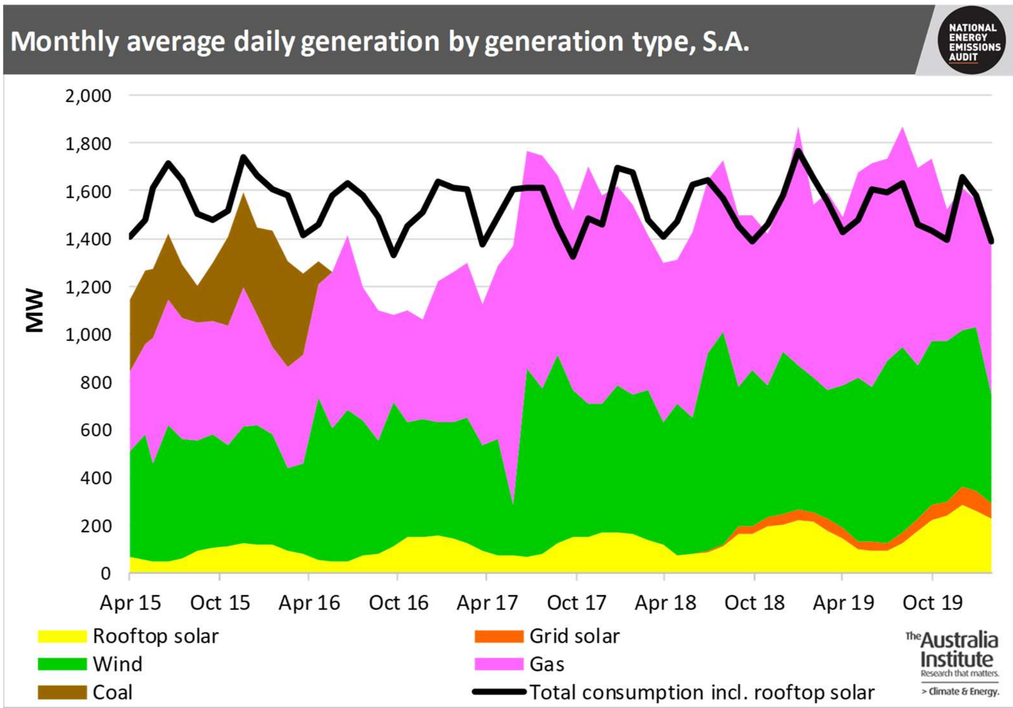
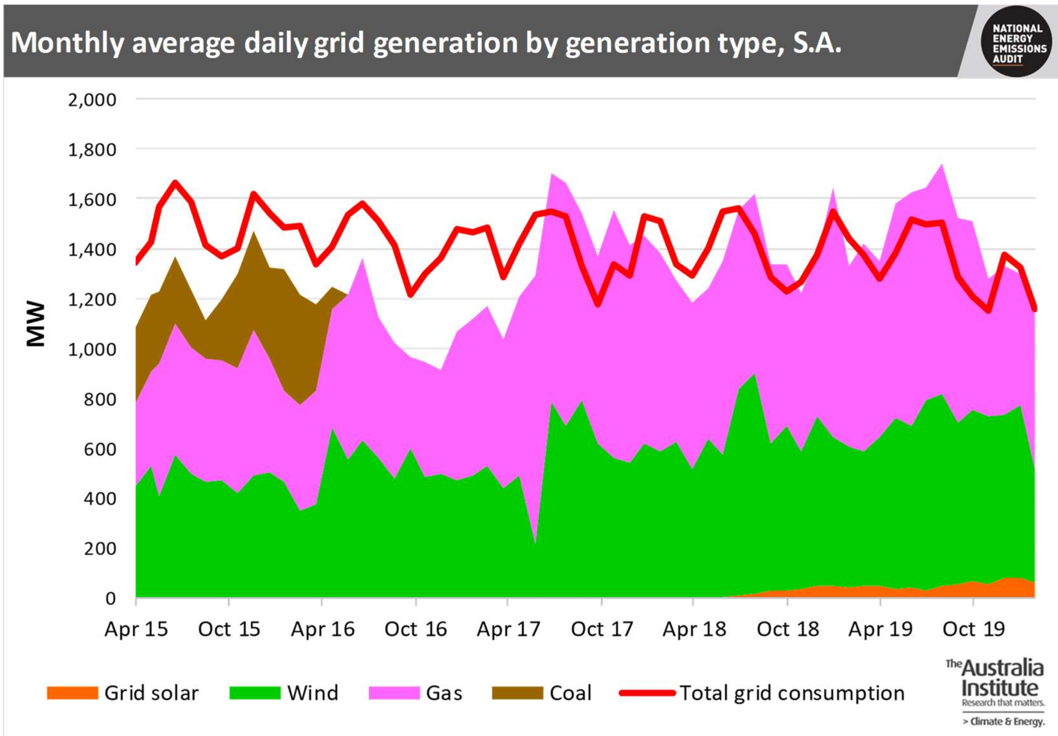


