2019-20 NEM Summer Operations Review Report

June 2020

Important notice

PURPOSE

AEMO has prepared this document to provide information in relation to the operation of the National Electricity Market over summer 2019-20.

This publication has been prepared by AEMO using information available at end May 2020

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VERSION CONTROL

Version	Release date	Changes
1.0	22/6/2020	Initial release
1.1	23/6/2020	Correct totals in Tables 1 and 5

Executive summary

This review of summer 2019-20 outlines the preparations undertaken by AEMO and National Electricity Market (NEM) participants prior to summer and considers the effectiveness of these preparations in minimising disruptions due to a number of power system events that occurred during the summer period.

While preparatory work by AEMO and the industry was effective in mitigating the power system impacts of a season characterised by record high temperatures, extreme and catastrophic fire danger, significant smoke and dust, and violent storm activity, it is clear these challenges continue to grow.

In this review, AEMO has identified further specific measures that will enable continued improvement to the operational visibility of the power system, decision-making processes, and market mechanisms, and ensure a resilient NEM power system into the future.

Australia's physical gas and electricity infrastructure is being increasingly challenged by extreme and high heat and fire periods. The need to harden these assets to more extreme climatic conditions and consider opportunities to enhance the inherent resilience of the NEM when planning and delivering either new projects or replacing existing infrastructure will be a necessary element of future NEM planning.

These include:

- The increasing impact of both heat and fire on electricity systems, noting that:
  - Increasingly high temperatures are raising demand and degrading the output of both conventional and renewable generators.
  - Extensive smoke haze from extreme fire conditions creates additional challenges for demand and solar forecasting.
  - Environmental limits and temperature tolerances for coal plants are increasingly being approached and exceeded.
  - Material impacts on wind generation at high temperatures have been detected for the first time. These are similar to the impacts on thermal generation seen in earlier summers, for which mitigation strategies were already in place.
- The vulnerability of key transmission lines and other major energy infrastructure to fire impacts. This highlights the need to integrate resilience measures into the planning, routing, design, and assessment of transmission projects and upgrades, to:
  - Increase thermal operating limits.
  - Introduce more fire-resistant construction.
  - Enhance interconnection between major load centres.
- The impact on gas infrastructure (required for gas-fired electricity generation) of increasing temperature periods that are at or above the design tolerance of pipelines and plant.

Scope of report

This report reviews the operation of the NEM from 1 November 2019 to 15 March 2020. The scope is limited to operational outcomes and does not include commentary on market and financial outcomes[1]. To minimise duplication of details contained in other reports that have been or will be shortly issued (for example, Reliability and Emergency Reserve Trader [RERT] Quarterly Reports, Power System Incident Reports, Direction Reports, and Forecasting Accuracy Reports), this report instead provides an overview with references.

Weather

Summer 2019-20 was Australia's second warmest on record. The mean, maximum, and minimum temperatures were all the second warmest on record for the season, each coming in behind the record set last year during summer 2018-19. Mean temperature anomalies were between 1°C and 4°C across the NEM. Weather sequences with extreme multi-region heatwaves, such as those experienced on 30 and 31 January 2020, are intensifying the pressure on the grid in an increasingly complex environment.

The hot conditions combined with the dry landscape and strong winds to produce dangerous fire weather conditions during December 2019 and January 2020. Accumulated Forest Fire Danger Index (FFDI) values for December were more than twice the average over large areas of Australia, and the accumulated FFDI value for December was the highest on record.

Bushfire smoke and raised dust affected the Sydney basin, the Australian Capital Territory, and central Victoria for much of December and January.

On 31 January, widespread thunderstorm activity across South Australia and Victoria was observed ahead of a cold front. One storm in southwest Victoria created a downburst that destroyed six transmission towers near Cressy, separating the Mortlake Power Station, the Alcoa Portland (APD) aluminium smelter, and South Australia from the rest of the NEM.

February and March saw generally milder and wetter weather, with heavy rainfall during the first half of February helping to extinguish fires but leading to flash flooding and land slips. Numerous sites around Sydney had their wettest four-day periods on record. A broad tropical airmass drawn south by a persistent trough through the central east of Australia resulted in tropical-like conditions in the southern regions of the NEM.

The review of summer weather forecast performance indicates that there continue to be significant challenges in forecasting high temperatures in major city centres. The results demonstrate a bias by weather forecast providers towards under-forecasting at high temperatures and are indicative of the challenges in accurately assessing generation reserve on peak demand days throughout summer.

Energy forecasting – demand

On Friday 31 January 2020, aggregate estimated underlying NEM demand[2] reached 38,055 megawatts (MW), which is the largest underlying demand on record[3]. This record suggests that increasing levels of consumption are being supported by the whole-of-grid, including rooftop photovoltaic (PV) generation, as similar trends in operational (grid-served) demand are not necessarily being observed as behind-the-meter generation increases.

Overall, load forecasting performance met its key performance indicators, with strong improvements in day-ahead performance in New South Wales and Queensland, while other regions remained reasonably stable between last summer and this summer. AEMO is continuing improvement efforts for all forecasts, with a strong focus on intra-day peak demand forecasting. During extreme conditions, a number of factors can

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[1] For in-depth discussion of market impacts during the third quarter of 2019 and first quarter of 2020, see AEMO's Quarterly Energy Dynamics reports, at https://aemo.com.au/energy-systems/major-publications/quarterly-energy-dynamics-qed.

[2] Underlying demand = operational demand (from the grid, not adjusted for RERT or load shedding) + estimated rooftop PV generation.

[3] See https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/Demand-terms-in-EMMS-Data-Model.pdf.

materially impact, at short notice, the peak demand forecast that is published to the market. These factors include:

- Active, and often price-driven, demand-side response.
- Distribution-level outages, which can have a significant impact on the demand outcomes.
- Activation of RERT resources, which can be called within 4-hour-ahead timeframes.
- Peak demands, which are increasingly driven by highly weather-sensitive cooling (air-conditioning) loads.
- Impact of smoke haze, which is difficult to forecast.

Supply capability

Supply from scheduled generating units

In preparing for summer, generators co-operated with AEMO to minimise the amount of time generation was unavailable during summer due to planned maintenance outages. AEMO and generators also reached agreement that AEMO would aim to provide (if possible) sufficient lead time should an outage not be able to proceed, if conditions presented themselves where this was warranted.

In general, plant availability across the summer period was in line with pre-summer forecasts, including an assumed delay in the return to service of generating units at the Mortlake and Loy Yang A power stations[4].

AEMO's review identified that during summer 2019-20, compared to the previous summer:

- Unplanned generation outages decreased.
- Indirect loss of generation as a result of unplanned outages of transmission circuits connecting power stations to the main transmission system increased, mostly due to severe weather conditions.

Supply from wind and solar generation

Large-scale solar generators were materially affected by both smoke and dust in December 2019 and January 2020, causing challenges in forecasting solar generation. There were similar impacts on rooftop PV generation.

For wind generation, extreme temperature turbine cut-out[5] was experienced at a large scale across South Australia and Victoria for the first time, on a number of occasions, most notably on 20 December 2019.

While overall statistics on the forecasting accuracy of wind and solar resources in the NEM demonstrate relatively low deviations on average, some specific extreme event challenges emerged throughout the course of this summer, due largely to the above issues.

The estimated average error for rooftop PV forecasts at the day-ahead and 4-hour-ahead timeframes decreased significantly in Queensland and New South Wales from last summer to this summer, despite an overall increase in installed capacity.

Semi-scheduled solar generation and rooftop PV was generally over-forecast, but semi-scheduled wind generation was generally under-forecast. This is largely due to a bias in weather forecasting; in general, wind speeds are under-forecast and irradiance is over-forecast. There are initiatives underway in the area of weather forecasting to reduce these biases.

Reserves

Prior to summer, AEMO determined an expected unserved energy (USE) of 0.0026% in Victoria over the 2019-20 summer period. USE is energy that cannot be supplied to consumers, resulting in involuntary load

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[4] See https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2019/2019-electricity-statement-of-opportunities.pdf?la=en&hash=7FE871D75A9C619AB66FA671477551B2.

[5] This is where the output of a wind turbine is significantly reduced by protection systems due to very high ambient temperatures.

shedding (loss of customer supply), as a result of insufficient levels of generation capacity, demand response, or network capability, to meet demand.

This translated into an additional 125 MW of reserves being required in the Victorian region to meet the reliability standard[6] for 2019-20. Modelling also found that, to ensure the availability of sufficient dispatchable reserves in each region, so that USE would be less than 0.002% of total energy demand in nine out of 10 years, 560 MW of additional combined reserves would be required in Victoria and South Australia.

Based on these forecasts, and through open tendering processes under the National Electricity Rules (NER), AEMO secured reserves under two categories:

- Long Notice Reserve – AEMO entered into contracts to secure the 125 MW of reserves required to meet the reserve shortfall plus an additional 12 MW of reserve (that is, 137 MW total contracted reserves) to account for the statistical underperformance of contracted reserves. The total availability costs for the long notice agreements were $1.71 million.
- Additional reserves in medium and short notice panel agreements – AEMO established panels of potential RERT providers that could offer 1,698 MW of reserves at short notice, on pre-negotiated contract terms, in South Australia, Victoria, New South Wales, and Queensland, to manage unexpected risks.

These RERT services were activated on four days over the summer period in response to low reserve conditions, as listed in Table 1, at a total cost of $38.1 million (or $39.8 million overall including availability costs). Had AEMO not activated these RERT services load shedding would have been required had the largest credible contingency event[7] at that time occurred. Table 1 also includes the estimated total avoided cost of load shedding as a result of the RERT activations of $87.0 million, assuming the largest credible contingency event had occurred for the duration of each RERT activation.

Table 1 RERT activations over summer 2019-20

Activation date	NEM region	Maximum capacity of RERT activated (MW)	Volume of RERT activated (MWh)	Total RERT cost ($ million)[A]	Estimated avoided cost of load shedding based on VCR ($ million)[B]
30 December 2019	Victoria	92	283	$3.72	$11.66
4 January 2020	New South Wales	68	232	$8.36	$9.77
23 January 2020	New South Wales	152	456	$7.54	$19.21
31 January 2020	Victoria	185	697	$7.54	$28.72
31 January 2020	New South Wales	134	418.5	$10.93	$17.63
Total	**-**	**-**	**2,086.5**	**$38.09**	**$86.99**

A. Total RERT cost refers to pre-activation, activation and intervention costs (the compensation paid to Market Participants due to the intervention event (for example, to compensate for energy generation which is displaced by RERT capacity), and to Eligible Persons (SRA holders) due to changes in interconnector flows, and therefore changes in the value of Settlement Residues). It does not include availability costs.

B. The avoided cost of load shedding was estimated as the RERT activation volumes multiplied by the relevant VCR. VCR is the value of customer reliability; for further details, see https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/scenarios-inputs-assumptions-methodologies-and-guidelines/value-of-customer-reliability.

Assuming these RERT costs are proportioned on a consumption basis, the average cost per household is estimated to be $3.24 in New South Wales and $2.43 in Victoria[8].

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[6] Set by the Australian Energy Market Commission (AEMC). The current reliability standard requires expected USE in a given financial year not to exceed 0.002% in any NEM region.

[7] The largest credible contingency event is the largest loss of a generation unit or transmission line that is considered reasonably possible.

[8] For further details of RERT costs and the avoided cost of load shedding refer to the Quarterly RERT Reports for this period - https://aemo.com.au/en/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert/rert-reporting

During the summer period, AEMO declared a total of 28 Lack of Reserve (LOR) conditions (either forecast or actual). The majority of these occurred in New South Wales, followed by Victoria. Eight were actual LOR2[9] conditions (four in New South Wales, three in Victoria, and one in South Australia). Queensland experienced one actual LOR1[10] condition, and there were no LOR conditions experienced in Tasmania.

Transmission performance

AEMO, in its role as system operator, began working with Transmission Network Service Providers (TNSPs) in July 2019 to prepare the networks for summer 2019-20. The key focus of this work was to:

- Complete bushfire mitigation activities before summer.
- Undertake preventative maintenance that could improve reliability outcomes for the network over the summer period.

Broad agreement was reached with TNSPs that only critical outages with no impact on generation or interconnectors would go ahead during summer.

There was an observed increase in the number of unplanned transmission network outages in all NEM regions during summer 2019-20 compared to the previous summer. The largest increase was in New South Wales, mainly due to the impact of bushfires.

Of note, a number of unplanned transmission outages that occurred were separation (both inter-regional and intra-regional) events. In summer 2019-20, six separation events occurred, compared to zero in summer 2018-19. Significant separation events due to forced outages of transmission equipment were:

- On 16 November 2019, two 500 kilovolt (kV) transmission lines in Victoria tripped, resulting in the disconnection of the South Australian region from the rest of the NEM and disconnection of supply to the APD aluminium smelter
- On 26 November 2019, Basslink and one 220 kV transmission line in Tasmania tripped, resulting in the disconnection of Tasmania from the rest of the NEM and the disconnection of load in Tasmania.
- On 4 January 2020, multiple transmission lines in southern New South Wales tripped, resulting in the separation of the NEM into two islands, north and south of this area, and a significant reduction in available generation, leading to a LOR2 condition in New South Wales and activation of RERT services.
- On 7 January 2020, one 330 kV line in northern New South Wales tripped, resulting in the Queensland region and part of the New South Wales region disconnecting briefly from the rest of the NEM.
- On 31 January 2020, six transmission towers in south-west Victoria collapsed in a storm, separating the Mortlake Power Station, the APD aluminium smelter, and South Australia from the rest of the NEM for 17 days.
- On 2 March 2020, a circuit breaker tripped, resulting in the disconnection of the South Australian region and Mortlake Power Station from the rest of the NEM for approximately eight hours

Also, on 25 January 2020, three 275 kV transmission lines and two 132 kV transmission lines all tripped, resulting in load being disconnected momentarily in Far North Queensland.

Reclassifications due to bushfires, including damage caused by the fires, were in place for long periods of time, which constrained intra- and inter-regional transfer and at times reduced regional reserves.

At times of falling minimum demands, maintaining power system voltages within both operational and system design limits is an emerging challenge. This issue was mainly observed during summer in Victoria.

Management of system strength was also a significant issue in the Victorian and South Australian regions.

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[9] LOR2 means there is a risk that supply will not meet the forecast operational demand if the largest generating unit is lost or the estimated reserve forecast error is larger than the available reserves.

[10] LOR1 means there is a risk supply will not meet the forecast operational demand if the two largest generating units are lost or the estimated reserve forecast error is larger than the available reserves.

Frequency performance

The 17-day separation of South Australia from the remainder of the NEM created significant challenges in maintaining adequate control of frequency within South Australia, however the frequency largely remained within the required standard.

During separation events, particularly when South Australia was separated from the rest of the NEM, difficulties were encountered for some periods in satisfying the requirements for contingency frequency control ancillary services (FCAS)[11]. These issues resulted in high FCAS prices. The significance of these issues in terms of risks to power system operations will be examined further as part of the power system investigations of these events.

Directions

More directions have been issued so far in 2019-20 than in any other year. The majority of these directions were issued to maintain system strength in South Australia. The separation of the South Australian region from 31 January to 16 February 2020 required AEMO to issue directions to a range of participants to ensure system security was maintained.

Operational improvements

Effectiveness of improvements introduced in 2019

Ahead of summer 2019-20, AEMO provided additional training for NEM operations staff, involving courses and exercises conducted using AEMO's NEM Simulator. This training focused on new and updated processes, systems, and procedures for managing uncertainty and high-risk events such as bushfires, severe storms, and heatwave conditions. The training also covered RERT and load shedding exercises. The preparatory work by AEMO and the industry was effective in mitigating the power system impacts of the summer heat, the fires and the separation events.

Lessons learned from summer 2020-21

The experiences from the operation of the NEM power system during this summer have provided lessons to AEMO in a number of areas, including the need for:

- Continued action to improve power system resilience.
- Action to improve the management of the impact of extreme conditions on the output of both conventional and renewable generation.
- Improvements to operational processes for operation of South Australia as an electrical island. AEMO has updated operating procedures and is working with stakeholders to implement strategies to better ensure power system security under these circumstances, while reducing market impacts.
- Improvements to the management of the directions process under extreme and unusual conditions.
- A review of processes for managing contingency FCAS under islanded conditions, with the aim of reducing periods when contingency FCAS requirements are not met.
- Improvements in processes for system operation under low demand conditions.
- Improvements to processes for assessing reserve levels following the separation of NEM regions, including separations within a region.
- Improvements to operational decision-making support tools and to the extent of real-time data available to inform these decisions[12].
- Stakeholders to be provided with more information, sooner, following major power system events.

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[11] Contingency FCAS is enabled to correct the generation/demand balance following a major contingency event, such as the loss of a generating unit, major industrial load, or large transmission element.

[12] This includes enhanced monitored of system stability and disturbances.

- Continued enhancements to forecasting systems, to provide more accurate deterministic demand and renewable generation forecasts, including weather forecasts, and continued collaboration with weather forecasting providers and the wider forecasting industry to improve uncertainty management, situational awareness, and extreme event forecasting information.

The management of preparations for summer 2020-21 will also need to account for the difficulties created by the COVID-19 pandemic. This includes ensuring that all essential pre-summer maintenance activities are completed so NEM summer supply reliability is not adversely affected.

Collaboration and communication

AEMO engaged with participants and stakeholders across the summer period through a number of mechanisms including Market Notices, NEM-wide briefings, summer readiness sessions in each jurisdiction, NEM weekly summer readiness outlook briefings, and industry teleconferences, as well as ad hoc engagement and emergency communications using the Power System Emergency Management Plan and the Victorian Electricity Emergency Communications Protocol.

Contents

Tables

Figures

1. Weather

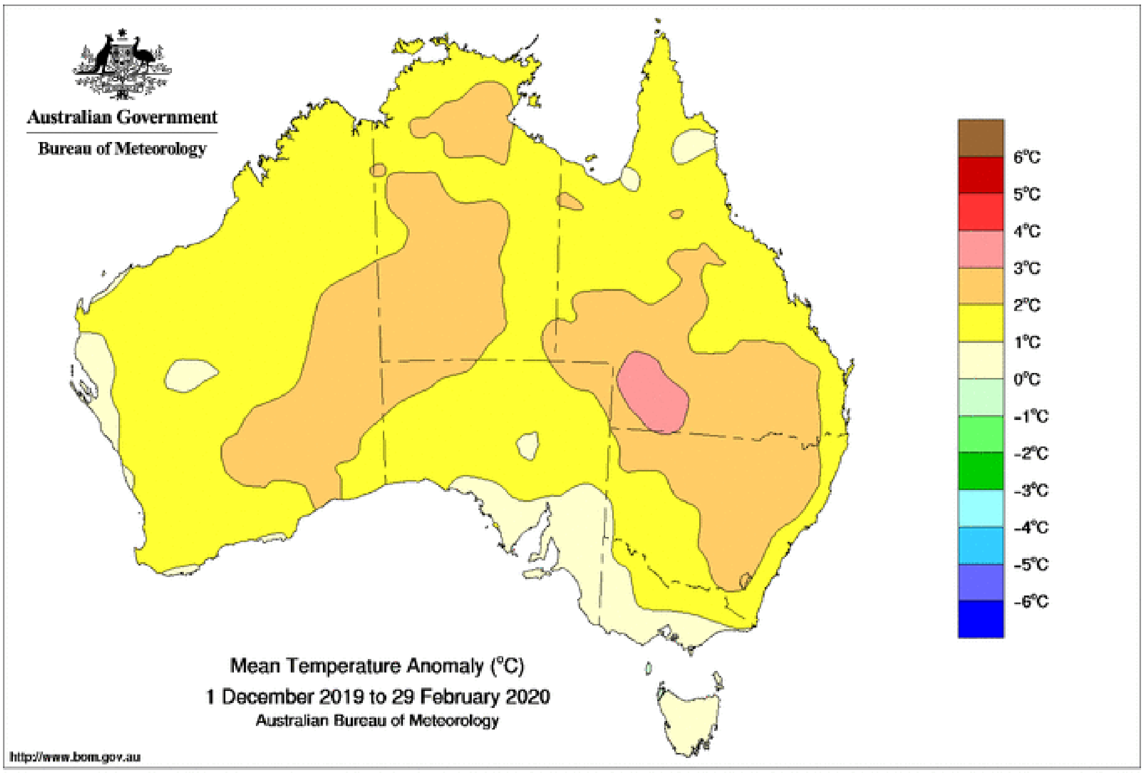
This section summarises:

- Weather conditions experienced over the 2019-20 summer and how actual conditions compare with those forecast prior to summer.
- The accuracy of weather forecasts used in inputs to AEMO's forecasting processes, and actions being taken with weather forecast providers to improve the accuracy of these weather forecasts.

1.1 Temperature

Summer 2019-20 (1 December 2019 through 29 February 2020) was Australia's second warmest on record. Each of the mean, maximum, and minimum temperatures were the second warmest on record for the season, each coming in behind the record set last year (summer 2018-19). Mean temperature anomalies were between 1 and 4°C across the National Electricity Market (NEM) (see Figure 1).

Figure 1 Mean temperature anomaly for summer 2019-20



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Most NEM regions experienced a very hot (and dry) December, above average temperatures in January, and February temperatures about or below average. Some points of note are:

- The national mean temperature for summer was 1.88°C warmer than average.
- The mean summer maximum temperature was 2.11°C warmer than average, and the mean minimum temperature was 1.64°C warmer than average.
- It was the warmest December on record for Australia, and the warmest December in all states and territories except Tasmania, for which it was in the top three.
- On two consecutive days, 17 and 18 December, records were set for Australia's hottest day on record. The national area-averaged maximum temperature on 18 December was 41.9°C, a whole degree higher than the value for 17 December (40.9°C). Both days exceeded the previous record of 40.3°C, which was set on 7 January 2013.
- Eleven days during December had a national area-averaged maximum of 40°C or more, seven of them consecutively from 23 to 29 December. Prior to December 2019, there had only been 11 such days on record in Australia since 1910 (seven of which occurred during summer 2018-19).
- The mean temperature for summer was the second warmest on record for Queensland (the warmest was 2005-06), the fourth warmest for New South Wales, and the sixth warmest for South Australia[13].
- For the southern parts of the NEM, summer 2019-20 was characterised by intense heatwaves followed by vigorous cold fronts which brought cool spells. As a result, numerous sites in South Australia, Victoria, and Tasmania recorded their highest summer temperature due to the intense heatwaves and/or record lowest summer daily maximum temperature due to the cool spells. Penrith Lakes reported 48.9°C on 4 January, the highest temperature ever measured in the Sydney basin (surpassing 47.8°C at Richmond in January 1939) and the hottest recorded in New South Wales this summer. Canberra reached 44.0°C, 1.2°C higher than the previous record for any Australian Capital Territory site. The Penrith record is also a new record high for any metropolitan area in Australia. Such temperatures are dangerously hot, and place extreme thermal stress on humans and power system assets.
- Hobart recorded 40.8°C on 30 December and 40.4°C on 31 January; Hobart has only reached 40°C on nine days over 134 years of records, and two of those days were this summer.
- South Australia experienced the highest mean minimum temperature on record for December. Adelaide (Kent Town) also recorded three consecutive days over 45°C between 18 and 20 December 2019.

