The challenge of ageing coal generators and the growing role of storage in grid reliability

Baringa Partners analysis

Climate Council
December 2024

Baringa is a certified B Corp™ with high standards of social and environmental performance, transparency and accountability.

Scope of this work

Baringa Partners has been engaged by the Climate Council to undertake a brief suite of analysis into the role of dispatchable technologies in ensuring a reliable supply of electricity. This analysis is not intended to be comprehensive but provides a snapshot of reliability in the National Electricity Market (NEM) and the role of dispatchable technologies – particularly coal and storage - in the context of energy transition. Analysis is largely based on recent historical data, to end of November 2024.

Contents of this report

To date, Australia's main national grid has delivered a very high level of reliability, with power outages uncommon and usually caused by network issues

Power outages are almost always caused by network issues

For the most part, Australians have enjoyed a very reliable electricity system, in which power outages and blackouts are not part of most people's day-to-day lives.

When they do occur, **the large majority of power outages are caused by network issues** (2018 data shows more than 95%*), such as electricity poles and wires coming down and interrupting local electricity supply. Of the remaining power outages occurring each year, these are almost entirely caused by technical system security issues. **Historically, less than 1% of power outages are caused by reliability events, where there is not enough electricity supply to meet demand**.

Reliability in the Australian National Electricity Market (NEM) is very high

The NEM is covered by the grid that spans the eastern and southern states of Australia.

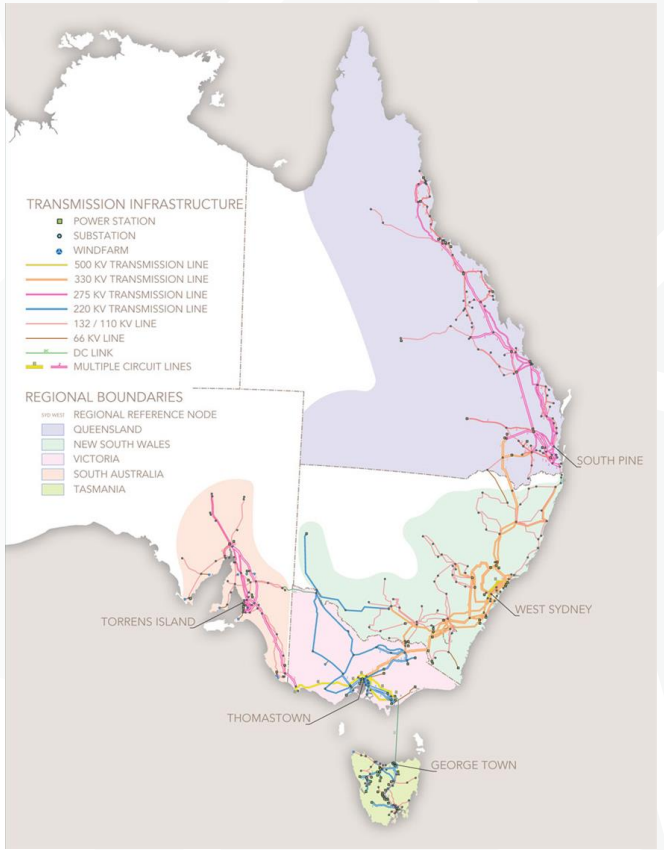
Currently, the level of reliability that is expected to be delivered (the 'reliability standard') by the NEM is 99.998%, which means that **99.998% of forecast customer demand should be met each year**. This standard is regularly reviewed by an independent panel and is informed by an assessment of the value customers place on reliability of electricity supply.

Between 2020 and 2028, an interim standard is also in place which sees a number of emergency measures triggered to support an even higher level of reliability, at 99.9994%.

The system is not aiming for 100% reliability, by design. The intention is that the reliability standard, and therefore the reliability achieved in the NEM, balances meeting customer demand most of the time with keeping costs as low as possible. There is a point at which customers would prefer to accept a (very low) level of disruption rather than pay more for investment required to avoid this.

Historically, the reliability standard has been met in most years. **There have been no breaches of the reliability standard in the NEM in more than 15 years.**

However, AEMO projects an increase in the probability of future breaches of the reliability standard. In response, governments and AEMO have introduced and continue to undertake measures to address the risk.