Figure 9 is the same as Figure 8, with the exception of supply from rooftop solar, which has been removed from both supply and demand in the graph. South Australia does not have largest total supply from rooftop solar of any of the five states in the NEM, but it does have the largest share of rooftop solar in total supply. This has meant that consumption of grid supplied electricity has been steadily falling in South Australia, as seen in Figure 9. This has presented particular challenges for AEMO, the system operator, and ElectraNet, the transmission network service provider, in managing the grid in South Australia, particularly on sunny days over the spring and autumn periods, when output from rooftop solar sometimes reduces demand for supply from the grid to very low levels during the middle of the day. This issue was discussed in the December 2019 *NEEA Report*, using the example of 10 November last year.

Figure 9



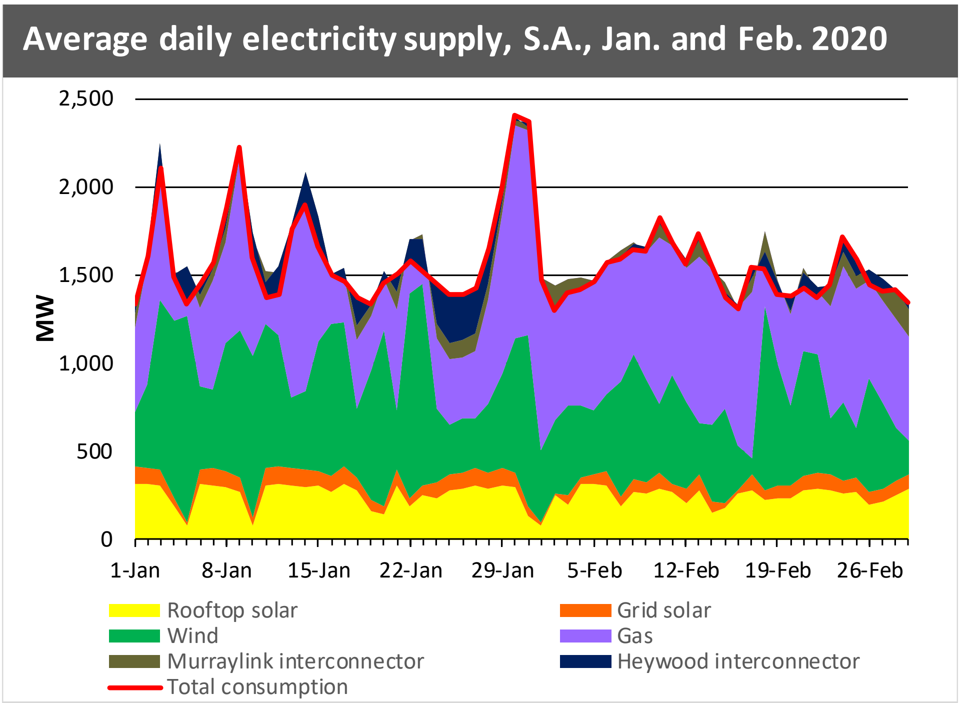
A separate, though related challenge for both secure and reliable grid operation is presented by the different technical characteristics of grid scale wind and solar generators, compared with gas generators. These issues have been very widely discussed elsewhere (and also misrepresented in much non-expert commentary), so further discussion is not needed here, other than a brief reference to the services provided by the two interconnectors.

The smaller of the two, Murraylink, uses DC, which means that it cannot provide frequency support or other security services. It can add to reliability, but that is limited by both its relatively small capacity and also, at times, by transmission constraints on the Victorian side of the connection. The much larger Heywood interconnector is an AC link, which, when operating, integrates South Australia fully into the rest of the NEM system. It was upgraded a few years ago to a “nameplate” capacity of 650 MW, making it much larger than any single generation unit in South Australia, and almost as large as the total 800 MW of the four unit Torrens Island B, the state's largest, though ageing, single power station.

