AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Load Shedding in Victoria on 24 and 25 January 2019

16 April 2019

An operating incident report for the National Electricity Market

Important notice

PURPOSE

This is AEMO's report of its review into load shedding events in Victoria on 24 and 25 January 2019, as a 'reviewable operating incident' under clause 4.8.15 of the National Electricity Rules (NER). It also incorporates AEMO's report under clause 3.20.6 of the NER on the activation of unscheduled reserves in the period leading up to the load shedding events.

This report is based on information available to AEMO up to the date of publication.

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INCIDENT CLASSIFICATIONS

Classification	Detail
Time and date of incident	1810 hrs on 24 January 2019 and 1100 hrs on 25 January 2019
Region of incident	VIC
Affected regions	VIC
Event type	Actual Lack of Reserve (LOR) level 3 in VIC
Generation Impact	No Generation impact determined
Customer load impact	266 MW of customer load shed in VIC on 24 January 2019 and 276 MW of customer load shed in VIC on 25 January 2019

ABBREVIATIONS

Abbreviation	Term
AEMO	Australian Energy Market Operator Limited
AEST	Australian Eastern Standard Time
APC	Administered price cap
C	Celsius
CPT	Cumulative price threshold
DI	Dispatch Interval
ESOO	Electricity Statement of Opportunities
FCAS	Frequency control ancillary service
LOR	Lack of reserve (severity indicated by level 1, 2, or 3)
MN	Market notice
MW	Megawatt
MWh	Megawatt hour
NEM	National Electricity Market
NER	National Electricity Rules
NSW	New South Wales
PD PASA	Pre-dispatch projected assessment of system adequacy
POE	Probability of exceedance
QLD	Queensland
QNI	Queensland – New South Wales Interconnector
RERT	Reliability and Emergency Reserve Trader
SA	South Australia
ST PASA	Short-term projected assessment of system adequacy
TAS	Tasmania
USE	Unserved energy
TNSP	Transmission Network Service Provider
VIC	Victoria
VCR	Value of Customer Reliability
VNI	Victoria – New South Wales interconnector
VPP	Virtual Power Plant

Executive summary

This report provides information about the load shedding events on 24 and 25 January 2019 in the Victorian region of the National Electricity Market (NEM), when grid demand exceeded the combined supply available from generation, additional contracted reserves, and inter-regional transfer capacity.

Controlled load shedding, or disconnection of customer supply, may be implemented when there is a shortage of electricity supply or to ensure transmission and distribution lines do not become overloaded. It can occur automatically in response to faults on the power system or, as was the case on 24 and 25 January 2019, may be initiated manually in response to current or immediately anticipated power system conditions.

Manually initiated load shedding is a last resort response to bring power flows into balance, averting the risk of system collapse or physical damage to parts of the power system. A relatively small amount of load shedding for a short period (generally on a rotational basis) reduces the potential for more widespread and prolonged customer supply interruptions.

Temperatures in South Australia (SA) broke new records on 24 January 2019 and Victoria (VIC) experienced extreme heat close to record levels. Simultaneous high temperatures in SA and VIC resulted in high electricity demands across both regions. On 24 and 25 January 2019, reductions in availability of electricity supply due to thermal inefficiencies, unexpected equipment failures, urgent maintenance activity, and reduced generation capacity meant there was not enough power generation in the SA and VIC regions to supply the demand.

AEMO activated Reliability and Emergency Reserve Trader (RERT) contracts to reduce demand in VIC and SA and directed on a synchronous condenser in New South Wales (NSW) to maximise flows into VIC across the VIC–NSW interconnector (VNI). These actions reduced the amount of load shedding required, but could not avoid the need to shed some load in VIC to balance the demand with available supply. The average cost of RERT payments for 24 and 25 January was approximately $10,000 per megawatt hour (MWh).

After all supply and demand response options available to AEMO had been exhausted, and as a last resort, AEMO instructed load shedding on both 24 and 25 January to balance the demand with available supply, and maintain the power system in a secure operating state.

24 January 2019

At 1810 hrs AEST[1] on Thursday 24 January 2019, after activating available reserve contracts under its RERT function, AEMO instructed AusNet Services to shed 75 megawatts (MW) of load in VIC. This was required to reduce the flow towards VIC on VNI sufficiently to maintain the power system in a secure operating state.

The load reduction required on 24 January was achieved by successively disconnecting the potlines at the Alcoa Portland aluminium smelter in VIC, the first of which was consuming approximately 266 MW at 1800 hrs. AEMO instructed AusNet Services to restore the load at 2032 hrs.

A number of factors contributed to the requirement to shed load on 24 January 2019:

- Demand for electricity in VIC and SA was high due to record temperatures in both regions.
- Up to 1,100 MW of thermal generation capacity in SA and VIC was unavailable.
- The RERT contracts activated in the two hours before load shedding had reached 392 MW across both regions, but this was insufficient to meet the shortfall at the time of maximum demand.

The maximum operational demand[2] and maximum temperatures observed in SA and VIC on 24 January 2019 are shown in Table 1 below.

[1] Australian Eastern Standard Time (Daylight Saving Time in Victoria minus one hour). All times in this report are AEST.

[2] Operational demand is demand to be met by scheduled, semi-scheduled, and significant non-scheduled wind generation plus net imports into a region.

Table 1 24 January 2019 max temperatures and operational demand SA and VIC

Region	Max °C	Max operational demand (MD)	Load shed (MW)
SA	47.7 @ 1445 hrs	3,240 MW @ 1900 hrs	0
VIC	41 @ 1731 hrs	9,328 MW @ 1810 hrs	266

25 January 2019

At 1100 hrs on Friday 25 January 2019, AEMO instructed AusNet Services to shed 100 MW of customer load in VIC and requested a further 150 MW at 1130 hrs. This was required to reduce the flow towards VIC on VNI sufficiently to maintain the power system in a secure operating state.

With no more generation available in VIC, all interconnectors flowing at capacity within network constraints and all available contracted reserves activated under RERT, AEMO's only remaining option to maintain power system security was to direct load shedding to balance the system. The Portland aluminium smelter was not available to be switched off again until 1300 hrs for technical reasons in line with advice from the asset owner. AEMO instructed AusNet Services to restore 50 MW of load at 1325 hrs, and the remainder at 1350 hrs.

A number of factors contributed to the requirement to shed load on 25 January 2019:

- Demand for electricity in VIC was high due to very high temperatures in the region.
- Approximately 1,600 MW of thermal generation capacity in VIC was unavailable.
- Other capacity reduced approximately 400MW between 1000 hrs and 1130 hrs.

The RERT contract reserves activated in the two hours before load shedding in VIC had reached 120 MW.

The maximum operational demand and maximum temperature observed in VIC on 25 January 2019 are shown in Table 2 below.

Table 2 25 January 2019 max temperatures and operational demand in VIC

Region	Max °C	Max operational demand (MD)	Load shed (MW)
VIC	42.8 @ 1300 hrs	9,298 MW @ 1100 hrs	271.6

Procurement of RERT for 2018-19

AEMO's Electricity Statement of Opportunities (ESOO) forecasts electricity supply reliability in the NEM over a 10-year period to inform the decision-making processes of market participants, new investors, and policy-makers as they assess future development opportunities.

In 2018, AEMO's ESOO modelling showed heightened risk of unserved energy (USE) over the next 10 years, confirming that, for peak summer periods, targeted actions to provide additional firming capability would be necessary to reduce risks of supply interruptions. The 2018 ESOO identified a particular risk of supply interruptions in Victoria exceeding the reliability standard for USE in 2018-19. This risk was observed to arise from reductions in supply from thermal generation as a result of coincident unplanned outages at times of expected low intermittent generation and high demand.

Based on these forecasts, AEMO established a pool of RERT providers under the National Electricity Rules (NER) that could offer reserves on various notice periods. In consultation with the Victorian and South Australian Governments, AEMO secured all resources offered in Victoria and South Australia that met the required cost, technical and verification criteria.

For 2018-19, all RERT resources were secured on a usage only basis. In 2017-18, some RERT contracts had both availability and usage cost components. As a result, the RERT costs over summer 2018-19 were significantly lower, at around 65% of the 2017-18 costs.

On 24 and 25 January 2019 at the time of load shedding:

- Generation capacity available from brown coal plant was at the extreme lower end of observations in the 2018 ESOO.
- The contribution of wind and solar generation was above ESOO simulations for comparable heat conditions.
- The hydro and gas contribution was very close to the 2018 ESOO observations.

Costs of RERT

RERT contract costs on 24 and 25 January 2019 in VIC and SA were approximately $30.6 million, with additional compensation amounts of $3.6 million payable to market participants as required by the NER. This brought the total RERT costs to $34.2 million.

- The average cost of RERT for 24 and 25 January 2019 was approximately $10,000 per MWh, representing a lower cost per MWh for energy consumers than the market price cap and price of wholesale energy at the time of load shedding, of $14,500 per MWh.
- Without activation of the RERT, AEMO estimates a further 1,252 MWh of load would have been required to be shed involuntarily. Applying the 2019 value of customer reliability (VCR)[3] of $41,534 per MWh, the cost of the load shedding avoided by using RERT is estimated at $52 million.
- Using typical commercial and industrial energy usage rates for the 2018 calendar year, the cost of RERT would equate to an annual average of approximately $0.79 per MWh in Victoria and $0.16 per MWh in South Australia[4].
- Using typical residential customer energy tariffs and usage rates over the 2018 calendar year, the total RERT contract costs on 24 and 25 January would equate to an average annual cost per residential customer of approximately $3.20 in Victoria and $0.80 in South Australia.

AEMO conclusions and observations

1. The power system was maintained in a secure operating state during 24 and 25 January 2019.
2. The reliability standard of 0.002% unserved energy (USE) was exceeded in VIC as a result of these events[5].
3. Activation of RERT reserves and ultimately load shedding were required on 24 and 25 January 2019 because the total available capacity reserves were insufficient to supply electricity demand in VIC and SA on 24 January and in VIC on 25 January.
4. Load shedding was directed only after all available contracted RERT had been activated to meet the expected reserve shortfall, and AEMO had taken other actions within its control to reduce constraints and maximise grid capacity by adjusting power system conditions.
5. Load shedding was achieved in a manner that was as consistent as reasonably practicable with AEMO's instructions.
6. AEMO followed all applicable processes under the NER prior to the RERT intervention events on 24 and 25 January 2019 and implemented intervention pricing in accordance with clause 3.9.3 of the NER.

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[3] The VCR is determined using data from the Bureau of Resources and Energy Economics and consumer surveys, and measures the value different types of energy consumers place on having reliable power supply. For more information, see https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Value-of-Customer-Reliability-review.

[4] The costs of RERT to commercial and industrial customers are provided as a typical guide only. Actual costs billed by retailers may vary significantly based on a number of factors including individual rates, consumption profiles, and contractual terms.

[5] The reliability standard specifies that expected USE should not exceed 0.002% of total energy consumption in any NEM region in any financial year.

7. Over the course of these incidents, AEMO issued appropriate and sufficiently detailed market information.
8. Registered participants took all reasonable steps to comply with instructions and directions issued by AEMO leading up to and during the load shedding events.

AEMO, together with the Energy Security Board (ESB) and Australian Energy Market Commission (AEMC), has several initiatives and programs of work underway which recognise the increasing frequency and severity of extreme weather events and seek to address the risk of supply not being able to meet maximum demand levels during those events. These include:

1. **Implementation of strategic reserves.**
   - Following a recommendation from the Finkel Review, the AEMC is currently finalising its determination on a strategic reserve to act as a safety net in exceptional circumstances as a replacement to the existing RERT mechanism, following a rule change proposal submitted by AEMO in March 2018.
   - Strategic reserves provide a fairly simple and complementary addition to enhance reliability, and are used only as a last resort to avoid shedding load. This would allow AEMO to identify opportunities that might not be economical in the energy market, but would still be preferred by consumers as alternatives to load shedding.
2. **Increasing transmission capacity as outlined in the 2018 Integrated System Plan (ISP)[6].**
   - Stronger interconnections and additional network capability will facilitate better access to supply and sharing of reserves between regions. On 24 and 25 January 2019, excess reserves were available in other regions but not accessible through existing interconnection capacities. AEMO's 2018 ISP identified a number of priority transmission projects that would help to address these limitations.
3. **Greater optimisation of distributed energy resources (DER).**
   - Optimised usability and control of existing (and future) DER will deliver significant benefits in periods of supply shortfalls. Programs like the Victorian Government's Solar Homes program will add large quantities of DER to the Victorian energy system. It will be extremely important that the contribution to system security and reliability of these new resources is optimised with appropriate standards, visibility, and controllability.
4. **Markets for DER.**
   - The development of appropriate market constructs is essential to incentivise the use of DER as an effective resource to improve system security and reliability, by creating new opportunities for economic investment in the development and aggregation of DER technologies.

[6] AEMO, Integrated System Plan, July 2018, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan.

Contents

Tables

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1. Report objective and scope

This is AEMO's reviewable operating incident and reserve activation report relating to the load shedding events in Victoria (VIC) on 24 and 25 January 2019 during a heatwave affecting South Australia (SA) and VIC. It is intended to provide a detailed review of the sequence of events leading to the load shedding required to balance the power system, and to meet the reporting requirements in clause 4.8.15 of the National Electricity Rules (NER).

Prior to the load shedding on both days, AEMO activated unscheduled reserve under reserve contracts entered into in accordance with AEMO's Reliability and Emergency Reserve Trader (RERT) function. Accordingly, this report also incorporates the reporting required under clause 3.20.6 of the NER.

This report is based on analysis of data obtained from AEMO systems and provided by transmission network service providers (TNSPs) and market generators.

1.1 Report format

This report is divided into sections which present and discuss:

- **Weather conditions** – the weather and demand forecasts, status of the power system and reserve availability in the relevant regions leading up to the load shedding events on 24 and 25 January 2019 (Section 2).
- **Forecasts** – forecasts for weather, demand and supply availability in the lead up to the load shedding events (Section 3).
- **Electricity supply** – the available electricity supply for each impacted region (generation and inter-regional flows) on 24 and 25 January 2019 (Section 4).
- **Sequence of events** – the sequence of events leading up to and during the load shedding and restoration on 24 and 25 January 2019, including market notices issued by AEMO (Section 5).
- **Load shedding** – why load shedding was required, and how it was implemented (Section 6).
- **Reliability and Emergency Reserve Trader** – contracted reserves activated by AEMO, including their cost and impact on dispatch (Sections 7 to 9, which comprise the report required by clause 3.20.6 of the NER).
- **Conclusions** – a summary of the performance of AEMO and registered participant equipment and processes before and during the load shedding events, and proposed actions for improvement (Section 10).

References to times in this report, unless otherwise specified, are to Australian Eastern Standard Time (AEST).

2. Weather conditions

2.1 Weather

SA and VIC experienced exceptionally high temperatures on Thursday 24 January, continuing into VIC on Friday 25 January 2019.