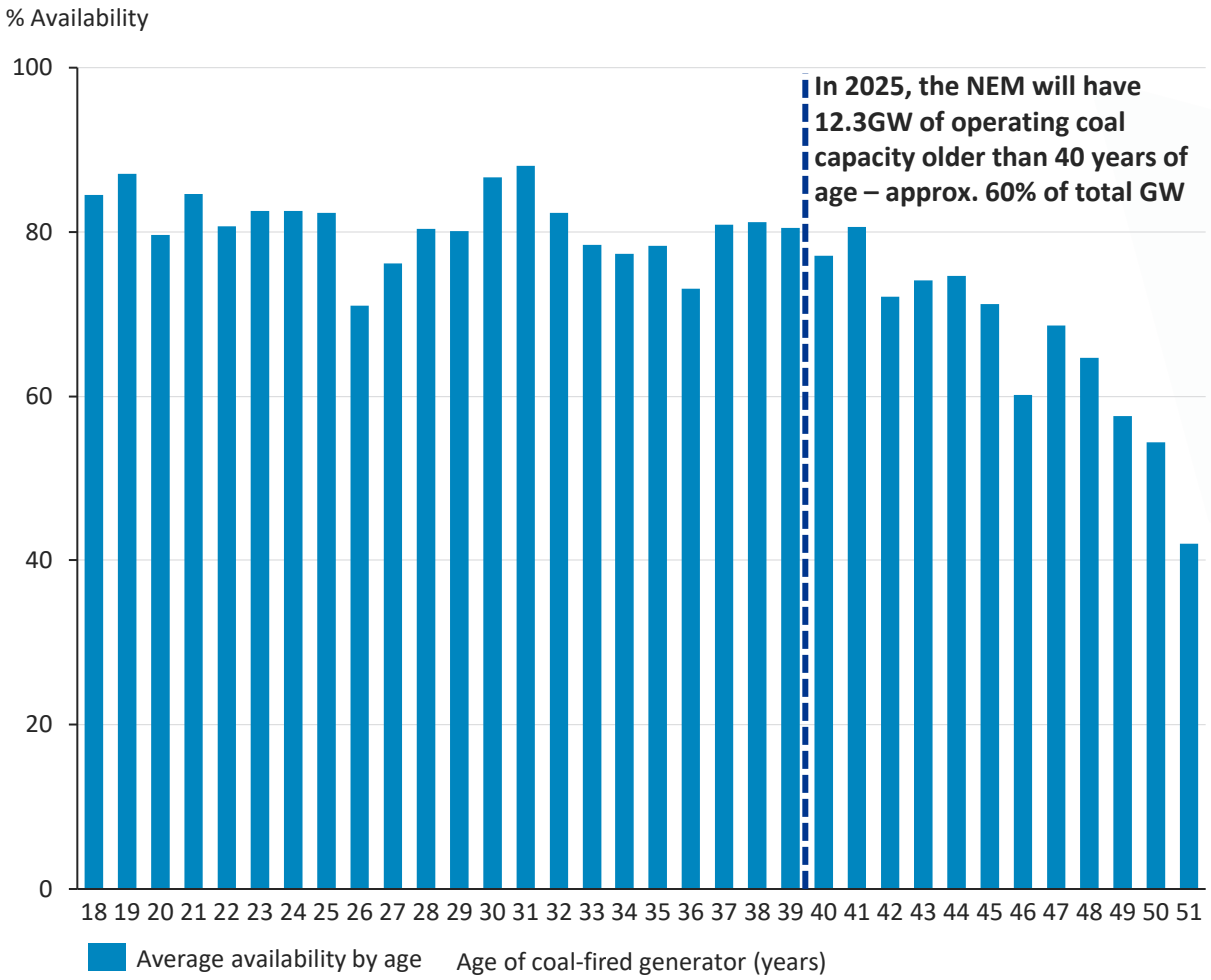


Source: National Electricity Market map sourced from the Australian Electricity Market Commission, here: https://www.aemc.gov.au/energy-system/electricity/electricity-system/NEM.

* 2018 analysis from the AEMC, Reliability Panel, Annual Market Performance Review 2018

The existing coal fleet is relatively old and becoming more unreliable as generators continue to age

Average availability of total coal capacity by age of generator



Data sourced from AEMO NEMWeb, data from 2014-2024; *AEMO, Technical Assessment Report – Review of GenCost 2023-24, here.