How electricity supply survived the loss of the Heywood interconnector

The loss of the Heywood interconnector on 31 January last, as described in the previous *NEEA Report*, therefore had a very significant impact on electricity supply in South Australia, which was isolated from the rest of the NEM, with the exception of the large Mortlake open cycle gas fired power station, the Portland aluminium smelter, and other consumers in a limited area of south west Victoria. Supply and consumption in South Australia over this period are shown in Figure 10.

Figure 10



As described in the previous issue, demand in South Australia, Victoria, and New South Wales was at a very high level at the time the interconnector was lost. AEMO acted immediately to stabilise the supply and demand balance in south west Victoria and south east South Australia, which includes the very large smelter load. Six windfarms connected to this now fragile part of the transmission grid (four in south Australia and two in Victoria) were required to completely shut down for as long as the interconnector was out of service, and required Mortlake to start up and continue operating. In addition, some other wind generators in South Australia were required to curtail output. It seems likely that these were mainly older wind farms with less sophisticated inverter controls, but confirmation on this point, and many other detailed matters will not be confirmed until AEMO publishes its power system incident report on the event.

The reduced wind generation, and correspondingly higher gas generation, can be clearly seen over the period from 31 January to 17 February, when a temporary repair restored limited capacity to the transmission line in Victoria. By curtailing wind generation, more gas generation was required, which meant more individual generation units, thereby ensuring increased reliability of supply, in the absence of the Heywood interconnector. During the period of complete separation, up to nine generating units at Pelican Point, Torrens Island B, Torrens Island A, Osborne, Quarantine and Barker Inlet were operating at any particular time, and never fewer than five. Once the partial connection was restored, the constraint was relaxed and operating gas units reduced to three or four, with an offsetting increase in wind generation.

AEMO judged that these measures were needed to minimise the risk of the South Australian electricity supply system being unable to respond to any other unforeseen event affecting either the security or the reliability of the system. Fortunately, a variety of actions to improve both security and reliability are now in train. The three battery systems in the state (Hornsdale, Dalrymple North and Tailem Bend) are already supporting both security and reliability. A further major increase in some crucial aspects of security will occur when the transmission operator, ElectraNet, commissions the four synchronous condensers it is currently installing; it expects this to be completed by the start of 2021. System security improvements are also being realised through advances in the technology embodied in the inverters being installed at new wind and solar farms. Reliability is being further increased by the various virtual power plants (VPP) projects now being rolled out in Adelaide.

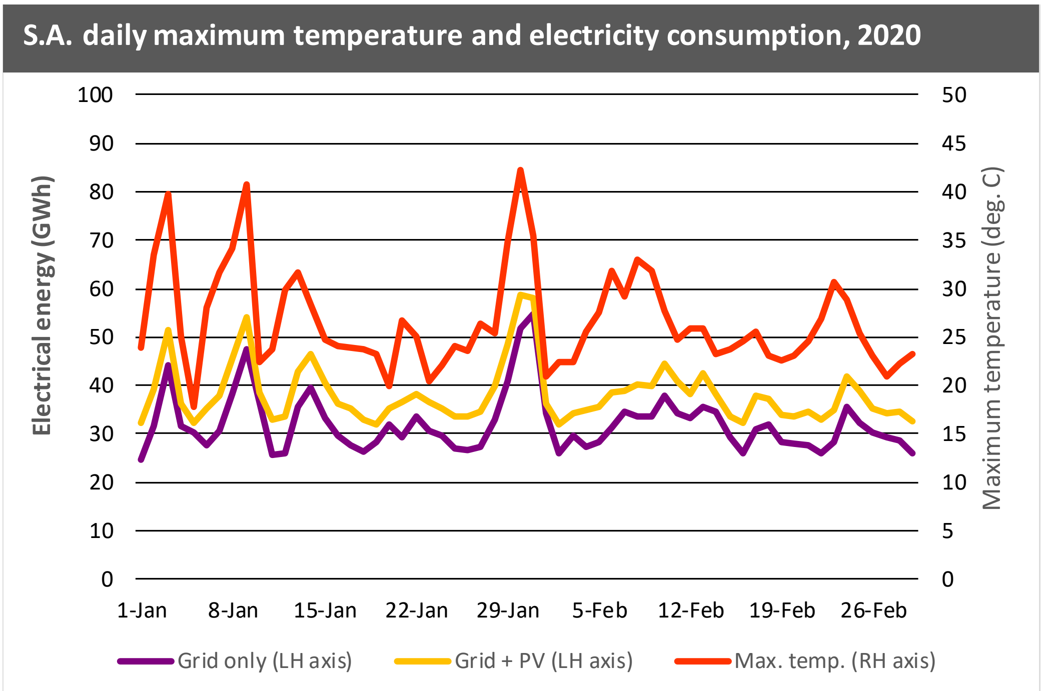
Over a longer time frame, ElectraNet, and its New South Wales counterpart, Transgrid are well advanced with planning a completely new interconnector between South Australia and New South Wales, which will greatly improve both security and reliability for South Australia. The main regulatory approvals have been received, and the parties are hoping to receive environmental and construction approvals in 2021. Finally, the reliability of supply in South Australia will be further increased if and when one or more of the pumped hydro projects proposed for various locations in upper Spencer Gulf is built.