SA

Record breaking temperatures were recorded across many parts of SA on 24 January 2019. Examples include:

- Port Augusta 49.5°C – highest temperature on record.
- Adelaide (West Terrace) 46.6°C – highest temperature on record.
- Adelaide (Kent Town) 47.7°C – highest temperature on record, exceeding previous record by 2°C.

VIC

A cool change crossed SA from the south-west on 25 January 2019, and the extreme heat shifted to VIC, where temperatures rose quickly. Melbourne (Olympic Park) reached 42.8°C by 1300 hrs. The cool front travelled from SA over the course of the day reaching Melbourne (Olympic Park) at 1303 hrs. Temperatures fell by around 14°C in 15 minutes following the passage of the front.

Figure 1 and Figure 2 show the actual maximum temperatures across Australia relative to the January average daily temperature.

Figure 1 shows the coincident heat (in brown) on 24 January across SA and VIC, where both regions were more than 12°C above the January average temperatures.

Figure 1 Observed maximum temperature above January average, Thursday 24 January 2019

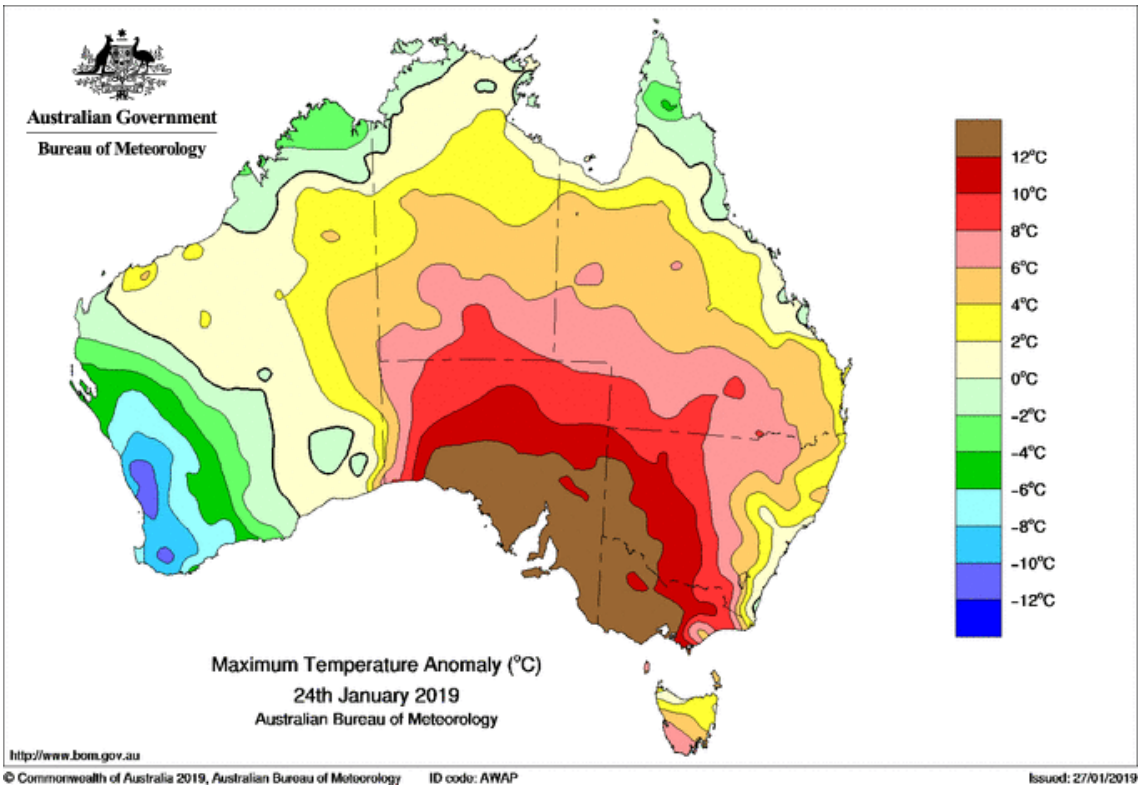
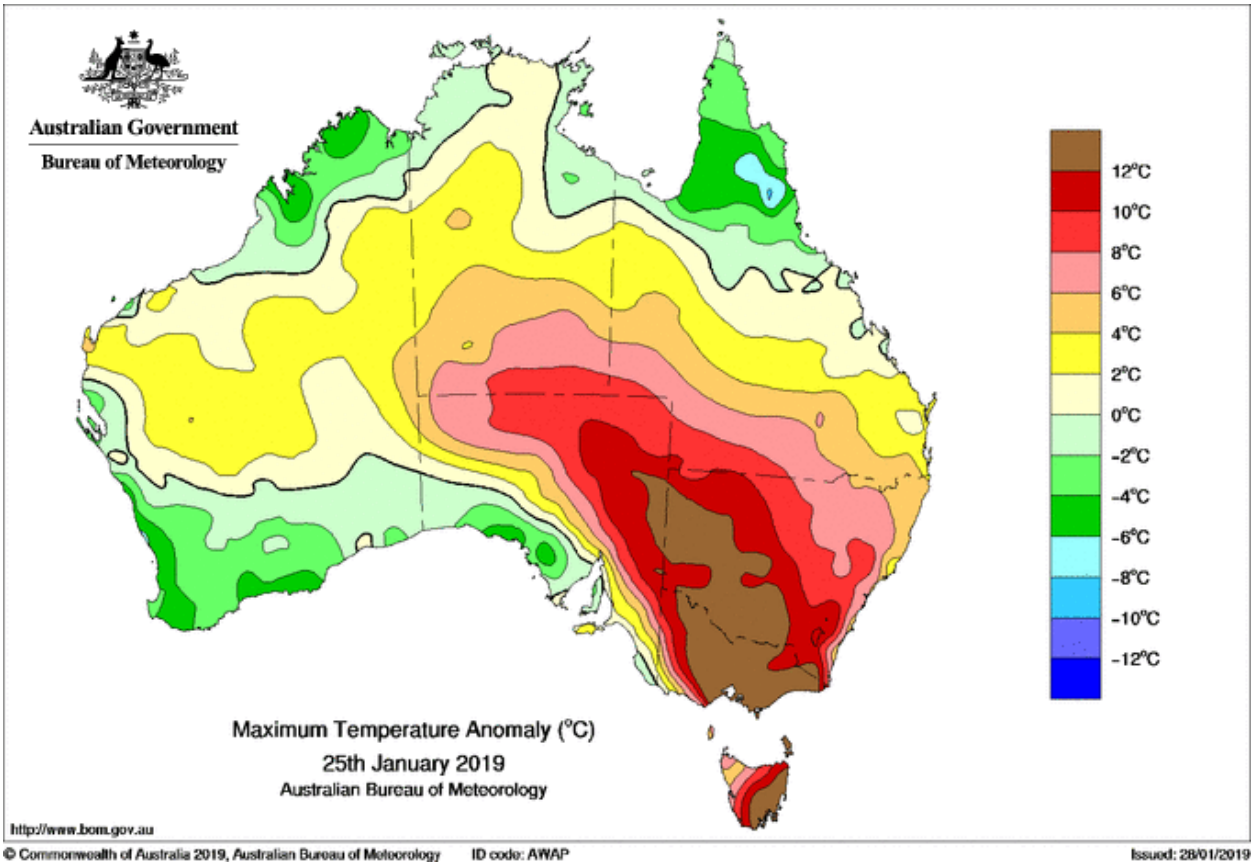


Figure 2 shows the high temperatures (brown) having moved from SA further into VIC on Friday 25 January.

Figure 2 Observed maximum temperature above January average, Friday 25 January 2019



3. Operational Forecasts

3.1 Weather forecasts

AEMO uses weather information from three weather service providers for its operational forecasting.

The progression of weather forecasts for the week spanning 19-25 January is shown in Table 3 and Table 4. These represent forecasts from the same weather service provider, for Melbourne (Olympic Park) and Adelaide (Kent Town) respectively. The actual maximum temperature for each day is shown in the bottom row of each table.

Table 3 Melbourne (Olympic Park) maximum temperature forecast progression 19-25 January

		Forecast for						
		Sat 19-Jan	Sun 20-Jan	Mon 21-Jan	Tue 22-Jan	Wed 23-Jan	Thu 24-Jan	Fri 25-Jan
Date of forecast	Sat 19-Jan	22	25	29	32	28	37	37
	Sun 20-Jan		24	27	31	26	38	36
	Mon 21-Jan			26	30	26	37	40
	Tue 22-Jan				30	25	37	42
	Wed 23-Jan					25	37	42
	Thu 24-Jan						39	42
	Fri 25-Jan							44
Actual		23.5	22.9	25.1	26.8	23.9	40.8	42.8

Table 4 Adelaide (Kent Town) maximum temperature forecast progression 19-25 January

		Forecast for						
		Sat 19-Jan	Sun 20-Jan	Mon 21-Jan	Tue 22-Jan	Wed 23-Jan	Thu 24-Jan	Fri 25-Jan
Date of forecast	Sat 19-Jan	29	33	35	38	39	43	32
	Sun 20-Jan		32	36	38	41	45	30
	Mon 21-Jan			34	37	40	45	30
	Tue 22-Jan				37	40	45	31
	Wed 23-Jan					40	45	30
	Thu 24-Jan						45	32
	Fri 25-Jan							29
Actual		28.7	32.8	36.4	39.9	42	47.7	31.9

3.2 Electricity demand forecasts

Temperature is a key factor in electricity demand forecasts. At temperatures over 35°C, every one-degree increase could result in a demand increase of approximately 100 megawatts (MW). Actual temperatures on 24 and 25 January were around 10% probability of exceedance (POE) levels[7].

Following the sequence of weather forecast updates shown in Table 3 and Table 4, AEMO's demand forecast progression for VIC (Table 5) and SA (Table 6) is illustrated below. Demand forecasts undergo continuous review, and several intra-day revisions were made as prevailing conditions and weather forecasts changed.

Table 5 and Table 6 show AEMO's forecasts of operational demand[8] for each day in the week from 19-25 January.

The 'actual demand' quantities shown at the bottom of each table represent the demand supplied by NEM registered market generators and inter-regional transfers and have not been adjusted for the dispatch of non-scheduled RERT reserves, load shedding directions, or any other demand side participation.

[7] POE means the probability, as a percentage, that a maximum demand forecast will be met or exceeded (for example, due to weather conditions). A 10% POE forecast is expected to be met or exceeded, on average, only one year in 10, so considers more extreme weather (also called 1-in-10-year conditions) than a 50% POE forecast, which is expected to be met or exceeded, on average, one year in two.

[8] For demand definitions, see http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/Demand-terms-in-EMMS-Data-Model.pdf.

Table 5 VIC daily peak operational demand forecast progression 19-25 January

		Forecast for						
		Sat 19-Jan	Sun 20-Jan	Mon 21-Jan	Tue 22-Jan	Wed 23-Jan	Thu 24-Jan	Fri 25-Jan
Date of forecast	Sat 19/01	5106	5440	6674	7414	6114	7869	8600
	Sun 20/01		5259	6669	7875	6735	9134	8343
	Mon 21/01			6679	7682	6249	9117	9065
	Tue 22/01				7472	6199	9000	8952
	Wed 23/01					6167	9000	9220
	Thu 24/01						8950	9220
	Fri 25/01							After peak*
Actual		4985	5468	7284	7880	6651	9328	9298

* Peak demand occurred at 1100 hrs on 25 January 2019 in VIC, hence the 1230 hrs forecast produced on the day (25 January 2019) was produced after peak demand had already been recorded.

Table 6 SA daily peak operational demand forecast progression 19-25 January

		Forecast for						
		Sat 19-Jan	Sun 20-Jan	Mon 21-Jan	Tue 22-Jan	Wed 23-Jan	Thu 24-Jan	Fri 25-Jan
Date forecast	Sat 19-Jan	1,555	1,821	2,342	2,652	2,793	3,092	2,184
	Sun 20-Jan		1,836	2,425	2,709	2,972	2,996	2,008
	Mon 21-Jan			2,307	2,688	2,846	3,050	2,108
	Tue 22-Jan				2,762	2,891	3,128	2,024
	Wed 23-Jan					2,885	3,166	2,105
	Thu 24-Jan						3,166	2,241
	Fri 25-Jan							2,362
Actual		1,528	1,808	2,449	2,776	2,992	3,240	2,063

Accurate forecasting of extreme temperatures presents a key challenge for peak-day electricity demand forecasting.

On 24 and 25 January, there were record daytime maximum temperatures and extreme overnight temperatures, followed by quick development of a cool change across Melbourne at approximately 1300 hrs on 25 January. At such extremes, accurately capturing the whole-of-day weather profile becomes critical to forecasting of demand.

Under-forecasting of the maximum daytime temperatures on both days, and the overnight temperatures leading into 25 January, contributed to under-forecasting of electricity demand for the morning of 25 January. The development of a cool change, arriving in central Melbourne shortly after 1300 hrs, resulted in a rapid drop in demand as temperatures fell over 14^0C in fifteen minutes.

As extreme weather events increase, AEMO continues to work closely with the weather forecasting industry to further develop extreme weather forecasting tools and enhance intra-day weather forecasting and situational awareness for energy demand and generation forecasting.

AEMO updates operational demand forecasts every 30 minutes. The figures below show the forecasts for the day ahead (midday the previous day), at 0800 hrs and 1000 hrs on the mornings of 24 and 25 January in VIC and SA. The actual operational demand is shown as a reference.