Table 2 Temperature statistics for extreme days at key weather forecast stations for summer 2019-20 (up to 1 March), compared to long-term averages

		Days Exceeding 30°C			Days Exceeding 35°C			Days Exceeding 40°C		
State	Station name	2019-20 count	Average count	Difference	2019-20 count	Average count	Difference	2019-20 count	Average count	Difference
SA	Adelaide (West Terrace)	33	33.1	-0.1	12	14	-2	9	3.4	5.6
QLD	Townsville Aero	83	74.3	8.7	11	3.3	7.7	0	1.2	-1.2
	Archerfield Airport	70	43.7	26.3	6	3.9	2.1	3	1.7	1.3
NSW/ACT	Sydney Airport	27	14.2	12.8	7	3.9	3.1	4	1.6	2.4
	Bankstown Airport	36	24.7	11.3	10	7.3	2.7	5	2.1	2.9
	Penrith Lakes	51	43.1	7.9	25	15.9	9.1	12	4.8	7.2
	Canberra Airport	41	35.1	5.9	19	10.9	8.1	4	2.2	1.8
VIC	Melbourne	23	21.6	1.4	9	9.4	-0.4	4	3.7	0.3
TAS	Hobart Airport	10	5.3	4.7	3	1.6	1.4	2	1	1

Note: Red shading indicates temperatures significantly exceeded long-term averages; blue that they were significantly lower than long-term averages.

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[13] The average was calculated by breaking the Australian continent and the main island of Tasmania up into a 0.05^0 grid by longitude and latitude – roughly 5km x 5km – with each grid cell assigned a maximum temperature based on the temperatures from the weather stations around it. An area-weighted average of the grid cells was then calculated.

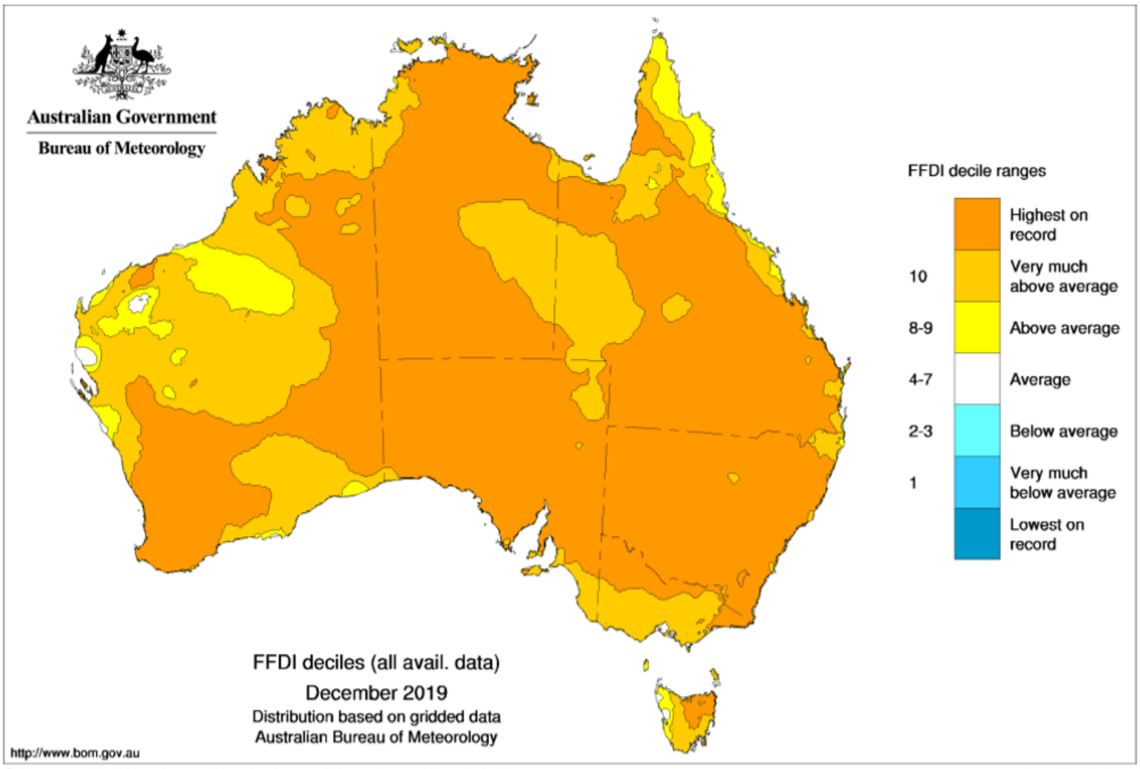
1.2 Fire weather

The hot conditions combined with the dry landscape and strong winds to produce dangerous fire weather conditions during December 2019 and January 2020. The Forest Fire Danger Index (FFDI) is one common measure of fire weather conditions, and reflects longer-term rainfall and temperature patterns, and shorter-term weather. Fire risk is driven by fire weather and fuel availability. Daily FFDI values can be accumulated (summed) over longer periods of time for comparison. The severe rainfall deficiencies and hydrological drought leading up to summer 2019-20 exacerbated the fire weather conditions; the accumulated FFDI values for spring 2019 were the highest on record for Australia as a whole (based on all years since 1950), with record high values observed in areas of all states and territories.

Record FFDI for December

Those dangerous fire weather conditions continued into summer, with December accumulated FFDI values the highest on record across large areas of the country (see Figure 2). Accumulated FFDI values for December were more than twice the average over large areas of Australia. The area averaged accumulated FFDI values for December were also the highest on record for each state and territory except Tasmania (second highest). That included the highest accumulated FFDI for any month in Queensland, New South Wales, the Australian Capital Territory, and South Australia. For Queensland, December 2019 continued a run of three consecutive months of the highest FFDI on record.

Figure 2 Accumulated FFDI deciles for December 2019 (based on all years since 1950)



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There were also individual days with FFDI values very much above average or the highest on record for December across large areas of the country. During December, daily FFDI values of 100 or above (the threshold for the catastrophic or code red category) were observed in all mainland States, the Australian Capital Territory, and the Northern Territory, and many areas had their highest FFDI on record for December. FFDI values were 100 or above across areas of southern South Australia, New South Wales, and Victoria on 20 and 30 December.

Dangerous fire weather conditions continued into early January, with daily FFDI values above 75 (extreme category) in areas of Victoria, New South Wales, and South Australia on several days between 1 and 10 January. Some areas in eastern Victoria and northern Tasmania, and across parts of New South Wales, had their highest daily FFDI values on record for January.

Fire weather conditions generally eased back from record levels in the second half of January, but accumulated FFDI values for January 2020 as a whole were very much above average over southern and western New South Wales, northeast Victoria, eastern Tasmania, and southwest Western Australia. There was also a final episode of significant fire weather affecting south-east Australia, particularly south-east New South Wales and eastern Victoria, at the end of January and start of February. New South Wales had its fourth-highest accumulated FFDI for January on record since 1950, and Tasmania had its third-highest accumulated FFDI for January.

Bushfire smoke and raised dust affected the Sydney basin, the Australian Capital Territory, and central Victoria for much of December and January.

1.3 Other weather notes

It was a very dry start to the summer and a wet finish. December was a record dry month with rainfall below average for the majority of Australia, while rainfall during January was mixed, and February was much wetter than average for parts of the east coast.

The dry conditions created an environment conducive to fires that burnt throughout December and January, approaching transmission infrastructure particularly in north-east New South Wales and south-east Queensland.

Heavy rainfall in the first half of February helped to extinguish fires but led to flash flooding and land slips with the potential to damage infrastructure.

Tropical cyclones Uesi, Damien, and Esther brought significant rainfall to many drought-ridden areas and significant humidity to south-eastern Australia. The Bureau of Meteorology (BoM) outlook published on 11 October 2019 stated that "fewer than average numbers of tropical cyclones are expected in the Australian region for the 2019-20 cyclone season (November-April)[14]. The Australian region saw six tropical cyclones this season, compared to an average of 11.

A broad tropical airmass drawn south by a persistent trough through the central east of Australia resulted in tropical-like conditions in the southern parts. On 31 January, AEMO asked Victorian consumers to reduce their energy usage between 1.00 pm and 8.00 pm following its forecast of the highest electricity demand since January 2014, due to extreme temperatures combined with unusually high humidity. Adelaide Airport recorded its highest precipitable water value[15] for January in at least 29 years, at 66.6 mm. Widespread thunderstorm activity across South Australia and Victoria was observed ahead of a cold front. One storm in the south-west of Victoria created a powerful downburst that destroyed six transmission towers in south-west Victoria, separating the Mortlake Power Station, the Alcoa Portland (APD) aluminium smelter, and South Australia from the rest of the NEM[16].

The late start to the monsoon onset in Darwin saw a build-up of heat in the northwest, contributing to heatwave conditions in Queensland, with hot days persisting until late January. A number of Queensland sites had their highest summer mean daily maximum temperature on record.

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[14] BoM, Australian Tropical Cyclone Outlook for 2019 to 2020, issued 11 October 2019, at http://www.bom.gov.au/climate/cyclones/australia/.

[15] "Precipitable water" is a measure of the amount of water in the atmosphere and so can indicate conditions with high humidity.

[16] AEMO, *Preliminary Report – Victoria and South Australia Separation Event, 31 January 2020*, published 17 April 2020, at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/power-system-operating-incident-reports.

1.4 Comparison of actual weather with pre-summer weather outlooks

The seasonal outlook for summer 2019-20, issued by the BoM in November 2019, forecast a high to very high chance of all NEM regions exceeding median maximum temperatures (see Figure 3), but only a high chance on the south-east coast and western Tasmania. The outlook assessed that all load centres in the NEM would have a very high chance of exceeding median maximum temperatures, except for Hobart, which would have a high chance.

Figure 3 Forecast chance of exceeding the median maximum temperature for Summer 2019-20, issued November 2019

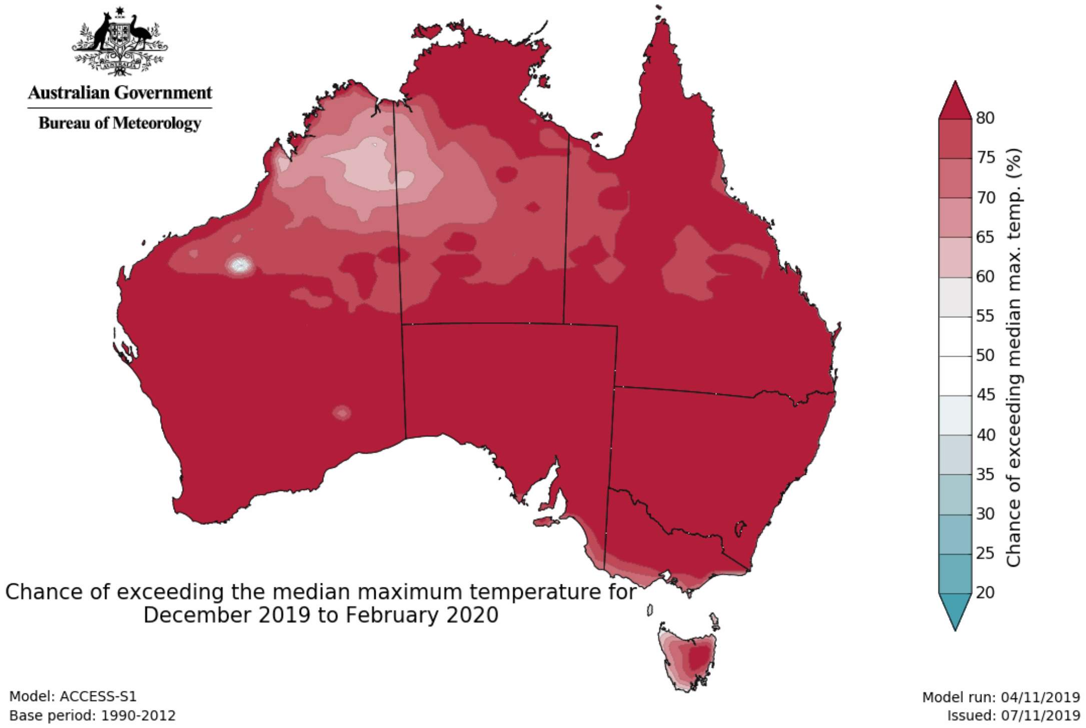
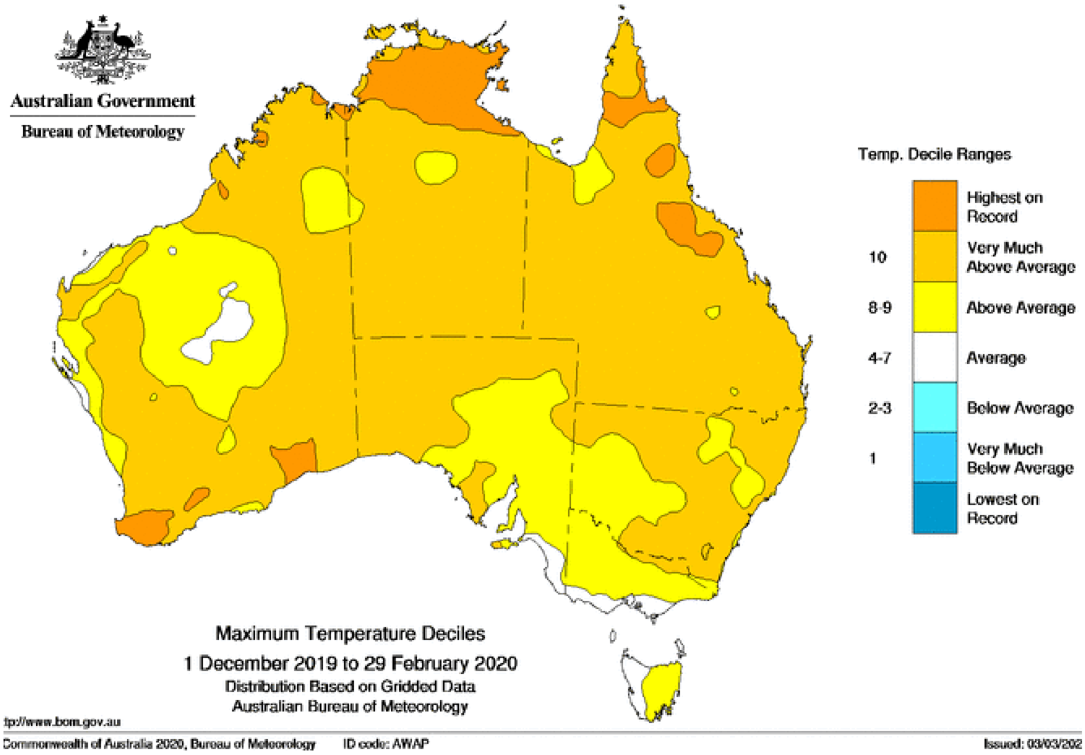


Figure 4 shows the actual maximum temperature deciles recorded, highlighting that all NEM regions did experience above or very much above average maximum temperatures throughout summer, and average conditions were recorded along the south-east coast of the mainland and western Tasmania. All load centres experienced above average maximum temperatures; Sydney and Brisbane very much above average.

Figure 4 Maximum temperature deciles for Summer 2019-20



1.5 Weather forecast accuracy

The growing penetration of renewable energy generation increases the importance of accurate weather forecasts to enable AEMO to accurately assess the adequacy of NEM reserves.

AEMO continues to work in close collaboration with a number of weather forecast providers, including the BoM and Weatherzone, to enhance forecasting information for the operation of the energy system. The first two bi-annual weather forecast accuracy analysis papers have been published on AEMO's website[17], comparing temperature forecasts at several critical NEM locations from three providers. A detailed summer 2019-20 analysis paper will be published in the coming months.

The review of summer weather forecast performance indicates continuing significant challenges with forecasting high temperatures in major city centres.

Figure 5 illustrates the probability density of forecast deviations (forecast – actual) by the best performing forecast provider for key NEM stations at the top 5% of summer temperatures. The results demonstrate a bias towards under-forecasting at high temperatures and are indicative of challenges in accurately assessing generation reserve on peak demand days throughout summer. This under-forecasting is coupled to the increasing weather sensitivity of electricity demand as the use of air-conditioning grows. Strong results at Archerfield are attributable to low temperature variance in Brisbane throughout the summer period.

AEMO is committed to continued collaboration with weather forecasting providers to improve its ability to forecast demand and supply availability, particularly during extreme weather events. Enhancements to existing extreme weather information are critical for AEMO to ensure sufficient resources are available to meet consumer demand to maintain public health and safety at all times.

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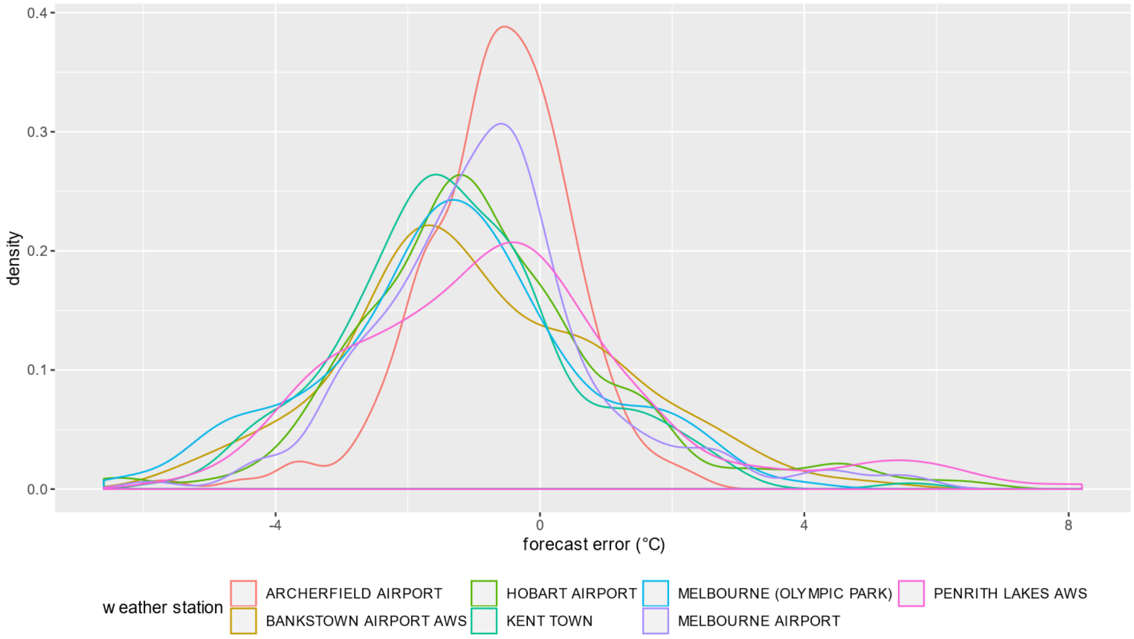
[17] At https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/load-forecasting-in-pre-dispatch-and-stpasa.

Figure 5 Best performing provider forecast performance at each major NEM weather station, top 5% of temperatures, day-ahead



2. Energy forecasting – demand

The scope of AEMO's operational forecasting functions covers forecasting of the load on the power system, the output of large-scale wind and solar generation, and the output of embedded rooftop photovoltaic (PV) generation.

This section deals with demand forecasting and shows how the changing nature of electricity load and increasing penetration of variable renewable energy resources are increasing the importance and complexity of accurate forecasting. Forecasting for wind and solar generation is covered in Section 3.

2.1 Demand outcomes

As more extreme weather occurs and records continue to be broken (see Section 1), and the number of rooftop PV installations continues to increase, demand forecasting models are required to extrapolate beyond their trained datasets and forecasting itself becomes more dependent on rapidly changing and multiple conditions. These events introduce complexities in the forecast requirements that require greater use of machine learning and other computational approaches and tools that can support appropriate decision analysis for real-time operations.

On Friday 31 January 2020, aggregate estimated underlying demand[18] in the NEM reached 38,055 megawatts (MW). This was the highest NEM demand on record[19], and significantly higher than the record set one day earlier (36,711 MW on Thursday 30 January 2020). The previous record of 36,417 MW was set on Friday 25 January 2019.

These records suggest that increasing levels of demand are being supported by all generation assets, including rooftop PV generation. As behind-the-meter generation increases, similar growth trends in operational (grid-served) demand are not being observed.

As generation from rooftop PV increases, daytime minimum operational demand records in the NEM continue to decrease, particularly in Victoria and South Australia where rooftop PV penetration levels are high:

- On New Year's Day 2020, Victorian operational demand dropped to 3,300 MW, its second lowest summer minimum operational demand on record. This value was reached during the middle of the day, representing the first time rooftop PV has driven operational demand to such a low level. (The minimum summer operational demand record of 3,217 MW, set on 12 November 2017, occurred during a short outage of a significant industrial load[20].)

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[18] Underlying consumption = operational demand (not adjusted for RERT or load shedding) + estimated rooftop PV generation.

[19] See https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/Demand-terms-in-EMMS-Data-Model.pdf.

[20] For the purposes of operations, AEMO considers the summer period to be 1 November through to 31 March.