Turning back to examine the actual events following the event on 31 January, one piece of good fortune was that, during February, the weather in South Australia was, on average, less warm than in February 2019; that is daily maximum temperatures were, on average, lower. Electricity consumption in South Australia is highly sensitive to daily temperature, so that lower maximum temperatures means lower demand for electricity. This lower consumption, compared with January and February 2019, explains the sharp dip in total annualised electricity consumption in the state during January and February, clearly visible in Figures 5, 6 and 7 above. The final part of this *Report* examines the relationship between hot weather and consumption of electricity in South Australia, by comparing January and February 2020 with the corresponding months in 2019.

The effect of hot weather on daily electricity consumption in South Australia

Figure 11 shows daily maximum temperature, as recorded by the Bureau of Meteorology at its Adelaide Airport weather station, and daily electricity consumption in South Australia, both exclusive and inclusive of electricity supplied by rooftop solar, during January and February 2019. Figure 12 shows the corresponding data for 2020.

Figure 11



In both graphs the relationship between electricity consumption and maximum temperature is consistently very close. The difference between electricity consumption in 2019 and 2020 is shown in Figure 13. It is obvious that considerably more electricity was consumed in 2019 than in 2020, corresponding to the significantly higher average daily maximum temperatures.

Figure 12

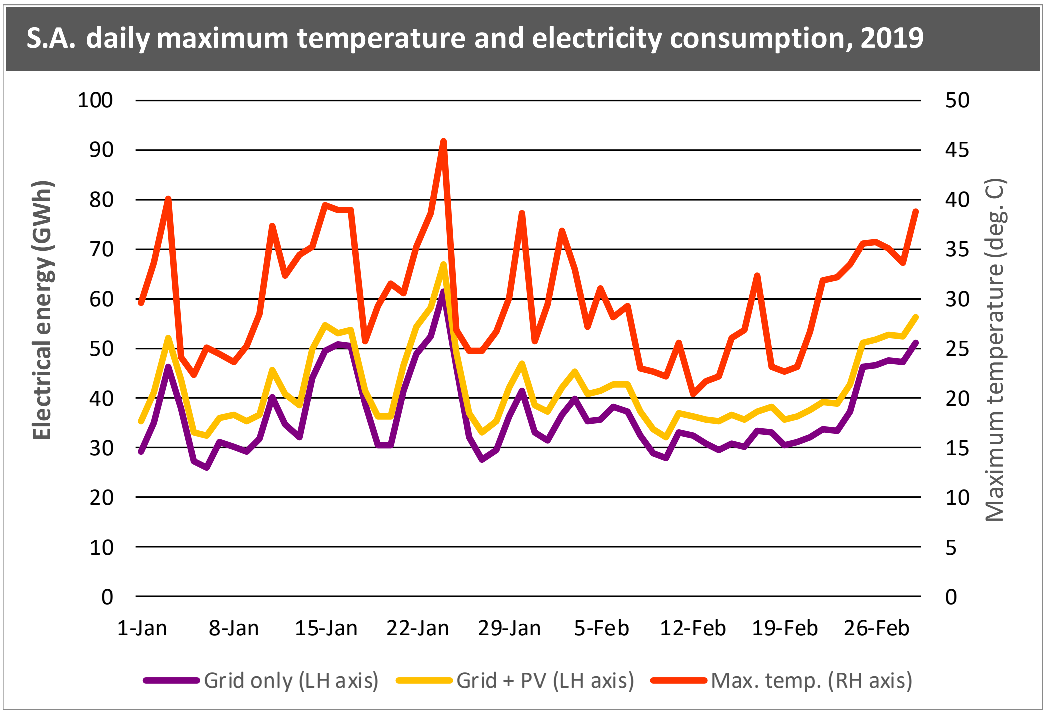
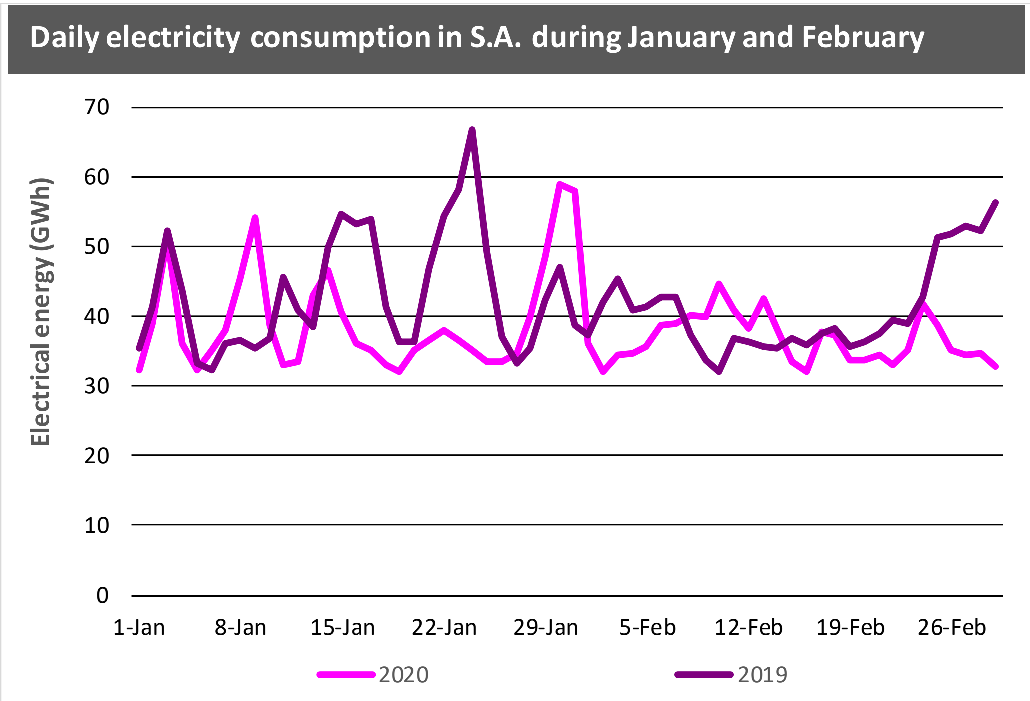