Figure 3 Forecast and actual operational demand in SA, 24 January

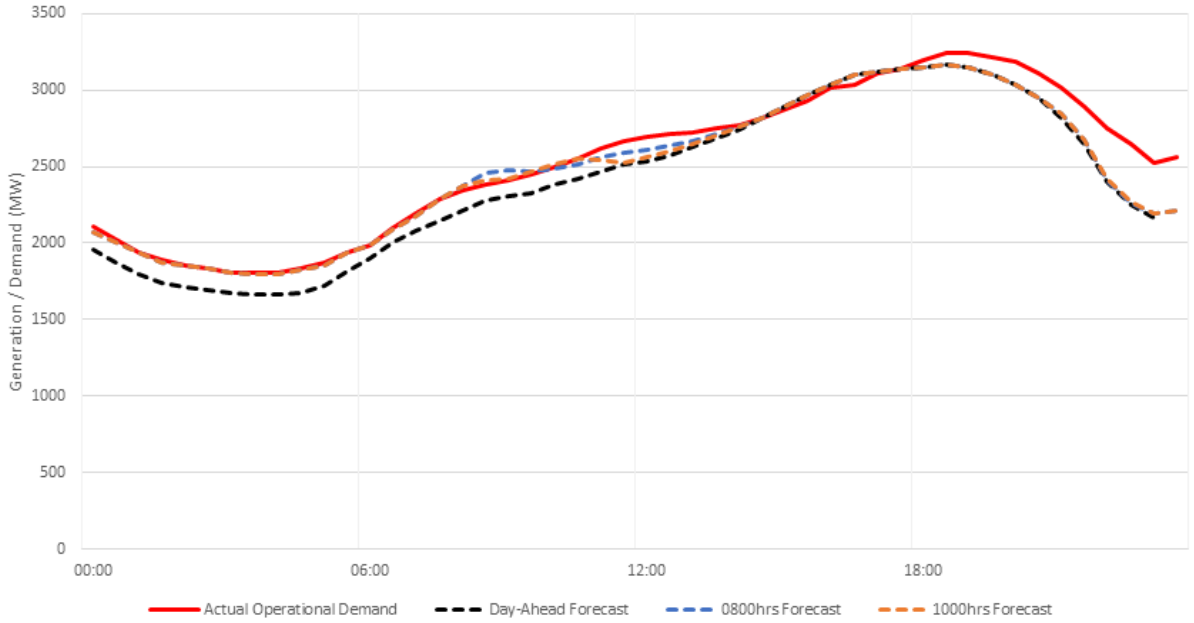
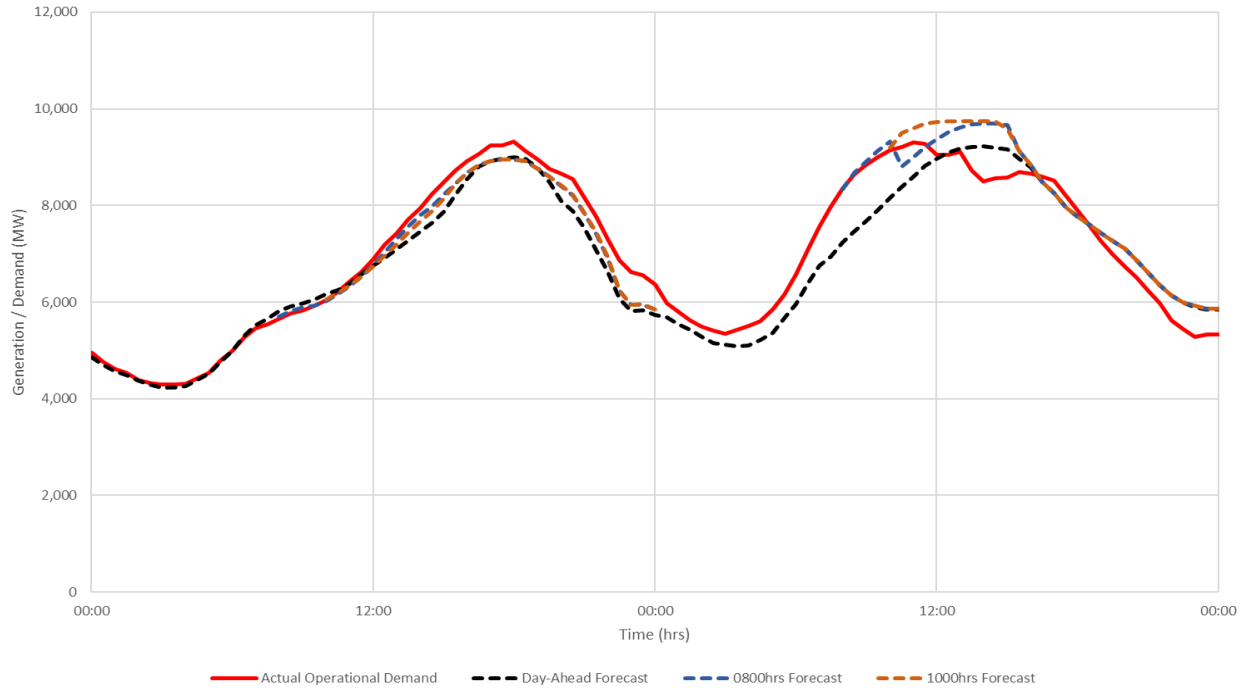


Figure 4 Forecast and actual operational demand in VIC, 24 January and 25 January



Demand-side activity – including RERT, load shedding, and voluntary demand side reduction – further challenged the accuracy of AEMO's forecasting, with activation schedules of non-scheduled RERT resources being reflected in the operational demand forecasts on both days.

AEMO is actively working with industry to gain visibility of demand side activity. Initiatives include Virtual Power Plant (VPP) demonstrations and improved RERT dispatch and automation.

3.3 Estimated actual demand

The estimated maximum demands on 24 and 25 January in VIC, considering RERT and directed load shedding, were:

- 24 January – 9,566 MW.
- 25 January – 9,632 MW.

Similarly, the estimated maximum operational demand in SA on 24 January was 3,265 MW.

Estimated rooftop solar generation is also represented in Figure 5 and Figure 6 below, to show the total electricity consumption by all consumers. Increasing penetrations of rooftop solar continue to produce later and shorter-duration peak operational demands.

Figure 5 Estimated actual demand in VIC, 24 and 25 January

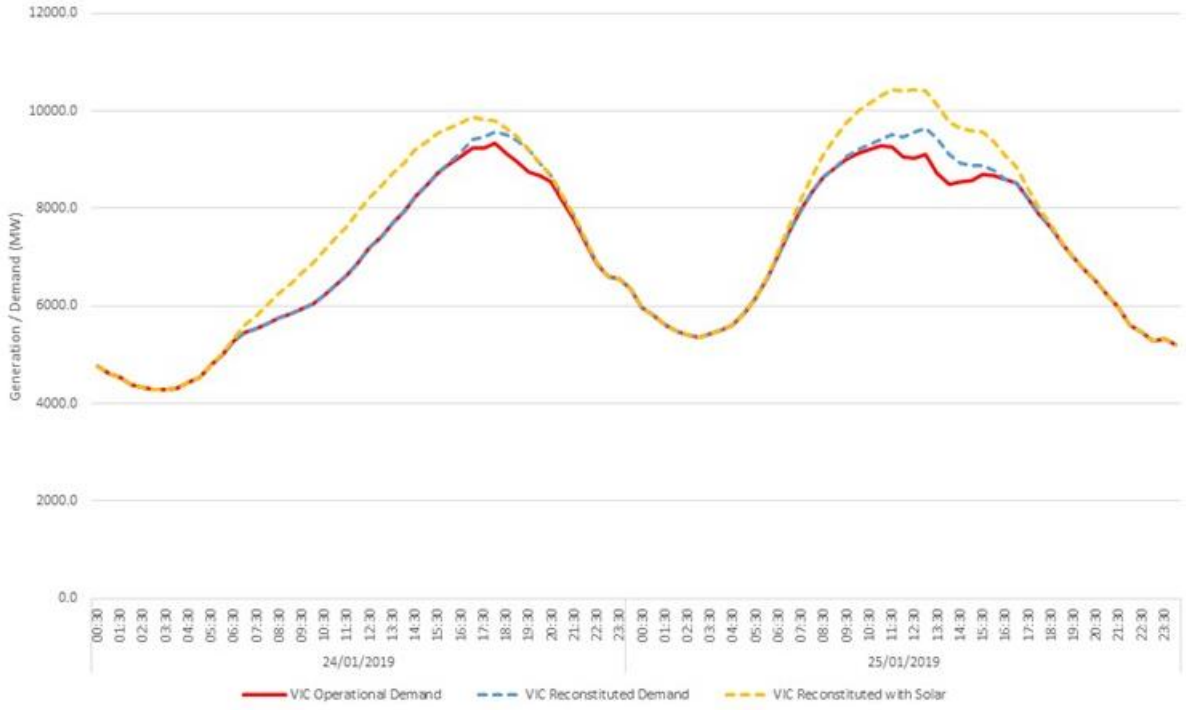
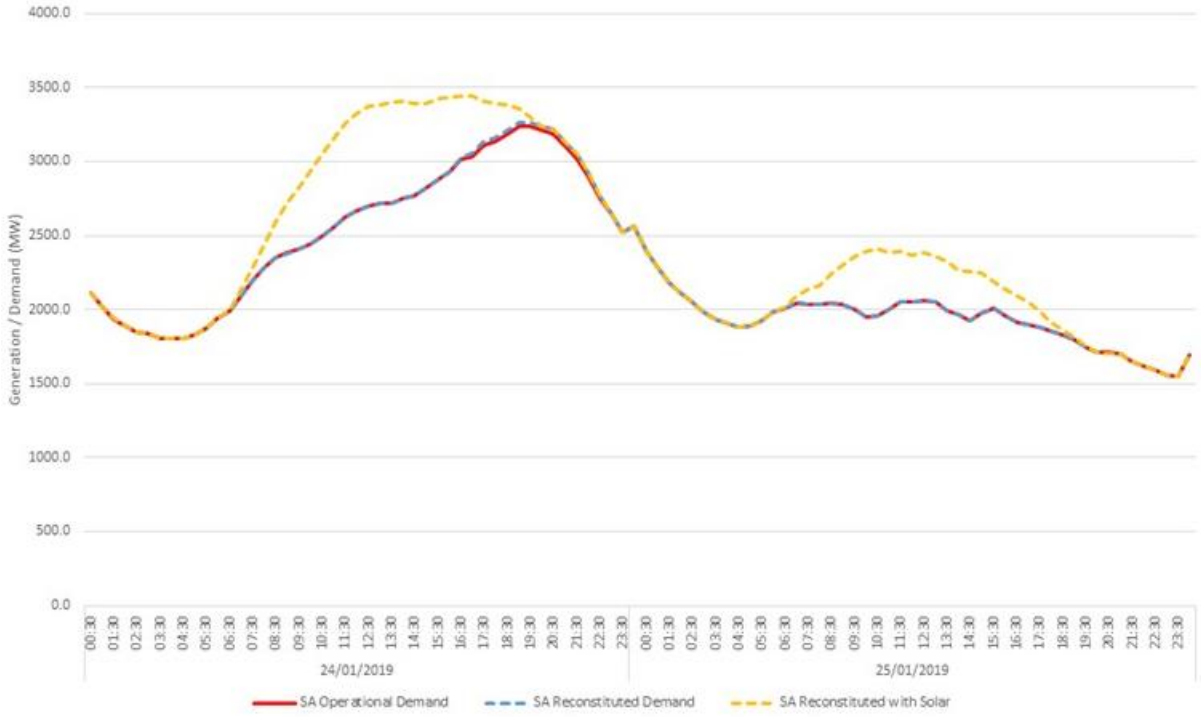


Figure 6 Estimated actual demand in SA, 24 and 25 January



3.4 Electricity supply forecasts

Figure 7 VIC 24 January forecast supply availability vs forecast and actual demand as at 1300 hrs on 23 January

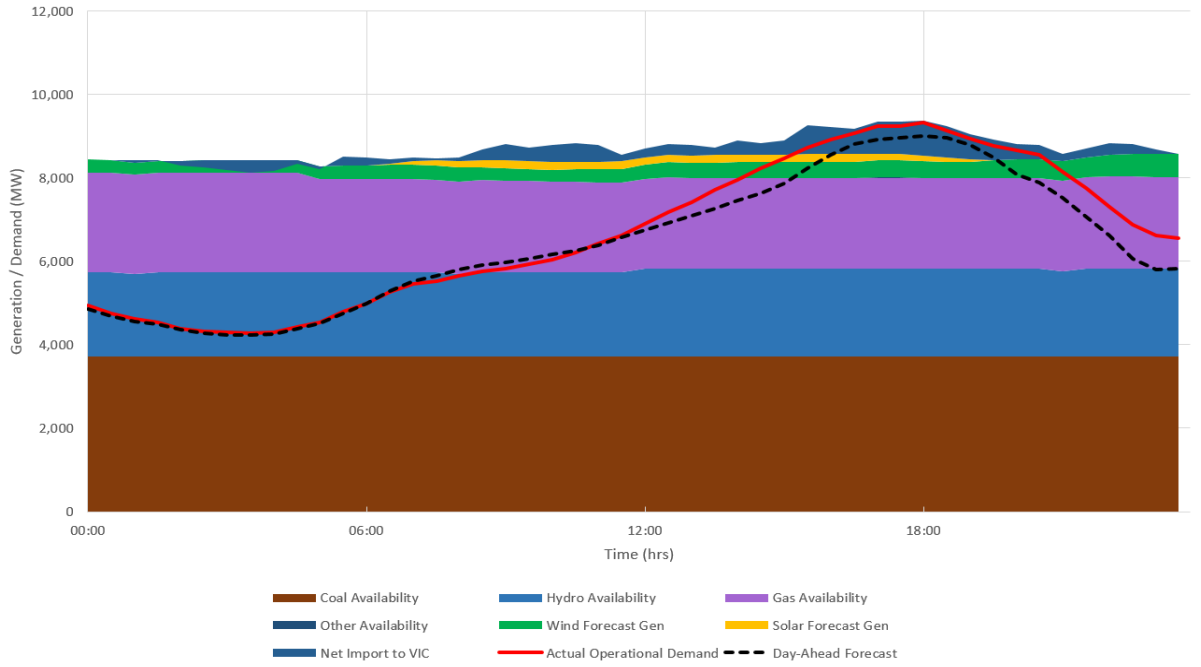
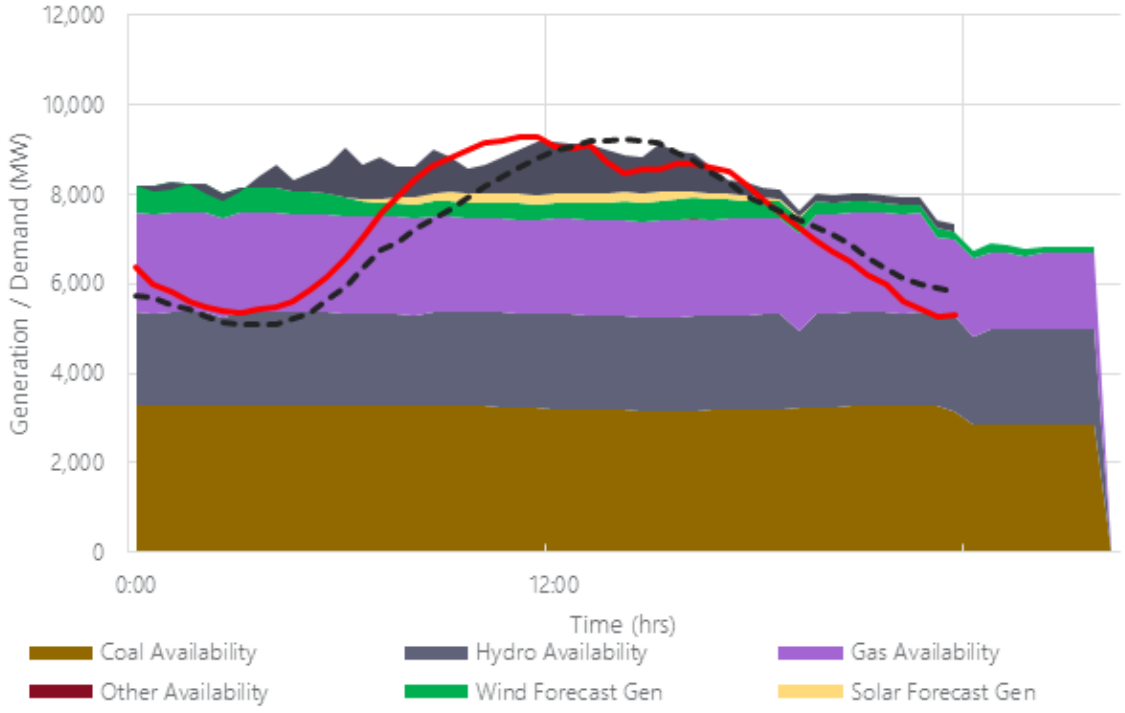


Figure 8 VIC 25 January forecast supply availability vs forecast and actual demand as at 1300 hrs on 24 January



4. Electricity supply

This section provides an overview of the status and capacity of the various generation sources in VIC and SA for 24 and 25 January 2019, together with available supply from other regions via interconnectors. Reduced capacity of the thermal generation fleet coupled with relatively low wind and solar generation output at the time of maximum demand meant that there was insufficient supply to meet maximum demand on both days.