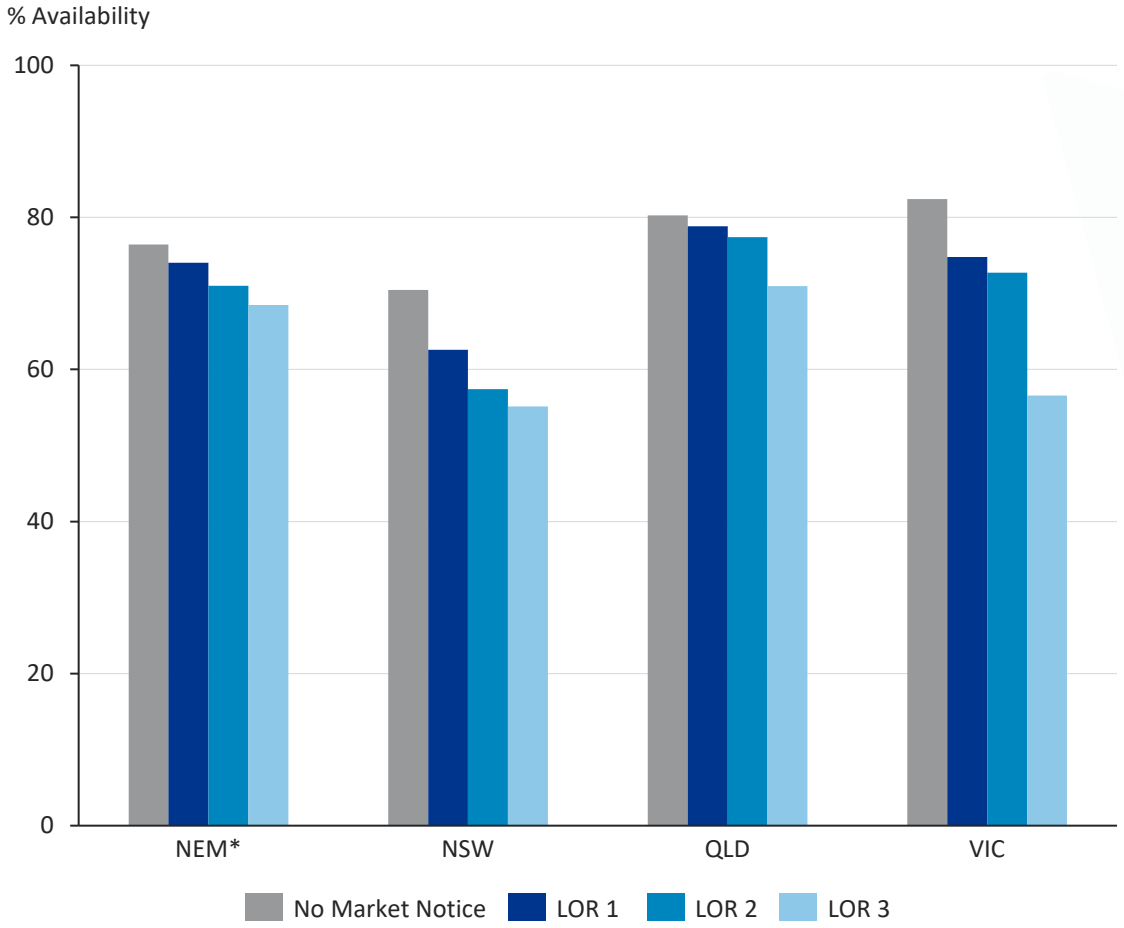
Commentary

- Despite recent closures, the National Electricity Market (NEM) still has a large fleet of operational coal-fired generators, with over 21 gigawatts (GW) of installed capacity remaining in the market, located in VIC, NSW and QLD.
- This coal fleet is ageing. While the youngest coal-fired generator is only 18 years old, some of the generators have been in operation since the 1970's. More than half of the remaining capacity of coal-fired generation is now 40 years or older.
- While the intended lifespan (economic life, or design life) differs by generator, in Australia the average lifespan is considered to be around 45 years*.
- Generators greater than 40 years old have historically exhibited a decline in availability. The analysis presented in the chart to the left, is based on data from 2014-2024.
  - Coal-fired generators which are within the first 40 years of their technical lifetime have exhibited an average availability of 81%.
  - By contrast, coal generators over the age of 40 years have exhibited an average availability of 65%, with an overall downward trend with years of age.
- The analysis highlights that our ageing fleet is becoming less dependable, and that creating the right environment for investment in replacement capacity – including renewables and complementary dispatchable technologies – is critical if we want to maintain reliability.
- The analysis also brings into question the value of keeping coal-fired generators running in the market for longer, given that ageing assets will not continue to provide the level of reliability they have in earlier years.

^Availability to the market, in this context, refers to how much of the year and at what volume the assets are available to generate, rather than being unavailable or at reduced capacity due to maintenance or unplanned outages. It is expressed as a percentage relative to being available at their full capacity all year round.

Coal outages are a primary driver of power outage warnings (when electricity demand is close to exceeding supply)

Average availability of total coal capacity during power outage risk conditions



Commentary

- Power outage risk conditions (known as 'Lack of Reserve' conditions, or 'LOR') typically occur when coal-fired generators are less available. The less coal is available, the greater the LOR risk, on average. As illustrated in the chart to the left, we see this trend across all three regions with coal-fired generators.
- When the risk of blackouts hits its highest level, with LOR 3 conditions, coal-fired generators are – on average – materially less available than under normal (non-LOR) conditions, suggesting this technology is often part of the problem (noting that any individual LOR event is likely to result from a range of coincident factors).
- While there will be other contributing factors to tight supply conditions (in particular network outages, and lower than expected renewables output will sometimes be a contributing factor), this analysis shows that coal-fired generator availability plays a clear role in these conditions.

What's a Lack of Reserve event?

The market operator, AEMO, will declare 'Lack of Reserve' conditions when it has assessed that there is a risk of a shortfall in available generation occurring, relative to anticipated demand, in the coming week.