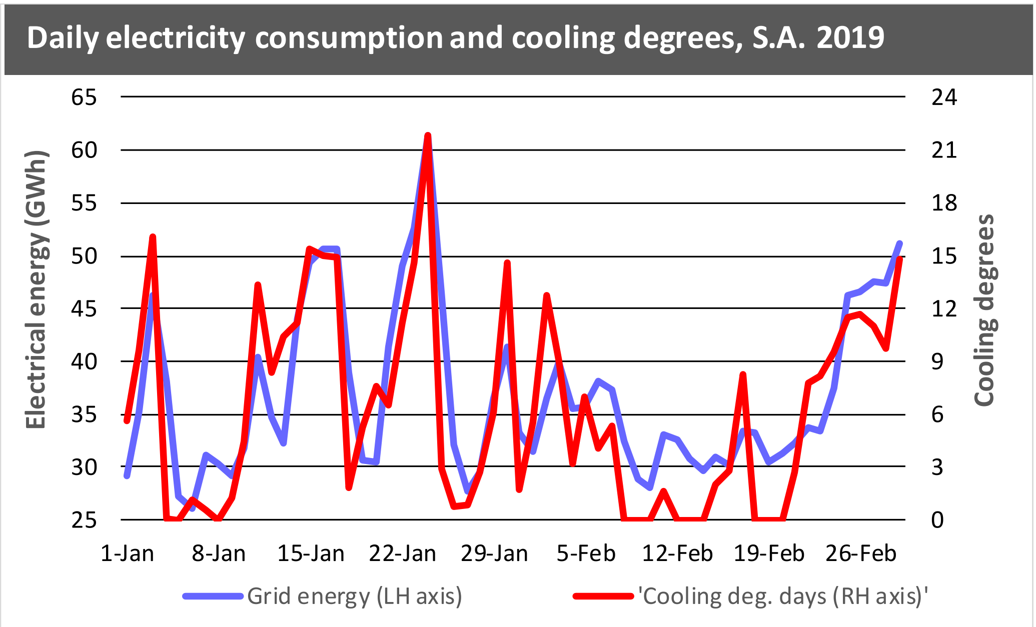
Figure 13



The relationship between hot weather and electricity consumption is of course very well established and understood, both within the electricity supply industry and by anyone interested in energy use in buildings. What makes the relationship so striking, and so important, in South Australia is the combination of several factors, particularly a smaller share of industrial demand for electricity than in other Australian states and a climate characterised by hot, dry summers, with large day to day changes in temperature. (In tropical and sub-tropical climates, higher humidity and less day to day variation in maximum temperatures means much more consistent electricity consumption.) The main contributor to high electricity consumption on hot days is of course space cooling (air conditioning), but refrigerators and freezers also contribute because, although they have to operate in all weathers, they have to work much harder on hot days. It can be clearly seen in Figure 11 that, during the most recent summer, electricity consumption was almost unaffected by temperature on days with maxima of 24 deg. C or below, but began to increase at higher daily maxima.

This relationship forms the basis for the concept of degree days which is the most widely used measure of the impact of high temperatures on cooling load, and hence on electricity demand. Degree days are a widely used measure of weather and climate, for many purposes, not just analysis of electricity demand. In Australia, cooling degree days are calculated as the difference between the daily maximum temperature and 24 degrees C and, in most applications, summed over a period of days or weeks. Total cooling degree days during January and February 2019 were 374, almost twice as many as the 193 during January and February 2020. Figure 14 shows the relationship between degree days and daily electricity consumption during January and February 2019.

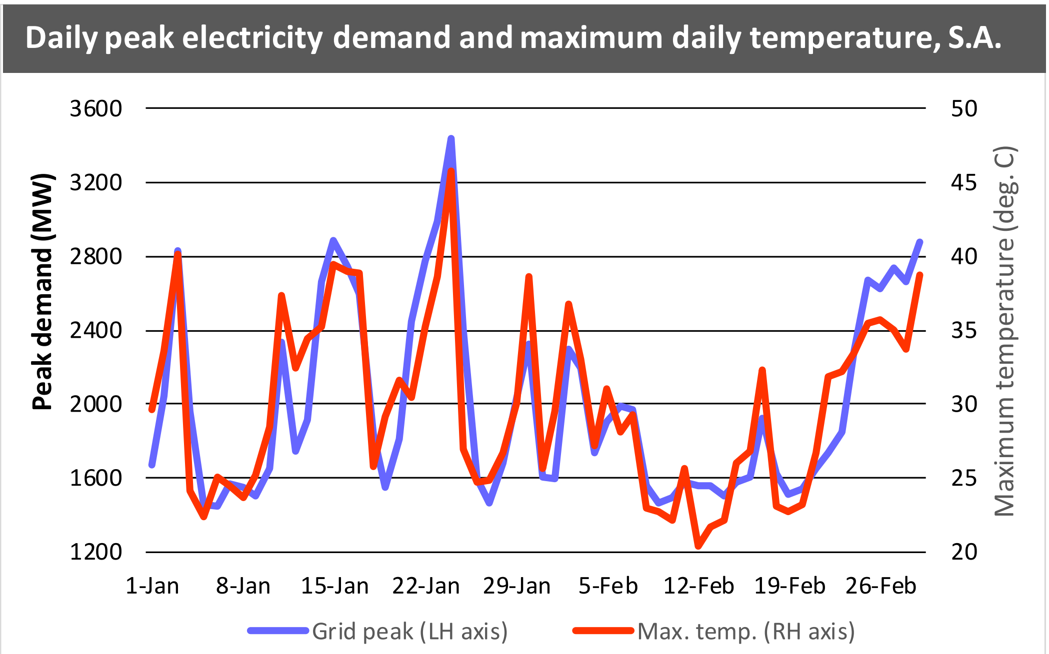
Figure 14



The value of the concept of degree days relies on the fact that below a specific daily temperature, electricity consumption for cooling is almost independent of temperature. As explained above, for South Australia this temperature appears to be about 24 deg. C, which explains why 24 deg. C is an appropriate reference for calculating cooling degree days. This can be clearly seen in Figure 14.