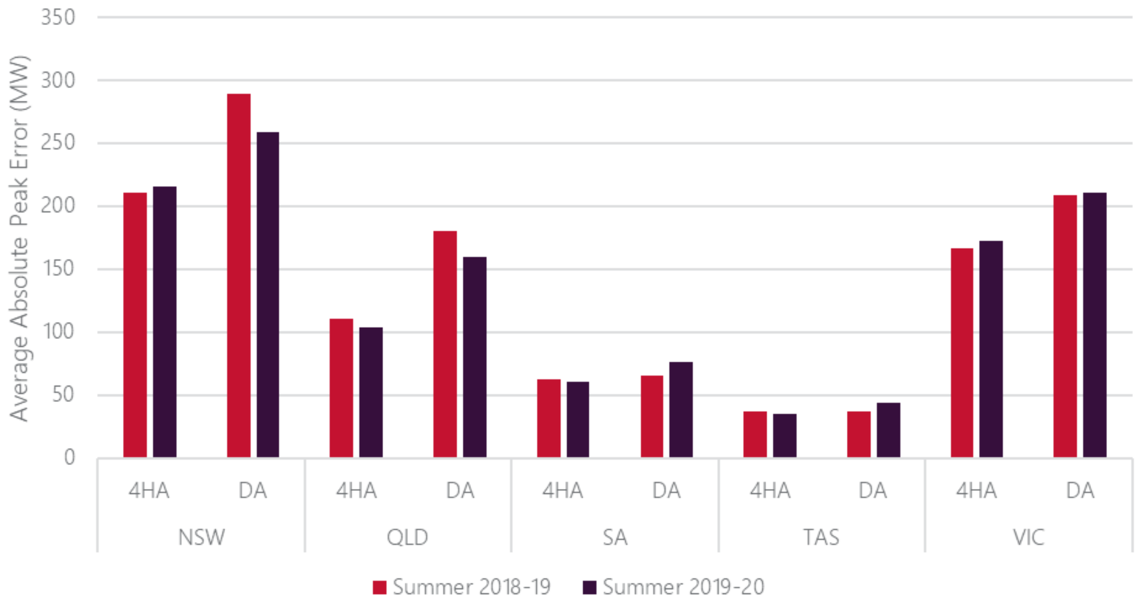
- South Australia experienced periods of very low demand this summer, with two of the five lowest summer operational demands on record. A new summer, and all-time, minimum demand record of 458 MW was set on 10 November 2019, when there was an estimated 838 MW of rooftop PV generation.

Weather sequences producing multi-region heatwaves, such as those experienced on 30-31 January 2020, are increasing the pressure on the grid as less supply is able to be drawn from neighbouring regions via interconnectors.

2.2 Demand forecasting performance

Short-term scheduled demand[21] forecast accuracy is closely monitored, in particular, for the peak interval of each day, for the 4-hour-ahead (4HA in Figure 6) forecasts and day-ahead (DA) forecast, as at the 1230 hrs pre-dispatch. Figure 6 compares the average absolute peak error performance for summer 2018-19 against summer 2019-20 for each of these time horizons.

Figure 6 Summer 2018-19 vs summer 2019-20 demand forecasting absolute average error



As factors that can contribute to demand forecasting error – such as the growth of rooftop PV installations and increased occurrence of extreme weather – continue to evolve, enhancing load forecasting tools remains a key improvement focus area for AEMO.

While the day-ahead peak forecast performance in New South Wales and Queensland improved this summer, the other regions remained reasonably stable or the average error increased slightly. The 4-hour-ahead accuracy in all regions remained relatively stable. Improving accuracy or even continuing with stable performance in an increasingly complex environment requires constant and continual improvement efforts, adopting best-practice tools such as consensus forecasting and machine learning techniques.

AEMO is continuing improvement efforts for all forecasts, with a strong focus on intra-day peak demand forecasting. During extreme conditions, a number of factors can materially impact the peak demand forecast that is published to the market, at short notice, including:

- Active, and often price-driven, demand-side response, which is not triggered until a high wholesale price eventuates. Price-responsive loads of this nature are not generally visible to AEMO and the timing and

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[21] See https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/Demand-terms-in-EMMS-Data-Model.pdf.

magnitude of their response is not forecast. AEMO has identified this summer that there is significant price-responsive load in the NEM that is not directly visible to AEMO.

- Distribution-level outages, which can have significant impact on the demand outcomes; again, outages at the distribution level are not forecast.
- Activation of Reliability and Emergency Reserve Trader (RERT) resources, which typically involve demand reduction, can be called within the 4-hour-ahead timeframe.
- Weather forecast accuracy. Demand sensitivity to temperature increases under extreme heat due to the increasing cooling load (due to more air-conditioning installations), meaning accurate forecasting of peak temperatures and timing of cool changes becomes increasingly critical. This is discussed in Section 1.5, and in published weather forecast accuracy reports[22].
- The demand ramp-up to the afternoon peak demand increasing in magnitude as rooftop PV penetration increases. This creates challenges for forecasting because the total generation from rooftop PV is estimated, as it cannot be directly measured.

Activation of RERT contracts was automatically forecast in AEMO's demand forecasting system for the first time in the summer of 2019-20. This enhancement, delivered prior to summer, enabled AEMO's control rooms and support staff to better review and schedule RERT. This methodology will be further explored to assist in the implementation of the Wholesale Demand Response Rule change, the Virtual Power Plant (VPP) Demonstrations, and other demand-side initiatives.

2.2.1 Demand forecasting accuracy: New South Wales example

New South Wales experienced one of its hottest summers on record, combined with days of heavy smoke from the surrounding bushfires.

High temperatures in New South Wales

This summer, 26 Sydney weather stations recorded their highest ever monthly maximum temperatures. Five days at Bankstown Airport, close to Sydney's demand centre, had maximums above 40°C, whereas last summer the temperature did not reach 40°C at this location.

These high temperatures can increase the tendency for under-forecasting temperature (because the training data sets for weather prediction models have fewer days with similar temperatures), and thus reduce the accuracy of these demand forecasts. In addition, models from weather forecasting providers aim to reduce the sum of squared errors, smoothing out temperature profiles and potentially missing temperature extremes. For further information, see AEMO's weather forecast analysis reports[23].

On Saturday, 4 January 2020, the actual maximum temperature was 5°C higher than the highest day-ahead forecast (see Figure 7), prompting up to 1,300 MW of weather-attributable deviations in the New South Wales demand forecast.

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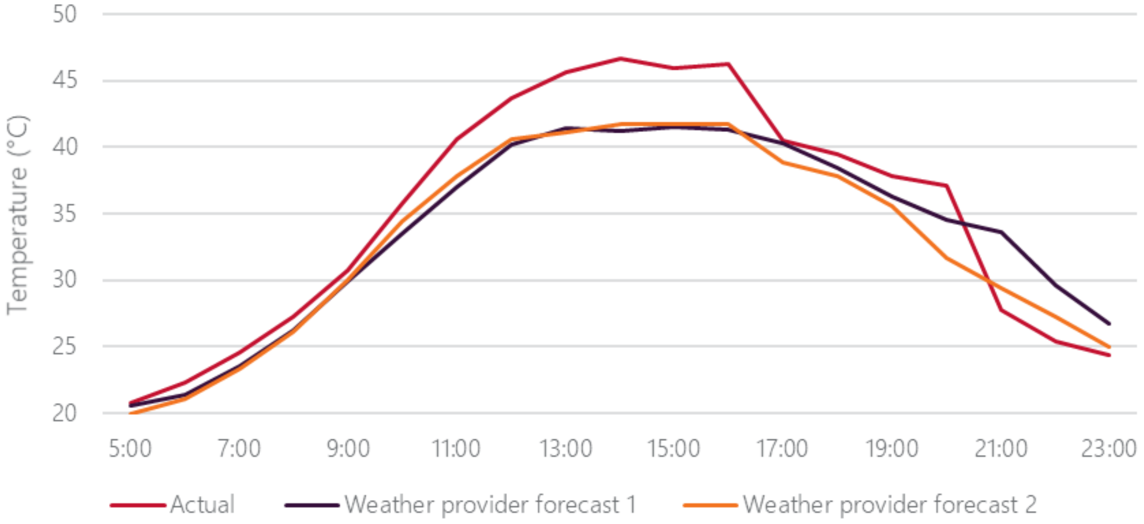
[22] See https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/load-forecasting-in-pre-dispatch-and-stpasa.

[23] At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/load-forecasting-in-pre-dispatch-and-stpasa.

Figure 7 Actual and forecast temperatures at Bankstown Airport on 4 January



Weekend peak demand

Summer 2019-20 saw the only weekend to occur in the top 15 highest demands of the past decade. On Saturday, 1 February 2020, peak operational demand reached 13,835 MW, making it the highest demand in New South Wales this summer and more than 350 MW higher than the next highest weekend demand on record. Two of the top five highest demands last summer occurred during the weekend – Saturday 4 January and Saturday 1 February.

Very high weekend demand creates challenges for forecasting load, because the model training data set is more limited (few weekend days, so there fewer hot days to compare), and weekend demands are more temperature-sensitive. Compared with a 35°C day, a 45°C day results in a 65% greater peak demand increase on weekends, compared to the increase that would be observed on weekdays. This is primarily because the use of residential air-conditioners is discretionary and attempts to remove stored heat in a building on start-up, compared to the always-on status of office air-conditioning systems.

Increasing residential consumption on peak days, combined with extreme temperatures which occurred more frequently on weekends this summer, caused this summer to have more peak demand days on weekends compared to previous summers.

Bushfire smoke

From November 2019 until the end of January 2020, Sydney experienced 47 days with unhealthy levels of PM 2.5 air pollution, predominantly caused by bushfire smoke. The record level of smoke this summer caused new challenges for demand forecasting due to the counteracting impacts on demand outcomes, shown in Table 3.

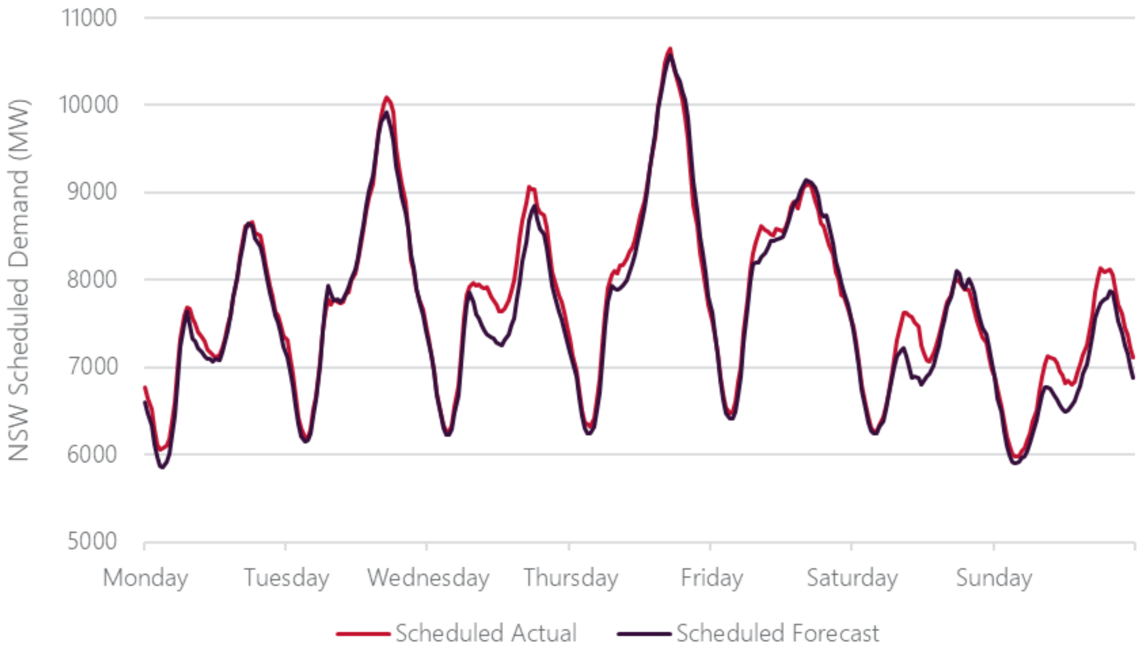
Table 3 The impact of bushfire smoke on demand outcomes

Smoke impact	Demand impact	Possible forecasting impact
Reduced air temperature	Reduction	Over-forecasting
Reduced direct heat to buildings	Reduction	Over-forecasting
Increased time indoors	Increase	Under-forecasting
Increased use of A/C	Increase	Under-forecasting
Reduced insolation on PV panels	Increase	Under-forecasting

One of the weeks with the poorest air quality due to bushfire smoke in Sydney was Monday, 18 November 2019 to Sunday 24 November 2019. Demand and weather deviations are shown in Figures 8 and 9 respectively:

- A weather deviation occurs where the actual weather differs from the forecast.
- A model deviation occurs where the demand forecasting model, even with perfect foresight, would not have captured the behavioural impact upon demand.

Figure 8 **New South Wales actual scheduled demand and day-ahead forecast, 18-24 November 2019**



From https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/Demand-terms-in-EMMS-Data-Model.pdf.

Figure 9 **New South Wales weather and model deviations, 18-24 November 2019**

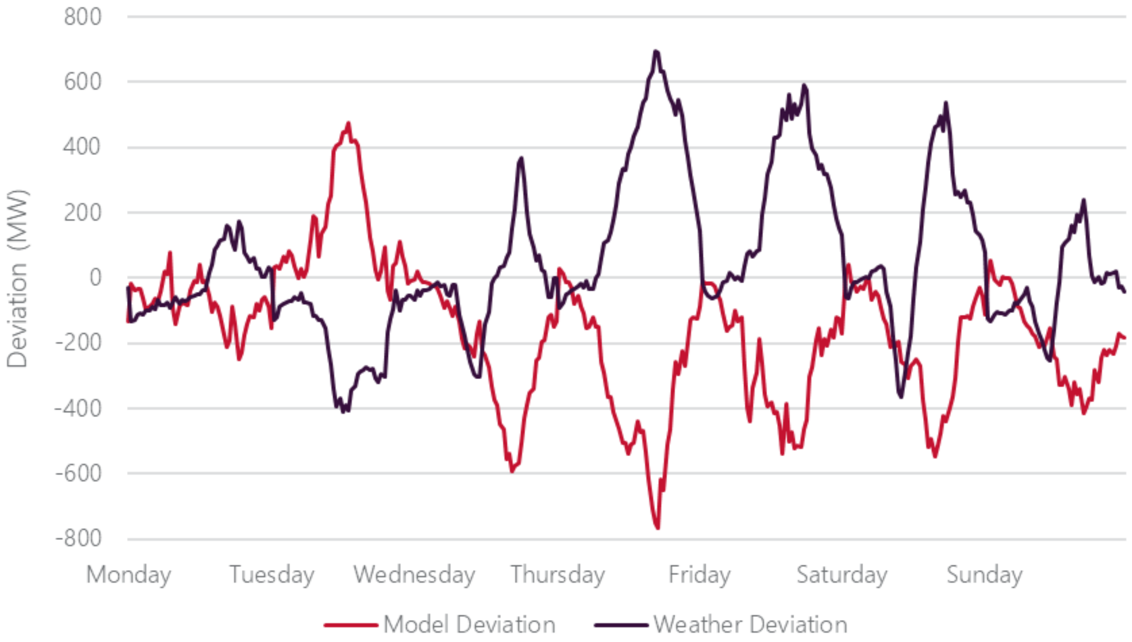


Figure 8 illustrates that the accuracy of the day-ahead forecasts during the smoky week was reasonably good. Figure 9 demonstrates the underlying factors that were counterbalancing to contribute to the resultant forecast:

- Persistent over-forecasting of temperature from Wednesday caused up to 700 MW of positive deviations, meaning the demand would have been over-forecast by up to 700 MW had it not been for the counterbalancing of model deviations.
- Persistent under-forecasting by AEMO's demand model from Wednesday caused up to 800 MW of negative deviations, meaning the demand would have been under-forecast by up to this amount had it not been for counterbalancing of weather deviations.

Currently, atmospheric weather models do not use smoke levels as an input that will account for a reduction in temperature; correction of these forecasts is required by meteorologist assessment. As such, the temperatures were over-forecast throughout the week, causing demand to be lower than it would have been had those temperatures eventuated. However, assessment of model outcomes suggests a behavioural impact due to the smoke kept people indoors, increasing the demand beyond what it would otherwise have been. The net impact across this week in Figure 9 was negligible on the New South Wales demand.

Rooftop PV forecasts performed well across this week; rooftop PV forecasting relies on on-the-day satellite imagery to 'see' the smoke and forecast its impact.

3. Supply capability

This section discusses supply capability from scheduled generating units and from solar and wind generation within a NEM region. Capability of supply from neighbouring regions is discussed in Chapter 6.

3.1 Outlook prior to summer

AEMO's *Summer 2019-20 Readiness Plan*[24] identified that:

- AEMO's 2019 NEM *Electricity Statement of Opportunities* (ESOO)[25] reported a level of 0.0026% expected unserved energy (USE) in Victoria for 2019-20, in excess of the 0.002% reliability standard[26]. This projection accounted for the potential for a delay in the return to service of either one or both of the Victorian generating units that were on long-term outages at the time.
- The 2019 NEM ESOO projected USE levels within the reliability standard in New South Wales and South Australia, but there remained a potential for the loss of consumer load in both regions, with expected USE levels of 0.00016% and 0.0002%, respectively [27]. In any region the actual occurrence of load shedding could be higher than forecast, and potentially significantly exceed the reliability standard, given particular combinations of weather events, plant outages, or bushfires.
- Approximately 3,700 MW of new additional capacity (primarily wind and solar) entered the NEM for summer 2019-20 compared to summer 2018-19, which helped at times to manage reserves during peak demand periods.

3.2 Preparing for summer

Generators co-operated with AEMO to minimise the amount of time generation was unavailable during summer due to planned maintenance outages. This process including identifying planned outages and moving them to either before or after summer where possible, depending on the level of risk, cost, and potential reliability concerns.

AEMO and generators also reached agreement that AEMO would aim to provide (if possible) sufficient lead time should an outage not be able to proceed, if conditions presented themselves where this was warranted.

For unplanned outages, AEMO and generators worked to identify and mitigate risks to plant availability.

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[24] At https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/summer-operations-report.

[25] At http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.

[26] USE means energy that cannot be supplied to consumers, resulting in involuntary load shedding (loss of customer supply), as a result of insufficient levels of generation capacity, demand response, or network capability, to meet demand. 'Expected' in this case is a mathematical definition, describing the weighted-average outcome. The current reliability standard requires expected USE in a given financial year not to exceed 0.002% in any NEM region.

[27] For details of modelling and forecasts, see AEMO's 2019 NEM ESOO, at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.

3.3 Supply from scheduled generating units

The availability of scheduled generating units is forecast by generators and advised to AEMO through the market systems. Actual availability will vary depending on plant condition and environmental conditions. This is a particular issue under high temperature conditions, as the output of scheduled generation (in particular, thermal generation) can be restricted due to a number of issues, including:

- Reduction of output of gas turbines as inlet air temperatures rise. Gas turbine units are in many cases equipped with systems to help manage this issue, but there are still impacts at extreme temperatures.
- Reduction of output for coal-fired generating units, which use cooling water from lakes, as they seek to avoid excessive lake water temperatures.
- Restrictions to power station auxiliary equipment as they reach operating limits due to extreme ambient temperatures.

Such reductions in output have created significant issues during earlier summers.

AEMO has worked with generators to better understand these risks and improve communication processes for the forecasting and management of this issue. These measures proved effective over summer 2019-20.

In general, plant availability across the summer period was in line with pre-summer forecasts.

For Victoria, there was some uncertainty around the return to service of a Loy Yang A and a Mortlake Power Station unit, which were on long-term outages. These units were originally scheduled to return to service in December 2019. Due to additional work required to fix identified issues during these long-term outages, the unit at Mortlake Power Station returned to service at the start of January 2020, and the unit at Loy Yang A returned to service at the end of January 2020.

In New South Wales, unplanned generator outages occurred on 23 January and 1 February 2020 that contributed to actual Lack of Reserve (LOR) 2 conditions being declared. Further details are provided in Section 4.

During summer 2019-20, incidents occurred that impacted the interconnection between states, limiting energy flows between NEM regions. Further details are provided in Section 6.

As well as working to identify and reduce the risks of plant outages during summer, AEMO and generators also focused on:

- Plant availability being reflected as accurately as possible in AEMO's market systems when generators were bidding to supply to the market. In most cases during summer 2019-20, bids were accurate, taking into account weather conditions and any plant issues.
- Communicating promptly, frequently, accurately, and with as much notice as possible about any availability issues with plant or units.

In general, generator bids and plant/unit availability issues were communicated with AEMO well in advance.

AEMO also communicated more frequently and proactively with generators, so they were aware of forecast temperatures that could affect operations and could review and update bids as necessary.

AEMO's review identified that during summer 2019-20 there was:

- Increased scheduled generator availability during the peak summer period (December and January), but reduced availability across February and March. In particular, New South Wales experienced some larger reductions in availability due to outages across a number of generators at the end of the peak summer period, but given the mild temperature conditions at that time, this did not cause reserve issues.
- An increase in the indirect loss of generation compared to summer 2018-19 as a result of unplanned transmission outages where these lines connected generators to the transmission network. This occurred in all NEM regions.

3.4 Supply from wind and solar generation

Due to its highly variable nature, the process by which the availability of wind and solar generation is assessed and forecast differs from that for scheduled generating units.

Wind and solar generators provide details of their technical parameters to AEMO through what is known as the energy conversion model. AEMO forecasts availability and output through its wind and solar forecasting systems[28], taking into account ambient conditions, weather forecasts, and advice from generators regarding equipment outages and restrictions.

3.4.1 Large-scale generation

Semi-scheduled solar generators were materially affected by both smoke and dust during December 2019 and January 2020, causing challenges in forecasting solar generation. Modelling suggests that a decrease of approximately 6% to 13% can be attributed to smoke plumes affecting the solar generators at times throughout the summer. Satellite imagery is a valuable tool for tracking smoke plumes in real time and adjusting forecasts on solar generation assets, similar to the way cloud is tracked. Numerical weather models, on which all weather forecasts rely beyond a forecasting horizon of approximately two hours ahead, may not capture impacts on irradiance and other weather parameters due to smoke. AEMO continues to investigate the impacts of smoke on generation assets and methods for adjusting forecasts accordingly.

While the overall statistics in the following charts for the forecasting accuracy of wind and solar resources in the NEM demonstrate relatively low deviations on average, some specific extreme event challenges emerged throughout the course of this summer (see Section 3.4.3):

- For wind generation, extreme temperature cut-out[29] was experienced at a large scale across South Australia and Victoria for the first time on a number of occasions, the most notable being 20 December.
- For solar generation, the challenge of forecasting solar resources during heavy smoke haze became evident across the summer.

Figure 10 details the average error (forecast – actual) at the 4-hour-ahead and day-ahead time horizons for aggregate semi-scheduled[30] solar generation in each NEM region. These forecasts are constrained pre-dispatch targets and reflect the impact of forecast security constraints and bids, rather than comparing to Unconstrained Intermittent Generation Forecasts (UIGF)[31]. Note that Tasmania does not currently have any semi-scheduled solar generators.

Figure 11 shows the average absolute error[32].

Figures 12 and 13 provide similar information for semi-scheduled wind generation.