4.1 Thermal generator outages and reductions

Four of the 10 normally available coal generating units in VIC were either offline or operating at reduced capacity on 25 January and in the preceding days.

Table 7 shows when this generation capacity became unavailable to the market.

Table 7 Thermal generator capacity not available in VIC on 24 and 25 January 2019

Date/ Market time	Thermal generating unit	Status	Outage/ reduction (MW)	Reason
19-1-19 at 00:00	Yallourn 4	OFF – UNAVAILABLE	355	Overdue maintenance
22-1-19 at 15:00	Loy Yang A3	OFF - UNAVAILABLE	530	Unplanned plant outage
24-1-19 at 08:00	Loy Yang A2	Reduced Capacity Availability	140	Unplanned capacity reduction
25-1-19 at 01:00	Yallourn 3	OFF - UNAVAILABLE	355	Unplanned plant outage
25-1-2019	Various	Reduced Capacity	232	Plant capacity reductions as equipment reached temperature-based operating limits

TOTAL Reduction from thermal plant outage and capacity reduction in VIC = **1,612 MW**.

4.1.1 Yallourn Unit 4 Maintenance

Where possible, all thermal generator major maintenance activities are typically completed before the start of summer. Yallourn unit 4 was scheduled for routine pre-summer maintenance after the completion of maintenance works on Yallourn unit 3. However, although originally due to return to service in November, full output at unit 3 was unable to resume until 9 January 2019. By that time, the planned maintenance was overdue and urgent. Table 8 shows the progression of planned maintenance outages for Yallourn unit 4.

Table 8 Planned maintenance scheduling of Yallourn unit 4

Date / Market time	Planned maintenance
20 December 2018	Yallourn unit 4 maintenance postponed and scheduled for 7 January to 14 January 2019 due to delayed return to service of Yallourn unit 3.
31 December 2019	Yallourn unit 4 outage further postponed by Energy Australia by two weeks to take place on 21 January – 28 January 2019 due to heat forecast for 7 – 14 January 2019 and delayed return to service of unit 3.
11 January 2019	Energy Australia advises that Yallourn unit 4 availability will be reduced from 17 January due to a fouling boiler.
14 January 2019	Energy Australia updates planned outage of Yallourn unit 4 to commence on 19 January through to 26 January 2019.
14 January 2019 to 19 January 2019	AEMO studies reveal no reserve issues in VIC for the outage period, and no other thermal capacity indicated that it would be unavailable or reduced during this time. As at 19 January 2019, no system security or reliability issues indicated for 19-26 January.
19 January 2019	Yallourn unit 4 taken off-line for overdue maintenance. No lack of reserve forecast for the outage period.

As at 19 January 2019, when the rescheduled Yallourn unit 4 outage was due to commence, forecast maximum temperatures in Melbourne were up to 37°C for 24 and 25 January. With all other thermal units expected to be available and a demand forecast of up to 8,600 MW (corresponding to a 37°C January day), no lack of reserve (LOR)[9] conditions were forecast for the scheduled outage period. AEMO only refuses permission for a generator outage to proceed on grounds of system security or reliability. Given the outlook as known on 19 January, the overdue maintenance was therefore allowed to proceed.

Forecast temperatures and demand for VIC (Melbourne) as at 19 January for the week of the rescheduled outage are shown in the tables below, together with the actual temperatures and demand that eventuated.

[9] Lack of reserve levels are explained in Section 6.2 of this report.

Table 9 Temperature forecast (°C) for the week 19-25 January as at 19 January 2019

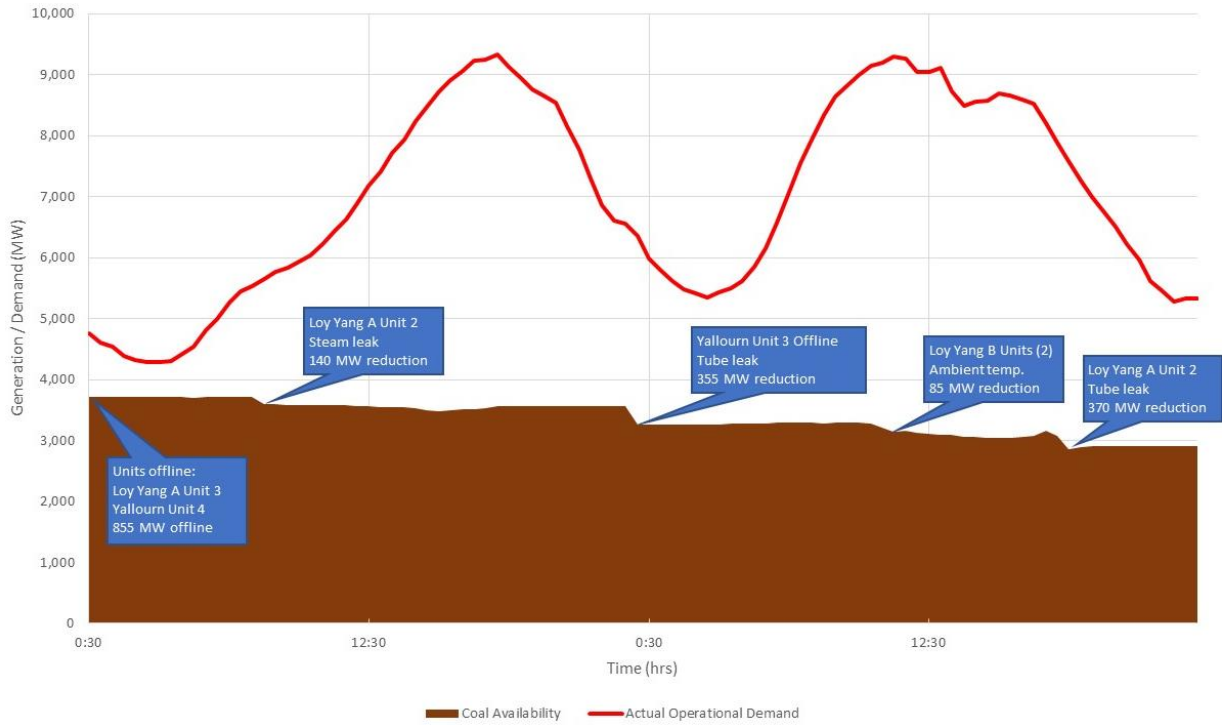
Melbourne (Olympic Park)	Sat 19 Jan	Sun 20 Jan	Mon 21 Jan	Tue 22 Jan	Wed 23 Jan	Thu 24 Jan	Fri 25 Jan
Forecast max	22	25	29	32	28	37	37
Actual max	23.5	22.9	25.1	26.8	23.9	40.8	42.8

Table 10 Demand forecast (MW) for the week 19-25 January as at 19 January 2019

VIC Demand	Sat 19 Jan	Sun 20 Jan	Mon 21 Jan	Tue 22 Jan	Wed 23 Jan	Thu 24 Jan	Fri 25 Jan
Forecast demand	5106	5440	6674	7414	6114	7869	8600
Actual demand	4985	5468	7284	7880	6651	9328	9298

Figure 9 shows the reductions in coal generation availability due to temperature and operational issues on 24 and 25 January 2019.

Figure 9 Coal generation and actual demand in VIC, 24 and 25 January 2019



4.2 Supply mix

Electricity in VIC and SA on 24 and 25 January 2019 was supplied by a combination of:

- Generation in VIC and SA comprising brown coal, gas, diesel, batteries, hydro, wind, large-scale solar, and distributed rooftop PV.
- Imports from New South Wales (NSW) and Tasmania via interconnections (the VIC–NSW interconnector (VNI) and Basslink).

The contribution of the various fuel types in the generation mix across the entire day on 24 January in SA and for both 24 and 25 January in VIC is shown in Figure 10 and Figure 11.

Figure 10 24 January SA, contribution to operational demand by fuel type

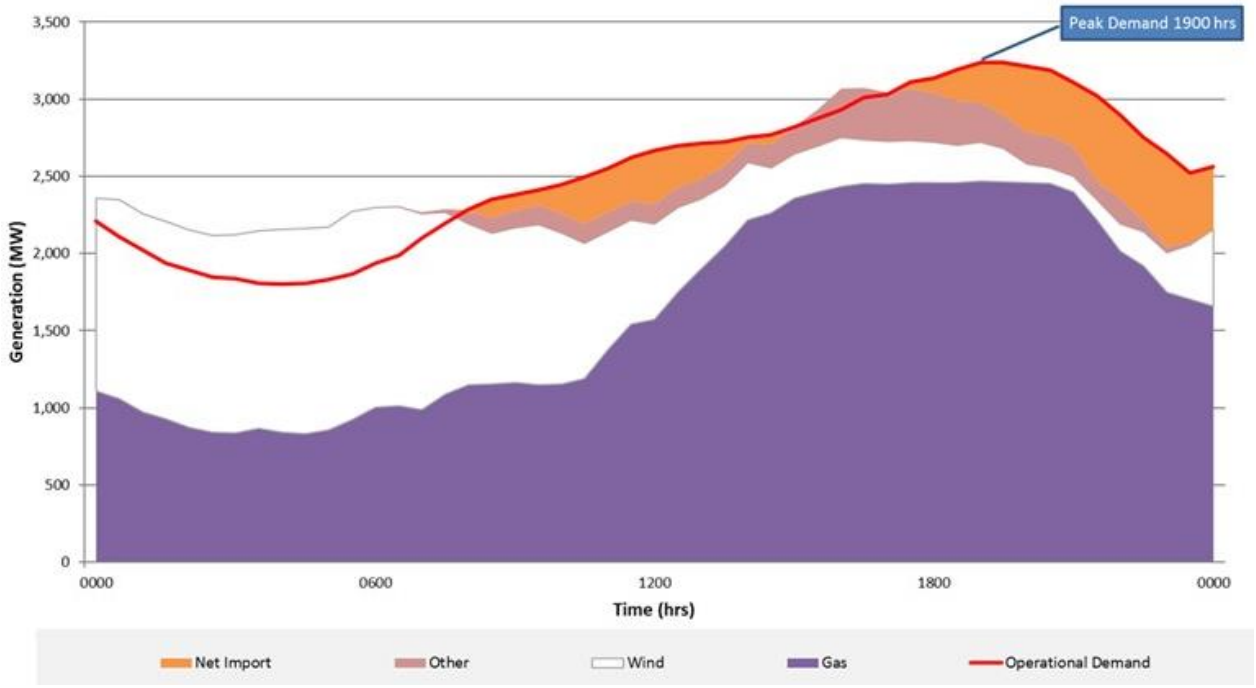
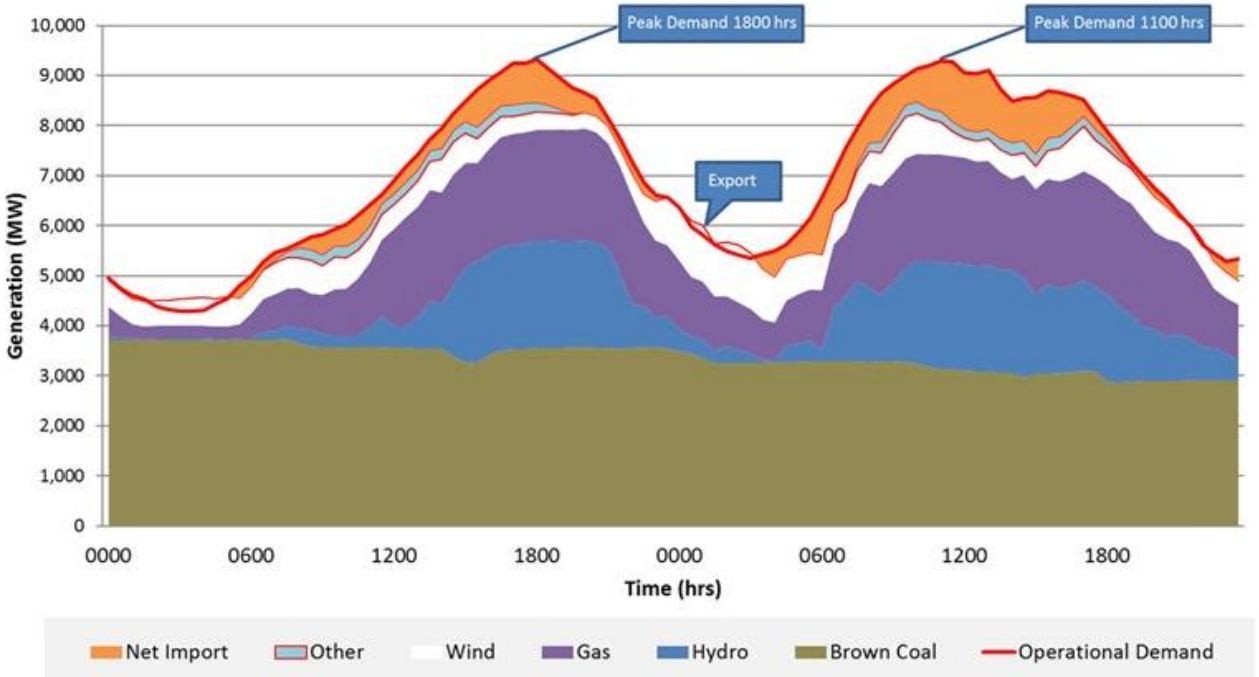


Figure 11 24 and 25 January VIC, contribution to operational demand by fuel type



4.2.1 Victorian scheduled generation supply 25 January 2019

Table 11 VIC scheduled generator supply 25 January (MW)

Power station	Summer capacity	25 January actual @ 1100 hrs
Bairnsdale	78.0	60
Ballarat Energy Storage System	28.8	0
Bogong / Mackay	300.0	293
Murray 1	950.0	1,496
Murray 2	560.0	
Dartmouth	165.0	142
Eildon	100.0	90
Hume VIC	29.0	34
Jeeralang A	189.0	168
Jeeralang B	216.0	204
Laverton North	300.0	289
Loy Yang A	2,114.0	1,498
Loy Yang B	980.0	942
Mortlake	518.0	523
Newport	475.0	482
Somerton	140.0	137
Valley Power	270.0	284
West Kiewa	68.0	66
Yallourn W	1,420.0	701
Total scheduled	**8,926**	**7,409**

4.2.2 Victorian semi-scheduled and significant non-scheduled generation supply 25 January 2019

Table 12 VIC semi-scheduled and significant non-scheduled generation supply 25 January (MW)

Power station	Summer capacity	25 January actual @ 1100 hrs
Ararat Wind Farm	195.0	79
Bald Hills Wind Farm	106.6	95
Challicum Hills	52.5	24
Crowlands Wind Farm	80.0	34

Power station	Summer capacity	25 January actual @ 1100 hrs
Kiata Wind Farm	31.1	25
Macarthur Wind Farm	420.0	40
Mortons Lane Wind Farm	19.5	6
Mt Gellibrand	132.0	62
Mt Mercer Wind Farm	131.2	112
Oaklands Hill Wind Farm	41.6	15
Portland Wind Farm	151.7	32
Salt Creek Wind Farm	54.0	17
Waubra	192.0	102
Yaloak South Wind Farm	28.7	28
Yambuk	30.0	8
Total (wind)	**1,665.9**	**679.0**
Bannerton Solar Park	88.0	86
Gannawarra Solar Farm	50.0	43
Karadoc Solar Farm	90.0	89
Wemen Solar Farm	87.8	28
Total (solar)	**315.8**	**246.0**

4.3 Supply compared to 2018 ESOO forecast

AEMO's Electricity Statement of Opportunities (ESOO) forecasts electricity supply reliability in the NEM over a 10-year period to inform the decision-making processes of market participants, new investors, and policy-makers as they assess future development opportunities.