On some summer days, of which 31 January 2020 is an example, the temperature may fall suddenly during the afternoon. Hypothetically, on such days, daily peak electricity demand, rather than daily electrical energy consumption, may be more closely related to maximum daily temperature. This relationship is shown in Figure 15, again for January and February 2019. Consistent with this hypothesis, the relationship between temperature and peak demand appears to be even closer than the relationship with daily energy, as shown in Figure 12.

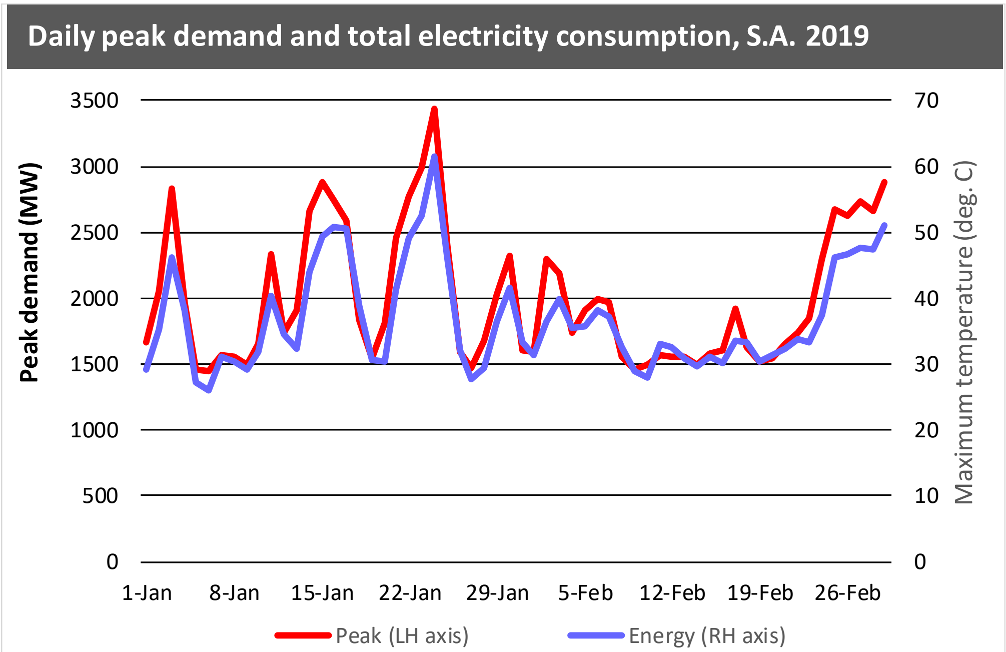
Figure 15



Finally, however, Figure 16 shows that the relationship between daily peak demand and daily total energy consumption is very close.

As already noted, the relationships described in these graphs are well known and understood by the electricity industry, but not so well understood by many electricity consumers. It is consumers, however, who have to pay the very high costs of having enough capacity in the electricity system to be able to supply and deliver all that they wish to use on peak days. These costs can be very extreme. For example, on Thursday 24 January 2019, which was the peak day seen in all the graphs presented here, the spot wholesale price stayed at its maximum allowed level of $14,500 per MWh for no less than 3.5 hours, during which period consumption totalled nearly 12 GWh. Total revenue at the spot price would be about $170 million. Of course, the great majority of market participants, both buyers and sellers, are hedged, and do not pay anything like the spot price. Nevertheless, this simple example does show the importance of designing and managing the system to reduce the dimension of extreme peak demand.

Figure 16



Ways of reducing peak demand, such as market based demand response and direct load control, have been known and discussed within industry and policy circles for many years, with little action until recently. However, in August 2018 the Australia Institute joined with two organisations representing the interests of electricity consumers and the environment, to ask Australian Energy Market Commission to introduce a change to the National Electricity Rules to provide a mechanism for wholesale demand response in the NEM. To simplify, what this means is that large electricity consumers, and businesses which aggregate consumption of groups of smaller consumers, could bid in the wholesale market to deliver a specified number of MW at a specified price in the form of reduced consumption. As at 20 March, the AEMC website says that it expects to make a final determination on the change by June 2020, with implementation commencing just ahead of Summer in late 2021. So far as electricity consumers in South Australia are concerned, the response can only be the sooner the better.