Lack of Reserve (LOR) conditions are tiered based on severity of the risk:

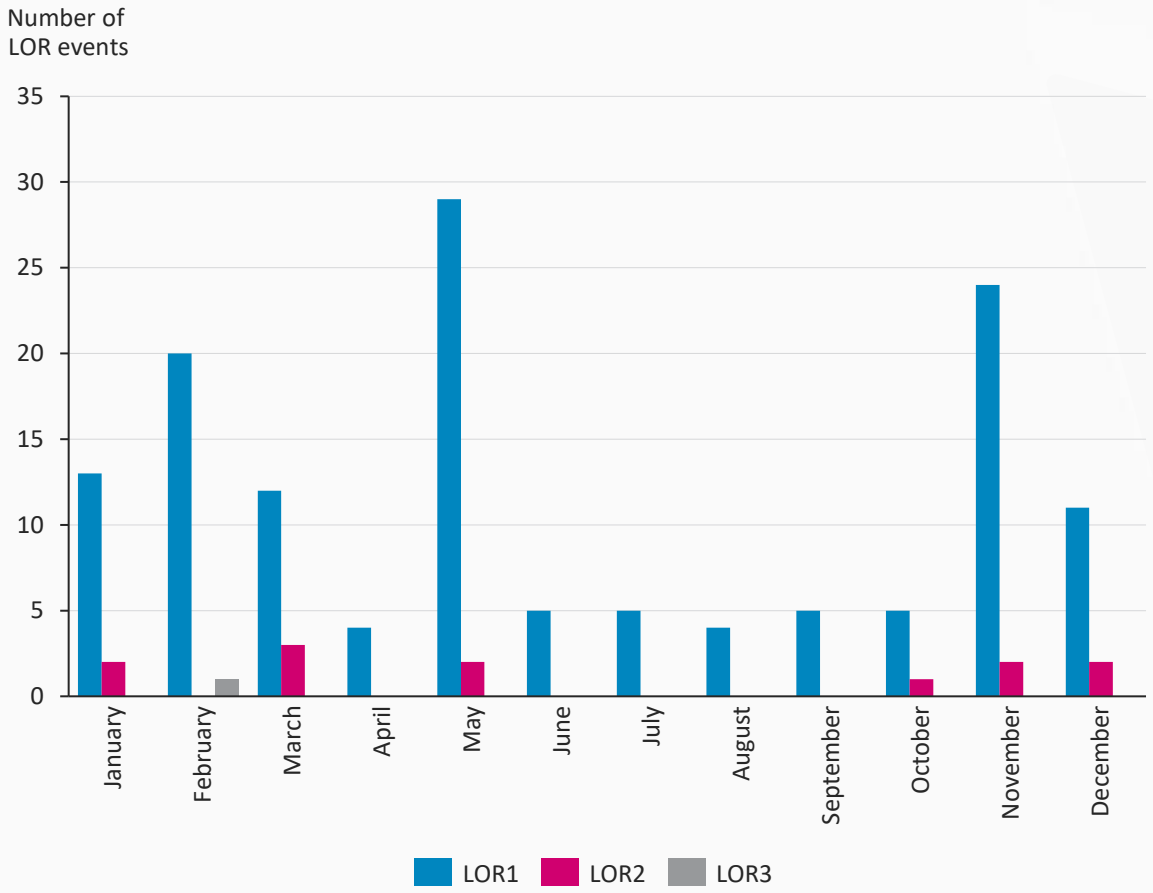
- LOR 1 (low risk) conditions: if the two largest identified shocks to the system (credible contingency events, such an unexpected outage of a generator unit) occurred at the period of tight supply, a shortfall would occur.
- LOR 2 (medium risk) conditions: if just the one largest identified shock to the system occurred at the time, a shortfall would occur.
- LOR 3 (high risk) conditions: a shortall is forecast to occur based on forecast available capacity and demand.

LOR events in this analysis represent AEMO forecasts of inadequate reserve in the last run before the actual period
Data sourced from AEMO NEMWeb. LOR data in this chart is from the last four years; *NEM refers to the three states with coal capacity aggregated.

 |

Power outage risk conditions occur throughout the year, not just in summer, and coal availability can contribute to these conditions year-round for different reasons

Timing of actual power outage risk conditions in 2023 and 2024 (to date)