In 2018, AEMO's ESOO modelling showed heightened risk of USE over the next 10 years, confirming that additional investment is required in a portfolio of resources to replace retiring capacity, and that, for peak summer periods, targeted actions to provide additional firming capability are necessary to reduce risks of supply interruptions.

The 2018 ESOO identified a 31% chance of load shedding occurring in Victoria in January and February 2019, with a 20% chance that the resulting USE would exceed the reliability standard for USE in 2018-19. Corresponding assessments for SA were 11% and 7% respectively. Simulations indicated that the risk of load shedding was greatest where reductions in supply from thermal generation due to coincident unplanned outages occurred at times of expected low intermittent generation and high demand.

The 2018 ESOO modelling factored in the impact of:

- A reduction in thermal generation reliability observed in recent years.
- Reduced output of wind and solar generation typically observed in extreme heat events.

In forecasting the availability of scheduled capacity, the ESOO took into account:

- Seasonal ratings sourced from generators, representing available capacity during weather conditions associated with 10% POE maximum demand, assuming the unit is fully in service.
- Full and partial forced outage rates that are applied stochastically over many Monte Carlo simulations to capture the range of availability.

The 2018 ESOO used eight historical reference years to model intermittent generation. These reference years were also used to model demand so that the correlation between intermittent generation and demand was maintained. The level of intermittent generation available during peak periods on 24 and 25 January was relatively high compared to historical observations, particularly on 25 January due to the early occurrence of the peak (1100 hrs) when solar availability was high.

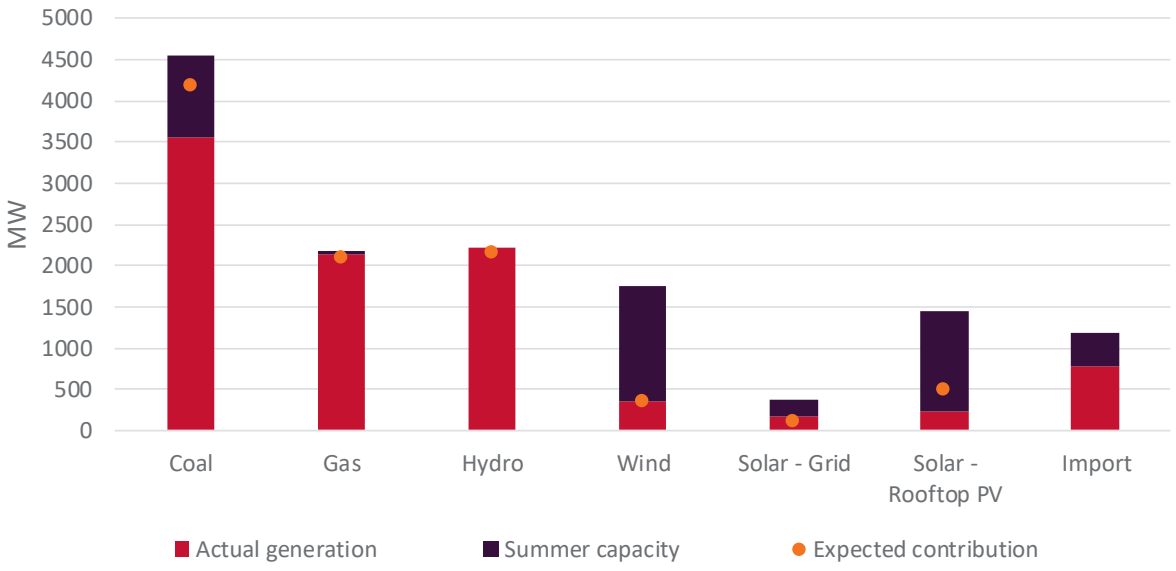
In summary, on 24 and 25 January:

- Generation capacity available from brown coal plant was at the extreme lower end of observations in the 2018 ESOO.
- The contribution of wind and solar generation was above ESOO simulations for comparable heat conditions.
- The hydro and gas contribution was very close to the 2018 ESOO observations.

4.3.1 Supply mix 24 January 2019 – SA and VIC

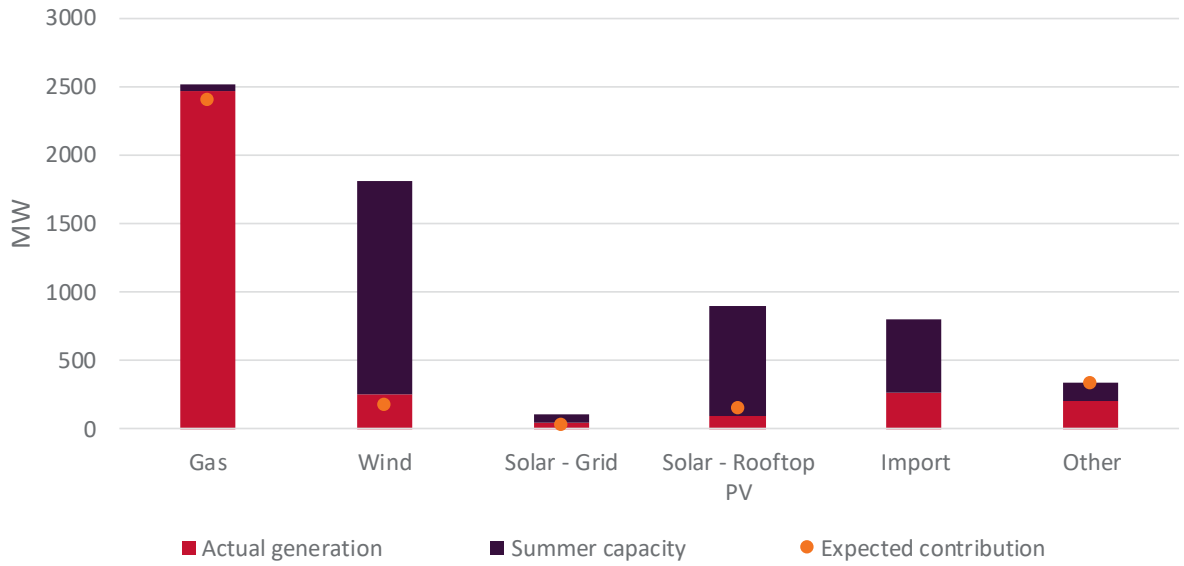
The contribution of each type of supply source to meet the demand on 24 January at 1800 hrs, just before the time of load shedding in VIC and at the time of peak demand, relative to the summer rated capacity and their expected contributions as modelled for AEMO's 2018 ESOO, are shown in Figure 12.

Figure 12 24 January – VIC actual generation by fuel type at trading interval ending 1800 hrs



The contribution of each type of supply source to supply the SA maximum demand at 1900 hrs, relative to the summer rated capacity, as well as their 2018 ESOO expected contributions, are shown in Figure 13.

Figure 13 24 January – SA actual generation by fuel type at peak demand at trading interval ending 1900 hrs

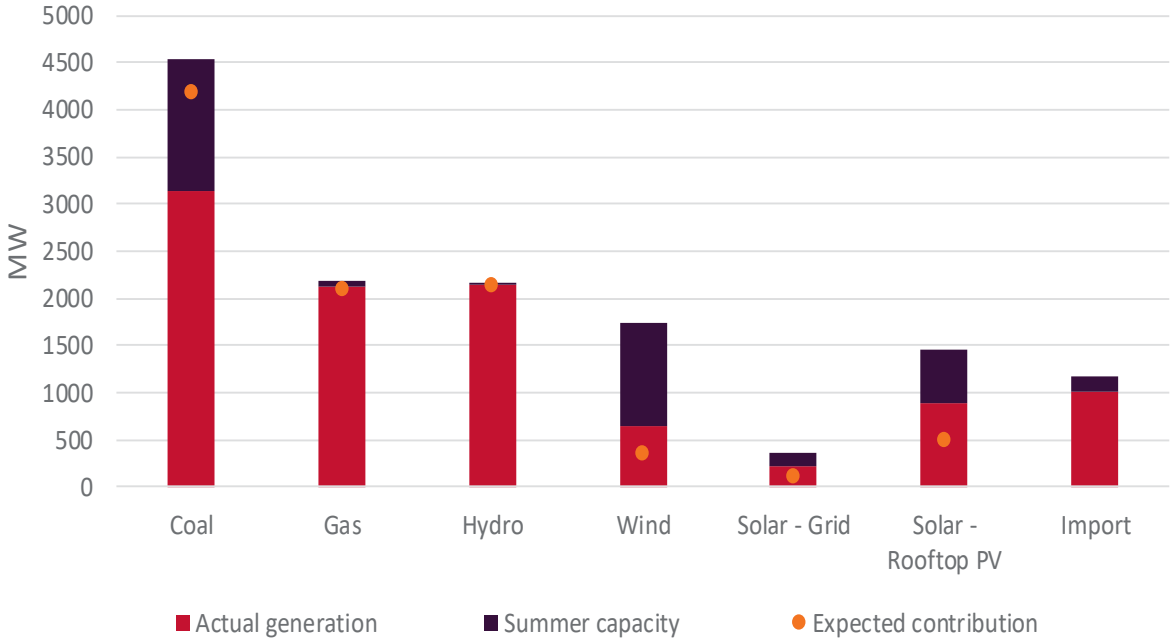


*Other includes liquid fuel generation and battery energy storage (note that this storage is limited).

4.3.2 Supply mix 25 January 2019 – VIC

The contribution to supply the demand on 25 January at 1100 hrs (just before the time of load shedding in VIC and at the time of peak demand), relative to the summer rated capacity, and their expected contributions as modelled in simulations for the 2018 ESOO, are shown in Figure 14.

Figure 14 25 January – VIC actual generation by fuel type at trading interval ending 1100 hrs

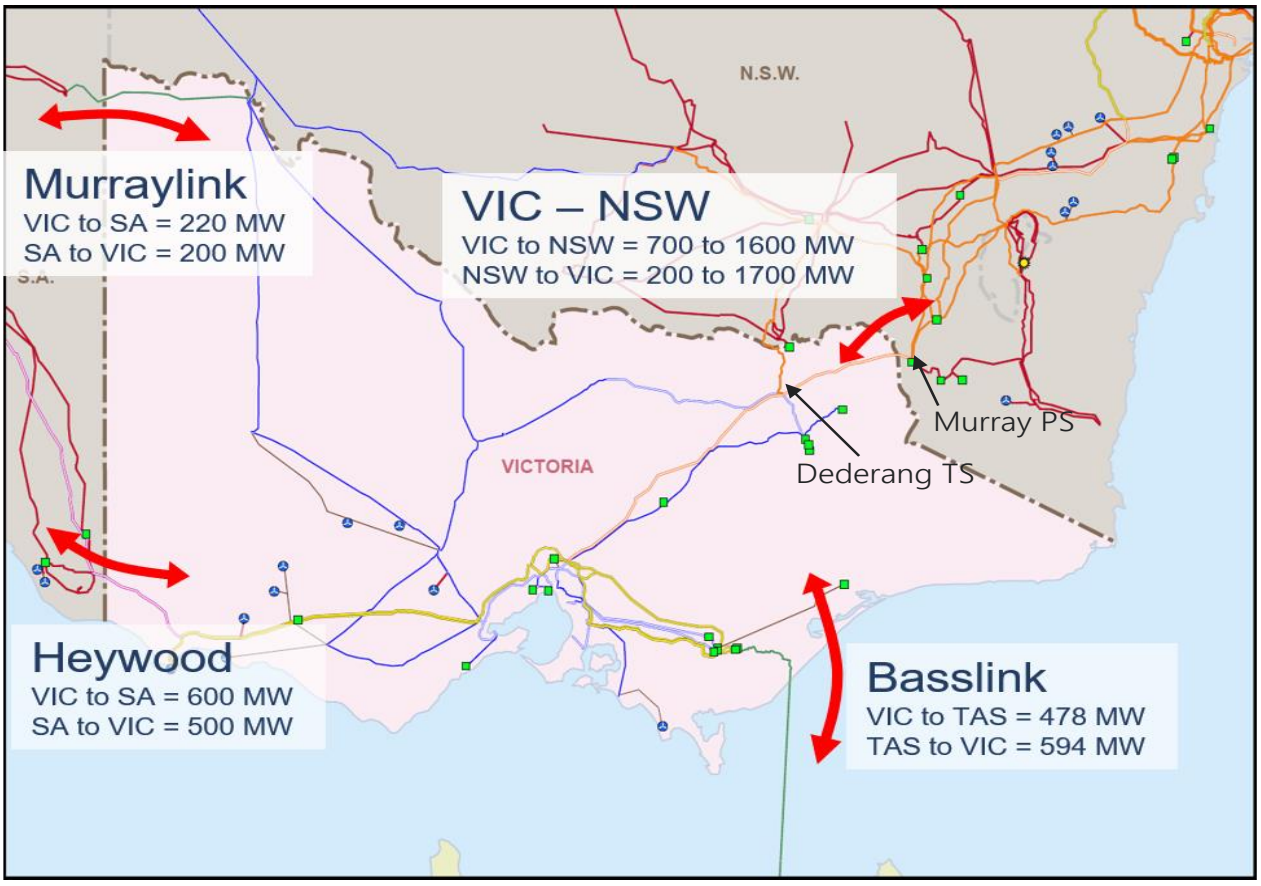


The expected generation contribution shown is calculated based on average contribution during at risk periods from the range of Monte Carlo simulations as reflected in the 2018 ESOO modelling. The contribution from coal generation was significantly less than expected and renewables was slightly more than expected, based on the 2018 ESOO modelling assumptions.