The installed aggregate capacity of semi-scheduled wind generators, and particularly solar generators, increased significantly from last summer to this summer. These results suggest that while semi-scheduled solar generation is generally over-forecast, semi-scheduled wind generation is generally under-forecast. This is likely to be an artefact of the Numerical Weather Prediction models being used in the solar and wind forecasting systems.

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[28] For further details, see https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/solar-and-wind-energy-forecasting.

[29] Where the output of a wind turbine is significantly reduced by protection systems due to very high ambient temperatures.

[30] See https://www.aemo.com.au/-/media/files/electricity/nem/participant_information/participant-categories-in-the-nem.pdf?la=en.

[31] Pre-dispatch targets represented the expected, security-constrained output of generation which can be directly compared to constrained actual generation for an assessment of forecast accuracy.

[32] The average of the errors with the sign of the error ignored.

Figure 10 **Summer 2018-19 vs summer 2019-20 semi-scheduled solar average error**

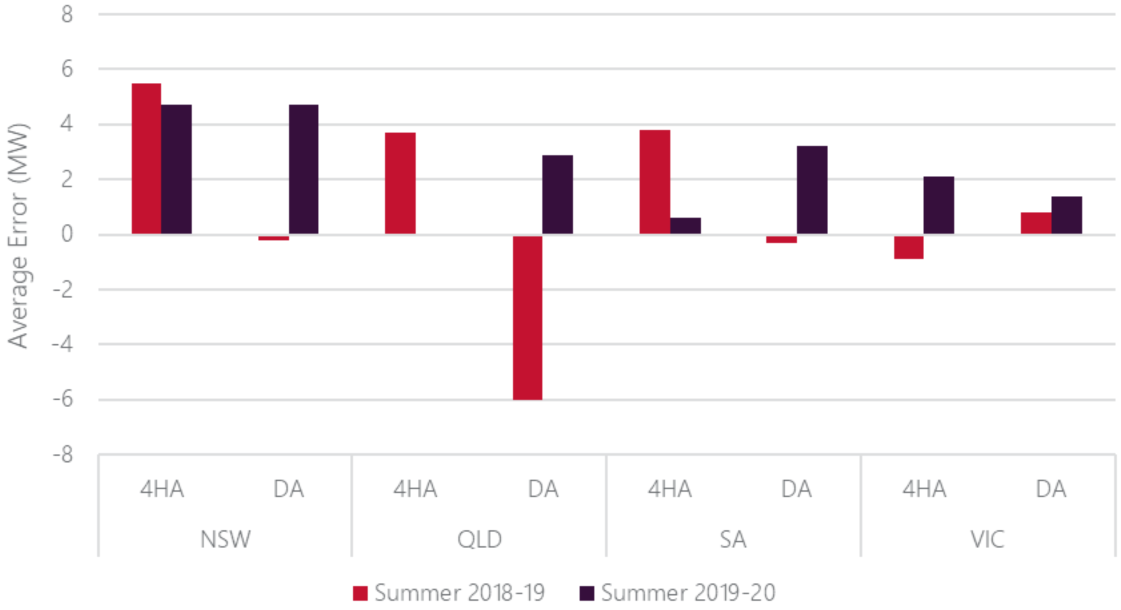


Figure 11 **Summer 2018-19 vs summer 2019-20 semi-scheduled solar absolute average error**

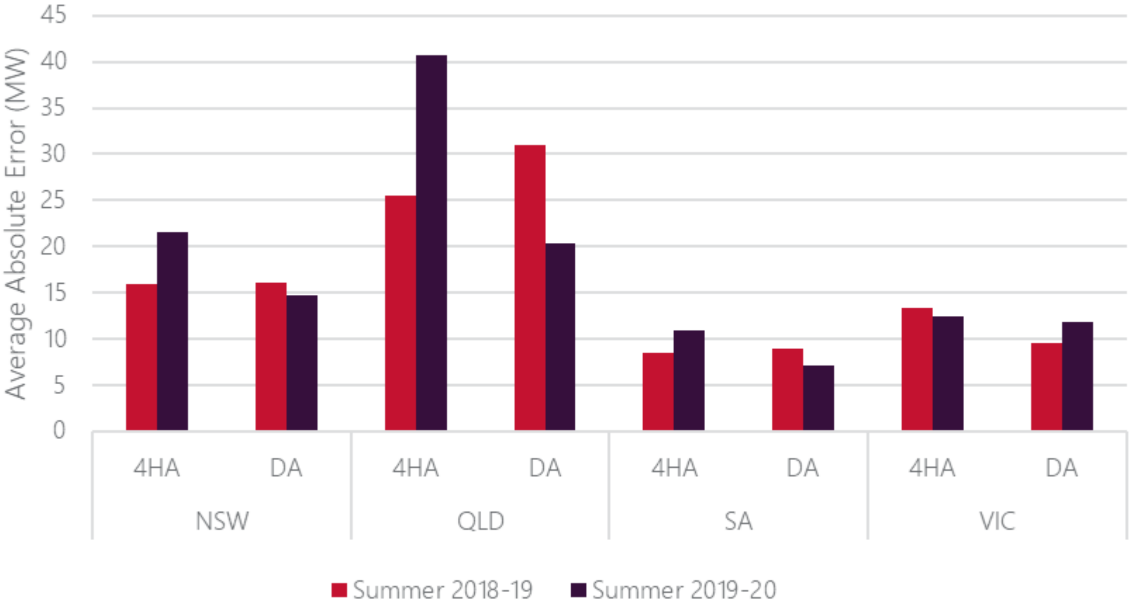


Figure 12 Summer 2018-19 vs summer 2019-20 semi-scheduled wind average error

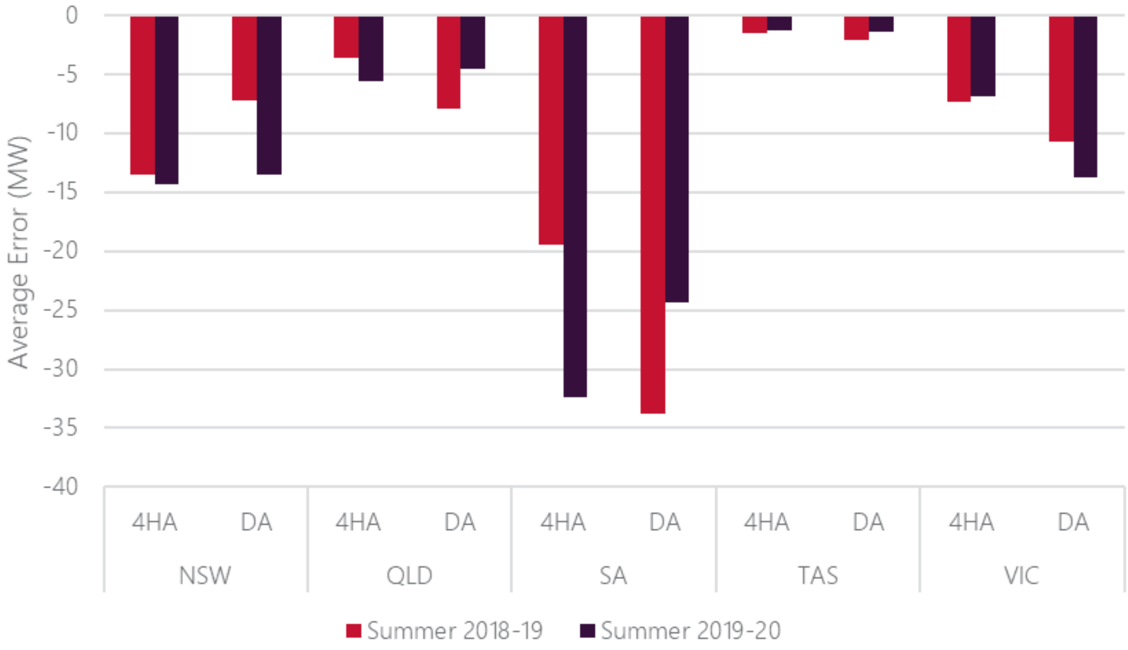
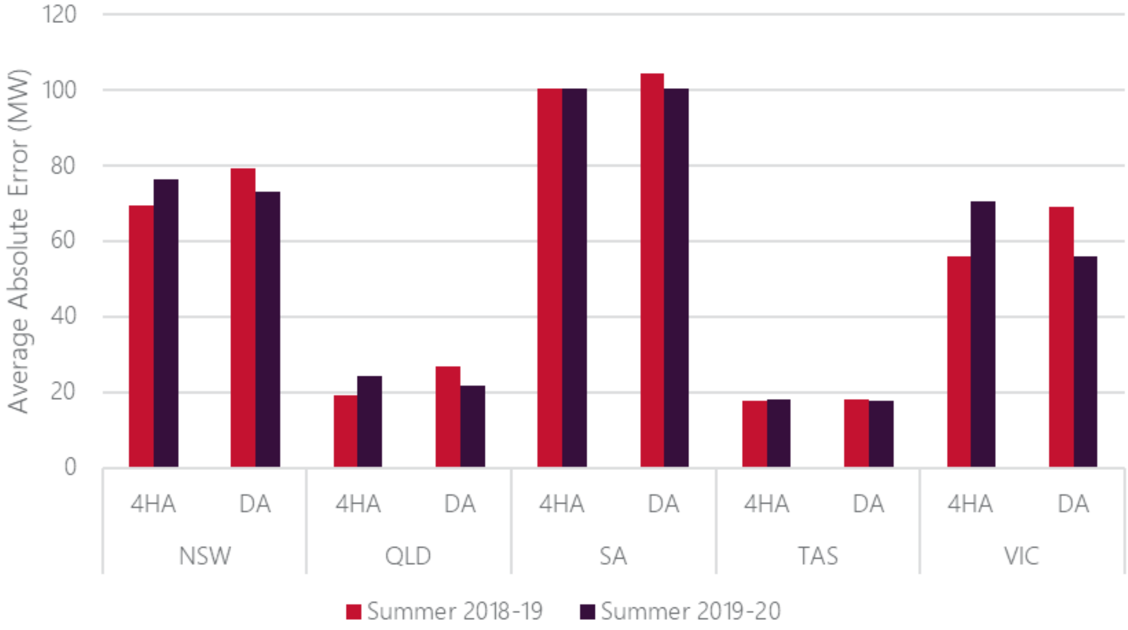


Figure 13 Summer 2018-19 vs summer 2019-20 semi-scheduled wind absolute average error



3.4.2 Rooftop PV generation

Average error decreased significantly in Queensland and New South Wales forecasts from last summer to this summer, despite an overall increasing installed capacity. However, all regions tended to over-forecast rooftop PV. Figure 14 shows the estimated average error of rooftop PV forecasts at the day-ahead and 4-hour-ahead timeframes, with Figure 15 showing the average absolute error.

Figure 14 Summer 2018-19 vs summer 2019-20 rooftop PV average error

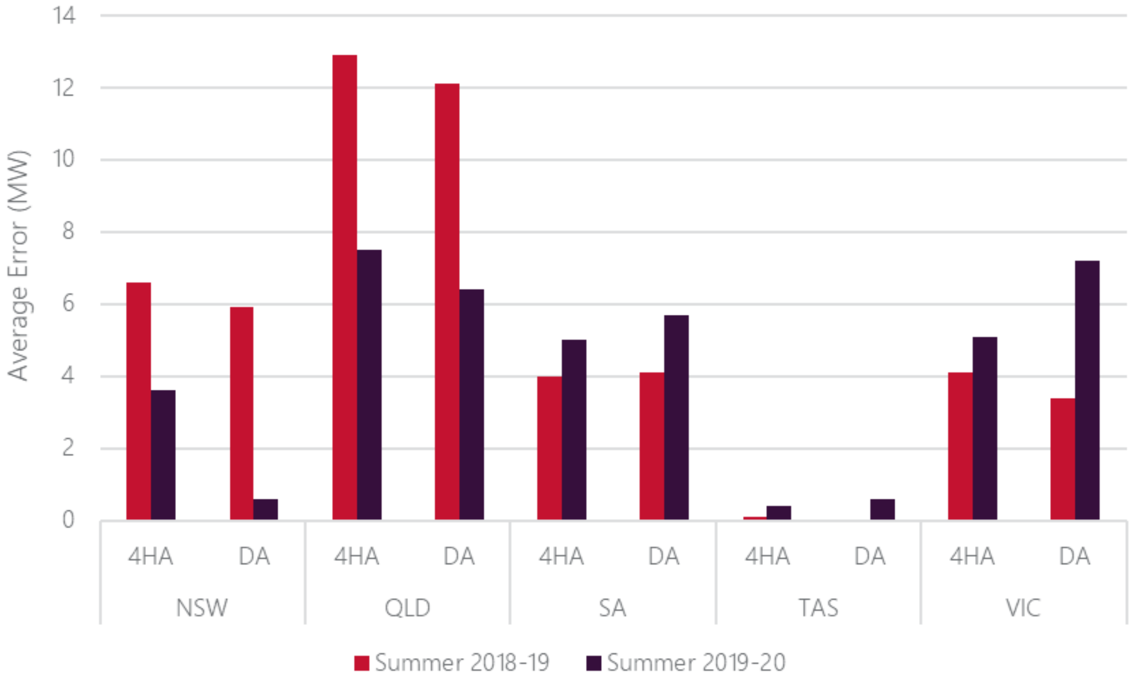
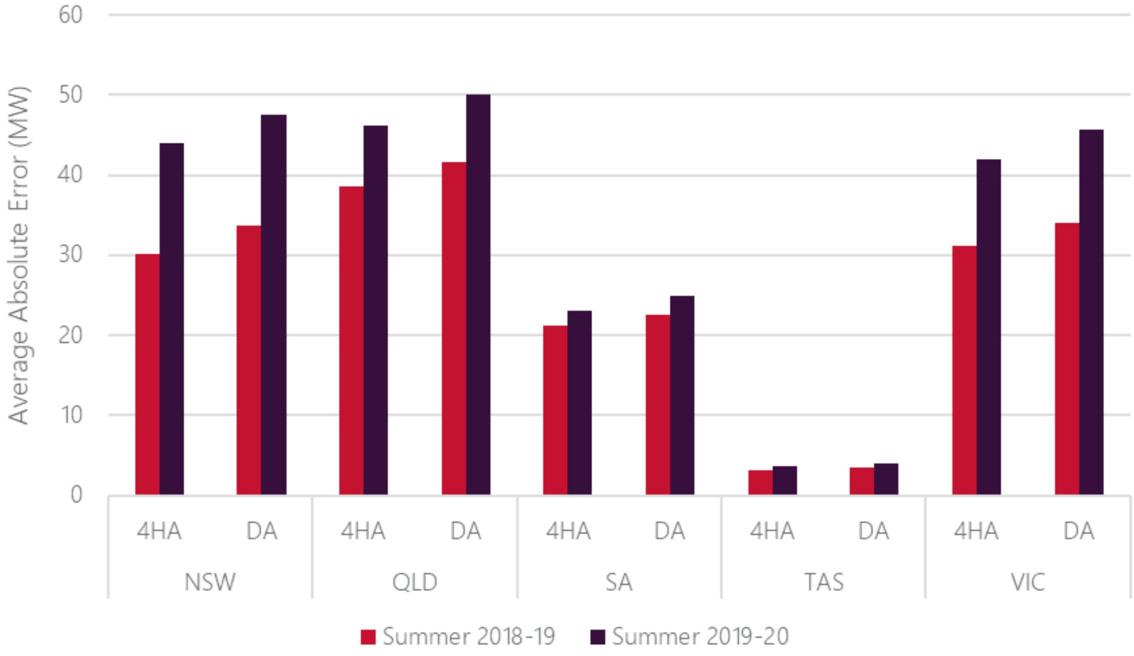


Figure 15 Summer 2018-19 vs summer 2019-20 rooftop PV average absolute error



3.4.3 Wind generation temperature de-rating

Two events in Victoria during the summer 2019-20 period demonstrate the challenges that can occur when forecasting available wind generation capacity. These phenomena were, and continue to be, experienced in all NEM regions; Victorian generation has been used as an example, due to the impact of these events on supply adequacy.

20 December 2019

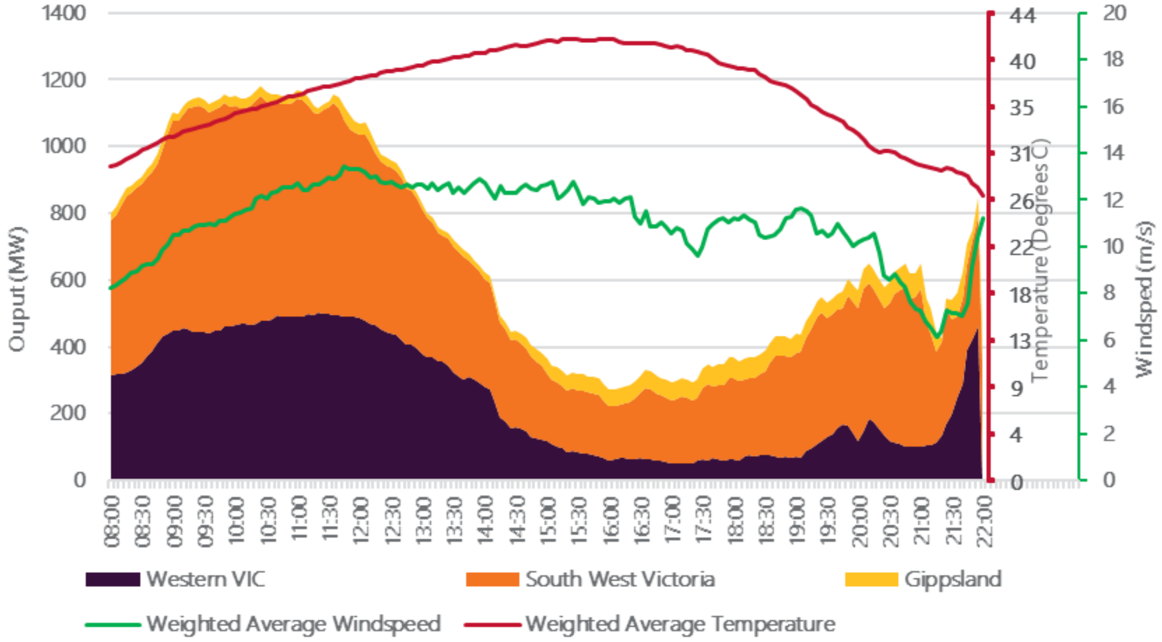
Many December weather records were broken across Australia during the heatwave conditions across much of the NEM from 16 to 21 December 2019. On 20 December, Adelaide and Melbourne reached 45.0°C and 43.5°C respectively.

In addition to very high demand in South Australia and Victoria on 20 December, wind generation was significantly de-rated due to high temperatures at turbine height, which resulted in high temperature cut-outs of the equipment on top of the wind turbines. Due to the potential for this to occur, AEMO had asked all wind farms and solar farms to advise of any deratings of their plants

Figure 16 shows Victorian wind generation during this day, against weighted temperatures and wind speeds. While wind speeds remained reasonably constant throughout the day, generation reduced by approximately 800 MW between 1200 hrs and 1730 hrs as temperatures exceeded 40°C at turbine height.

The resultant loss of this generation resulted in an unforecast LOR2 condition[33] and the requirement for RERT to be contracted[34] (RERT was not activated, due to generation output improving from 1730 hrs and demand decreasing in Victoria from 1800 hrs).

Figure 16 Victoria, 20 December 2019, weighted wind speed and temperature vs generation



31 January 2020

Co-incident extreme weather conditions were encountered across four regions of the NEM on 31 January 2020. As the day progressed, storms developed across large areas in South Australia and western Victoria, associated with the arrival of a cool change.

Wind farms in Victoria experienced four different phenomena that led to reductions in generation, causing deviations between forecast and actual generation throughout the day (both prior to the separation event and into the evening):

- High temperature de-rating.
- High wind de-rating.

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[33] Refer to Section 4.3.

[34] See https://aemo.com.au/en/news/aemo-publishes-q4-2019-rert-report.

- Low wind drop-out.
- Network outages.

Forecast wind speeds were in the vicinity of 7-10 m/s. This is within the range for which very small fluctuations in a meteorological sense can produce significant fluctuations in wind generation output, due to the cubic relationship between wind speed and generation.

The review found that:

- During convection (environments conducive to showers and thunderstorms), winds can behave erratically in a manner that is not accurately forecast by global weather models.
- The weather models were able to forecast a general reduction in wind throughout the day but were unable to capture localised impacts due to storms.
- Variable wind conditions increase the complexity for AEMO in making a highly accurate reserve assessment.
- While the management of plant limitations (such as high temperature de-rating) by market participants improved since the beginning of the 2019-20 summer period, examples from this event suggest that sites are updating availability for use in AEMO's assessment of system adequacy only after turbines are already de-rated, and often only after AEMO contacts site operators.

4. Reserves

This section summarises the basis on which AEMO assesses the adequacy of reserves and the uncertainty of reserve forecasts, actions taken to increase available reserves, and details of specific instances of low reserve conditions over summer 2019-20.

4.1 Forecasting supply and reserves adequacy

4.1.1 Reliability standard

AEMO produces long-term supply and demand forecasts to highlight any times a NEM region is at risk of not meeting the reliability standard. The standard is that each region has enough resources to meet 99.998% of its consumer demand each year[35] (which corresponds to a USE of 0.002%). These resources can include imports from another region, if that other region is forecast to have enough spare energy at the time. AEMO's assessment against the reliability standard identifies potential gaps and opportunities for market response.

4.1.2 Lack of reserve (LOR) conditions

For more short-term assessments, AEMO assesses reserves by using information about generator availability, forecast operational demand, forecast wind and solar generation, and the capacity and limits of interconnection between NEM regions.

If this assessment identifies that forecast supply may not be adequate to meet forecast demand and provide a necessary buffer, AEMO is required to declare LOR[36] conditions to give market participants the opportunity to respond.

LOR conditions indicate the system does not have enough capacity (LOR3), or enough spare capacity if something major and unexpected happens, like the loss of a generator or interconnector (LOR1 and LOR2).

Power systems around the world are built and operated with a certain level of reserve – a buffer to help maintain power system reliability for energy consumers. Pre-determined reserves in the NEM refer to spare capacity to provide this buffer, over and above the level of demand that is forecast at any given time.

AEMO informs the market of LOR conditions when forecasts indicate these pre-determined reserve levels are at risk, to encourage a response from market participants:

- Generators may offer in more supply.
- Consumers (generally large industrial or commercial consumers) can reduce their demand.
- Planned transmission outages may be recalled into service, if this is constraining electricity supply.

All three responses have the effect of improving the reserve margins and maintaining power system reliability.