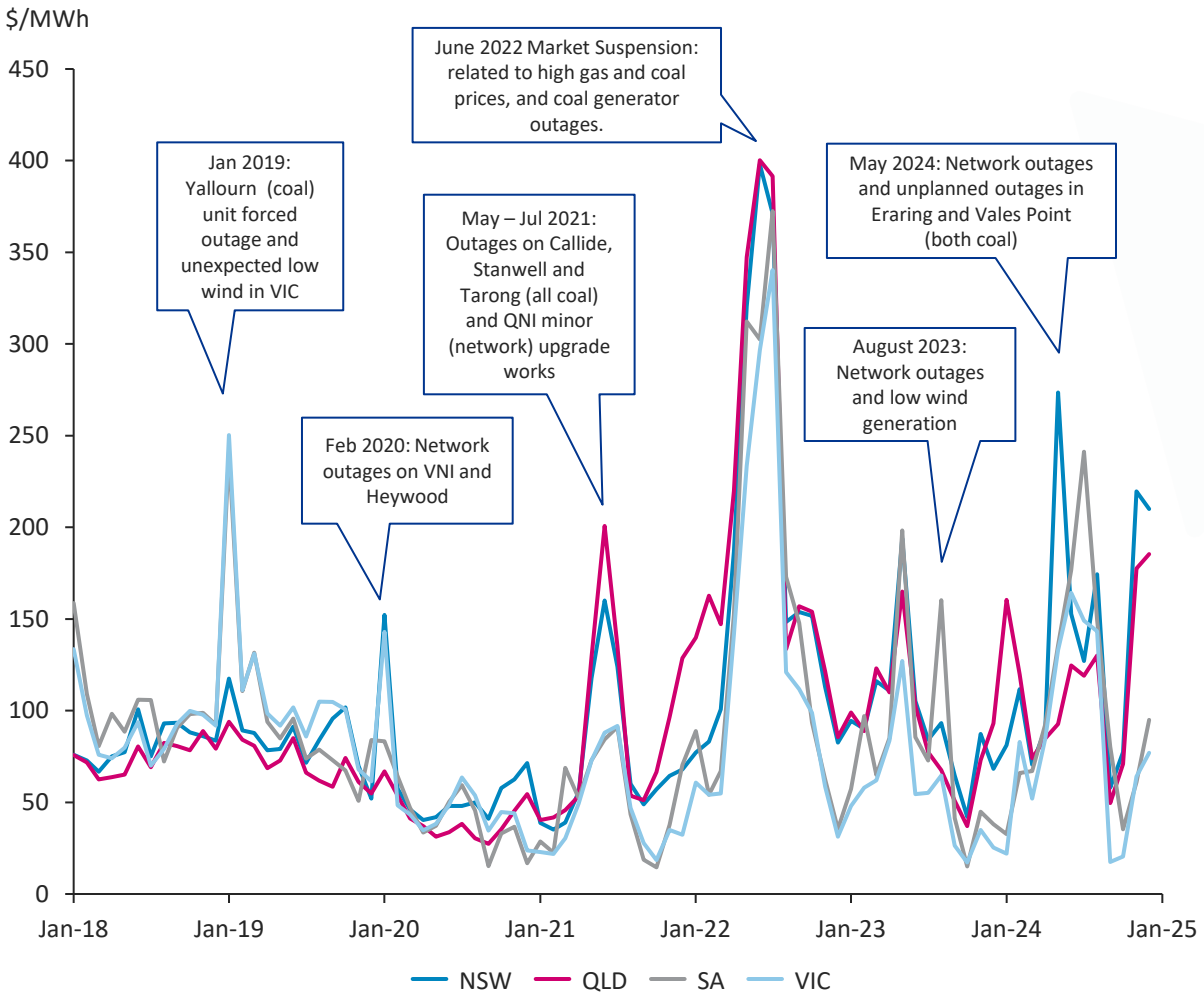
Data sourced from AEMO NEMWeb. LOR data in this chart is from 2023 and 2024 (YTD).

Commentary

- Power outage risk conditions (lack of reserve, or LOR, conditions) in the NEM occur throughout the year. This is illustrated in the chart to the left, which includes actual LOR events from the last two calendar years (YTD 2024) across the mainland NEM regions. Each occurrence is accompanied by a description of the conditions from the market operator, often citing anticipated high demand and/or low generator availability as the cause for concern.
- In summer months, high demand conditions associated with hot weather are typically one of the drivers of LOR conditions, along with unplanned coal generator outages.
- Outside of the hot summer months, coal availability can also play a role in LOR conditions. Coal generators typically operate with some reduced availability at different times outside of the summer months, to accommodate maintenance schedules, which can create challenges for the system if demand peaks.
- The majority of LOR events have occurred in NSW in recent years. For the 2023 and 2024 (YTD) LOR events in the mainland NEM regions, captured in the chart to the left:
  - two thirds of the events with LOR conditions occurred in NSW;
  - one quarter in QLD;
  - and the remaining were shared between VIC and SA.
- This chart captures the number of actual LOR events (non-consecutive periods of LOR conditions). An individual LOR event can span from a half hour through to many hours in duration.

Coal outages have contributed to most major price spike events in the NEM in recent years

Monthly average wholesale prices (Mainland NEM)



Data sourced from AEMO NEMWeb.