4.4 Interconnector flows

VIC has inter-regional transmission links (interconnectors) with NSW, SA, and Tasmania. The locations and capacities of these interconnectors are shown in Figure 15. SA is interconnected only with VIC.

Figure 15 VIC interconnections and nominal maximum transfer capacities



Depending on power flows in the network and the network constraints in place at any given time to maintain power system security, the transfer capacity of an interconnector can be lower than its nominal maximum. This was the case on 24 and 25 January where some interconnector limits were reduced due to thermal or other limitations of equipment within the interconnected transmission networks. These limits are reflected in the actual capacity of the relevant interconnector in the following sections.

The VNI has a nominal maximum capacity of 1,700 MW for flow from NSW to VIC. However, Murray power station - geographically located in NSW - is electrically connected into Dederang terminal station in VIC.

When power flows from NSW to VIC, the power flow on the interconnector is the capacity of NSW to VIC (1,700 MW) minus Murray generation flowing into Dederang. The capacity of Murray power station is approximately 1,500 MW, so the remaining interconnector capacity is reduced to 200 MW when at full output.

Maximum Basslink capacity from Tasmania to VIC for January 2019 was reduced from 594 MW down to 478 MW on advice from Basslink in December 2018.

4.4.1 24 January Interconnector flow

Values in red in Table 13 below indicate flows exceeding actual capacity at that time.

Table 13 Interconnector actual capacities and flows on 24 January

	Nominal capacity (to/from VIC)	Actual capacity (to VIC) at 1810 hrs	Actual flow (to VIC) at 1810 hrs
VNI	1,700 MW*	164 MW Murray generating 1,536 MW	413 MW Murray generating 1,536 MW
Heywood	500/600 MW	500 MW	35 MW
Murraylink	200/220 MW	- 41 MW (flow to SA)**	-45 MW (flow to SA)
Basslink	594/478 MW	478 MW	483 MW

* Less Murray generation.
** At this time (1810 hrs on 24 January 2019), flow on the Murraylink interconnector was restricted to 41 MW from VIC to SA due to other system conditions in VIC.

Direction to Snowy Hydro to provide voltage control to maximise transfer across the VIC–NSW interconnector

At 1639 hrs on 24 January, AEMO directed Snowy Hydro to synchronise a synchronous condenser at the Tumut 3 power station. This was to maximise flows across the VNI and to alleviate a post contingent voltage collapse constraint violation for VNI. The deployment of the synchronous condenser at Tumut power station enables VNI to maintain high flow levels securely. Without the synchronous condenser operation, AEMO would have had to reduce flow on VNI. The direction for voltage support therefore reduced the amount of required load shedding in VIC on 24 January.

4.4.2 25 January Interconnector flow

Values in red in Table 14 below indicate flows exceeding actual capacity at that time.

Table 14 Interconnector actual capacities and flows on 25 January

	Nominal capacity (to/from VIC)	Actual capacity (to VIC) at 1100 hrs	Actual flow (to VIC) at 1100 hrs
VNI	1,700 MW*	100 MW Murray generating 1,500 MW	5 MW Murray generating 1,500 MW
Heywood	500/600 MW	475 MW	528 MW
Murraylink	200/220 MW	97 MW	122 MW
Basslink	594/478 MW	478 MW	478 MW

* Less Murray generation.

5. Sequence of events

Key events leading up to and during the load shedding on 24 and 25 January 2019 are summarised below.

AEMO issued and updated a significant number of LOR 1 and LOR 2 market notices for this period on the preceding days, which are not listed in this report.

In addition, AEMO took several operational actions to adjust system parameters in ways that would maximise the capacity of the entire NEM power system to flow power securely towards the high demand regions.

5.1 24 January 2019

Table 15 Sequence of key events impacting 24 January 2019 (times AEST)

Date / Market time	Event
23 January 2019	
23/01/2019 13:13	Following the 1330 hrs pre-dispatch projected assessment of system adequacy (PD PASA) run, AEMO forecast LOR 2 conditions in VIC for 24 January 2019. AEMO sought a market response and had not yet estimated the latest time to intervene (market notice [MN] 66542).
23/01/2019 16:18	PD PASA Forecast LOR 3 Notice issued for VIC and SA for 24 January 2019. AEMO sought a market response and updated the latest time to intervene as 0800 hrs on 24 January 2019 for the 24 January 2019 reserve shortfall. Refer to market notices 66556, 66558 and 66559.
23/01/2019 20:45	Forecast LOR 3 condition in VIC and SA for 24 January cancelled. Refer to market notices 66569, 66570.
24/01/2019 06:24	Yallourn trader informed AEMO Yallourn W unit 3 had been rebid to remain in service at 320 MW until 2300 hrs with risk of trip due to steam leak. Prior bids had indicated Yallourn W unit 3 would be taken out of service at 1000 hrs.
24 January 2019	
24/01/2019 06:22	Loy Yang A trader informed AEMO Loy Yang A unit 2 had a steam leak, severity uncertain and staff would keep AEMO informed.
24/01/2019 07:29	Loy Yang A trader informed AEMO Loy Yang A unit 2 would reduce output from 530 MW to 400 MW but remain in service as long as possible, and staff would keep AEMO informed.
24/01/2019 08:00	AEMO assessed the forecast reserves and determined that an intervention was not immediately required for the 24 January 2019 forecast reserve shortfall.
24/01/2019 08:25	Latest time to intervene was determined as 1330 hrs on 24 January 2019 for the 24 January 2019 forecast reserve shortfall (MN 66588 and 66589).
24/01/2019 08:43	Forecast LOR 3 in VIC Region for 25 January 2019. Refer to market notices 66593, 66607.
24/01/2019 13:30	AEMO assessed the forecast reserves and determined that an intervention was not immediately required for the 24 January 2019 forecast reserve shortfall.
24/01/2019 13:54	AEMO issued requests for tender for the provision of additional reserve in VIC and SA for 24 January 2019 (MN 66616).
24/01/2019 13:54	Intention to commence RERT contract negotiations. Refer to market notice 66616.
24/01/2019 14:24	AEMO gave instructions to pre-activate and activate RERT contracts in response to the 24 January 2019 forecast reserve shortfall (MN 66619). AEMO contacted contract providers to enquire about the possibility of extending the activation period beyond the maximum activation times. A few of the providers confirmed that their MW response could be extended. AEMO intervention event commenced at 1430 hrs (MN 66629)
24/01/2019 15:00	Actual LOR 1 declared in VIC from 1500 hrs (MN 66621). Following RERT activation, forecast LOR 3 cancelled in VIC (MN 66623).
24/01/2019 16:00	Actual LOR 2 in VIC from 1600 hrs (MN 66630).
24/01/2019 16:04	Constraint equations #RT_VIC1_O_E and #RT_VIC1_P_E invoked from Dispatch Interval (DI) ending 1605 hrs until DI ending 2230 hrs, including all activated MWs from VIC RERT contracts.

Date / Market time	Event
24/01/2019 16:35	Constraint equations #RT_SA1_O_E and #RT_SA1_P_E invoked from DI ending 1635 hrs until DI ending 2130 hrs, including all activated MWs from SA RERT contracts.
24/01/2019 16:39	AEMO direction in NSW issued to Snowy Hydro for voltage control to maintain VNI flows (MN 66634).
24/01/2019 16:41	VIC–NSW interconnector (VNI) began to exceed transfer limits and constraints violated.
24/01/2019 16:41	First fast acting RERT activated to maintain interconnector flow within transfer limits.
24/01/2019 17:03	PD PASA Forecast LOR 3 Notice issued for VIC for 24 January 2019 (MN66637).
24/01/2019 17:03	PD PASA Forecast LOR 3 Notice issued for SA for 24 January 2019 from 1800 hrs (MN 66638).
24/01/2019 17:40	Actual LOR 2 declared in SA from 1740 hrs (MN 66666).
24/01/2019 17:52	AEMO informed Ausnet that involuntary load shedding was likely within 15 to 20 minutes.
24/01/2019 17:55	All RERT exhausted.
24/01/2019 18:10	Actual LOR 3 declared in VIC from 1810 hrs, AEMO directed Ausnet to shed 75 MW of load immediately in accordance with priority load shedding schedules. The first Portland Smelter potline consuming approximately 266 MW of electricity was sufficient to clear LOR 3 in both VIC and SA regions.
24/01/2019 18:14	Actual LOR 3 in VIC declared (MN 66670).
24/01/2019 19:05	AEMO directed Ausnet to shed second Portland Smelter potline (190 MW) as potline 1 (266 MW) was to be returned to service. Note: to prevent damage, potlines can only be taken out of service for a maximum of one hour each.
24/01/2019 19:10	First Portland Smelter potline returned to service.
24/01/2019 19:50	Second Portland Smelter potline returned to service.
24/01/2019 20:00	Actual LOR 3 cancelled for VIC at 2000 hrs, with AEMO direction to Ausnet cancelled (MN 66708 and 66710). Manual override on the VIC energy price was removed after DI ending 2000 hrs.
24/01/2019 21:15	AEMO direction to Snowy Hydro cancelled from 2115 hrs (MN 66724).
24/01/2019 21:50	Actual LOR 2 cancelled for SA at 2150 hrs (MN 66721). Actual LOR 1 and 2 cancelled for VIC at 2150 hrs (MN 66723 & 66722).
24/01/2019 22:30	End of RERT Dispatch and end of intervention event (MN 66726).

5.2 25 January 2019

Table 16 Sequence of key events impacting 25 January 2019 (times AEST)

Date / Market time	Event
23/01/2019 10:08	Market reporting for forecast extreme temperature in SA on 24/01/2019 and VIC on 25/01/2019 (MN 66533).
23/01/2019 16:29	Forecast LOR 2 for VIC region on 25/01/2019 (MN 66559).
24 January 2019	
24/01/2019 08:43	Short-term projected assessment of system adequacy (ST PASA) Forecast LOR 3 in VIC on 25/01/2019 (MN 66593).
24/01/2019 11:51	ST PASA Update of forecast LOR 3 in VIC on 25/01/2019 (MN 66607).

Date / Market time	Event
24/01/2019 13:46	Following the 1400 hrs PD PASA run, AEMO forecast LOR 3 conditions in VIC for 25 January 2019. AEMO sought a market response and noted the latest time to intervene as 0800 hrs on 25 January 2019 (MN 66613).
24/01/2019 15:29	PD PASA Cancellation of forecast LOR 3 in VIC on 25/01/2019 (MN 66623).
24/01/2019 21:25	PD PASA Forecast LOR 3 in VIC on 25/01/2019 (MN 66714).
25 January 2019	
25/01/2019 04:40	PD PASA Update of forecast LOR 3 in VIC on 25/01/2019 (MN 66728).
25/01/2019 07:37	Notified intention to commence RERT contract negotiations. AEMO issued requests for tender for the provision of additional reserves in VIC for 25 January 2019 (MN 66743).
25/01/2019 07:51	PDPASA Update of forecast LOR 3 in VIC on 25/01/2019. Latest time to intervene was updated to 0900 hrs on 25 January 2019 for the 25 January 2019 forecast reserve shortfall (MN 66744).
25/01/2019 08:00	Actual LOR 1 declared in VIC from 0800 hrs (MN 66746).
25/01/2019 08:45	AEMO instruction to pre-activate a reserve contract for the 25 January 2019 forecast reserve shortfall.
25/01/2019 08:50	PDPASA Update of forecast LOR 3 in VIC on 25/01/2019 (MN 66747).
25/01/2019 08:57	First RERT activation instruction given. Refer to market notice 66749. AEMO gave instructions to activate reserve contracts in response to the 25 January 2019 forecast reserve shortfall (MN 66749). All available contracts activated as per the timeline in Figure 18. AEMO intervention event commenced at 0900 hrs (MN 66822)
25/01/2019 0900	AEMO contacted reserve providers about possible activation on shorter notice than contract minimum lead times. Several confirmed that their MW response could be delivered sooner than minimum lead times. AEMO contacted reserve providers about extending the activation period beyond maximum activation times. Several confirmed that MW response could be extended.
25/01/2019 09:05	Loy Yang A trader informed AEMO of Loy Yang A unit 2 steam leak, to be taken out of service at 1700 hrs.
25/01/2019 09:10	Constraint equations #RT_VIC1_O_E and #RT_VIC1_P_E were invoked for Contracts V1 to V9 from DI ending 0910 hrs until DI ending 1630 hrs.
25/01/2019 09:45	Actual LOR 2 declared in VIC from 0945 hrs (MN 66751).
25/01/2019 10:01	PDPASA Update of the forecast LOR 3 in VIC on 25/01/2019 (MN 66752).
25/01/2019 10:53	Contingency Analysis Load Shed violation for trip of Dederang to South Morang (VIC–NSW interconnector) line 1 overloading line 2.
25/01/2019 10:55	Constraint equation V>>V_NIL_3 violating.
25/01/2019 10:49	PDPASA Update of the forecast LOR 3 in VIC on 25/01/2019 (MN 66767).
25/01/2019 11:00	Actual LOR 3 declared in VIC from 1100 hrs. Direction to AusNet Services to shed 100 MW of load as per priority load shedding schedule to maintain interconnector flows within operational transfer limits. On Alcoa advice, Portland smelter potlines could not be disconnected until 1300 hrs following 24 January load shedding. Standing advice from Alcoa is that insufficient restoration time between potline disconnections risks damage to the smelter.
25/01/2019 11:04	Actual LOR 3 declared in VIC (MN 66768).
25/01/2019 11:14	Notice of load shedding direction in VIC. (MN 66773).
25/01/2019 11:30	AusNet Services directed to shed additional 150 MW of load as per priority load shedding schedule to maintain NSW to VIC interconnector flow within operational transfer limits. VIC energy prices reach the cumulative price threshold (CPT), with energy prices capped at the administered price cap (APC) of $300 per megawatt hour (MWh).

Date / Market time	Event
25/01/2019 13:25	Direction to AusNet Services to restore 50 MW of load as per priority load shedding schedule (MN 66812).
25/01/2019 13:50	Actual LOR 3 cancelled for VIC at 1350 hrs. Load restoration direction to Ausnet Services to restore all remaining shed load as per priority load shedding schedule (MN 66817 and 66819). Manual override on the VIC energy price was removed after DI ending 1350 hrs.
25/01/2019 16:30	Loy Yang A2 taken out of service at 1739 hrs, was generating approximately 270 MW at 1700 hrs.
25/01/2019 16:30	End of RERT Dispatch and end of intervention event (MN 66827).
25/01/2019 18:00	Actual LOR 1 cancelled for VIC at 1800 hrs (MN 66832).