AEMO will issue both forecast (to encourage a response) and actual LOR condition notifications. The three tiers for LOR notices are:

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[35] The reliability standard is set out in clause 3.9.3C(a) of the NER. It is a maximum expected USE in a region of 0.002% of the total energy demanded in that region for a given financial year. Importantly, USE is defined to exclude USE associated with certain power system security events.

[36] Lack of Reserve (LOR) is described in clause 4.8.4 of the NER. Section 4.3 of this report outlines tiered LOR thresholds (LOR 1,2, and 3) in more detail.

- LOR1 signals a reduction in pre-determined electricity reserve levels, and LOR1 notification simply provides an indication to the market to encourage more generation. At this level, there is no impact to power system security or reliability.
- LOR2 signals a tightening of electricity supply reserves, and notification provides an indication to the market to encourage more generation. At this level, there is still no impact to power system security, however a loss of the largest generator in a region, or a serious constraint on the transmission network, could result in a LOR3 condition.
- LOR3 signals a deficit in the supply-demand balance, in which, if there is insufficient market response to remove the LOR3, controlled load shedding will be required. AEMO views load shedding as a last resort to securely manage the wider power system.

When a low reserve period is identified, AEMO will declare a low reserve condition (LRC) and go to the market seeking a response from participants using the tiered notifications described above. If the market does not respond, AEMO may decide to use reserve contracts through RERT to reduce the likelihood of a loss of customer supply.

Reserve forecasts for summer 2019-20

To identify the conditions where additional reserves may be required, AEMO provides a range of forecast information under a range of operating conditions on both supply and demand to assist industry and governments in their decision-making. From an operational perspective, these forecasts include information provided under AEMO's:

- Medium Term Projected Assessment of System Adequacy (MT PASA) – two-year outlook for supply and demand, based on historical and projected demand, as well as average and more severe summer weather conditions.
- Short Term (ST) PASA – seven-day outlook for supply and demand, based on forecast weather conditions at the time.
- Pre-dispatch (PD) PASA – up to a 40-hour outlook in 30-minute horizons, based on the most current weather, supply, and demand information.
- Dispatch forecast – a 30-minute outlook in five-minute increments, based on real-time demand and supply information using telemetered data from the power system.

The purpose of these forecasts is to assess the likelihood of electricity demand and the supply availability across a range of time horizons, to inform planning on the adequacy of reserves, or operational decisions in real time on actions that may need to be taken to improve reserve margins, or improve power system operating conditions.

Before summer 2019-20, AEMO assessed the accuracy of these forecasts, and updated them as more detailed information around demand, generation, and transmission assets, and more specific weather forecast information, became available. As these forecasts were updated, AEMO worked collaboratively with industry and government to support sufficient reserves being available during summer 2019-20 to meet the expected conditions.

4.2 Additional reserves for summer 2019-20

As explained in the Quarter 4 2019 RERT report[37], the 2019 ESOO identified a particular risk of supply interruptions in Victoria exceeding the reliability standard for USE in 2019-20. This risk was observed to arise in Victoria, under a scenario where the unplanned outages of two major power stations, Loy Yang A2 (500 MW) and Mortlake unit 2 (259 MW) in Victoria, extended into the peak summer period, posing a significant risk of insufficient supply that could lead to material involuntary load shedding.

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[37] At https://aemo.com.au/-/media/files/electricity/nem/emergency_management/rert/2020/rert-quarterly-report-q4-2019.pdf?la=en.

AEMO determined an expected USE of 0.0026% in Victoria for 2019-20 over the summer period. This translated into an additional 125 MW of reserves being required in the Victorian region to meet the reliability standard for 2019-20. In addition, the ESOO modelling found that to ensure the availability of sufficient dispatchable reserves (MW) would be available in each region such that USE is less than 0.002% of total energy demanded in nine out of 10 years, 560 MW of additional reserves in Victoria and South Australia would be required to meet the reliability standard.

Based on these forecasts and through open tendering processes under the NER, AEMO secured reserves under two categories:

- Long Notice Reserve – AEMO entered into contracts to secure the 125 MW of reserves required to meet the reserve shortfall reported in the 2019 ESOO under expected conditions, plus an additional 12 MW of reserve (that is, 137 MW total contracted reserves) to account for statistical underperformance of contracted reserves when called upon on a given day.
- Additional reserves in medium and short notice panel agreements – AEMO established panels of potential RERT providers that could offer 1,698 MW of reserves in short or medium notice periods, on pre-negotiated contract terms, in South Australia, Victoria, New South Wales, and Queensland, to manage unexpected risks such as demand exceeding forecast expectations, and unplanned events resulting in a reduction in generation and/or network capacity.

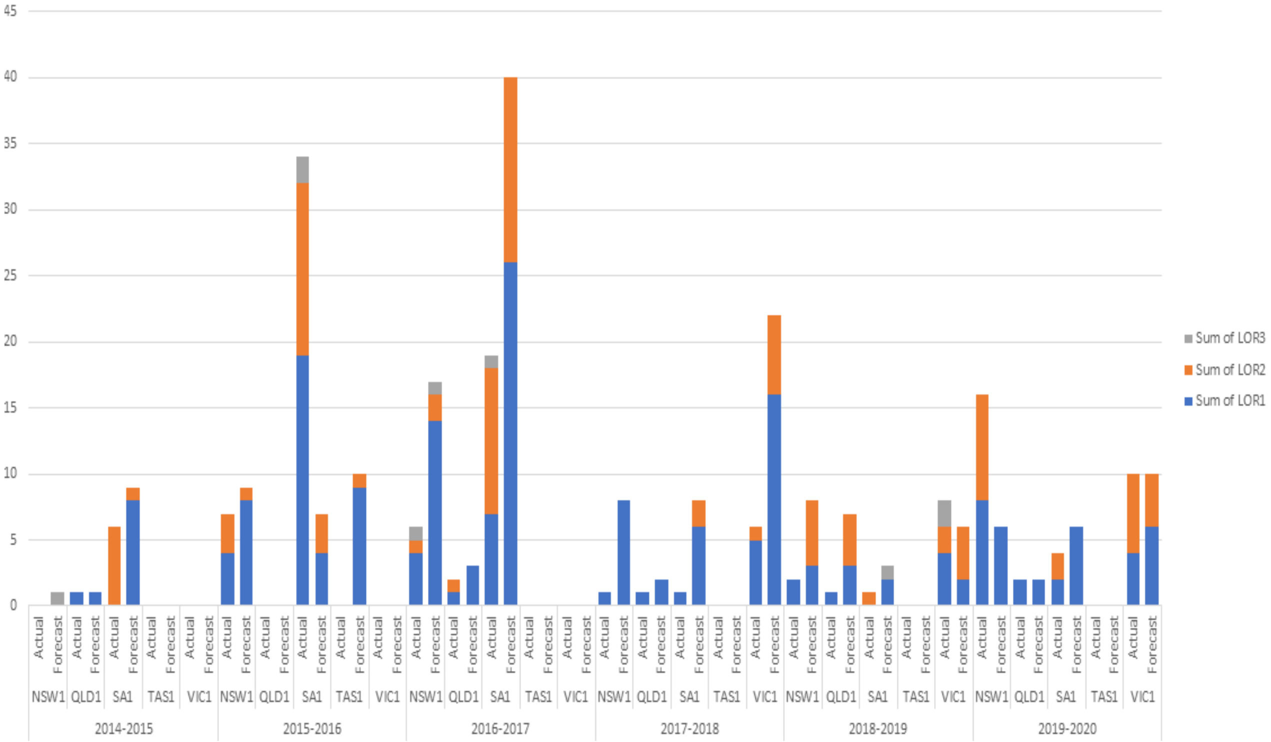
Demand side response outside of this mechanism also made significant contributions to improving reserves under tight supply conditions. These contributions are summarised in Section 4.4.2.

4.3 Lack of Reserve (LOR) declarations in summer 2019-20

During the summer period from 1 November 2019 to 23 March 2020, AEMO declared a total of 28 LOR conditions (either forecast or actual). Of the 28 LOR conditions, the majority occurred in New South Wales, followed by Victoria. No LOR conditions occurred in Tasmania.

Figure 17 shows historical summer LORs from 2014-25 to 2019-20.

Figure 17 Forecast and actual LORs for summer, 2014-15 to 2019-20, by NEM region



Note: Summer 2019-20 covers period from 1 November 2019 to 23 March 2020.

Figure 17 highlights a rising trend in the number of reserve conditions until 2017-18, as reserves reduce when capacity is withdrawn from the NEM (until it is replaced over time). Since 2017-18, there has been a moderation in the number of reserve conditions as new generation has entered the market.

4.4 Review of performance in summer 2019-20

4.4.1 Forecast Uncertainty Measure (FUM) Values

The accuracy of reserve forecasts depends on a number of factors, notably the accuracy of:

- AEMO's demand forecasts.
- AEMO's wind and solar generation forecasts.
- AEMO's forecasts of transfer capacity over the transmission system.
- Generators' forecasts of availability of generating units.

AEMO has developed a process to assess the uncertainty of the reserve forecasts depending on the forecast operating and environmental conditions and the time horizon for the forecast. This process provides an estimate of uncertainty known as the Forecast Uncertainty Measure (FUM), which is taken into account when assessing the level at which forecast LOR conditions are declared[38].

This section compares the performance of the FUM between the summer 2019-20 and summer 2018-19.

In the second half of 2018, AEMO consulted with stakeholders on a number of changes to the Reserve Level Declaration Guidelines, including:

- Inter-regional and intra-regional network limitations.
- Accounting for interconnector support.
- Improved modelling of energy limited plant.
- Changes to confidence level.

Following the implementation of these changes in December 2018, there was a notable decrease in the maximum FUM value that was observed from summer 2018-19 to summer 2019-20[39], in every NEM region (see Figures 18 to 22) A decrease in the FUM value can lower AEMO's requirement for reserves in each region, potentially resulting in fewer forecast or actual LOR declarations.

More detail on the most recent FUM performance is available in the NEM *Lack of Reserve Framework Report* for the quarter ending 31 March 2020[40].

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[38] For further details, see https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Reserve-Level-Declaration-Guidelines.pdf.

[39] These changes applied only for later part of summer 2018-19 but applied fully for summer 2019-20.

[40] At https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/nem-lack-of-reserve-framework-quarterly-reports.

Figure 18 FUM performance for New South Wales region, summer 2018-19 vs summer 2019-20

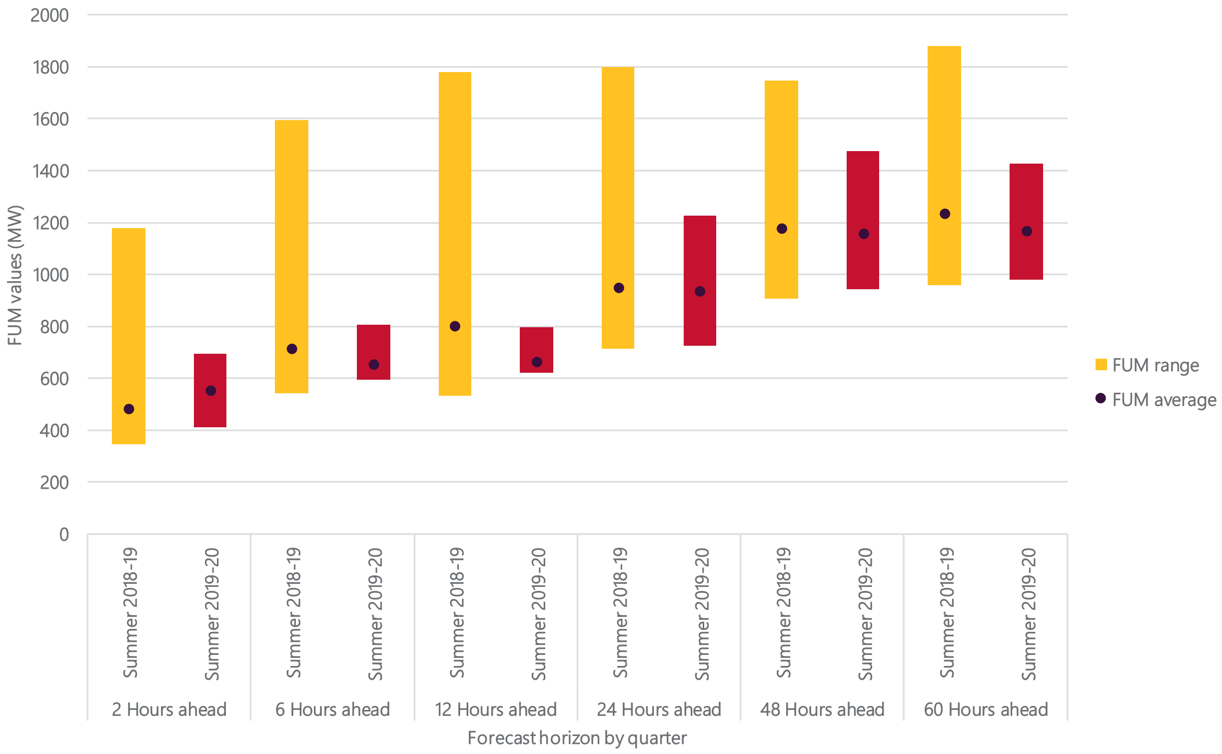


Figure 19 FUM performance for Queensland region, summer 2018-19 vs summer 2019-20

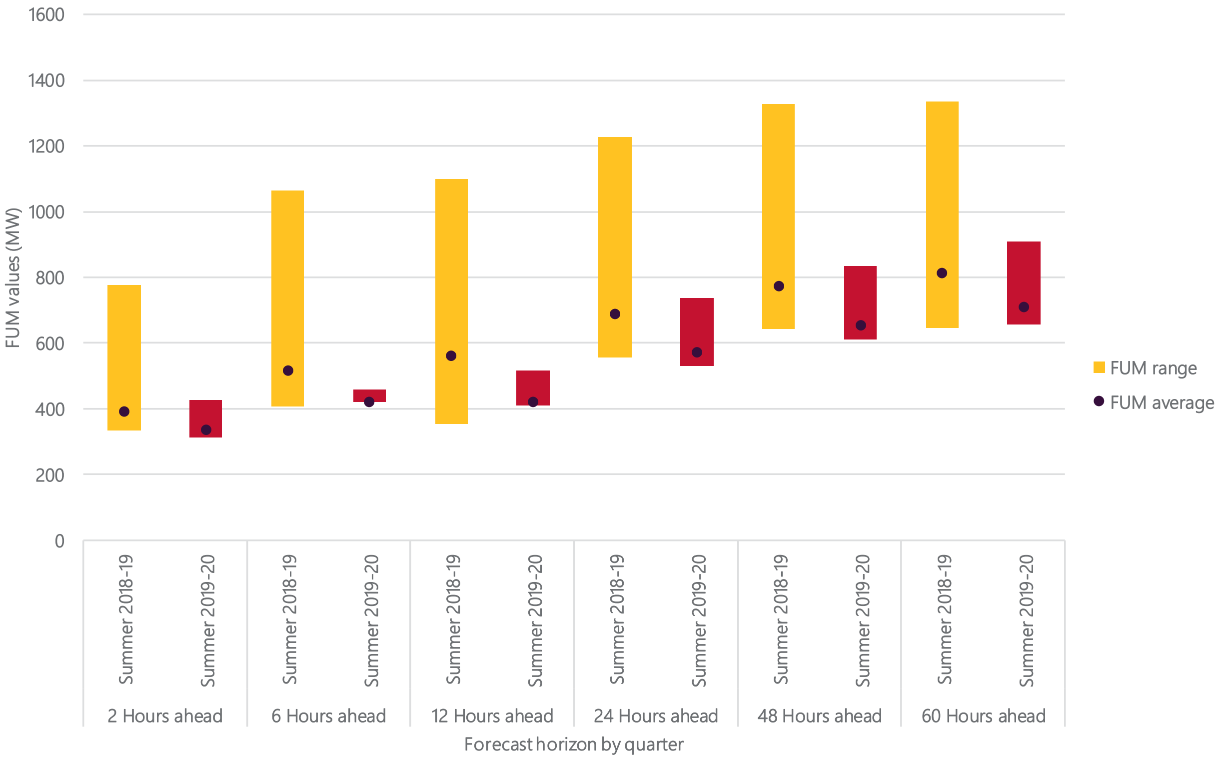


Figure 20 FUM performance for South Australia region, summer 2018-19 vs summer 2019-20

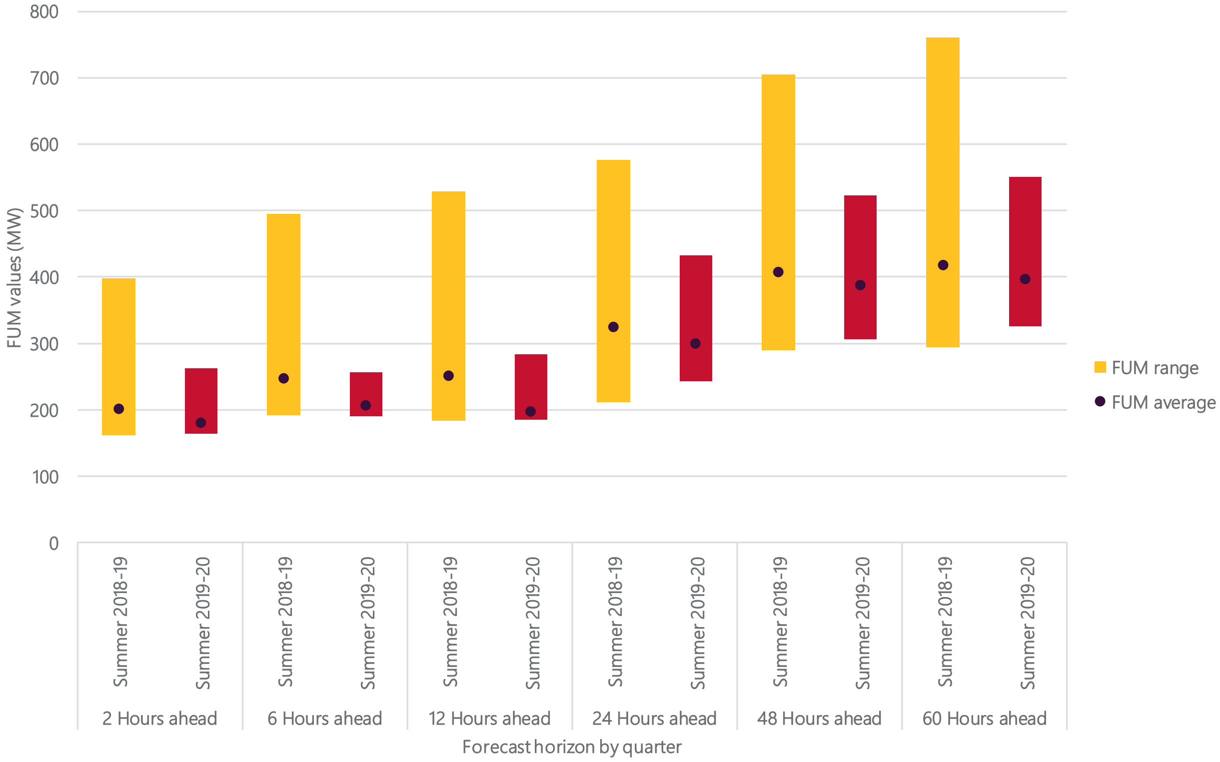


Figure 21 FUM performance for Tasmania region, summer 2018-19 vs summer 2019-20

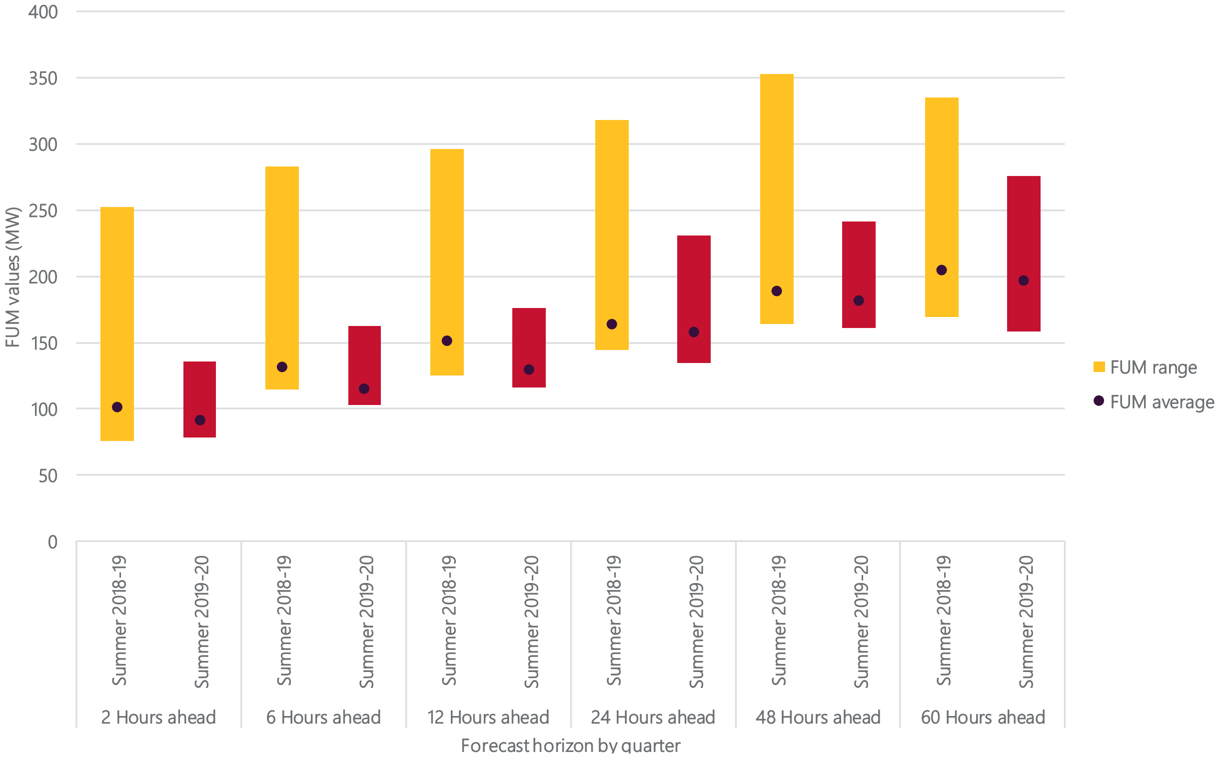
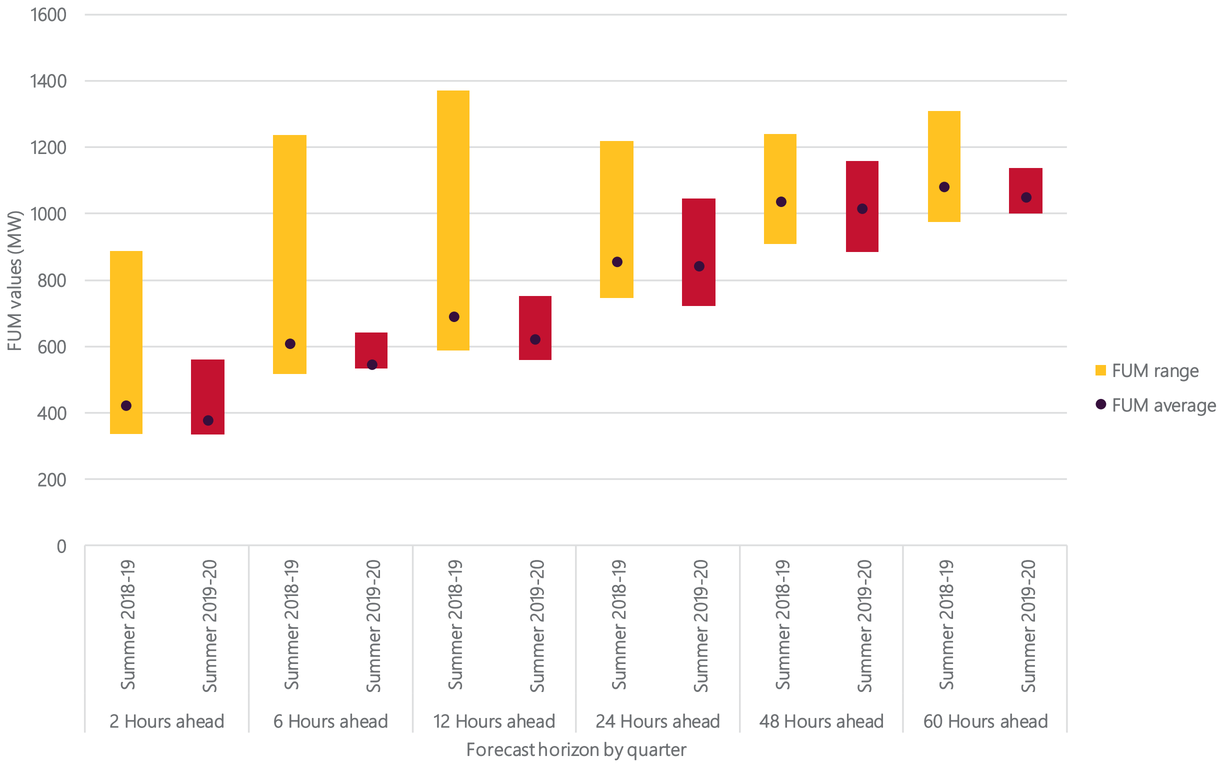


Figure 22 FUM performance for Victoria region, summer 2018-19 vs summer 2019-20



4.4.2 Summary of instances of actual low reserve conditions (LOR2)

Eight actual LOR2 conditions were declared across the NEM during summer 2019-20, summarised in Table 4. Further information about these events is available in AEMO's LOR quarterly reports[41].

Table 4 Summary of instances of low reserve conditions (LOR2)

Region	Date	Description of event
VIC1	20 December 2019	• An actual LOR2 was declared due to a large difference between wind generation availability in PD PASA and actual wind generation in Victoria. • This divergence was principally due to wind farm availability, submitted by market participants, not reflecting the observed high-temperature derating and cut out, and thus this unavailability was not reflected in PD PASA. • AEMO determined that the semi-scheduled availability input in PD PASA calculations was incorrect, resulting in suspect reserve conditions being forecast in PD PASA. As a result, AEMO used additional information to determine and declare an actual LOR2. • AEMO has estimated that there was up to 240 MW of demand side response during the high price period in the early evening. • AEMO declared an actual LOR2 condition in Victoria.

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[41] At https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/nem-lack-of-reserve-framework-quarterly-reports.

Region	Date	Description of event
NSW1	4 January 2020	• Multiple transmission lines in southern New South Wales tripped, resulting in the separation of the NEM into two islands, north and south of this area. • The incident also resulted in disconnection of generation and load, and a reduction in generation availability. • AEMO's preliminary report found that major bushfires in this area played a significant role in this event and contributing network conditions. • RERT was activated – see Section 5.2. • Excluding RERT, AEMO has estimated that there up to 400 MW of voluntary demand side response during the high price period in the early evening. • AEMO declared an actual LOR2 condition in New South Wales and RERT services were activated.
NSW1	23 January 2020	• A LOR1 was forecast then cancelled in the ST PASA timeframe, due to fluctuations in demand forecasts and generator availability. • A LOR1 was forecast in the PD PASA timeframe, due to a decrease in generator availability. • On this day, the demand forecast was adjusted upwards to reflect current trends, causing a forecast LOR2. • An actual LOR2 was declared earlier than forecast due to a significant and rapid decrease in generation availability. • RERT was activated – see Section 5.2. • Excluding RERT, AEMO has estimated that there was up to 360 MW of voluntary demand side during the high price period in the early evening. • AEMO declared an actual LOR2 condition in New South Wales and RERT services were activated.
VIC1	30 January 2020	• An actual LOR2 was declared without first being forecast due to an unplanned generator outage. • The unplanned loss of a major generator caused reserves in Victoria to rapidly reduce. • The time of the unplanned outage aligned with the evening peak operational demand in Victoria which was high due to extreme temperatures. • The event affected both Victoria and South Australia regions due to interconnector restrictions. • In response to the high prices early evening, AEMO has estimated a demand side response of up to 68 MW. • Reserves increased as demand decreased after the evening peak and the actual LOR2 condition was cancelled.
SA1	30 January 2020	• At the same time as the previous event, an actual LOR2 was concurrently declared in South Australia. • Interconnector flow into South Australia dropped rapidly to balance supply across the two regions. • The time of the unplanned outage aligned with the evening peak operational demand in South Australia, which was high due to extreme temperatures. • As set out above, AEMO has estimated a demand side response of up to 68 MW. • Reserves increased as demand decreased after the evening peak and the actual LOR2 condition was cancelled.

Region	Date	Description of event
VIC1	31 January 2020	• Forecast demand gradually increased over the days leading up to this event. • On 31 January 2020, towers supporting two 500 kV transmission lines in western Victoria were destroyed, resulting in the disconnection of the South Australian region, APD aluminium smelter, and Mortlake Power Station (MOPS) from the rest of the NEM power system. • Excluding RERT, AEMO has assessed that there was no significant demand side response due to market prices or from network reliability programs. • The loss of the MOPS generation from the rest of the Victorian region, coupled with the loss of the interconnector to South Australia, resulted in a LOR2 condition in Victoria. • AEMO declared an actual LOR2 condition in Victoria and RERT services were activated – see Section 5.2.
NSW1	31 January 2020	• At the same time as the previous event, the New South Wales – Victoria Interconnector was constrained down due to the Victoria – South Australia separation event, and the forecast demand rose. • In response to the high prices in the region, AEMO has estimated that there was up to 430 MW of demand side response, the majority from industrial load. • AEMO declared an actual LOR2 condition in New South Wales and RERT services were activated -– see Section 5.2.
NSW1	1 February 2020	• Forecast demand gradually increased over the days leading up to this event, resulting in a forecast and subsequent actual LOR1, with generation availability remaining reasonably constant over this time. • During actual LOR1 conditions, a sudden decrease in generation availability decreased available reserve further, causing an actual LOR2 declaration. • AEMO has estimated that there was approximately 50 MW of demand side response due to the high prices during the evening peak.

5. RERT

This section details the RERT resources which were available over summer 2019-20, the instances when these reserves were activated, and improvements to the RERT process implemented prior to summer.

5.1 Actual RERT resources available

RERT is an intervention mechanism under the National Electricity Rules (NER) that allows AEMO to contract for off-market emergency reserves, such as generation or demand response, when other reserve options will not be sufficient. These RERT services are activated in response to an LOR2 condition to increase reserve levels and reduce the likelihood of a loss of customer supply.

AEMO has observed a significant increase in NEM reliability risk following the retirement of a number of baseload generators (including Hazelwood, Northern, Munmorah, Wallerawang, and Anglesea power stations). The reliability risk is further exacerbated by a combination of extreme weather conditions and higher outage rates from ageing generation assets.

As noted in Section 4.2, AEMO contracted 137 MW of Long Notice RERT in Victoria for summer 2019-20 and established medium and short notice panel arrangements for 1,698 MW of reserves across the NEM. The total availability cost[42] for the Long Notice RERT agreements was $1.71 million.

AEMO contracted for Short Notice Reserve on the following occasions in Q4 2019 and Q1 2020:

- On 20 December 2019, in response to an actual LOR2 condition in Victoria, AEMO contracted 90 MW of RERT for a reserve shortfall of 122 MW.
- On 30 December 2019, in response to a forecast LOR2 condition in Victoria, AEMO contracted 200 MW of RERT for a reserve shortfall of 346 MW.
- On 4 January, in response to an actual LOR2 condition in New South Wales, AEMO contracted 368 MW of RERT for a reserve shortfall of 257 MW.
- On 23 January, in response to a forecast LOR2 condition in New South Wales, AEMO contracted 520 MW of RERT for a reserve shortfall of 258 MW.
- On 30 January, in response to an actual LOR2 condition in South Australia and Victoria, AEMO contracted 227 MW of RERT in South Australia and 60 MW in Victoria, for a reserve shortfall of 165 MW in South Australia and 495 MW in Victoria.
- On 31 January, in response to a forecast LOR2 condition in Victoria, AEMO contracted 235 MW of RERT for a reserve shortfall of 699 MW.
- On 31 January, in response to an actual LOR2 condition in New South Wales, AEMO contracted 478 MW of RERT for a reserve shortfall of 275 MW in New South Wales.

Note that no costs were incurred in contracting for Short Notice Reserves.

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[42] Availability payments are subject to change, any changes will be captured in routine revised statements.

5.2 Instances of activation of RERT – brief summaries based on RERT reports[43]

Since contracting and panelling for RERT in November 2019, as set out in Section 4.2, AEMO has activated RERT on four occasions in Victoria and New South Wales.

Table 5 shows the amount of RERT services activated on these days. The various activations were due to extreme conditions on the power system as a result of hot temperatures, high demand, and bushfires[44]. The activation of RERT within Victoria and New South Wales assisted in the avoidance of potential load shedding during these extreme conditions.

Table 5 RERT services activated during summer 2019-20

Activation date	Region	Maximum capacity of RERT activated (MW)	Volume of RERT activated (MWh)	Total RERT cost ($ million)[A]	Estimated avoided cost of load shedding[B] based on VCR ($ million)
30 December 2019	Victoria	92	283	$3.72	$11.66
4 January 2020	New South Wales	68	232	$8.36	$9.77
23 January 2020	New South Wales	152	456	$7.54	$19.21
31 January 2020	Victoria	185	697	$7.54	$28.72
31 January 2020	New South Wales	134	418.5	$10.93	$17.63
Total	-	-	**2,086.5**	**$38.09**	**$86.99**

A. Total RERT cost refers to pre-activation, activation and intervention costs (the compensation paid to Market Participants due to the intervention event (for example, to compensate for energy generation which is displaced by RERT capacity), and to Eligible Persons (SRA holders) due to changes in interconnector flows, and therefore changes in the value of Settlement Residues). It does not include availability costs.

B. The avoided cost of load shedding was estimated as the RERT activation volumes multiplied by the relevant VCR. VCR is the value of customer reliability; for further details, see https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/scenarios-inputs-assumptions-methodologies-and-guidelines/value-of-customer-reliability.

Following the Enhanced RERT rule change, AEMO is required to publish quarterly RERT reports under NER 3.20.6. The first quarterly report, covering October to December 2019, was published on 13 February 2020, while the report covering the January to March 2020 period was published on 14 May 2020[45].

The total cost of RERT including availability costs was $39.8 million. The quarterly RERT reports include the estimated average cost of RERT per household, and the Q1 2020 RERT report includes an estimation of the avoided cost of load shedding as a result of these RERT activations, assuming the largest credible contingency at the time had occurred for the duration of each RERT event.

5.3 Improvements to the RERT process

A number of improvements were applied to the process for contracting RERT this year, with a view to AEMO taking actions that have the least distortionary effect on the operation of the market, and actions taken

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[43] For reports, see https://aemo.com.au/en/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert/rert-reporting.

[44] See Section 4.4.2 for further details.

[45] Quarterly RERT reports are at https://aemo.com.au/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert/rert-reporting.

aiming to maximise the effectiveness of reserve contracts at the least cost to end use consumers of electricity, as stipulated in the RERT principles.

AEMO categorises RERT into the following three types based on their pre-activation and activation times:

- Type 1 – contracts that can be exercised (pre-activated and activated) in less than 30 minutes. These contracts are pre-activated and activated post-contingency when an actual LOR3 occurs.
- Type 2 – contracts which be pre-activated for a forecast LOR2 condition, but once pre-activated, can be activated in less than 30 minutes. As for Type 1, these contracts are activated post-contingency.
- Type 3 – contracts whereby activation requires more than 30 minutes. These contracts need to be pre-activated and activated in advance to ensure RERT is delivered on time.

During the majority of RERT events this summer, a large portion of the RERT contracts utilised were short notice Type 1 and Type 2 contracts. This resulted in minimal activation payments and market distortions, as these categories of RERT can be activated post-contingency (during an LOR3 condition). Therefore, this not only minimises impacts on the market but also maximises the effectiveness of reserve contracts at the least cost to end use consumers of electricity.

Following the Enhanced RERT rules changes, AEMO has new obligations under the NER. AEMO is reviewing its RERT procedures and processes to ensure compliance with the new RERT framework.

6. Transmission network performance

The performance of the transmission network is key to ensuring that supply from bulk generators can be delivered between regions and within regions to distribution networks.

This section summarises:

- Measures that were taken prior to summer 2019-20 to maximise the availability of the transmission network.
- The performance of the transmission network over summer, including brief summaries of the significant events which occurred on the transmission network.

6.1 Maximising network availability

Transmission network outages have the potential to impact interconnector capacity and/or generator capacity, and therefore reserve conditions, depending on the level of demand and network conditions on any given day. Maximising the availability of the transmission network over summer 2019-20 relied on active co-operation between AEMO and Transmission Network Service Providers (TNSPs) to ensure appropriate maintenance before summer and minimal planned outages during summer (especially at high demand times).

Even though extensive preparation work occurred across the networks, a high number of separation and severe weather events still occurred that were difficult to predict and plan for.

TNSPs are required to advise AEMO of the rating of their transmission lines and other equipment as part of normal operations. TNSPs provide information about their equipment, including rating application levels, application rules, and rating values. This information can be provided as static data for use under specified conditions, or as telemetered dynamic real-time data for use in dispatch timeframe, or it can be hand-dressed manually in AEMO's control system in urgent circumstances.

During the summer period, in particular under high temperature conditions, the transfer capability of transmission lines can be impacted. When operating the network, any changes to line capability are usually managed through changes in thermal line ratings (static or dynamic), and these values are automatically included in the constraint equation calculations.

Forecasting of these values is achieved as follows:

- For static ratings, there are defined rules and times modelled in Pre-dispatch and PASA.
- For dynamic ratings, forecast values are determined using a number of approaches depending on circumstances (static profiles, default temperature profiles or special forecast models).

6.1.1 Preparing for summer

AEMO and TNSPs began preparing the networks for summer 2019-20 in July 2019. The key focus of this work was to:

- Complete bushfire mitigation activities by before summer.
- Undertake as much preventative maintenance as practical to improve reliability outcomes for the network over the summer period by November 2019.
- Ensure no planned maintenance was scheduled on high demand days. Broad agreement with TNSPs was reached that only critical outages with no impact on generation or interconnectors would go ahead during summer. This plan was executed successfully across the networks.

6.1.2 Performance during summer

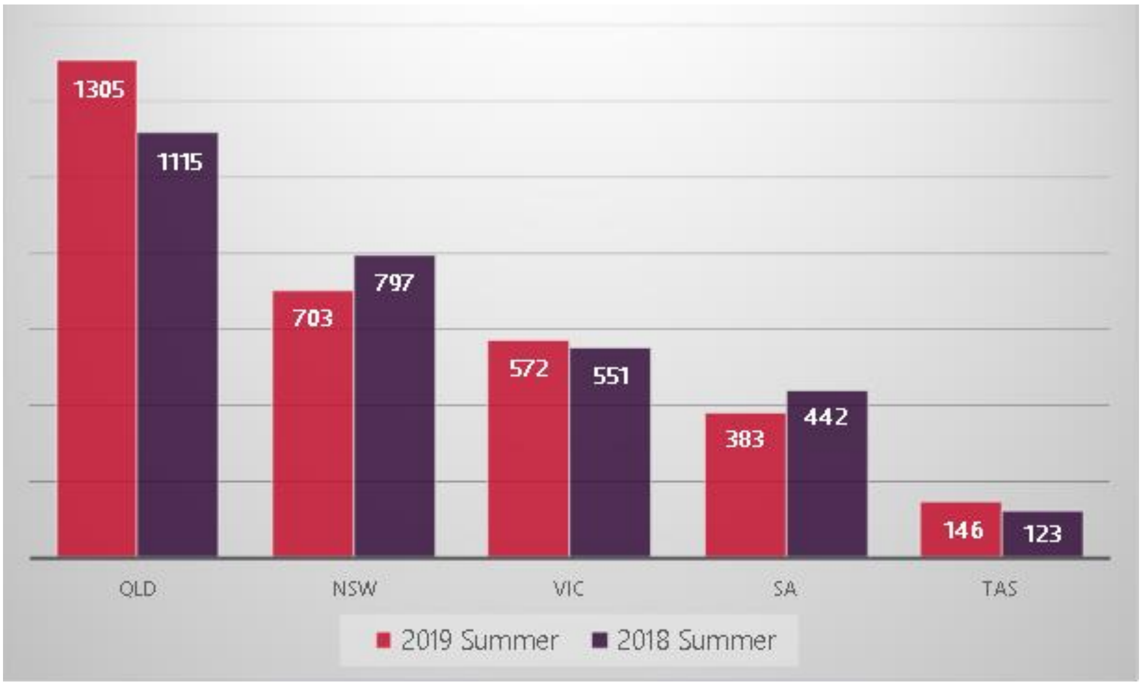
Planned outages

Proactive communication and collaboration with TNSPs ensured that planned maintenance for bushfire risk management was completed before summer, and there were no planned outages at peak times that reduced the maximum available capacity when it was needed.

AEMO also worked with TNSPs to continuously monitor forecasts and recall any planned outages that could coincide with peak demand periods. Over summer, AEMO only allowed planned outages to proceed on high temperature days if it was agreed that work would be completed before the demand peak, sufficient reserves were available to meet demand, or the outages did not affect any generation or interconnector capacity.

Figure 23 highlights that an increased number of planned outages was accommodated in Queensland, Victoria, and Tasmania during this summer, compared to the previous summer. The number of outages undertaken can vary over time because they are dependent on the work required, including regular maintenance, new generator connections, and a variety of other network-related work.

Figure 23 Number of planned outages in NEM regions, summer 2019-20 vs summer 2018-19

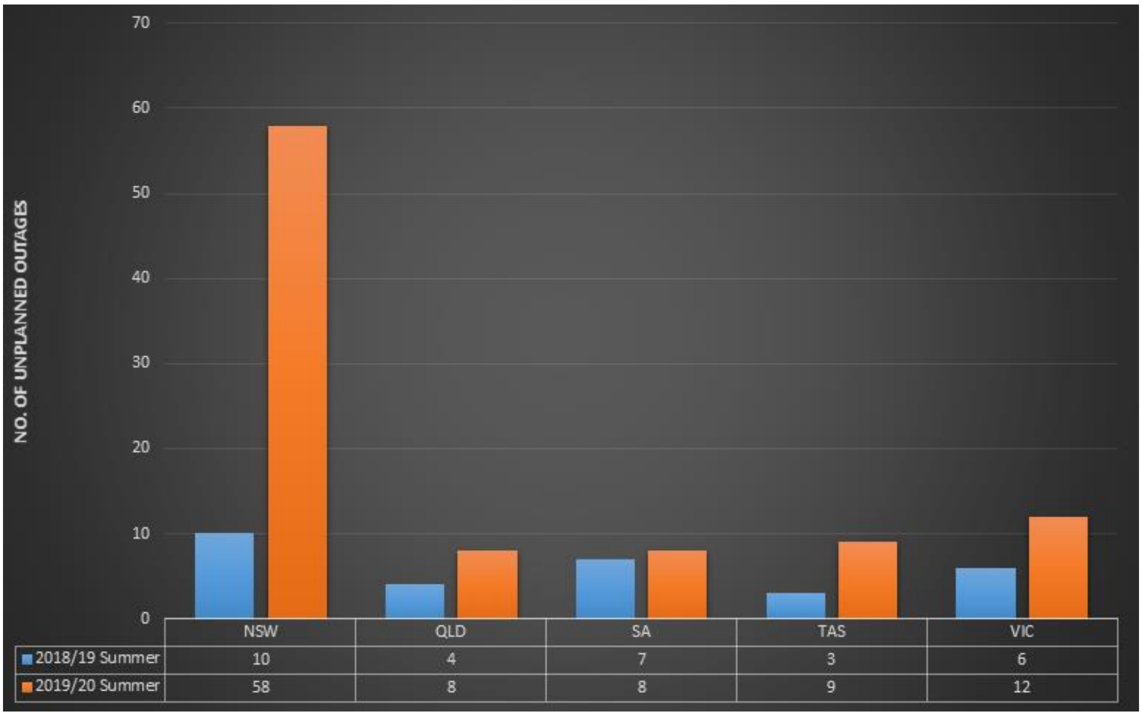


Note: Summer period for both is the period 1 November to 15 March of the following year.

Unplanned outages

There were more unplanned transmission network outages in all NEM regions during summer 2019-20 than during the previous summer, shown in Figure 24. The largest increase occurred in New South Wales.

Figure 24 Number of unplanned transmission outages in NEM regions, summer 2019-20 vs summer 2018-19



	NSW	QLD	SA	TAS	VIC
🟦 2018/19 Summer	10	4	7	3	6
🟧 2019/20 Summer	58	8	8	9	12

Note: summer 2019-20 covers the period from 1 November 2019 to 15 March 2020.

The increase in unplanned outages in New South Wales was mainly due to bushfires impacting the transmission network between November 2019 and January 2020.

A large proportion of bushfire-related unplanned outages occurred between 21 December 2019 and 4 January 2020. In particular, events resulting in LOR declarations included:

- On 30 December, there was an unplanned outage due to bushfires which significantly reduced the New South Wales to Victoria interconnector transfer limit and resulted in an actual LOR1 condition in Victoria.
- On 4 January, Victoria and New South Wales separated due to bushfire-related unplanned outages. During this event, reserves in New South Wales decreased quickly and an actual LOR2 was declared.

While it did not cause a LOR declaration, there was another unplanned outage on 7 January 2020 which impacted power system security, causing the separation of the New South Wales and Queensland regions.

Voltage control

At times of falling minimum demands, maintaining power system voltages within both operational and system design limits is an emerging challenge. This issue was mainly observed during summer in the Victorian region.

Such voltage control issues are becoming, or will become, increasingly evident, not just during summer periods but during other times of the year, and in other NEM regions.

AEMO managed this issue during summer according to the standard operating procedures with no breach of operating limits.

Voltage management in low load conditions is an ongoing operational issue that needs to be actively managed, and AEMO will continue to work with stakeholders to identify and pursue more efficient longer-term outcomes to avoid adverse market impacts and reliability and security risks. The potential for distributed energy resources (DER) to participate in the provision of these services will also be explored.

To address this issue:

- A Regulatory Investment Test for Transmission (RIT-T) process in Victoria for additional reactive power support is currently underway[46].
- AEMO has operational procedures in place to manage voltage control during periods of low demand across the NEM.
- AEMO has negotiated a Non-Market Ancillary Service (NMAS) agreement with a Victorian generator to help manage voltage during periods of low demand. During summer 2019-20, this agreement was used on numerous occasions.
- AEMO looks forward to working with the Energy Security Board (ESB) and Australian Energy Market Commission (AEMC) to explore market design changes that incentivise avoidance of minimum load conditions that impose avoidable system costs, such as markets that support load shifting and ramping.

System strength in South Australia and Victoria

AEMO has published recent studies[47] outlining the minimum number of synchronous machines required to maintain system strength in South Australia and Victoria. System strength reflects the sensitivity of power system to disturbances, and the stability and dynamics of generating systems and the power system to both:

- Remain stable under normal conditions, and
- Return to steady-state conditions following a disturbance (such as a fault).

Large synchronous machines (hydro, gas, and coal generation, and synchronous condensers) inherently contribute to system strength. Inverter-connected generation (batteries, wind, and solar generation) does not presently provide an inherent contribution to system strength[48]. However, some collaborative effort is underway across industry and internationally to investigate system strength from inverter-connected sources using grid-forming technology.

Operating procedures are currently in place to ensure a minimum number of synchronous generating units are always in service in South Australia and Victoria. A permanent technical solution is currently being commissioned in South Australia, with the solution expected to be operational by mid-2020[49]. A system strength gap has been identified in Victoria and a solution is currently being sought through a tender process[50].

AEMO's operating procedures identify the conditions and generator dispatch combinations needed to satisfy the system strength requirements. Where natural market outcomes do not deliver the specific needs for system strength, AEMO has powers under the National Electricity Law and NER to direct the necessary resources into service.

Figure 27 (in Section 8) compares the number of directions issued in the NEM over the last eight years, as at 15 March 2020[51] .

Between 2017 and 2020, the majority of Market Notices AEMO issued for directions were due to system strength requirements in South Australia.

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[46] An outline of the process and further information is at https://www.aemo.com.au/initiatives/major-programs/victorian-reactive-power-support-regulatory-investment-test-for-transmission. The third and final report in the Victorian Reactive Power Support RIT-T process was published in December 2019.

[47] See https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/limits-advice.

[48] For more information, see AEMO, *Power System Requirements*, March 2018, at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability.

[49] ElectraNet, the TNSP for South Australia, determined that the installation of synchronous condensers on the network is the most efficient and least-cost option. A synchronous condenser operates with a large rotating shaft connected to and turning synchronously with the frequency of the power system, as large electric motors and synchronous generators do, but the shaft spins freely and can be used to adjust technical conditions on the network. For more information about this project, see https://www.electranet.com.au/what-we-do/projects/power-system-strength/.

[50] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/victorian-planning/victorian-transmission-network-service-provider-role/aemo-invitation-to-tender-for-system-strength-services-victoria.

[51] Refer to Section 8 for a more detailed discussion of directions.

Reclassifications

AEMO reclassifies non-credible contingency events as credible contingency events[52] if abnormal conditions increase the likelihood of this event occurring (for example, due to severe weather conditions, lightning, and bushfires). The reclassification criteria are set out in section 11 of the Power System Security Guidelines (AEMO procedure SO_OP_3715)[53].

AEMO reclassified 677 events as credible contingencies in summer 2019-20. On six instances, an actual contingency occurred while it was reclassified as a credible contingency.

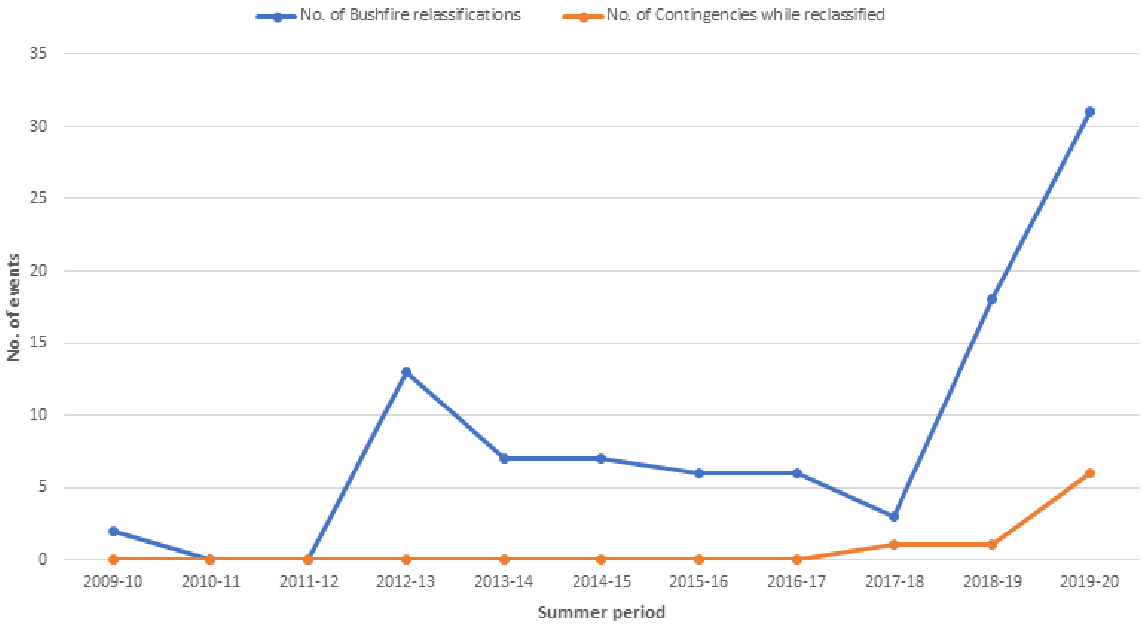
Of these reclassifications, 641 were due to lightning events, and for these there were no instances where the actual contingency occurred (that is, two transmission lines tripped together) while it was reclassified as a credible contingency due to lightning.

There were 31 instances where AEMO reclassified a non-credible contingency event as credible due to the risk of bushfires. Six contingencies actually occurred during these reclassification events due to bushfires. The number of reclassifications due to bushfires, and the number of times the actual contingency occurred, was significantly higher than previous summer periods (see Figure 25).

During five reclassifications for other reasons (the most common being severe weather), there were no instances where a contingency occurred while it was reclassified as credible contingency.

There were no adverse impacts to the power system due to contingency events while reclassified as credible, as AEMO has already modified the operation of the power system due to the reclassification process.

Figure 25 Historical summer bushfire reclassifications, 2009-10 to 2019-20



Note: 2019-20 covers the period from 1 November 2019 to 15 March 2020. All other years cover the period from 1 November to 30 April.

Specifically looking at reclassifications, AEMO observed that the average length of time a non-credible contingency event was reclassified as credible due to bushfires during summer 2019-20 was 159 hours (approximately seven days), compared to 38 hours (approximately one and a half days) in summer 2018-19. In

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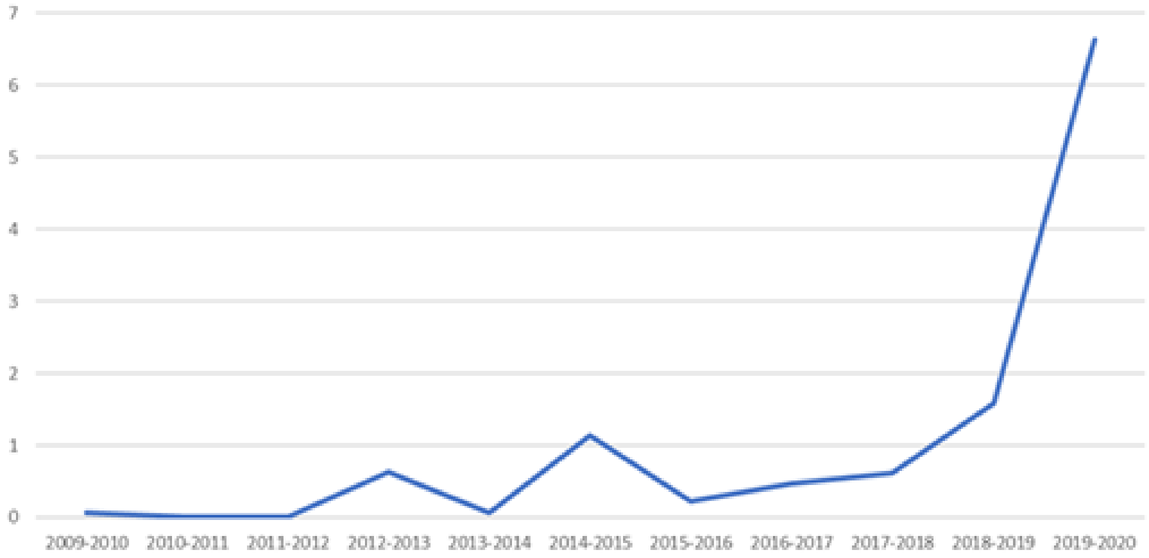
[52] A credible contingency event is defined in the NER as a "contingency event" which AEMO considers to be reasonably possible in the circumstances. Examples could include the unexpected automatic or manual disconnection of one operating generating unit, or the unexpected disconnection of one major item of transmission plant (other than as a result of a three-phase electrical fault anywhere on the power system). A non-credible contingency event is defined in the NER as a "contingency event" other than a "credible contingency event". Examples include three-phase electrical faults on the power system, or simultaneous disruptive events such as multiple generating unit failure or double circuit transmission line failure.

[53] At http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Power-system-operation.

fact, in summer 2019-20 this average duration was significantly higher than all previous summer periods (see Figure 26.

Figure 26 Average duration (in days) of reclassification, 2009-10 to 2019-20



Note: 2019-20 covers the period from 1 November 2019 to 15 March 2020. All other years cover the period from 1 November to 30 April.

Major events on the transmission network 1 November 2019 to 15 March 2020

Six separation events and one widespread interruption occurred during this period, summarised in Table 6.

Table 6 Summary of major events on the transmission network, 1 November 2019 to 15 March 2020

Date	Region	Summary
16 November 2019	Victoria	Two 500 kV transmission lines in Victoria tripped, resulting in the disconnection of the South Australian region from the rest of the NEM power system for nearly five hours, and disconnection of electrical supply to the APD aluminium smelter in Victoria for nearly three hours. AEMO's preliminary report[A] identified that this non-credible contingency event was caused by spurious signals from telecommunications equipment. The incident remains under investigation by AEMO.
26 November 2019	Tasmania	Basslink and one 220 kV transmission line in Tasmania tripped, resulting in the disconnection of Tasmania from the rest of the NEM for approximately two hours, and disconnection of load in Tasmania. The load was disconnected as designed by a frequency control special protection scheme (FCSPS). This was a credible contingency event as the reclassification of the loss of the Basslink interconnector (for flow in the direction of Victoria to Tasmania only) with any Tasmanian transmission line as a credible contingency remains in force[B].
4 January 2020	Victoria and New South Wales	Multiple transmission lines in southern New South Wales tripped, resulting in the separation of the NEM into two islands, north and south of this area, for just under seven hours. The incident also resulted in disconnection of 34 MW of generation and 43 MW of load, and a reduction of 2,267 MW of generation availability. AEMO's preliminary report[C] found that major bushfires in this area played a significant role in this event and contributing network conditions. AEMO declared a LOR2 condition in New South Wales and RERT services were activated or made ready. The incident remains under investigation by AEMO.
7 January 2020	Queensland and New South Wales	One 330 kV line in northern New South Wales tripped resulting in the disconnection of the Queensland region and part of the New South Wales region from the rest of the NEM power system for 13 minutes. This was a credible event, however, the pre-existing unplanned outage of another 330 kV line in the same area meant that a separation event resulted. The incident remains under investigation by AEMO.

Date	Region	Summary
25 January 2020	Queensland	Three 275 kV transmission lines, two 132 kV transmission lines, and one Kareeya Power Station unit all tripped, resulting in 214 MW of load being disconnected in Far North Queensland momentarily. Two of the 275 kV transmission lines tripped due to lightning. The incident remains under investigation by AEMO.
31 January 2020	South Australia and Victoria	Six transmission towers in south-west Victoria were destroyed in a storm, separating the Mortlake Power Station, the APD Portland aluminium smelter and South Australia from the rest of the NEM for 17 days. A preliminary report has been published[D].
2 March 2020	South Australia and Victoria	A circuit breaker at Heywood Terminal Station tripped, resulting in disconnection of the South Australian region and Mortlake Power Station from the rest of the NEM power system for approximately eight hours. This was a credible event, however, the pre-existing unplanned outage of a 500 kV transmission line meant that the event resulted in the separation of South Australia. The incident remains under investigation by AEMO.

A. At https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2019/preliminary-incident-report---16-november-2019---sa---vic-separation.pdf?la=en&hash=F26C20C49BD51164AE700A30F696A511.

B. Except for faults on either of the two George Town to Pacific Aluminium 220 kV transmission lines or the George Town to Tamar Valley power station 220 kV transmission lines – refer to Market Notice No. 53957 issued at 1209 on 13 June 2016.

C. At https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-nsw-and-victoria-separation-event-4-jan-2020.pdf?la=en.

D. At https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-31-jan-2020.pdf?la=en.

7. Frequency performance

This section summarises:

- The availability of contingency frequency control ancillary services (FCAS) required to ensure that the frequency performance following credible contingency events meets the requirements of the frequency operating standard (FOS).
- General frequency performance over summer, including a brief summary of events where there were major frequency excursions.

7.1 Overall frequency performance

Statistics on frequency and time error performance over this period are available[54] in AEMO's:

- Quarterly Monitoring Report on Frequency and Time Error Monitoring for Q4 2019.
- Weekly Frequency Monitoring Reports from the week ending 6 January 2020.

7.2 Contingency FCAS requirements

Prior to summer 2019-20, changes were made in the assumptions for load relief. Load relief is the change in demand expected due to a change in frequency[55].

As part of a review of contingency FCAS[56] requirements, AEMO has been progressively reducing assumed mainland load relief from 1.5% to 0.5%. The first reduction was made on 12 September 2019, and as of 7 November 2019, load relief was reduced to 1%. It was then reduced progressively over summer to 0.5 % on 16 January 2020.

During separation events, particularly when South Australia was separated from the rest of the NEM, difficulties were encountered for some periods in satisfying the requirements for contingency FCAS, because contribution from imports was unavailable and only local resources could meet FCAS requirements. These requirements are to ensure that any frequency deviations which would occur on loss of generation or load would be maintained within the limits set by the FOS for islanded operation. These issues arose, in part, because of the conflicting requirements to maintain adequate system strength and continuity of supply.

This resulted in high FCAS prices[57]. This was particularly the case for a period of about a day following the separation event on 31 January, when the impact of a loss of a Mortlake Power Station generating unit on the frequency in the South Australian island needed to be managed by FCAS. The installation of a temporary

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[54] At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/frequency-and-time-deviation-monitoring.

[55] Since the NEM commenced, mainland load relief has been assumed to be 1.5%; this means that for a 1% change in frequency (0.5 Hertz), the total mainland demand is assumed to change by 1.5%. For further details, see https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/load-relief.

[56] Contingency FCAS is enabled to correct the generation/demand balance following a major contingency event, such as the loss of a generating unit or major industrial load, or a large transmission element. Contingency services are enabled in all periods to cover contingency events but are only occasionally used (if the contingency event actually occurs).

[57] See *Quarterly Energy Dynamics Report* for Q1 2020, at https://aemo.com.au/energy-systems/major-publications/quarterly-energy-dynamics-qed.

system protection scheme on 1 February meant enablement of FCAS was no longer required to manage this contingency, so the level of contingency FCAS required was reduced.

The significance of these issues, in terms of risks in power system operations, will be examined further as part of the power system investigations of these events.

7.3 Significant frequency events

16 November 2019 – Separation between South Australia and Victoria regions

At 1806 hrs, South Australia separated from Victoria after two 500 kilovolt (kV) lines tripped. The frequency initially rose to 50.85 hertz (Hz) but then reduced in accordance with the FOS. During the remaining period of separation (until 2305 hrs), the frequency in this island stayed within the Normal Operating Frequency Band (NOFB) for an islanded system (49.5 Hz to 50.5 Hz).

The frequency performance is being analysed as part of the power system investigation for this incident. A report on the results of this investigation will be published later in the year.

26 November 2019 – Trip of Basslink

At 0043 hrs, Basslink tripped when it was transferring 250 MW from the Victoria region to the Tasmania region, and 263 MW of industrial load in the Tasmania region was tripped by the frequency control special protection scheme as intended.

4 January 2020 – Separation between New South Wales and Victoria regions

As set out in Section 6.1.2 of this report, this separation occurred at 1510 hrs. Following separation, frequency in the Victorian region rose to about 50.4 Hz and frequency in the main section of the New South Wales region fell to about 49.5 Hz.

The details of frequency performance are set out in the preliminary report on this incident[58] and the frequency performance is being analysed as part of the power system investigation for this incident. A final report on this investigation will be published later in the year.

7 January 2020 – Separation between Queensland and New South Wales regions

As set out in Section 6.1.2 of this report, a separation occurred at 0327 hrs. Following separation, the frequency in Queensland fell to 49.69 Hz. There was only a small change in the frequency in the New South Wales region. The frequency in Queensland met the FOS for a separation event in terms of containment, stabilisation, and recovery.

The frequency performance is being analysed as part of the power system investigation for this incident. A report on the results of this investigation will be published later in the year.

20 January 2020 – Underfrequency event

An underfrequency event began at 1259 hrs and ended at 1312 hrs. The frequency cycled around the edge of the NOFB but did not return to within this band within five minutes as required by the FOS. The minimum frequency reached was 49.80 Hz.

This incident is being investigated and details of the results of this investigation is included in the Quarterly Frequency and Time Error Monitoring – Q1 2020 report[59].

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[58] See https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-nsw-and-victoria-separation-event-4-jan-2020.pdf?la=en.

[59] At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/frequency-and-time-deviation-monitoring.

28 January 2020 – Mainland frequency oscillation

From 1723 hrs to 1834 hrs, the mainland frequency cycled around the upper limit of the applicable NOFB of 49.85 Hz to 50.15 Hz. This was in part due to bad data feeding the dispatch system for the New South Wales region. The maximum frequency recorded was 50.28 Hz.

This event is being investigated further by AEMO and more detailed information will be provided in the next Quarterly Frequency and Time Error Monitoring – Q1 2020 report.

31 January 2020 – Separation between South Australia and Victoria regions

At 1324 hrs, South Australia separated from Victoria after the Moorabool – Mortlake 500 kV line and the Moorabool – Haunted Gully 500 kV line tripped (due to storm damage to six transmission towers). Following the separation event, South Australia reached a maximum frequency of 50.72 Hz. The minimum frequency recorded in other mainland regions was 49.65 Hz.

The details of frequency performance are set out in the preliminary report on this incident[60] and the frequency performance is being analysed as part of the power system investigation for this incident. A report on the results of this investigation will be published later in the year. Information will also be provided in the next Quarterly Frequency and Time Error Monitoring – Q1 2020 report.

31 January to 17 February 2020 – Operation of South Australia region as an island

Due to the severing of two 500 kV transmission circuits in Victoria, the South Australia region and a section of the Victoria region[61] were required to operate as an island for this extended period. The frequency in this island remained within the NOFB for an islanded system (49.5 Hz to 50.5 Hz) during this period. The battery storage systems in South Australia made a major contribution to the provision of FCAS services during this period.

The frequency performance is being analysed as part of the power system investigation for this incident. A report on the results of this investigation will be published later in the year. Information will also be provided in the next Quarterly Frequency and Time Error Monitoring –Q1 2020 report.

2 March 2020 – Separation between South Australia and Victoria regions

At 1200 hrs, South Australia separated from Victoria after a circuit breaker at Heywood Terminal Station tripped. Following the separation event, the frequency deviations were minimal, as the interconnector was lightly loaded at the time. The South Australia region remained separated until 2005 hrs.

The frequency performance is being analysed for this incident. Information will be provided in the next Quarterly Frequency and Time Error Monitoring – Q1 2020 report.

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[60] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/power-system-operating-incident-reports.

[61] Comprising the APD smelter and Mortlake Power Station.