Valuable as they will be, these changes are unlikely to greatly change the large increases in total electrical energy consumption on hot days. Notwithstanding the large share of renewable electricity already being generated in South Australia, and the state's commitment to continue moving towards 100% renewable electricity, high electricity consumption will continue to be associated with higher gas fired generation, and more emissions, for some years yet. Continuing very high consumption on hot days will also mean continuing high power bills for consumers, caused both directly by the larger amount of electricity consumed and indirectly by the eventual pass through of higher wholesale costs when very high demand for generation drives up wholesale prices on hot days. There are therefore significant benefits to be gained by reducing the volume of electricity which households and businesses have to use to achieve and maintain acceptable level of thermal comfort.

How this can be achieved has been well known for many years. Relevant changes include:

- increasing the average operating efficiency of the stock of air conditioning and refrigeration equipment in the state;
- ensuring that all air conditioning systems, large and small, are properly maintained and correctly operated;
- ensuing that new air conditioning systems are not over-sized for the cooling task required;
- improving the thermal efficiency of the existing housing stock, particularly the notoriously thermally inefficient stock of private rental properties;
- upgrading the currently weak to non-existent inspection, certification and enforcement of mandatory minimum energy performance standards for new houses and apartments.

None of the problems such changes would address are confined to South Australia, but they are more severe than in some other parts of the country, because the temperature extremes experienced in South Australia during summer mean that the financial and social costs of poor quality housing are higher in the state than in some other parts of Australia. All electricity consumers will eventually benefit from the lower costs and improved reliability of supply which will flow from reducing peak demands. These actions will also deliver significant social equity benefits because low income households will derive the greatest improvements in their living conditions. At the extreme, comprehensive improvement in the thermal performance of all housing will reduce heat related ill health and death among older and lower income members of the population.

APPENDIX: NOTES ON METHODOLOGY

Data on annual consumption of electricity, and seasonal peak demand, are for each of the six states. All other data are for the states constituting the National Electricity Market (NEM) only, i.e. they exclude Western Australia. All data are reported as annual moving averages. This approach removes the impact of seasonal changes on the reported data. Annualised data reported in *NEEA Electricity Update* will show a month on month increase if the most recent monthly quantity is greater than the quantity in the corresponding month one year previously. Most data are presented in the form of time series graphs, starting in June 2011, i.e. with the year ending June 2011. Some graphs start in June 2008. These starting dates have been chosen to highlight important trends, while enhancing presentational clarity.

Defining the particular meaning of the various terms used to describe the operation of the electricity supply system will help in understanding the data discussed.

Demand, as defined for the purpose of system operation, includes all the electricity required to be supplied through the grid level dispatch process, operated by AEMO. This includes all the electricity delivered through the transmission grid to distribution network businesses, for subsequent delivery to consumers. It also includes energy losses in the transmission system and auxiliary loads, which are the quantities of electricity consumed by the power stations themselves, mostly in electric motors which power such equipment as pumps, fans, compressors and fuel conveyors. Auxiliary loads are very large: in 2011 they amounted to 6.3% of total electricity generated and currently about 5.6%. Most of this load is at coal fired power stations, where it can be as high as 10% of electricity generated at an old brown coal power station and 7% at a black coal fired power station. Auxiliary loads are much lower at gas fired power stations, and close to zero at hydro, wind and solar power stations. Both demand and generation, as shown in the *Electricity Update* graphs, are adjusted by subtracting estimates of auxiliary loads. Thus demand, as shown, is equal to electricity supplied to distribution networks (and a handful of very large users that are connected directly to the transmission grid) plus transmission losses.

Generation is similarly defined to include only electricity supplied by large generators connected to the transmission grid. It does not include electricity generated by rooftop PV installed by electricity consumers, irrespective of whether that electricity is used on-site ("behind the meter") by the consumer or exported into the local distribution network. From the perspective of the supply system as a whole, the effect of this generation, usually termed either "embedded" or "distributed" generation, is to reduce the demand for grid supplied electricity below the level it would reach without such distributed generation. That effect can be clearly seen in the regular total generation graph; the gap between the red line – electricity sent out to the grid from large grid connected power stations – and the yellow line – that electricity plus estimated electricity generated by distributed solar systems – is the electricity supplied by those systems.