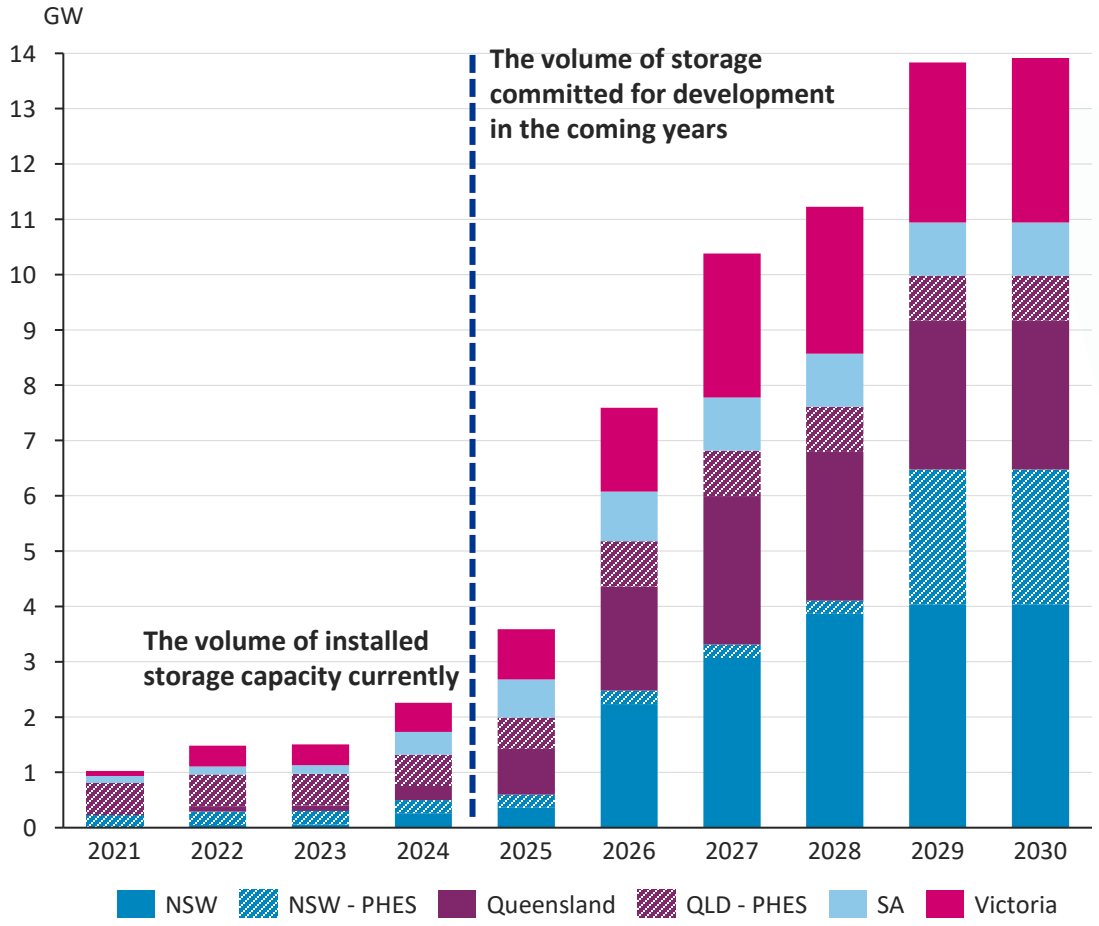
Commentary

- In the NEM, periods of sustained high wholesale electricity prices typically reflect shocks to the system, which result in very expensive generators or demand reduction contracts being drawn on to help to meet demand. Major events are not uncommon in the NEM, with multiple having occurred in the last few years. These events have a material enough impact on prices that they are visible as spikes in monthly average prices.
- Shocks to the system which trigger these major high-priced events in the NEM are most often caused by unplanned network or generation outages.
  - Network outages on major transmission lines can limit the supply of electricity from one part of the network to another.
  - High priced events can also occur when large generators have unplanned ('forced') outages or there is unexpectedly low generation from renewables, without enough capacity available to replace the significant loss.

  Of the major events called out in the chart to the left, most of the events, including the most significant event, coincided with coal-fired generator unit outages.
- Some key high-price events are shown on the chart, including:
  - In Jan 2019, the loss of units in Yallourn coal power station meant the system was missing significant levels of dispatchable capacity. This occurred in tandem with low wind conditions leading to tight system conditions and high prices.
  - In May 2021, an explosion at Callide coal power station caused several other generators to trip offline, reducing supply and increasing prices. Reduced interconnector capacity at this time also contributed to high prices.
  - In June 2022, high demand coincided with high gas prices, high coal prices, coal supply chain issues, and coal generator outages.

The volume of storage installed on our main national grid is set to continue to grow significantly in the coming years. Batteries are already contributing to system security.

Historic and future committed storage in the NEM



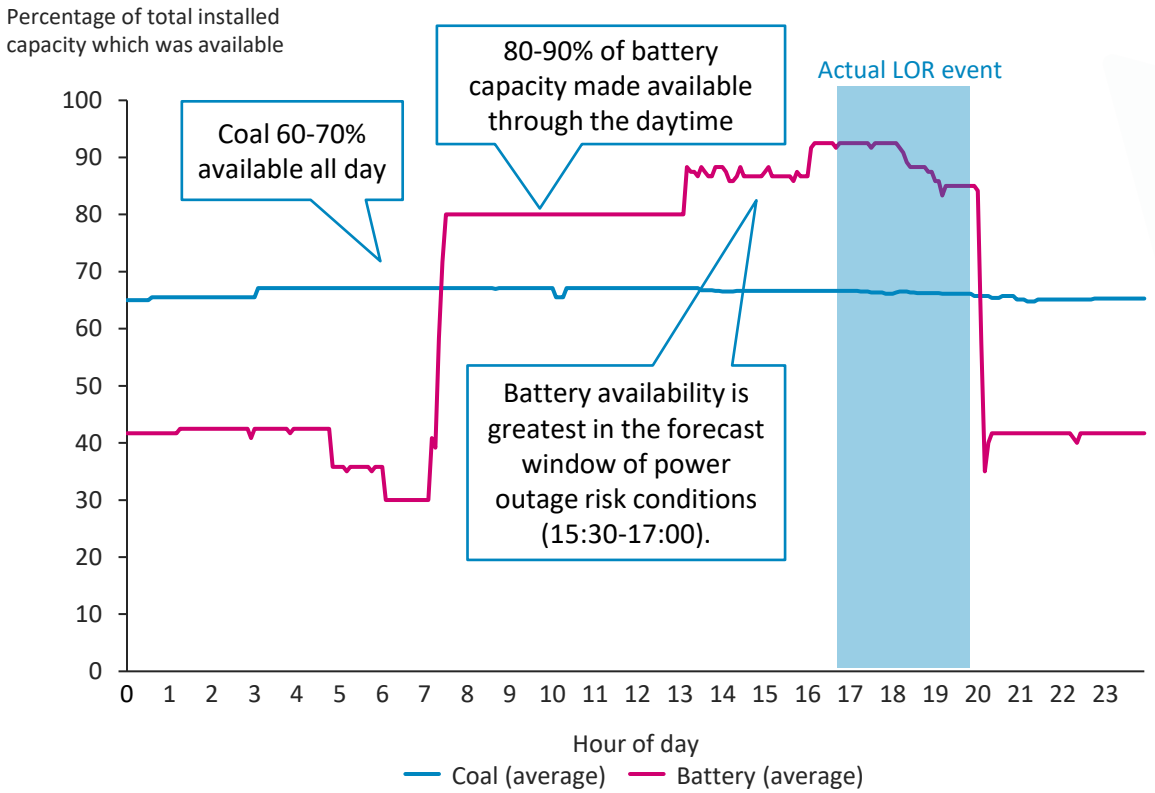
Commentary

- Storage capacity is growing rapidly in the National Electricity Market (NEM) – including batteries, pumped hydro energy storage, and anticipated development of emerging technologies like compressed air storage.
- Based on the total volume of batteries already installed in the NEM, as well as committed projects expected to be developed in the coming years, total battery capacity is expected to be at least 10.7 GW by 2030. The NEM also has an additional 2.45GW of pumped hydro projects committed to be built, including Snowy 2.0.
- As large coal generators continue to retire across the NEM, this storage will increasingly operate as a complement to wind and solar, soaking up excess electricity and helping to meet demand in peak periods or windows in which renewables output is low.
- Storage plays an important role time-shifting generation – it typically charges when there is a lot of clean, low cost, electricity and then provides this back to the market when demand is high. This is particularly valuable to the system as increasing volumes of rooftop and large-scale solar are installed, sometimes contributing to a glut of electricity in the middle of the day. Storage can soak up this excess, preventing it from being wasted, and send it back into the market in the evening when demand goes up and the sun is going down, to reduce our need for other types of generation like gas-fired.
- Storage, and particularly batteries, are and will continue to play an important role in providing technical system services too. Their ability to turn on and off quickly means batteries are highly responsive to signals from the AEMO to help keep the whole electricity system in balance. For some system services, batteries have already taken over as the primary source of these services from coal.

Capacity includes existing and committed projects. Baringa's NEM Reference Case projections (Q3 2024). PHES is Pumped Hydro Energy Storage.

Case Study: Batteries made themselves available during the recent NSW heatwaves and power outage warnings, while many coal generators were partially unavailable

NSW coal and battery availability – 26 November 2024



- A Forecast LOR3 was issued for the NSW region for the 26th of November, from 15:30 to 19:00 hours, a week in advance.
- An Actual LOR1 condition was declared by AEMO from 16:30 until 19:30 hours.

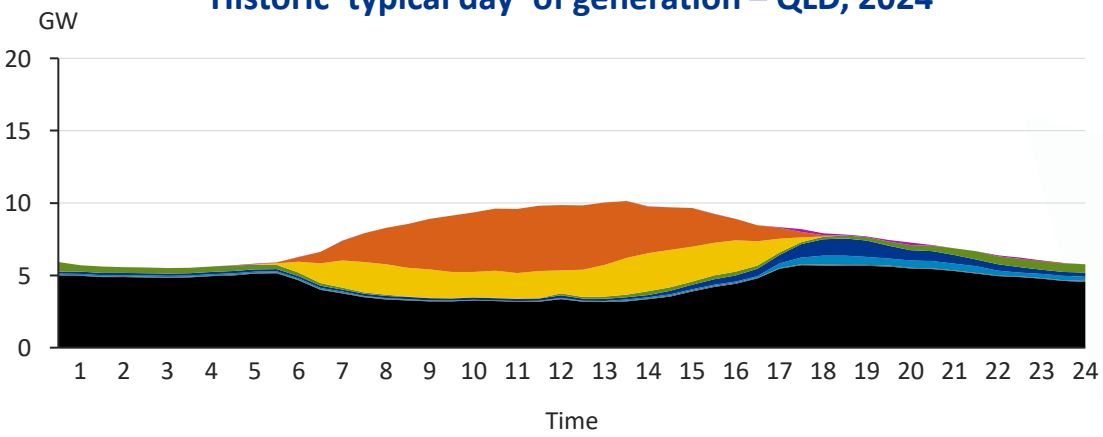
Data sourced from AEMO NEMWeb.

Commentary

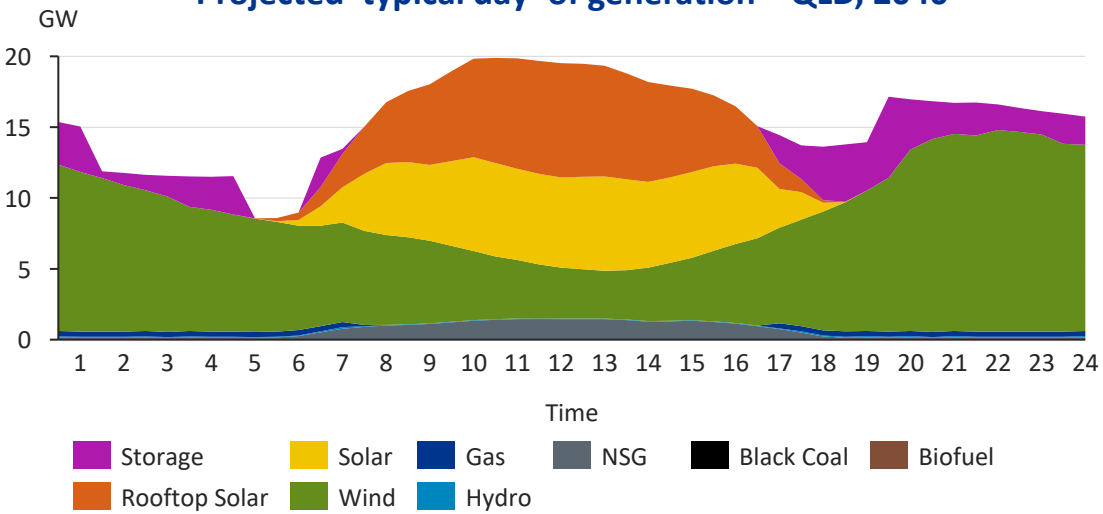
- Late November 2024 saw heatwave conditions spread across much of eastern Australia, with higher-than-average electricity demand expected in NSW as a result.
- These conditions coincided with a number of NSW coal generators operating at less than full capacity:
  - Bayswater: two units unavailable;
  - Eraring: one unit unavailable;
  - Vales Point: one unit unavailable.
- Analysis of the capacity that different generators bid into the market on the day, relative to their total capacity, indicates that batteries in NSW bid 80-90% of their total capacity into the market through the day so that the market operator could dispatch this capacity at the time it was needed most. For two-hour batteries, this meant the batteries could provide two hours of power when selected as part of the least cost energy mix through the day.
- In contrast, the same availability profile for coal in NSW indicates that, on average, less than 70% of total coal in NSW was available through the day.
- As the volume and duration of batteries available in NSW continues to grow, it is expected that this pattern of 'showing up' with strong availability when needed in the system will continue, helping to bolster reliability.

Future projections show that storage will play a complementary role with renewables to maintain reliability of the electricity system.

Historic 'typical day' of generation – QLD, 2024



Projected 'typical day' of generation – QLD, 2040



NSG is 'non-scheduled generation', which includes generation of different technology types which is below the minimum size threshold for registering as scheduled in the NEM. Storage includes pumped hydro and battery.

Upper chart data from AEMO NEMWeb – 1 November 2024, Queensland; Lower chart based on Baringa's NEM Reference Case projections (Q3 2024) – 1 November 2040, Queensland.

Commentary

- To demonstrate the role that storage can play in maintaining reliability, we compare a typical day in 2024 with the same day in future (2040), taken from Baringa's market projections.
- In 2024, the QLD grid is dominated by baseload coal generation across the day, with significant rooftop and utility scale solar generation during the daytime hours. Across the evening peak, hydro and gas ramped up to meet demand, along with the limited quantity of storage currently in operation. QLD exported electricity to NSW through the middle of the day and imported from NSW in the evening.
- By the 2040s, all coal generators are expected to have been retired from service, with the remaining technology mix dominated by wind and solar power, as well as a complementary suite of flexible technologies that can work around solar and wind, including different types of storage, flexible gas, and non-scheduled generation. On this 'typical day' from 2040, QLD is exporting electricity to NSW through the evening and night.
- The analysis shows the role that storage is expected to play in maintaining reliability of the system:
  - Utility-scale and rooftop solar PV dominate the generation mix through the daytime.
  - The wind power that is most favourable to develop in the QLD market is that in regions with a typical wind profile that's lower through the day and higher in the evenings and overnight, complementing other renewables.
  - Storage, which is expected to be a mix of technologies, including batteries and pumped hydro assets of different durations, is projected to complement the renewables by absorbing the excess and least cost electricity and dispatching this back into the market when solar is less available or not available.
- The electricity demand in QLD is expected to drop off in the morning and evening peak windows, which can be seen in this projected example day. This is due to a significant component of Queensland's assumed demand by 2040 coming from hydrogen production, which is then able to (and incentivised to) turn down its electricity use in these peak windows, meaning less electricity required than at other times of the day.