6. Load shedding

6.1 What is load shedding?

Controlled load shedding, or disconnection of customer supply, may be implemented when there is a shortage of electricity supply or to ensure transmission and distribution lines do not become overloaded. It can occur automatically in response to faults on the power system or – as was the case on 24 and 25 January 2019 – may be initiated manually in response to current or potential power system conditions.

Manually initiated load shedding is a last resort response to avert the risk of system collapse or damage to parts of the power system. A relatively small amount of load shedding for a short period (generally on a rotational basis) reduces the risk of more widespread and prolonged customer supply interruptions.

6.2 Explanation of reserve levels

Reserve levels are described in AEMO's Reserve Level Declaration Guidelines, made under clause 4.8.4A of the National Electricity Rules. A simplified interpretation is shown below. Actual or forecast LOR conditions are indicated by the amount of the margin or buffer between the supply of electricity available to a region and the expected operational demand.

6.2.1 Lack of reserve level 1 (LOR 1)

A LOR 1 condition exists when supply exceeds demand by an amount less than the larger of either the forecasting uncertainty measure determined by AEMO, or the sum of the two largest credible supply contingencies for the region.

6.2.2 Lack of reserve level 2 (LOR 2)

A LOR 2 condition exists when supply exceeds demand by an amount less than the larger of the forecasting uncertainty measure determined by AEMO or amount of the single largest credible supply contingency for the region.

6.2.3 Lack of reserve level 3 (LOR3)

A LOR 3 condition is indicated when the available capacity reserves for a region are equal to or less than expected operational demand (there is no buffer), meaning load shedding is occurring or expected to occur.

6.3 Load shedding on 24 and 25 January 2019

AEMO uses available generation and interconnector capacity and electricity demand forecasts to calculate the reserve available in the power system. If there is insufficient reserve, AEMO will take operational action to maintain power system security.

The lack of reserve conditions: LOR 1, LOR 2, and LOR 3, must be notified to the market and may result in further AEMO action. AEMO's response will depend on the severity of the conditions, time considerations, and whether any market response is available. If reserves are at actual LOR 2 levels, AEMO will consider intervening in the market to maintain power system security. At actual LOR 3 level, load shedding is occurring or is about to occur.

6.3.1 24 January 2019

At 1810 hrs AEST on Thursday 24 January 2019, AEMO instructed AusNet Services to shed 75 MW of customer load in VIC. Following the activation of reserve contracts under RERT in VIC and SA, electricity demand in the combined VIC and SA regions still exceeded the capacity of available generation and interconnector support. This caused power flow on the NSW–VIC interconnector, Murraylink, and Basslink to exceed their transfer limits at the time, with no viable dispatch solution to resolve the violations. To reduce the interconnector flow, and therefore maintain the power system in a secure operating state, AEMO instructed AusNet Services to shed customer load in VIC.

To maintain flow on the interconnectors within limits, load could be shed in either the VIC or SA region, in accordance with the equitable load shedding arrangements for the NEM and the load shedding procedures. Given the amount of load to be shed (100 MW) across both regions, disconnection of a single potline at the Alcoa Portland aluminium smelter was sufficient to balance supply and demand across both VIC and SA regions without the need for additional customer load shedding.

6.3.2 25 January 2019

At 1100 hrs on Friday 25 January 2019, AEMO instructed AusNet Services to shed 100 MW of customer load in VIC and requested a further 150 MW at 1130 hrs. Following the activation of available reserve contracts under RERT in VIC, electricity demand in VIC still exceeded the capacity of available generation and interconnector support together with the RERT reserves.

This would have caused power flow on the NSW–VIC interconnector to exceed its transfer limit at the time, while the VIC–SA interconnector at Heywood was already operating at its transfer limit. Load shedding was therefore instructed to reduce NSW–VIC interconnector flow, and therefore maintain the power system in a secure operating state. The requested quantity of load shedding was achieved by distributors disconnecting load blocks under pre-determined load shedding arrangements, with the total reductions shown in the tables below.

Table 17 25 January VIC, load shed at 1100 hrs

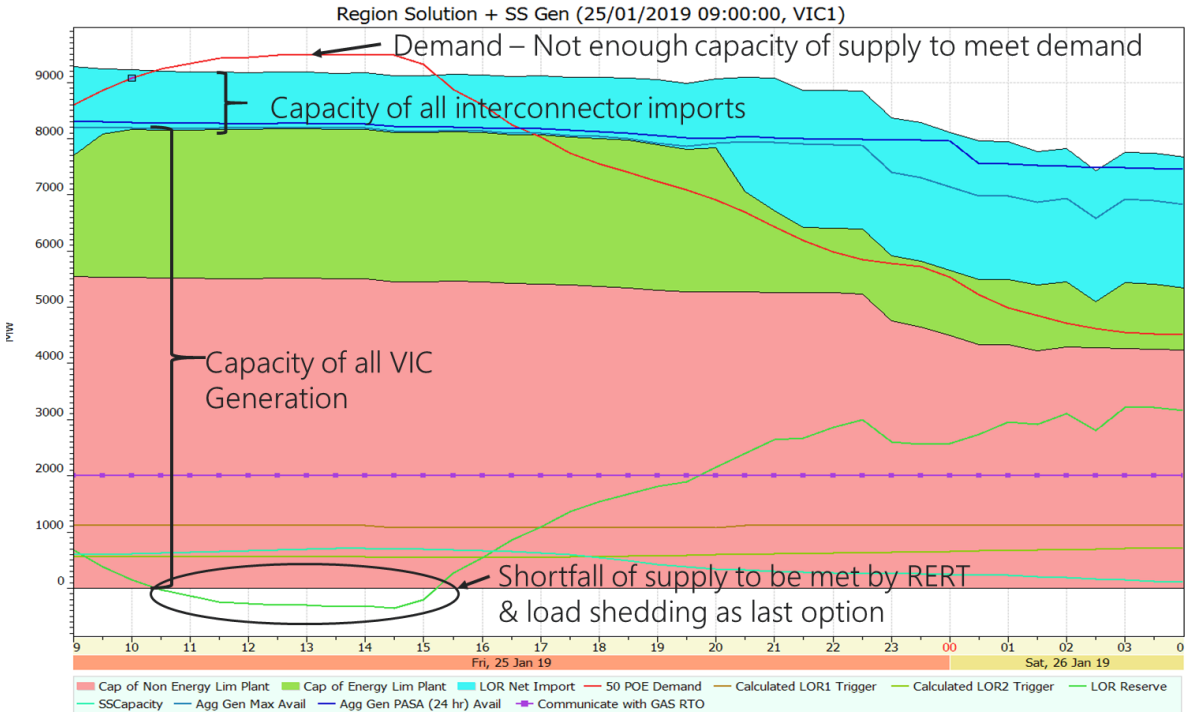
DNSP(s) AusNet requested to shed load	Requested load shed (MW)	Actual load shed (MW)
CitiPower	19	19.9
AusNet Services	19	22
Powercor	26	26.4
Jemena	12	13.8
UE	24	26.7
Total	**100**	**108.8**

Table 18 25 January VIC, load shed at 1130 hrs

DNSP(s) AusNet requested to shed load	Requested load shed (MW)	Actual load shed (MW)
CitiPower	29	29.9
AusNet Services	29	31
Powercor	39	44.8
Jemena	18	19.9
UE	36	36.4
Total	**151**	**162**

Figure 16 shows the reserve forecast at 0900 hrs on 25 January 2019. It shows that with all VIC available generation capacity on and all available interconnector capacity, demand would exceed supply at approximately 1100 hrs.

Figure 16 VIC Pre-dispatch at 0900 hrs 25 January 2019



7. Reliability and Emergency Reserve Trader (RERT)

The RERT is a function conferred on AEMO under the NER. AEMO enters into reserve contracts for capacity not otherwise available to the market, if needed to ensure the NEM reliability standard for a region is met, or to maintain power system security. Reserves secured for RERT may come from sources including major industrial plants that can reduce their demand rapidly and at short notice, demand response aggregators, and additional generation that is not normally available to the market.

The 2018 ESOO identified a particular risk of supply interruptions in Victoria exceeding the reliability standard for USE in 2018-19. This risk was observed to arise from reductions in supply from thermal generation as a result of coincident unplanned outages at times of expected low intermittent generation and high demand.

Based on these forecasts, through open expression of interest processes under the NER conducted prior to summer, AEMO established panels of potential RERT providers that could offer capacity reserves on short or medium notice periods, on pre-negotiated contract terms[10]. In consultation with the Victorian and South Australian Governments, AEMO secured all resources offered in Victoria and South Australia that met the minimum required cost, technical and verification criteria for providing this capability. For 2018-19, all RERT resources were secured on a usage only basis (without availability charges), reducing RERT costs in 2018-19 to around 65% of the 2017-18 costs.

Since the load shedding events, AEMO received additional interest from potential alternative sources, with successful offers included on RERT panels after a second open expression of interest process[11].

Each RERT resource has different response lead times, activation conditions and response capability, therefore not all resources can necessarily be activated for a given shortfall event.

Table 19 and Table 20 show the RERT volumes activated in VIC and SA on 24 January and 25 January 2019.

7.1.1 24 January 2019

Table 19 Thursday 24 January 2019, SA and VIC RERT volume activated

Trading Interval ending	RERT activated (MW) SA	RERT activated (MW) VIC	RERT activated – cumulative total (MW)
24/01/2019 16:30	0	20	20
24/01/2019 17:00	6	105	111
24/01/2019 17:30	216	176	392
24/01/2019 18:00	216	176	392
24/01/2019 18:30	216	180	396
24/01/2019 19:00	216	180	396

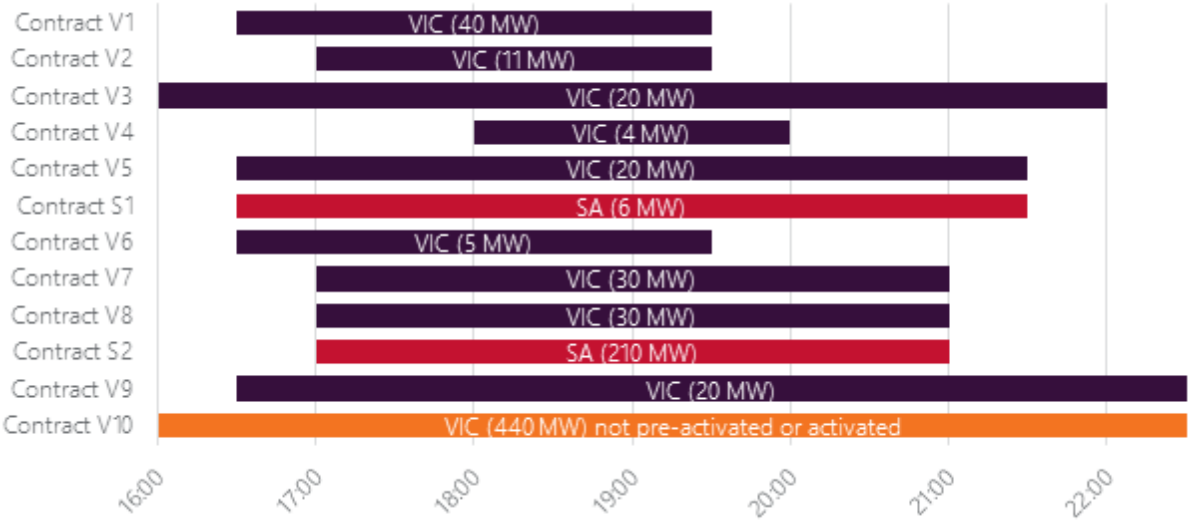
[10] In addition to an open tender for long notice RERT, which resulted in one contract in VIC and SA.

[11] Call for expressions of interest at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Emergency-Management/RERT-panel-expressions-of-interest.

Trading Interval ending	RERT activated (MW) SA	RERT activated (MW) VIC	RERT activated – cumulative total (MW)
24/01/2019 19:30	216	180	396
24/01/2019 20:00	216	124	340
24/01/2019 20:30	216	120	336
24/01/2019 21:00	216	120	336
24/01/2019 21:30	6	60	66
24/01/2019 22:00	0	40	40
24/01/2019 22:30	0	20	20
Total megawatt hour (MWh)			**1,621**

All available reserve contracts were activated on 24 January 2019, with the exception of Contract V10. This was because, as at the latest pre-activation time under that contract (0800 hrs on 24 January 2019), AEMO assessed the forecast reserves and all available options, and determined that pre-activation of Contract V10 was not required.

Figure 17 Timing, size, and location of reserve contracts activated on 24 January 2019



7.1.2 25 January 2019

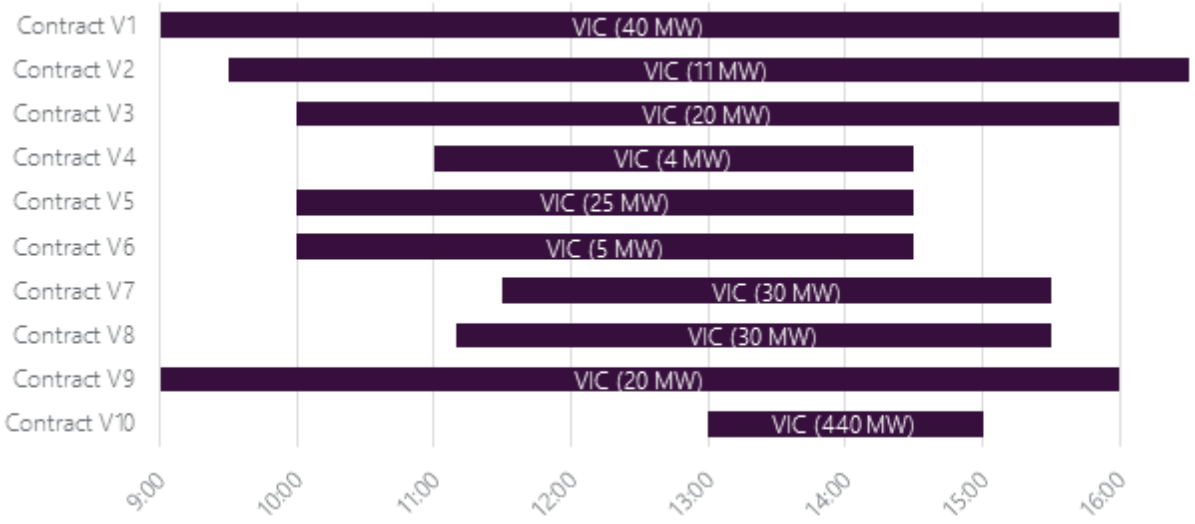
Table 20 Friday 25 January 2019, VIC RERT volume activated

Trading Interval ending	RERT activated (MW)
25 Jan 09:30	60
25 Jan 10:00	71
25 Jan 10:30	116
25 Jan 11:00	120

Trading Interval ending	RERT activated (MW)
25 Jan 11:30	154
25 Jan 12:00	184
25 Jan 12:30	184
25 Jan 13:00	184
25 Jan 13:30	454
25 Jan 14:00	454
25 Jan 14:30	344
25 Jan 15:00	336
25 Jan 15:30	166
25 Jan 16:00	106
25 Jan 16:30	11
Total MWh	**1,472**

At 0900 hrs on 25 January 2019, insufficient market response had been provided, and LOR 3 conditions were still forecast to apply for 25 January 2019. AEMO determined that additional reserves were required to maintain the reliability of the power system, and activated the contracts accordingly. All available contracts were activated for 25 January 2019.