8. Directions

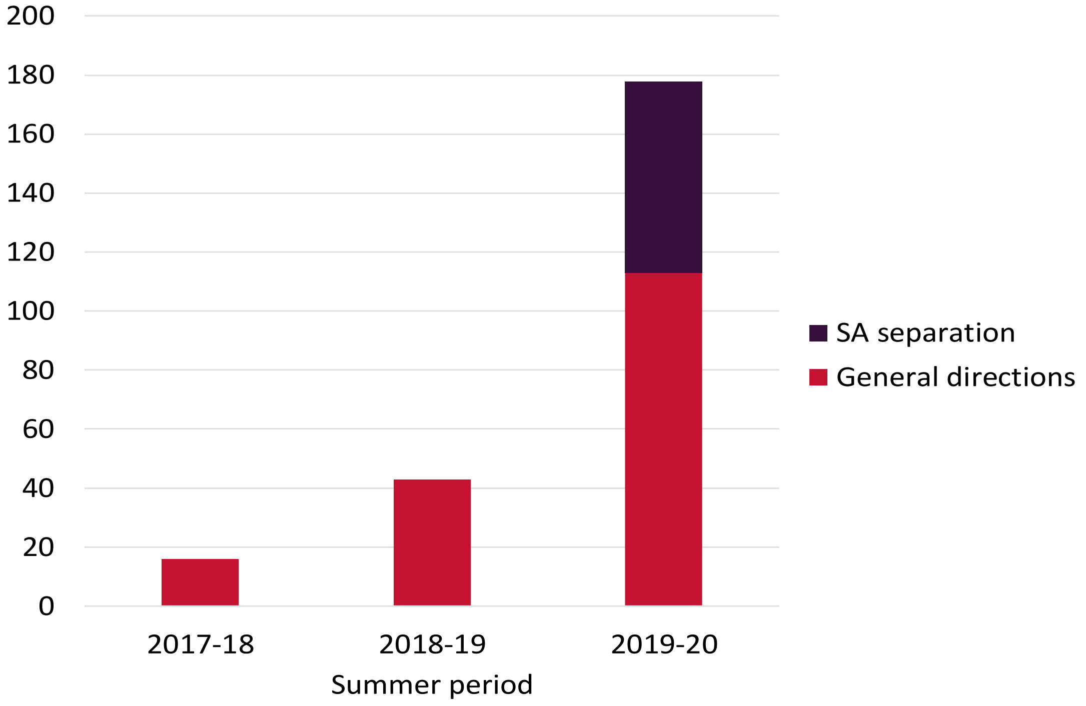
The figures and discussion in this section include all directions issued during summer up to and including 15 March 2020.

There were more directions in summer 2019-20 than in previous summers (see Figure 27). In 2019-20, the majority of directions were issued to maintain system strength in South Australia. The increased incidences of low system strength may be due to generally lower energy prices in South Australia, causing critical synchronous plant to be withdrawn for commercial reasons.

The increase in directions can in part be attributed to 65 directions issued during separation of the South Australian region from 31 January to 16 February 2020. The majority of these directions were to remove wind farms in the vicinity of the interconnection between Victoria and South Australia from service and to operate plant in western Victoria that was connected to the South Australian island. Other directions were also required for system strength and to ensure adequate frequency control in South Australia. AEMO has updated operating procedures and is working with stakeholders to implement strategies to better ensure power system security under these circumstances while reducing market impacts. Refer to Section 9.2.4 for further details.

Details of individual directions are provided in direction reports published by AEMO[62].

Figure 27 Number of summer directions issued in the NEM



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[62] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/market-event-reports.

9. Operational improvements

This section reviews the effectiveness of operational improvements introduced in 2019 and the lessons learnt over last summer.

9.1 Effectiveness of improvements introduced in 2019

Preparing for summer

Ahead of summer 2019-20, AEMO provided a range of additional training for NEM operations staff. This training focused on new and updated processes, systems, and procedures, for managing uncertainty and high-risk events such as bushfires, severe storms, and heatwave conditions. The training also covered RERT and load shedding exercises.

Training for this summer used AEMO's NEM Simulator, providing real-life examples of the processes and systems to be used through the summer period. A range of online learning courses were also developed in-house for both control room and support staff, providing an effective and efficient method for delivery.

The training provided was in addition to normal annual training activities that focus on system restarts, managing complex environmental impacts on the power system, contingency and reserves management, and undertaking directions.

AEMO is continually enhancing its processes to improve system resilience under extreme conditions. Recent enhancements have included:

- Extreme storms – TNSPs regularly assess the wind speed ratings of vulnerable transmission lines which are then taken into account by AEMO in the operation of the system.
  - As an example, wind speed de-ratings were applied to some New South Wales transmission lines following the bushfire events in January 2020. Similarly, a wind speed de-rating is applied to the Victorian to South Australian interconnector when running on the temporary structures in South Western Victoria.
- Solar storms – AEMO has recently added a feature in Indji[63] to assist in assessing the impact of these on the Power System.
- Bushfires – the impact of 'megafires' was considered by the cross-industry Power System Security Working Group (PSSWG) led by AEMO in 2019. Each TNSP identified areas of particular risk, from which the working group defined a common risk assessment framework for maintaining auto-reclose or considering a manual energisation. The Power System Security Guidelines (AEMO procedure SO_OP_3715) have also been updated to account for the risk of large bushfires being present in easements with multiple lines[64].

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[63] Indji is the system used by AEMO to track lightning and bushfires.

[64] At http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Power-system-operation.

Performance during summer

The additional training provided to NEM operators ahead of summer was found to be valuable preparation for the very challenging period. It led to an increase in situational awareness, and feedback from control room staff and observations indicated better and faster response times to events.

Additional training also improved operator response to complex incidents that had not been encountered previously, such as the extended islanding of the South Australian region.

The establishment of a dedicated RERT team again allowed better management of the RERT process and allowed NEM operations staff to focus on system issues.

Preparation for future summers

AEMO will continue to:

- Monitor changes to Rules, processes, and procedures.
- Deliver training to NEM operators so they are up to date and can work efficiently with participants.
- Refine tools to simplify decision-making, improve communication, and allow timely response to incidents.
- Undertake work to improve communication with wind and solar generators.

9.2 Lessons learned from summer 2019-20

9.2.1 Operational processes to improve system resilience under extreme conditions

AEMO is currently working with the AEMC to develop a new framework for 'Protected Operation'. This will support the existing reclassification and protected events frameworks by catering for 'indistinct events', which may include foreseeable network scenarios that are not covered by the existing frameworks, or unforeseen events that must be managed in real time. These discussions are being finalised by the AEMC and are expected to result in an NER Rule change process commencing in coming months.

9.2.2 Operational communication with major non-scheduled generating units

On several occasions this summer, AEMO experienced difficulty in communicating special operational requirements to major non-scheduled generating units. To address this issue, AEMO proposes to develop standing agreements with these non-scheduled generators on how to reduce and disconnect generation when instructed by AEMO.

9.2.3 Impact of extreme conditions on output of wind and solar generation

Forecasting of both demand and supply factors was challenging at some points of the summer. This was a particular issue on several occasions, mainly due to the over-forecasting of available generation:

- The impact of high temperature cut-outs on wind turbines is not included in AEMO's forecasting systems. On several occasions, the availability of wind farms was over-forecast on critical high-demand days. While weather forecasts indicated that some risk was present, AEMO is continuing investigations into how such events can be best managed in future by both participants and AEMO's forecasting systems. This issue is similar to issues encountered in previous summers for thermal generation. As a result of these earlier issues mitigation measures were introduced for thermal generation which meant that any such issues for thermal generation were adequately managed over this summer.
- The impact of smoke haze in reducing the output of PV cells (for both solar farms and rooftop PV) has shown a need to enhance forecasting systems. AEMO continues to work to understand the impact of smoke on the NEM and ways to improve short-term forecasts should such events occur again.
- Experience with regards to the impact of smoke on electricity demand and generation is providing a platform for further analysis and development in forecasting capability.

- A combination of satellite tracking, updated numerical weather modelling, and enhanced personnel training is required to ensure smoke risks are understood and well forecast.

Such operational measures can help maintain resilience in the shorter term. However, in the longer-term other measures may be required, such as:

- Increases to thermal ratings.
- Construction using fire resistant materials.
- Enhanced interconnection between major load centres.

Similar issues of resilience under extreme conditions apply to both the electricity distribution networks and the gas transmission infrastructure upon which gas-fired generation is dependent.

9.2.4 Difficulties in operating a South Australian island for extended periods

AEMO has reviewed the extended islanding of the South Australian region, which occurred in January and February, closely and has updated operating procedures associated with the islanding of South Australia. AEMO is also working with SAPN, ElectraNet, the South Australian Government, and market participants to implement strategies to better ensure power system security in South Australia during island events while reducing market impacts. Some of the initiatives underway are described below.

Process to manage directions

Directions have in the past been rare events, but this is no longer the case, particularly in South Australia. There is thus a need to improve the process AEMO uses to manage these directions.

These improvements are being conducted in stages. Current proof of concept for a directions and system strength operator interface is underway, using a web-based interface that utilises the pre-dispatch data. In addition, a new function is being added to reduce the workload involved for the issuing of direction notices. Under this function, directions reports will be automatically created, allowing the shift manager to focus on operating the power system.

It should be noted that, while the need for such directions is likely to extend to other regions in the future, instances in South Australia are expected to reduce with installation of synchronous condensers and further storage systems, and the development of the second AC interconnection between South Australia and the remainder of the NEM through the Project Energy Connect transmission line.

Processes to manage contingency FCAS under islanded conditions

These will be reviewed with the aim of reducing periods when contingency FCAS requirements are not met.

9.2.5 Separation between regions not at the regional boundary

There is no guarantee that a separation between two regions will occur neatly at the formal regional boundary. Separations occurred at other points on three occasions during summer 2019-20[65]. This creates problems with the assessment of the reserve situation in the separated sections of the NEM. AEMO will investigate how this issue can be addressed as part of its current project to improve the ST PASA process.

9.2.6 Operational decision-making

Operational decision-making support tools

The changing nature of the power system means continuous improvements are required to the tools that support operational decision-making and the extent of data available to inform these decisions. The experiences of this summer have highlighted this need.

In particular:

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[65] See Section 6.1.2.

- There will be a need to achieve visualisation of data regarding distributed energy sources and integration of this data into SCADA systems.
- There will be a greater range of systems and issues to manage, therefore a need to have tools which present information in a uniform way. It is essential that these tools can be adapted quickly to ensure that they remain fit for purpose in a rapidly changing environment.
- Decision support tools will need to deal with increased volumes and types of data, often from external sources.
- There will need to be a focus on developing tools further into the areas of assistance for pro-active and pre-emptive forward-looking tools and actions beyond core competencies in reactive or passive monitoring.
- New technical advances should be taken advantage of, including:
  - Advanced visualisation techniques, to improve the operator's ability to understand the situation and make effective decisions by avoiding data overload.
  - Advanced data analytics, which can greatly assist in any move from deterministic approaches towards decision-making processes based on probability contingency measures.

Improved tools for visibility and situational awareness

In 2019, AEMO undertook a review of the current status of its operational decision-making support tools and the challenges they will face in the future. As a result of this, a major project has been launched to enhance these tools.

As more inverter-connected plant is installed in the NEM power system, stability issues relating to low system strength – such as oscillatory behaviour associated with control system interaction – will become more common and important to address. High-speed monitors (HSMs) including phasor measurement units (PMUs) will enable AEMO to detect and respond effectively to these dynamic stability issues and facilitate more accurate modelling of the dynamic characteristics of the power system.

AEMO is currently working with several TNSPs to import continuously streamed data from their PMUs and through the Wide Area Monitoring Software (WAMS) project ensuring this data is used as effectively as possible. Specific initiatives in this area are summarised below.

High-speed monitoring project

AEMO has recently commenced a high-speed monitoring project to ensure:

- Operations staff will be able to respond quickly and effectively to rapidly developing power system issues to ensure the power system remains secure.
- Planning and Operations staff can fine tune models used to represent the dynamic characteristics of the power system, which will contribute to more accurate power system limits.
- Power system performance can be more effectively monitored as the power system continues to evolve.

The project has two phases. The first phase will assess the number, location and type of HSMs that will be required to:

- Manage dynamic stability in real time.
- Facilitate the assessment of load models for contingency FCAS and offline dynamic stability studies.
- Improve the accuracy of generating unit dynamic models.
- Monitor the delivery of primary frequency control.

An important outcome of Phase 1 will be a standard setting out AEMO requirements for HSMs installed in the NEM. This first phase is due for completion by mid-2020. The second phase will focus on implementation of the outcomes of phase 1 and is expected to take at least two years to complete.

Wide Area Monitoring

AEMO has commenced a project to update the existing Phasorpoint software to the Wide Area Monitoring System (WAMS). This project will allow AEMO's operational teams to access high speed data from the increasing number of PMUs being installed in the NEM and is central to several projects AEMO is working on that require high speed data, such as the HSM review and primary frequency control (PFR).

The project will:

- Update to the latest version of the software (now called WAMS).
- Increase the number of PMUs from the current six to greater than 200.
- Improve visualisation and analysis capabilities.

WAMS is scheduled to be implemented by mid-2020.

9.2.7 Need by participants for more timely information on major incidents

Participants in several areas have had a consistent theme in feedback on the need for more detailed advice following major power system incidents, including:

- Very prompt market communication that an event has occurred and the area of impact. AEMO will consult with participants to seek to rationalise the number of Market Notices that are required to be issued on days of extreme events, and on ways to swiftly deliver brief information on major power system events.
- Prompt indication of specific changes to the network (forced outages). AEMO considers that such an initiative would require significant investment and would need to be prioritised on a cost benefit basis.
- Issuing preliminary power system event reports with details of the event (not analysis) within a week of the event. AEMO continues to prepare preliminary reports for significant events to provide useful information to industry regarding the event and its impact on power system operations. The timeframe and approach depend on the particular event and priorities at that time. With the increasing complexity of the power system, the increasing frequency of extreme weather events and the need to not only manage the events, but also report on them, will influence the time taken to prepare reports. AEMO reviews, on an ongoing basis, its internal process for preparing and approving reports to ensure they are fit for purpose to provide accurate and complete information, as well as enable the timely release of information.

9.2.8 Issues with both near-record maximum demands and record minimum demands

Summer 2019-20 has highlighted that power system now needs to meet the challenges of both high demands in the early evening during heatwaves and low demands during the night and in the middle of the day. These low demand periods create challenges for voltage control and frequency control.

9.2.9 Contribution of demand side response to reliability of supply

During summer 2019-20, demand side response (including RERT) made a significant contribution to avoiding the need for load shedding on several occasions[66]. This emphasises the need to continue to enhance capabilities in this area.

9.2.10 Impact of ash and dust on transmission network

Ash or dust pollution led to failures of transmission equipment under misty conditions[67]. Such conditions increase the risk of multiple contingency events on the transmission network and the distribution network. This is not a new issue and has occurred on a number of occasions in the past but is difficult to forecast.

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[66] See Section 5.2.

[67] This is because a build-up of dust or ash on insulators can result in fault currents tracking between high voltage conductors and earthed structures.

9.2.11 Preparation for summer 2020-21

Outcomes from last summer emphasised the value of the preparations taken prior to the start of the season. The process for preparing for summer 2020-21 will be similar, as far as possible, to that undertaken for this summer. Such preparations will face special challenges due to the impact of the COVID-19 pandemic.

The Australian Competition and Consumer Commission (ACCC) has granted interim authorisation to AEMO to allow electricity industry participants to co-operate on certain measures to ensure safe, secure, and reliable operation of Australia's energy systems, ongoing energy supply, and integrity of wholesale markets during the COVID-19 pandemic. AEMO will use this process where necessary to manage generator and transmission maintenance so it can be completed prior to summer.

9.2.12 Opportunities for enhancements to forecasting processes

Some important challenges associated with the increased penetration of renewable energy in the NEM can be observed from the forecast performance in summer 2019-20.

In the near term, AEMO requires additional lead indicators to accurately forecast a wide range of factors that can cause a reduction in wind generation output. The way in which AEMO quantifies risk and uncertainty and, more importantly, acts on that risk will need to continue to evolve:

- The self-forecasting initiative has proven to provide benefits in the 5-minute dispatch forecast horizon[68]. Enhancements to forecasts at longer timeframes within-day are required.
- AEMO is continuing to explore enhancements in consensus forecasting and probabilistic forecasts for short-term forecasting. This will include enhanced machine learning techniques to forecast renewable energy generation risk and uncertainty.
- Collaboration with the weather forecasting industry is ongoing, with the aim of uplifting the weather forecasts required for wind and solar generation forecasting, particularly in creating better lead indicators for the near term, deemed "now-casting".
- Management of renewable plant remains an ongoing challenge, and AEMO is collaborating with industry including turbine manufacturers to ensure all semi-scheduled and non-scheduled generators can provide best practice information with regards to the submission of availability information for AEMO's reserve assessment.

Peak demands are now driven by cooling loads which are highly weather-sensitive, particularly on weekends. As the penetration of rooftop PV and utilisation of air-conditioning continue to increase, forecasting is increasing in complexity.

AEMO is continuing to adapt demand forecasting methods, aligned with industry best practice, to ensure forecasting performance remains strong as load shapes and responsiveness change.

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[68] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/solar-and-wind-energy-forecasting/participant-forecasting.

10. Collaboration and communication

This section summaries the real-time operational communication undertaken over summer by AEMO, and regular communication conducted with participants, governments, consumers, and media regarding NEM operational issues.

10.1 Operational communication

AEMO issued Market Notices to inform market participants about prevailing market and/or system conditions, according to existing AEMO operational procedures[69].

AEMO's Market Notices over summer 2019-20 included these key operational categories:

- Reserve Market Notices – AEMO issued reserve-related Market Notices for both actual and forecast LOR conditions.
- RERT Market Notices – when AEMO activated RERT services, market participants including relevant contracted RERT service providers.
- Reclassification Market Notices – AEMO issued these when a non-credible contingency was reclassified as a credible contingency, so the prevailing system risk could be managed effectively.
- Inter-Regional Transfer limit variation – AEMO issued Market Notices to inform the market of inter-regional limit changes due to reclassifications, abnormal events, and transmission outages.
- Extreme Temperature Market Notices – AEMO issued Market Notices to market participants when forecast temperatures in metropolitan cities were equal to or greater than the generation capacity reference temperatures, asking participants to review their generating plant bids considering the local temperature and revise availability as necessary.
- Directions – AEMO issued directions to generating plant to maintain system security or reliability. In these cases, AEMO issues Market Notices to all market participants informing them of either the requirement to direct, or that a direction had occurred. Individual Market Notices are also issued to the relevant market participant, with specific instructions AEMO requires the market participant to take to keep the system secure or reliable.

10.2 Industry and government communications

AEMO continued to engage closely with generators and NSPs throughout the year about operational matters. AEMO proactively sought information from TNSPs and generators in particular about their plant availability and/or any issues regarding their operation.

Throughout summer, AEMO maintained proactive dialogue with generators whenever high temperatures and demand was forecast in any region.

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[69] AEMO publishes Market Notices at http://www.aemo.com.au/Market-Notices.

Other engagement mechanisms across the summer period included a NEM-wide briefing, summer readiness sessions in each jurisdiction, NEM weekly summer readiness outlook briefings, and industry teleconferences, as well as ad hoc engagement and emergency communications using the Power System Emergency Management Plan (PSEMP) and the Victorian Electricity Emergency Communications (VEEC) Protocol.

AEMO continued to conduct on-site jurisdictional summer readiness sessions where jurisdiction-specific information around summer preparedness was shared. These sessions were conducted in a three-week period across October 2020 and involved Responsible Officers, Jurisdictional System Security Coordinators, and other emergency officers in each NEM jurisdiction, as well as senior staff from TNSPs and government energy departments.

The NEM-wide briefing was held in Sydney on 27 November 2019 and involved a broad cross-section of industry, government, and emergency services attendees. The agenda included the weather outlook for the summer from Weatherzone and a summary of AEMO's preparedness activities for the summer period. The session provided an opportunity for many who are not generally directly engaged in the lead up to summer to ask questions and clarify processes and procedures ahead of the summer period.

From 7 November 2019 to 26 March 2020, AEMO (with support from the BoM) conducted NEM weekly summer readiness outlook briefings to the Responsible Officers, Jurisdictional System Security Coordinators and other emergency officers in each jurisdiction. Each briefing was accompanied by a briefing pack with jurisdictional outlooks for NEM and gas as well as a weather report.

The VEEC Protocol and PSEMP were activated for briefings on four occasions across the summer period, mainly in relation to fires and heat-related impacts on the NEM in New South Wales, Queensland, and Victoria. The PSEMP and VEECP were also activated for the South Australia – Victoria separation event on 31 January 2020.

Industry teleconferences provide an opportunity for AEMO to convey core messages to a large audience including user groups, generators, retailers, and other market participants regarding changes to processes, or to otherwise brief industry and jurisdictions on key developments. AEMO delivered several industry teleconferences regarding key operational changes, including updates to contingency FCAS. Further industry teleconferences were initiated following the South Australia – Victoria separation event of 31 January 2020, allowing AEMO, AusNet Services, and others to keep the industry abreast of the recovery from the event.

Outside of these formal mechanisms, there was a high volume of direct communications between AEMO, TNSPs, and jurisdictions around the separations and other events. Increased concern around the potential impact of COVID-19 also resulted in a number of briefings across the industry and government.

10.3 Media and consumer communications

Building on learnings and feedback from the previous summer, a key focus for AEMO during summer 2019-20 was to take a leading role in creating widespread stakeholder awareness and understanding of expected conditions, technical requirements, and plans to manage the power system during high demand conditions.

AEMO implemented a comprehensive communications and engagement program to proactively inform industry and government stakeholders on the plans and actions in place to mitigate risks to energy supply during the summer months.

Stakeholder engagement commenced in November 2019, with AEMO's Communications and Corporate Affairs team hosting its biannual National Electricity Market External Communications Committee (NEMECC) meeting to outline and collaborate on the summer communication activities that were also presented at the NEM industry briefing.

AEMO's summer readiness communication program centred on two key AEMO reports, flagging forecast operational conditions in the 2019 NEM ESOO (August) and contingency plans to maintain a safe and reliable energy supply during summer in the Summer 2019-20 Readiness Plan (December).

These reports were distributed through targeted print, radio, television, and online media, supported by interviews with AEMO's executives and media assets.

In addition to these publications, AEMO produced regular editorials and podcasts published via AEMO's digital news platform (Energy Live) and amplified through AEMO's social media channels with complementing infographics.

Further, detailed and plain-language fact sheets on technical topics such as RERT, LOR, and load shedding were provided to journalists with briefings and shared socially by energy market bodies and network businesses.

Beyond stakeholder engagement, AEMO also focused on ensuring electricity users, the general public, and media received co-ordinated and timely awareness and advice when facing LOR conditions and the possibility of load shedding.

AEMO's Communications and Corporate Affairs team also provided continued and transparent support to manage energy-sector issues throughout the summer, including widespread and prolonged bushfires, interconnector separation events, and LOR conditions throughout the NEM.

11. Conclusion

Preparations undertaken by AEMO and participants prior to this summer were effective in minimising disruptions due to the significant number of power system events that occurred during summer.

AEMO's review indicates that the challenges faced over summer periods continue to grow, creating a clear imperative for continued improvement in operating processes and market mechanisms to maintain and enhance the resilience of the NEM power system.

In addition, Australia's physical gas and electricity infrastructure is being increasingly challenged by extreme and high heat and fire periods. The need to harden these assets to more extreme climatic conditions and consider opportunities to enhance the inherent resilience of the NEM when planning and delivering either new projects or replacing existing infrastructure will be a necessary element of future NEM planning.