Figure 18 Timing, size, and location of reserve contracts activated on 25 January 2019



AEMO issued market notices to inform the market that it had intervened by activating RERT and declaring that intervention pricing would commence from Dispatch Interval (DI) ending 1605 hrs on 24 January 2019, and DI ending 0910 hrs on 25 January 2019. Further market notices were issued after de-activation of the reserves, confirming the interventions ended at DI ending 2230 hrs on 24 January 2019 and DI ending 1630 hrs on 25 January 2019.

8. Intervention assessment

8.1 Assessment of market response and latest time to intervene

Under NER clause 4.8.5A(a) and (c), AEMO must notify the market of an anticipated power system security or reliability issue and the latest time for a market response to address that issue before AEMO intervenes in the market. The activation of unscheduled reserves under RERT contracts is defined in the NER as an AEMO intervention event.

For both 24 and 25 January 2019, AEMO assessed the latest times to intervene based on the times that LOR 2 conditions were forecast to begin, and on the lead times required to activate sufficient RERT contracts to reduce the risk to supply reliability at the least cost to market customers. AEMO issued invitations to tender for short-notice reserve contracts for both days. This was done in an effort to maximise the pool of available reserve contracts, and the amount of time available for a market response before an intervention would become necessary.

At 1618 hrs on 23 January 2019, AEMO issued market notices seeking a market response and indicating the latest time for intervention by AEMO as 0800 hrs on 24 January 2019, for the 24 January 2019 forecast reserve shortfall (market notice [MN] 66558 and MN 66556).

At 1346 hrs on 24 January 2019, AEMO issued a market notice seeking a market response and indicating the latest time for intervention by AEMO as 0800 hrs on 25 January 2019, for the 25 January 2019 forecast reserve shortfall (MN 66613).

AEMO revised the latest times to intervene several times as conditions changed throughout the days. The final published latest times to intervene for the two days were as follows:

- 1330 hrs on 24 January 2019 for the 24 January 2019 forecast reserve shortfall.
- 0900 hrs on 25 January 2019 for the 25 January 2019 forecast reserve shortfall.

8.2 Decision to intervene

By 1430 hrs on 24 January 2019, insufficient market response had been provided, and LOR 2 conditions were forecast to continue. Consequently, AEMO determined that additional reserves were required to maintain the reliability of the power system. AEMO issued activation instructions using the RERT interface developed for this purpose. All reserve contracts available at that time were activated. One contract in VIC could not be activated because pre-activation had not been initiated. At the latest pre-activation time of 0800 hrs on 24 January 2019, AEMO's assessment of the forecast reserves indicated that this contract would not be required.

At 0900 hrs on 25 January 2019, insufficient market response had been provided, and LOR 3 conditions were still forecast for that day. AEMO determined that additional reserves were required to maintain the reliability of the power system and activated the contracts accordingly. All available contracts were activated for the day.

AEMO issued market notices to inform the market that it was activating RERT and declared that intervention pricing would commence from DI ending 1605 hrs on 24 January 2019 (MN 66629), and DI ending 0910 hrs on 25 January 2019 (MN 66749). Later market notices announced that the reserves had been de-activated and the interventions ended at DI ending 2230 hrs on 24 January 2019 (MN 66726), and DI ending 1630 hrs on 25 January 2019 (MN 66827).

8.3 Cost of intervention

NER clause 3.20.2(b)(2) requires that when AEMO activates reserve contracts, it should aim to maximise the effectiveness of the activation at the least cost to end-use consumers of electricity. Accordingly, AEMO activated reserve contracts based on cost, capacity, time to activate, minimum activation time, and the profile of the forecast lack of reserve.

Table 21 Costs associated with the 24 and 25 January 2019 RERT event ($ million)

	Pre-activation costs	Activation costs	Other costs*	Total cost
24 January 2019	0.015	6.434	3.337	9.786
25 January 2019	12.005	12.167	0.237	24.409

* Other costs represent 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.

8.3.1 Total RERT cost

The cost of contracted RERT payments for 24 and 25 January 2019 in VIC and SA was approximately $30.6 million. Some payments remain subject to finalisation with RERT providers. When intervention event compensation payments due to Market Participants under the NER are included, the total cost associated with delivering demand management through RERT was approximately $34.2M.

All costs derived below are based on this total cost.

8.3.2 RERT cost $ per megawatt hour

Considering the volume of RERT, an average cost of RERT for 24 and 25 January 2019 was approximately $10,000 per megawatt hour (MWh), below the $14,500 per MWh wholesale market price cap which applied at the time of load shedding.

8.3.3 Involuntary load shedding avoided due to RERT

Without application of the RERT, AEMO estimates that a further 1,252 MWh of load would have been required to be shed involuntarily. The RERT mechanism in this instance mitigated the additional economic and social impacts of more widespread load shedding. Applying the 2019 value of customer reliability (VCR)[12] of $41,534 per MWh, the cost of the load shedding avoided by using RERT would have been $52 million.

8.3.4 Averaged cost of RERT to each consumer

Using typical commercial and industrial energy usage tariffs for the 2018 calendar year, the cost of RERT would equate to an annual average of approximately $0.79 per MWh in Victoria and $0.16 per MWh in South Australia[13]

Using standard energy rates, and typical residential customer usage tariffs over the 2018 calendar year, the total RERT contract costs on 24 and 25 January would equate to an average annual cost per residential customer of approximately:

- $3.20 in Victoria.
- $0.80 in South Australia.

[12] The VCR is determined using data from the Bureau of Resources and Energy Economics and consumer surveys, and measures the value different types of energy consumers place on having reliable power supply. For more information, see https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Value-of-Customer-Reliability-review.

[13] The costs of RERT to commercial and industrial customers is provided as a typical guide only. Actual costs billed by retailers may vary significantly based on a number of factors including individual rates, consumption profiles and contractual terms.

8.4 Intervention process

AEMO's general process for deploying RERT is documented in its Procedure for the Dispatch and Activation of Reserve Contracts[14]. AEMO considers that it followed all applicable processes under NER clause 4.8 prior to the activation of reserves. The sequence of events tables in Section 5 include events relating to the activation of RERT reserves.

9. Changes to dispatch outcomes

9.1 Application of intervention pricing

AEMO declares intervention pricing for periods subject to an AEMO intervention event, which includes the activation of RERT contracts. Under intervention pricing, NER clause 3.9.3(b) requires AEMO to set the dispatch price and ancillary service prices at the value which AEMO, in its reasonable opinion, considers would have applied had the intervention event not occurred. AEMO determines and publishes these prices in accordance with its Intervention Pricing Methodology[15].

Intervention pricing was applied for this event in accordance with NER 3.9.3(b), for the intervention periods from:

- DI ending 1605 hrs on 24 January 2019 to DI ending 2230 hrs on 24 January 2019.
- DI ending 0910 hrs on 25 January 2019 to DI ending 1630 hrs on 25 January 2019.

During intervention pricing, AEMO performs two runs to generate dispatch targets and spot prices. Dispatch targets are produced from a run which includes the physical impact of the intervention; while energy and ancillary services prices are produced from an intervention pricing run which aims to remove the impact of the intervention.

NER clause 3.12.2(a)(1) requires AEMO to determine compensation for specified categories of 'affected participants' and market customers that would return them to the position they would have been had the intervention not taken place. This required AEMO to perform a revised intervention pricing run for the purposes of compensation, that more closely reflected feasible dispatch outcomes

The following section compares the physical run and the revised intervention pricing run, to assess the impact of RERT on actual dispatch outcomes.

9.2 Changes in generation and interconnector flows

During these intervention events, the addition of RERT capacity in VIC and SA had the effect of reducing the requirement for load shedding at a time when the system was under extreme stress.

Consequently, without explicitly reducing the demand that can be served in the model, the removal of the extra RERT capacity leads to non-feasible outcomes where the interconnector flows consistently exceed their transfer limits for the next dispatch interval. This would not be allowed to occur in practice and this is the

[14] AEMO. Power system operating procedure SO_OP 3717, "Procedure for the dispatch and activation of reserve contracts", 28 June 2011, available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3717---Procedure-for-the-Dispatch-and-Activation-of-Reserve-Contracts.pdf.

[15] Intervention Pricing Methodology, available at http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/2018/Intervention-Pricing-Methodology.pdf.

reason why a second intervention run was required to ensure that the generation and interconnector flow outcomes for compensation were in accordance with the NER requirement.

Table 22 to Table 25 below highlight increased generation from all regions in the revised pricing run, compared to the physical run.

Table 22 Summary of total energy generation during 24 January 2019 RERT event (MWh)

	NSW	QLD	SA	TAS	VIC
Physical run	64,955	57,691	17,784	10,232	51,967
Revised pricing run	65,734	57,294	17,820	10,271	52,204
Change	**779**	**-397**	**36**	**39**	**237**

Table 23 Summary of total energy generation during 25 January 2019 RERT event (MWh)

	NSW	QLD	SA	TAS	VIC
Physical run	80,274	67,484	18,334	12,642	58,750
Revised pricing run	80,516	67,491	18,756	12,685	59,314
Change	**242**	**7**	**422**	**43**	**564**

Table 24 Summary of total interconnector flow during 24 January 2019 RERT event (MWh)

	Terranora	QNI*	VIC–NSW	Heywood	Murraylink	Basslink
Physical run[A]	-243	-1,940	-1,147	914	247	3,042
Revised pricing run[A]	-192	-1,591	-1,446	1,207	289	3,048
Change	**51 MWh less into NSW**	**349 MWh less into NSW**	**299 MWh more into VIC**	**293 MWh more into SA**	**42 MWh more into SA**	**6 MWh more into VIC**

* QLD–NSW interconnector

A. Positive numbers are for flows flowing north or west, negative for flows flowing south or east.

Table 25 Summary of total interconnector flow during 25 January 2019 RERT event (MWh)

	Terranora	QNI	VIC-NSW	Heywood	Murraylink	Basslink
Physical run[A]	-767	-6,642	315	-3,144	-641	3,222
Revised pricing run[A]	-778	-6,634	87	-3,466.	-719	3,236
Change	**12 MWh more into NSW**	**8 MWh less into NSW**	**228 MWh less into NSW**	**322 MWh more into VIC**	**79 MWh more into VIC**	**14 MWh more into VIC**

A. Positive numbers are for flows flowing north or west, negative for flows flowing south or east.

10. Conclusions

AEMO is required to review and report on the load shedding and RERT events of 24 and 25 January 2019 in accordance with clauses 4.8.15 and 3.20.6(a) respectively.

Under clause 4.8.15, AEMO must assess the adequacy of the provision and response of facilities or services, and the appropriateness of actions taken to restore or maintain power system security.

Under clause 3.20.6, in respect of RERT, AEMO must report on:

- the circumstances giving rise to the need for the activation of unscheduled reserves;
- the basis on which AEMO determined the latest time for that activation of unscheduled reserves and how it determined that a market response would not have avoided the need for it;
- the changes in dispatch outcomes due to the dispatch of scheduled reserves or activation of unscheduled reserves;
- the processes implemented by AEMO to dispatch the scheduled reserves or activate the unscheduled reserves;
- if applicable, why AEMO did not follow any or all of the processes set out in rule 4.8 prior to the activation of unscheduled reserves; and
- if applicable, why AEMO considered it impractical to set spot prices and ancillary service prices in accordance with clause 3.9.3(b).

AEMO conclusions

1. The power system was maintained in a secure operating state during 24 and 25 January 2019.
2. The reliability standard of 0.002% unserved energy (USE) was exceeded in VIC as a result of these events[16].
3. Activation of RERT reserves and ultimately load shedding were required on 24 and 25 January 2019 because the total available capacity reserves were insufficient to supply electricity demand in VIC and SA on 24 January and in VIC on 25 January.
4. Load shedding was directed only after all available contracted RERT had been activated to meet the expected reserve shortfall, and AEMO had taken other actions within its control to reduce constraints and maximise grid capacity by adjusting power system conditions.
5. Load shedding was achieved in a manner that was as consistent as reasonably practicable with AEMO's instructions.
6. AEMO followed all applicable processes under the NER prior to the RERT intervention events on 24 and 25 January 2019 and implemented intervention pricing in accordance with clause 3.9.3 of the NER.
7. Over the course of these incidents, AEMO issued appropriate and sufficiently detailed market information.
8. Registered participants took all reasonable steps to comply with instructions and directions issued by AEMO leading up to and during the load shedding events.

[16] The reliability standard specifies that expected USE should not exceed 0.002% of total energy consumption in any NEM region in any financial year.

AEMO observations

AEMO, together with the Energy Security Board (ESB) and Australian Energy Market Commission (AEMC), has several initiatives and programs of work underway which recognise the increasing frequency and severity of extreme weather events and seek to address the risk of supply not being able to meet maximum demand levels during those events. These include:

1. **Implementation of strategic reserves**
   - Following a recommendation from the Finkel Review, the AEMC is currently finalising its determination on a strategic reserve to act as a safety net in exceptional circumstances as a replacement to the existing RERT mechanism, following a rule change proposal submitted by AEMO in March 2018.
   - Strategic reserves provide a fairly simple and complementary addition to enhance reliability, and are used only as a last resort to avoid shedding load. This would allow AEMO to identify opportunities that might not be economical in the energy market, but would still be preferred by consumers as alternatives to load shedding.
2. **Increasing transmission capacity as outlined in the 2018 Integrated System Plan (ISP)[17].**
   - Stronger interconnections and additional network capability will facilitate better access to supply and sharing of reserves between regions. On 24 and 25 January, excess reserves were available in other regions but not accessible through existing interconnection capacities. AEMO's 2018 ISP identified a number of priority transmission projects that would help to address these limitations.
3. **Greater optimisation of distributed energy resources (DER).**
   - Optimised usability and control of existing (and future) DER will deliver significant benefits in periods of supply shortfalls. Programs like the Victorian Government's Solar Homes program will add large quantities of DER to the Victorian energy system. It will be extremely important that the contribution to system security and reliability of these new resources is optimised with appropriate standards, visibility and controllability.
4. **Markets for DER.**
   - The development of appropriate market constructs is essential to incentivise the use of DER as an effective resource to improve system security and reliability, by creating new opportunities for economic investment in the development and aggregation of DER technologies.

[17] AEMO, Integrated System Plan, July 2018, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan.