RELIABILITY PANEL AEMC

REVIEW

Reliability Panel AEMC

FINAL REPORT

2022 ANNUAL MARKET PERFORMANCE REVIEW

30 MARCH 2023

INQUIRIES

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ABOUT THE RELIABILITY PANEL

The Panel is a specialist body established by the Australian Energy Market Commission (AEMC) in accordance with section 38 of the National Electricity Law and the National Electricity Rules. The Panel comprises industry and consumer representatives. It is responsible for monitoring, reviewing and reporting on reliability, security and safety on the national electricity system, and advising the AEMC in respect of such matters.

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FOREWORD

I am pleased to present this report setting out the findings of the Reliability Panel's (Panel's) annual review of market performance, for the period FY2021-22.

The Panel has reviewed the performance of the National Electricity Market (NEM) in terms of reliability, security, and safety over the 2021-22 period, in accordance with the requirements of the National Electricity Rules (NER) and the terms of reference issued by the Australian Energy Market Commission (AEMC).

Power system reliability is about having sufficient capacity to meet customer demand for energy and is primarily driven by investment in capacity in the market. Power system security is primarily the responsibility of the Australian Energy Market Operator (AEMO) and it concerns the operation of the power system within its technical limits. The Panel's role in safety for the purposes of this report relates primarily to the operation of assets and equipment within their technical limits. The Panel has considered both historic trends and projections of reliability and security in the NEM.

For this review, the Panel has also considered the learnings that arose from June 2022 where a confluence of events led to unprecedented challenges in operating the NEM. This was a historic time for the NEM with an assembly of high commodity prices, domestic market price caps, planned and unplanned outages of scheduled generating plant, low output from semi-scheduled generation and high winter demand conditions resulting in the suspension of the market.

This year's market performance review shows that during the reporting period the system maintained high levels of reliability and security in the face of exceptionally challenging circumstances. In particular:

- Despite the challenges in June 2022, load shedding was avoided and customers maintained a reliable supply. This was the result of the extraordinary efforts of AEMO that issued directions, activated the RERT, facilitated outage cancellations, contracted for additional reserves and worked with industry and market bodies to maintain a reliable supply to customers during this volatile period.
- The Panel considers these events illustrate a changing set of reliability and security risks to be managed as the power system continues to transition.
- Future reliability in the NEM will be more challenging than it has been or is currently. While short-term reliability performance is expected to remain within acceptable levels, challenges are likely in the medium to long-term, particularly if there is an acceleration in the rate of thermal generator retirements.
- The Panel is considering long-term reliability risks through its review of the form of the reliability standard and supports the ongoing work considering enhancements to existing NEM arrangements for coordinated transmission and generation investment as the NEM transitions.
- Security outcomes were mostly acceptable during the review period, driven by sustained improvement in frequency performance, a reduction in the number of security directions,

a decrease in system restart ancillary services costs and generally stable levels of reviewable operating incidents and reclassifications.

- However, there were some events that continue to pose challenges as the complexity and difficulty of operating the system within its technical envelope increases. This includes the re-emergence of sub-synchronous voltage oscillations in the West Murray Zone whose root cause is not understood, the Callide generator event and the high amount of protection and control system mal-operation reviewable operating incidents.
- The Panel supports continuing investigations to understand the root cause of voltage oscillations in the West Murray Region and explore enhancing the NER frameworks to define acceptable limits of sub-synchronous power system oscillations in the NEM and acceptable generator performance in such events.
- The Panel also supports closely monitoring the load under the control of under-frequency relays in South Australia, Queensland, Victoria and New South Wales when there are high levels of DPV operating.

These findings show the continued importance of evolving market and regulatory frameworks to maintain the high levels of reliability and security across the power system that consumers have come to expect and enjoy at an affordable price. Without further efforts to ensure market and regulatory frameworks are fit-for-purpose as the power system transitions, consumers could be left either paying too much for the reliability and security they demand or with undesirably lower levels of reliability and security. There are a number of reforms underway to address concerns relating to reliability and security as the NEM continues its transition. The events from June further highlight important areas for review.

Finally, the Panel greatly appreciates the staff of the AEMC secretariat for their efforts in coordinating the collection and collation of information presented in this report, for their interpretation and analysis of the data, their collaboration with the Panel in developing the report, and for their detailed drafting on behalf of the Panel.

Charles Popple

Chairman, Reliability Panel and Commissioner,

SUMMARY

1 This report sets out the findings of the Panel's FY2021-22 Annual Market Performance Review (AMPR). The AMPR is conducted in accordance with the National Electricity Rules (NER) and terms of reference provided by the AEMC.[1]

2 This review covers the period from 1 July 2021 to 30 June 2022. The review found that reliability, security and safety outcomes across the National Electricity Market (NEM) were mostly acceptable, however observed some emerging areas of concern.

3 The reliability standard was not breached during this review period and is not expected to breach in the near-term. Medium to long-term reliability, however, faces additional challenges. Future reliability will rely on significant levels of new investment to address already announced closures and appropriate investment signals to incentivise the right mix of power system resources.

4 Positive security outcomes were driven by improved frequency performance, a reduction in security directions and a decrease in system restart ancillary services (SRAS) costs. Despite this, concern remains regarding voltage oscillations in the West Murray Zone (WMZ) and protection mal-operation in reviewable operating incidents.

5 The Panel observed no incidents relating to safety throughout this review period.

6 Most of the data included in this report is already publicly available in various other reports. As with previous reports, the value of this report comes from the Panel, with its diverse membership, collating and interpreting all the information and data to make sense of what is happening across the power system and market. Accompanying the FY2021-22 AMPR, the Panel has published a data file so that stakeholders can use key data sets more easily.

7 Stakeholders should note this year the Panel also developed a companion document to the AMPR final report: *"The Reliability, Security and Safety Frameworks in the NEM — an explanatory statement for the 2022 AMPR"* (explanatory statement). The explanatory statement provides details and explanation of the NEM reliability, security and safety frameworks that are relevant to this AMPR. The Panel has developed this explanatory statement to complement the AMPR as well as to be a stand-alone summary of reliability, security and safety frameworks in the NEM. The Panel intends to update this explanatory statement on an annual basis as NER frameworks evolve.[2]

Key event — June 2022: Administered Price Period and market suspension

8 The Administered Price Period (APP) and market suspension event that occurred between 12 June 2022 and 24 June 2022 was an extreme event that arose out of a confluence of planned and unplanned thermal outages, low variable renewable energy (VRE) generation

1 For the complete standing terms of reference see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

2 The explanatory statement can be found on the review's website at https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

periods, high customer demand, high commodity prices, and the level of domestic price caps.

9 Average electricity market prices rose significantly due to the factors mentioned above, resulting in a breach of the Cumulative Price Threshold (CPT) in Queensland on 12 June 2022, and New South Wales, South Australia and Victoria on 13 June 2022 when the Administered Price Cap (APC) was applied in these NEM regions. After the application of the $300/MWh APC, several generators rebid their energy volumes offered to the market, significantly reducing the generation capacity available for dispatch. This large-scale generation withdrawal occurred requiring unprecedented AEMO intervention. On 15 June the Australian Energy Market Operator (AEMO) was no longer able to practically operate the market and so suspended the market until 24 June 2022.

10 AEMO was able to use its powers of intervention to maintain NEM reliability. AEMO issued directions, activated the Reliability Emergency Reserve Trader (RERT), facilitated outage cancellations, contracted for additional reserves and worked with industry and market bodies to maintain a reliable supply to customers during this volatile period. AEMO was faced with a range of challenges in its intervention which included the management of fuel availability and energy limits. AEMO interventions were successful and avoided the need for customer load shedding. The Panel considers this a significant achievement for which AEMO should be recognised.

11 The Panel considers these events to illustrate a changing set of market and physical reliability risks which NER frameworks may need to evolve to better address. These changes to the power system's risk profile include:

- Fuel supply arrangements that are now exposed to international market and geo-political event volatility
- A more energy-limited power system
- A power system exposed to weather-related reliability risk
- A coal generation fleet that is less available than in the past.

12 The Panel identifies a set of issues associated with the NER frameworks that applied in June 2022, with many processes that have occurred or are occurring to address these, including:

- The APP-related market price settings at the time were not designed to manage the risks that led to the market being suspended. The APC has subsequently been revised to $600/MWh until 30 June 2025, with broader MPC and CPT arrangements being considered through an upcoming AEMC rule change, that has been submitted by the Panel.
- There are multiple compensation frameworks with different objectives, eligibility, time-frames and processes. These may not have been well understood by market participants at the time. This includes how the AEMC's compensation arrangements operated alongside directions and market suspension compensation administered by AEMO. A lack of prior experience of the administered pricing compensation arrangements may have contributed to issues relating to generator withdrawal. The Panel notes that market participants are now more familiar with these arrangements, having observed their operation during and after June 2022, which partially mitigates the issue.

- Gas and electricity market arrangements do not have price caps that are aligned in energy equivalent terms.

13 The Panel also makes the following general observations:

- There may be merit in better understanding how energy limit considerations are integrated with NEM frameworks.
- Further analysis aimed at investigating aligning the gas and electricity governance frameworks may be warranted.
- Consideration could be given to developing a process for assessing risk across the fuel and electricity supply chain.
- A review of administered pricing compensation arrangements and the other forms of compensation should be considered to determine opportunities for harmonisation and simplification.

Reliability

14 A reliable power system has enough generation, demand response and network capacity to supply consumers with the energy that they demand with a very high degree of confidence.

15 The Panel's assessment in this AMPR indicates that reliability in the NEM will be more challenging in the future than it has been in the past or is currently. The Panel identifies short-term reliability performance is expected to remain within acceptable levels but additional challenges are likely in the medium to long-term, particularly if there is a material acceleration in the rate of thermal generator retirements.

16 The Panel's AMPR assessment identified:

- No breach in either the reliability standard or the interim reliability measure (IRM) for the period 2021-22.
- Near-term reliability in the NEM is expected to remain high given the February 2023 Electricity Statement of Opportunities (ESOO) indicates that levels of USE will be maintained within the reliability standard and interim reliability measure (IRM) on the basis of already committed developments.
- Medium-term reliability in the NEM will rely on significant levels of new investment to address already announced closures. Medium-term reliability risks are associated with the timely delivery of new investments and the potential for early thermal generator retirement. The ESOO forecasts breaches against the reliability standard in New South Wales from 2027-28, Victoria from 2028-29 and Queensland in 2029-30.
- The NEM's long-term reliability performance post-2030 is dependent on having fit-for-purpose frameworks to signal and appropriately incentivise the right level and mix of power system resources for a fundamentally weather-driven power system. The ESOO forecasts the reliability standard will be breached in South Australia in 2030-31.

17 The Panel notes the role of jurisdictional scheme delivery for addressing the reliability gap in different regions identified in AEMO's ESOO. The Panel's modelling of reliability for its 2022 RSS review identified investment under the NSW Roadmap would help to maintain reliability

in NSW following Eraring's closure.

18 The continued growth in Consumer Energy Resources (CER) also represents an opportunity for the NEM to address future reliability needs. The significant growth in solar PV capacity continues and while only minimal when compared to solar, 2021-22 saw the highest amount of batteries installed in the NEM since reporting began.

19 While current reliability performance remains acceptable and within both the IRM and reliability standard, there was a significant increase in low reserve conditions in the NEM during the review year. This significant increase was driven by winter-related reliability risk and may be becoming more attributable to forecast uncertainty than has been the case in previous years. The Panel notes that forecast uncertainty-related reliability risk is likely increasing in the NEM.

20 Market price outcomes in the second half of the review year illustrate the circumstances that led to the June market suspension event as a confluence of high commodity prices, domestic market price caps, planned and unplanned outages of scheduled generating plant, low output from semi-scheduled generation, and high winter demand conditions led to unprecedented challenges operating the NEM and the suspension of the market. The Panel has identified the Commonwealth imposed wholesale gas market price cap of $12/GJ on electricity market price outcomes as a potential issue for consideration in the next AMPR.

21 The Panel supports the ongoing work considering enhancements to existing NEM arrangements that provide for coordinated transmission and generation investment as the NEM transitions which enhances the long-term interests of consumers while also balancing efficient outcomes with providing appropriate levels of investor certainty.

22 The Panel will continue to monitor the penetration of CER on system load as it expects its impact to become more pronounced in the future.

Security

23 Power system security involves maintaining the numerous components within their allowable equipment ratings, maintaining the system in a stable condition within defined technical limits and returning the power system to operate within normal conditions following a disturbance.

24 The Panel notes that system security outcomes in the NEM were mostly acceptable during the review year, driven by:

- The sustained improvement in NEM frequency performance following the introduction of mandatory primary frequency response.
- A reduction in the number of security directions in South Australia following commissioning of the four synchronous condensers that have addressed the system strength gap in that region.
- Generally stable levels of reviewable operating incidents and reclassifications.
- A decrease in SRAS costs following the merger of the two Queensland sub-regions.

- AEMO's extensive analysis of system security risks through its Power System Frequency Risk Review (PSFRR), which has informed its practical operation of the system and its collaboration with NSPs.

25 While overall security outcomes were good in 2021-22, there are some areas of concern arising from the security events that occurred during the review year. The Panel particularly notes:

- Protection and control system mal-operation remains the greatest source of reviewable operating incidents, with the use of more special protection schemes (SPS) in response to an increasingly complex system. Whilst such schemes have the potential to mitigate the effect of high-impact, low-probability events, there are potentially severe security risks associated with mal-operation and potential adverse interactions between protection systems. These are partially mitigated by SPS design in accordance with remedial action scheme (RAS) guidelines.
- Gaps in existing NER frameworks relevant to defining acceptable limits to sub-synchronous power system oscillations in the NEM and acceptable generator performance in such events. The Panel considers learnings from AEMO's work on the Connections Reform Initiative in response to the oscillations observed in the WMZ should be considered further given the likely re-occurrence of such issues as IBR penetrations increase and levels of system strength decline.
- Multiple incidents of synchronous condensers tripping in New South Wales illustrate the need to explore further and assess the technical performance of the synchronous condensers due to how their performance standards are defined.
- The amount of load under the control of under-frequency relays in South Australia, Queensland, Victoria and New South Wales is now well below the levels anticipated in the NER when there are high levels of Distributed PV (DPV) operating. The Panel notes that the effectiveness of under-frequency load shedding (UFLS) systems in response to the Callide event were undermined by increasing penetrations of DPV. While sufficient UFLS was available in this event to maintain Queensland frequency within the extreme frequency tolerance band of 47 Hz, the Panel is concerned that the risks of a black system event are rising. The Panel considers further review be progressed and any changes to the framework be implemented via the rule change process if required.

26 In response to these outcomes and events, the Panel recommends the following:

- Continue investigations to understand the root cause of voltage oscillations in the WMZ region and explore enhancing NER frameworks to define acceptable limits of sub-synchronous power system oscillations in the NEM and acceptable generator performance in such events. AEMO is currently working with network service providers (NSPs) to define acceptable operational limits.
- Explore whether there is benefit in establishing principles as part of the NER for performance standards and compliance monitoring for system strength services.
- Monitor the load under the control of under-frequency relays in South Australia, Queensland, Victoria and New South Wales as it is now well below the levels anticipated in the NER when there are high levels of DPV operating.

Safety

27 The safety of the power system and associated equipment, power system personnel and the public is covered in general terms under the National Electricity Law (NEL). There is however no national safety regulator specifically for electricity. Instead, state and territory legislation governs safety generally which includes the safe supply of electricity and the broader safety requirements associated with electricity use in households and businesses.

28 The Panel notes that its safety role for the purposes of this report is narrow and relates primarily to the operation of assets and equipment within their technical limits and not to the broader safety requirements governed by jurisdictional legislation.

29 AEMO noted that there were no incidents in 2021-22 where AEMO's management of the power system has resulted in a safety issue with respect to maintaining the system within relevant standards and technical limits.

30 There were also no instances in 2021-22 where AEMO issued a direction and the directed participant did not comply on the grounds that complying with the direction would be a hazard to public safety, or materially risk damaging equipment or contravene any other law.

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1 INTRODUCTION

This report has been prepared as part of the Reliability Panel's (the Panel) Annual Market Performance Review (AMPR) of the National Electricity Market (NEM). It covers the 2021-22 financial year. Under the National Electricity Rules (NER or the Rules), the Panel must undertake this review annually.

This year the Panel also developed a companion document to the AMPR final report: *"The Reliability, Security and Safety Frameworks in the NEM — an explanatory statement for the 2022 AMPR"* (explanatory statement). The explanatory statement sets out the:

- Role of the Panel and AMPR process
- Frameworks used to deliver power system reliability, security and safety in the NEM
- Set of metrics used by the Panel to monitor and report on reliability, security and safety outcomes in the NEM for the purposes of AMPR reporting.

The explanatory statement is intended to be a companion document and should be read in conjunction with the AMPR final report. It also serves as an explanatory report for those interested in understanding more about the current frameworks.[3]

1.1 Background and purpose of the report

The functions and powers of the Panel are set out in section 38 of the National Electricity Law (NEL). Among other things, the Panel is required to:

- Monitor, review, and report on, in accordance with the Rules, the safety, security and reliability of the national electricity system
- At the request of the AEMC, provide advice in relation to the safety, security, and reliability of the national electricity system
- Undertake any other functions and powers conferred on it under this Law and the Rules.

Consistent with these functions, clause 8.8.3(b) of the NER requires the Panel to conduct a review of the performance of certain aspects of the market, at least once every financial year and at others such times as the AEMC may request.

The Panel must conclude each annual review no later than the financial year following the financial year to which the review relates. The Panel must conduct its annual review in terms of:

- Reliability of the power system
- The power system security and reliability standards
- The system restart standard
- The guidelines referred to in clause 8.8.1(a)(3) of the NER[4]

3 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

4 The guidelines referred to in clause 8.8.1(a)(3) of the NER govern how AEMO exercises its power to issue directions in connection with maintaining or re-establishing the power system in a reliable operating state.

- The policies and guidelines referred to in clause 8.8.1(a)(4) of the NER[5]
- The guidelines referred to in clause 8.8.1(a)(9) of the NER.[6]

The AEMC may provide the Panel with standing terms of reference[7]in relation to the AMPR.[8]

1.2 Scope of the report

As noted, the Panel has undertaken this review in accordance with the requirements in the NER and the terms of reference issued by the AEMC. The AEMC requested that the Panel review the performance of the market in terms of reliability, security, and safety of the power system.

In this report the Panel has considered the following definitions of reliability and security in relation to the power system:

- **Reliability** — have enough capacity (generation, demand response and networks) to supply customers
- **Security** — able to operate within defined technical limits, even if there is an incident such as the loss of a major transmission line or large generator.

For more exhaustive definitions of the above, please refer to the explanatory statement.

This report is divided into four main chapters to consider matters, including:

- Key events: The Panel has considered key events relevant to the 2021-22 financial year. Specifically:
  - The events leading up to the June market suspension
  - The security incidents that occurred during the market suspension period.
- Reliability: The Panel has reviewed the reliability performance of generation and bulk transmission (i.e. interconnection). In doing so, it has considered:
  - Current and historic NEM reliability performance
  - Forward-looking reliability risks
  - NEM Reserve level events and constraint impacts
  - AEMO interventions for reliability and RERT
  - Market price signals and investment incentives.
- Security: The Panel has reviewed the performance of the power system against the relevant technical standards. In particular, the Panel has had regard to:
  - Power system security incidents/risk management
  - Management of power system security risks

5 The policies and guidelines referred to in clause 8.8.1(a)(4) of the NER govern how AEMO exercises its power to enter into contracts for the provision of reserves.

6 The guidelines referred to in clause 8.8.1(a)(9) of the NER identify, or provide for the identification of, operating incidents and other incidents that are of significance for the purposes of the definition of 'reviewable operating incident' in clause 4.8.15 of the NER.

7 The current terms of reference from the AEMC in relation to this review can be found at https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

8 Clause 8.8.3(c1) of the NER.

    - Frequency performance
    - AEMO interventions for security
    - System services procurement and use.
- Safety: The NEL and NER set out the functions and powers of the Reliability Panel, which include a function to monitor and report on safety in accordance with the Rules. The NER does not specify additional requirements in relation to safety performance monitoring. However, the Panel can provide advice in relation to the safety of the national electricity system, at the request of the AEMC.

Taken together, this final report provides key insights and observations on the reliability, safety and security of the power system throughout the reporting period. The body of the report is also complemented by appendices that provide the complete set of charts, as well as an accompanying data file so that stakeholders can use key data sets more easily.

2 JUNE 2022 APP/MARKET SUSPENSION EVENT

BOX 1: KEY OBSERVATIONS

In June 2022, a confluence of high commodity prices, domestic market price caps, planned and unplanned outages of scheduled generating plant, low output from semi-scheduled generation, and high winter demand conditions led to unprecedented challenges operating the NEM and the suspension of the market.

Average electricity market prices rose significantly due to the factors mentioned above, resulting in a breach of the CPT in QLD on 12 June 2022, and NSW, SA and VIC on 13 June 2022 when the APC was applied in these NEM regions. After the $300/MWh APC was applied, several generators rebid their energy volumes offered to the market, significantly reducing the generation capacity available for dispatch. This large-scale generation required unprecedented AEMO intervention. On 15 June 2022 AEMO was no longer able to practically operate the market, and so suspended the market, which lasted until 24 June 2022.

During the June event AEMO used its powers of intervention to maintain NEM reliability. AEMO issued directions, activated the RERT, facilitated outage cancellations, contracted for additional reserves and worked with industry and market bodies to maintain a reliable supply to customers during this volatile period. AEMO was faced with a range of challenges which included the management of fuel availability, energy limits, and storage. Through AEMO's intervention, work from the other market bodies and industry more generally, there was no customer load shedding. The Panel considers this a significant achievement for which the various parties, but particularly AEMO, should be recognised.

The Panel considers these events illustrate a changing set of market and physical reliability and security risks which NER frameworks may need to evolve to better address. These changes to the power system's risk profile include:

- Fuel supply arrangements that are now exposed to international markets and geo-political event volatility
- A more energy-limited power system
- A power system exposed to weather-related reliability risk
- A coal generation fleet that is less available than in the past.

The Panel identifies a set of issues associated with the NER frameworks that applied in June 2022, with many processes that have occurred or are occurring to address these, including:

- The APP-related market price settings at the time were not designed to manage the risks that led to the market being suspended. The APC has subsequently been revised to $600/MWh until 30 June 2025, with broader MPC and CPT arrangements being considered through an upcoming AEMC rule change, that has been submitted by the Panel.

- There are multiple compensation frameworks with different objectives, eligibility, time-frames and processes. These may not have been well understood by market participants at the time. This includes how the AEMC's compensation arrangements operated alongside directions and market suspension compensation administered by AEMO. A lack of prior experience of the administered pricing compensation arrangements may have contributed to issues relating to generator availability. The Panel notes that market participants are now more familiar with these arrangements, having observed their operation during and after June 2022, which partially mitigates this issue.
- Gas and electricity market arrangements do not have price caps that are aligned in energy equivalent terms.

The Panel also makes the following general observations:

- There may be merit in better understanding how energy limit considerations are integrated with NEM frameworks.
- Further analysis aimed at investigating aligning the gas and electricity governance frameworks may be warranted.
- Consideration could be given to developing a process for assessing risk across the fuel and electricity supply chain.
- A review of administered pricing compensation arrangements and the other forms of compensation should be considered to determine opportunities for harmonisation and simplification.

The review period of 1 July 2021 to 30 June 2022 included the administered price period (APP) and market suspension event that occurred between 12 June 2022 and 24 June 2022. This APP/market suspension was an extraordinary event for the NEM which saw the large-scale withdrawal of generation capacity requiring unprecedented levels of AEMO intervention leading to the suspension of the market on 15 June 2022 on the basis it had become impossible to operate.

While it was an extraordinary event, there was no customer load shedding and AEMO was able to use its existing powers of intervention. Combined with the work from the other market bodies and industry, physical supply was maintained for customers. The APP/market suspension event however stress-tested NEM reliability and risk management frameworks and provided an opportunity for the Panel to make observations and identify issues to inform the future development of NEM frameworks.

This chapter provides a summary and presents the Panel's considerations in respect to NEM reliability frameworks. This chapter includes:

- A summary of the event, characteristics and sequence
- The Panel's observations on how the event informs understanding of a changing market and reliability risk profile
- Actions in response to the event

- Panel recommendations.

This chapter's contents are complemented by the reliability and security chapters which present reliability and security metrics that also capture the APP/market suspension event.

2.1 Event Summary

In June 2022, a confluence of high commodity prices, domestic market price caps, planned and unplanned outages of scheduled generating plant, low output from semi-scheduled generation, and high winter demand conditions led to unprecedented challenges operating the NEM and the suspension of the market.

This section summarises the conditions leading up to the event and the sequence of events during the APP/market suspension period. It is a high-level summary to inform the Panel's discussion of risks and recommendations. A more complete event timeline is provided in Appendix A.1. Stakeholders should also refer to AEMO's incident report[9], the AER's market events report[10] and the AEMC's final determination on amending the APC for additional information.[11]

2.1.1 Conditions and circumstances leading up to the event

The NEM in early 2022 experienced a historic increase in fuel prices due to a confluence of factors. In addition to the increase in prices, sufficient volumes of coal were becoming increasingly difficult to source, with tight gas market supplies also a factor.[12]

Wholesale gas prices across the east coast markets rose to unprecedented levels. In June 2022 gas prices averaged $28.4/GJ, compared to $8.2/GJ in Q2 2021.[13] This saw domestic prices peak at $41.2/GJ on 30 June 2022.-Coal market prices also exceeded $400/t representing a 500% increase in a year.

A significant amount of thermal coal-fired generation capacity was out of service for planned maintenance and unplanned outages. In the lead-up to the market suspension, an estimated 6,000 MW of generation capacity was not in operation. This situation led to a tight market and the in-service generators running more than they otherwise would have, therefore requiring larger quantities of fuel than would otherwise be expected.

There were also unseasonably cold temperatures on the east coast leading to higher demand than would be normally expected in early June. South-east Australia saw average temperatures drop as much as 4-8ºC from Wednesday 8 June to Sunday 12 June 2022. This was driven by a series of cold fronts moving over eastern and northern parts of Australia. Driven by the onset of winter conditions and a drop in average temperatures (discussed

9 For more information see https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/market_event_reports/2022/nem-market-suspension-and-operational-challenges-in-june-2022.pdf.

10 For more information see https://www.aer.gov.au/system/files/AER%20June%202022%20Market%20Events%20Report-%20FINAL%20VERSION%20-%2014%20December%202022.pdf.

11 For more information see https://www.aemc.gov.au/rule-changes/amending-administered-price-cap.

12 Gas market availability issues in the lead up to the APP/market suspension event are illustrated by fired Sydney contingency gas trigger event on 25 May 2022 and AEMO's invoking of the Gas Supply Guarantee on 1 June 2022.

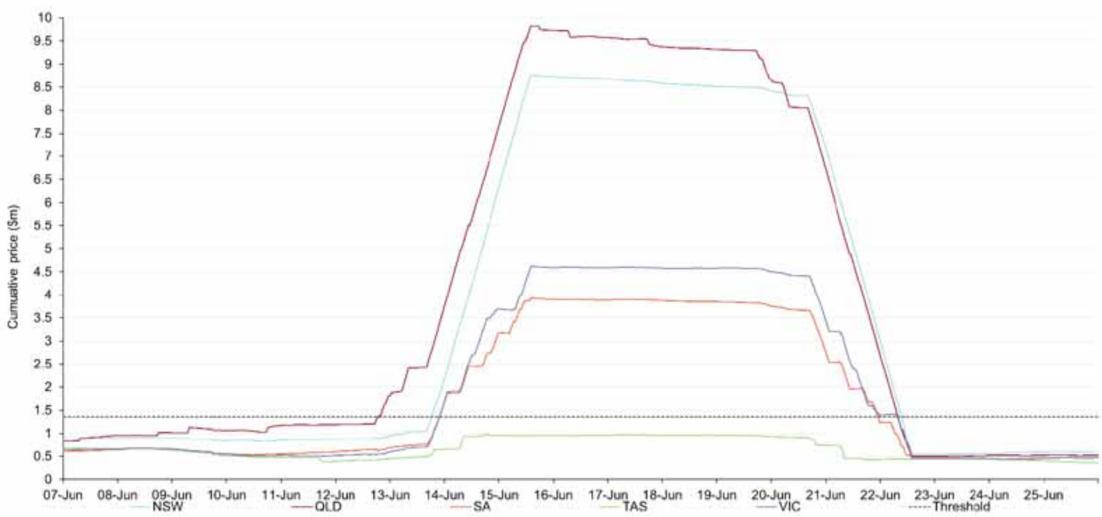
13 AEMO's Quarterly Energy Dynamics (QED) Q2 2022 Report.

further below), consumer demand across the mainland eastern states increased to record levels. Queensland set a new Q2 maximum demand record of 8,255 MW, exceeding the previous record by 83 MW. Victoria reached its highest Q2 maximum demand since 2011 and was 492 MW higher than 2021's Q2 maximum.

2.1.2 Sequence of events during the APP/market suspension period

- On Friday 10 June 2022, there were noticeable changes in generator bidding as the rolling sum of spot prices for the previous seven days in some NEM regions approached the CPT, which would trigger an APP.
- A significant reduction in generation volumes were offered to the market on 10 June 2022 which saw the first actual LOR level 2 conditions in this series of events. This necessitated the first reliability directions.
- On the evening of Sunday 12 June 2022, the CPT was exceeded for the Queensland region. The APC of $300/MWh was applied, with price scaling applied to other regions during periods when energy was flowing toward Queensland. During the evening of Monday 13 June 2022, the CPT was also exceeded for New South Wales, Victoria and South Australia. The application of the APC in those regions coincided with reductions in the volume of generation offered to the market. Figure 2.1 shows the regional cumulative prices over the APP/market suspension period indicating when the different regions entered APP.

Figure 2.1: Regional cumulative prices 7 June to 25 June 2022



Source: AEMO NEM suspension and operational challenges in June, incident report, August 2022.

- As observed by the AER in its recent June 2022 market events report, generators cited commercial reasons for withdrawal alongside other reasons such as preserving fuel for peak periods, or challenges managing efficient dispatch.[14]
- AEMO intervened by directing generators to make generation capacity available to be dispatched for system reliability and implemented manual processes to manage capacity and energy limitations on generating facilities. In its incident report, AEMO note that without these directions and other measures, such as outage cancellations and contracting for additional reserves, AEMO would have had to initiate significant customer load shedding, with forecast shortfalls at certain times up to around one third of NEM winter peak demand.[15]
- Over subsequent days, AEMO coordinated with generators, emergency reserve providers, network service providers and jurisdictions to manage system operations and maintain reliable supply to consumers. AEMO directed generators, activated reliability and emergency reserve trader (RERT) resources and deferred network outages. AEMO also worked with jurisdictions and generators to facilitate fuel supply chain interventions to maintain supply of gas and coal for electricity generation given challenges in fuel supply availability.
- Despite this, there were occasions when the market came very close to customer load shedding in mainland regions of the NEM, including one occasion on 13 June 2022 when flows on QNI exceeded secure limits for approximately 60 minutes. Supply demand balance issues were also responsible for flows on the Victoria – New South Wales Interconnector (VNI) exceeding secure limits during two periods of under 30 minutes on 15 June 2022, and a low mainland frequency event on 17 June 2022. Further commentary on these events is provided in Section 4.1.1.
- Directed capacity reached close to 5 GW on 14 and 15 June 2022, and the large number of constraints necessary to manage directions and supply limitations created issues for AEMO's automated systems and processes which became impossible to manage. Ultimately these issues resulted in AEMO suspending the market at 1400 hrs on 15 June 2022, with prices determined according to the published market suspension pricing schedule (MSPS).[16]

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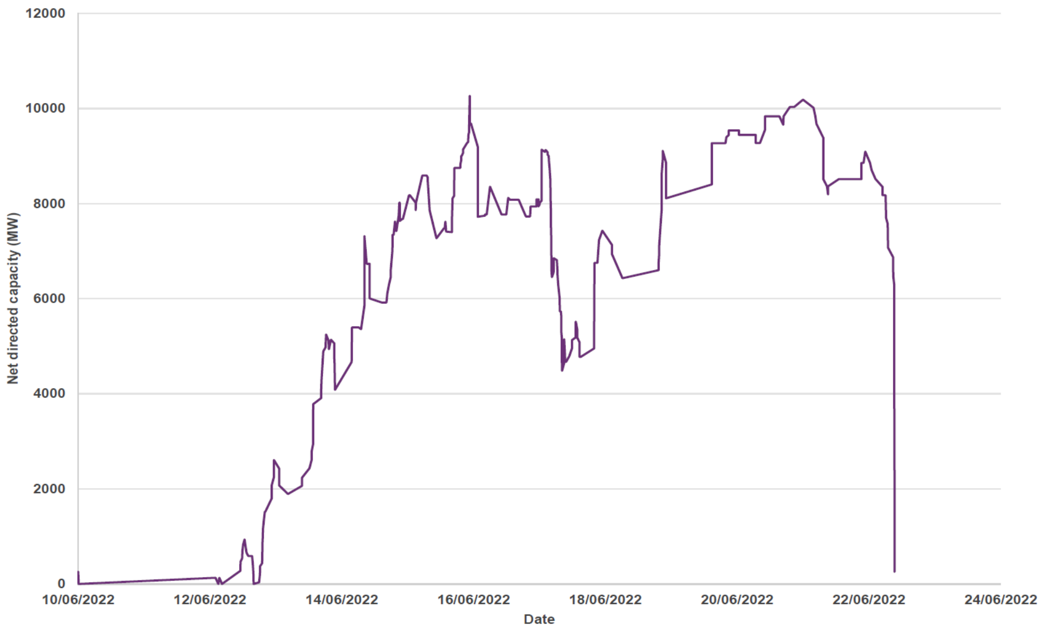
14 AER's June 2022 market events report, AER findings, December 2022, p. 13.

15 AEMO's NEM Suspension and operational challenges in June 2022, Incident Report, August 2022, p. 4.

16 An additional and emerging complication of market operation in this period was that NEMDE could not find a feasible dispatch solution in some intervals without breaching one or more constraints – known as "over-constrained dispatch" (OCD). Compliance with clauses 3.8.1(b), 3.8.1(c) and 3.9.1 of the NER requires that instances of OCD in dispatch must be resolved to establish a dispatch price, either through an automated "constraint relaxation re-run" procedure in NEMDE itself, or if that fails through offline manual resolution of conflicting constraints. Manual resolution of this number of constraints was not feasible, and consequently it was not possible to reliably establish a dispatch price for these intervals. For more information see https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/market_event_reports/2022/nem-market-suspension-and-operational-challenges-in-june-2022.pdf?la=en.

Figure 2.2: Total net directed capacity in the NEM



Source: AEMO NEM suspension and operational challenges in June, incident report, August 2022.
Note: The total net directed capacity presented is the total net position of directions taking account of the capacity of MWs under direction at that time and cancelled directions. Figures have been adjusted to avoid any double counting of directed generator capacity.

- AEMO continued to issue directions following the market suspension, as well as activating the RERT mechanism in New South Wales and Queensland on three occasions during the suspension period. The volumes and number of directions progressively declined after 18 June 2022 as some large generating units returned to service, with all directions cancelled by 23 June 2022.
- On 22 June 2022, AEMO, having briefed industry and jurisdictions, released its criteria and process for ending the market suspension. Following a staged process, normal dispatch pricing was resumed from 0400 on 23 June 2022, and the suspension was formally lifted at 1400 hrs on 24 June 2022.

2.2 Market settings in a changing reliability/market risk profile

The June APP/market suspension event indicated that certain existing framework elements may no longer be fit for purpose given a changing set of physical and market-related reliability risks. This section presents the Panel's considerations on:

- The emerging market and physical reliability risks illustrated by the June APP/market suspension event
- Issues with existing market frameworks that ultimately led to AEMO's decision to suspend the market.

2.2.1 A changing market and physical reliability risk profile

The NEM's physical and market reliability risk profile is undergoing a shift.

- The physical reliability risk profile is shifting as the NEM transitions from being capacity-limited thermal power system to being a weather-driven, energy-limited (both renewables and thermal fuel) power system with declining thermal generation availability.
- The market risk profile has changed as fuel supply arrangements for Australian electricity generation shifted from being domestically focused, and insulated from international market pricing and volatility, to being coupled with international markets and exposed to geo-political event-induced volatility.

The circumstances leading into, and events during the June APP/market suspension period illustrate the shift in risk profiles in the NEM. This section presents the Panel's considerations on key elements of this shift including:

- Fuel supply arrangements that are now exposed to international market and geo-political event volatility
- A more energy-limited power system
- A power system exposed to weather-related reliability risk,
- A coal generation fleet that is less available than in the past.

Fuel supply arrangements that are now exposed to international-market and geo-political event volatility

The events during the June APP/market suspension event illustrate the set of risks for Australia's electricity industry associated with internationally linked fuel (coal and gas markets).

At the commencement of the NEM, Australia's electricity fuel supply arrangements were insulated from international events with little volatility and prices generally set by long-term bilateral supply agreements. The NEM APP settings were designed with this world in mind and were fit for purpose in a lower fuel price and lower volatility environment.

The commencement of LNG exports from the east coast of Australia in late 2014 radically shifted gas supply and pricing dynamics.[17] The increase in gas market prices in particular flows through to electricity market prices given the role of gas-fired generation as a marginal price setter.

Internationally coupled fuel markets expose Australia's electricity generation sector to high levels of price volatility, associated with geo-political event risk. In regard to the June APP/market suspension event, the impact of the European conflict drove fuel and gas prices to unprecedented levels in the months leading up to 10 June 2022 and contributed to tight

17 For more information see https://www.rba.gov.au/publications/bulletin/2015/mar/pdf/bu-0315-4.pdf.

supply conditions. The combination of high demand and tight supply resulted in an extended period of very high average NEM electricity prices leading to the APP being imposed.[18] [19]

The APP/market suspension event illustrates that while the power system needs to be more robust, the impact on affordability and the long-term interests of consumers must also be taken into account. This is particularly important when looking at the NEM market settings in relation to higher-levels of fuel price and supply volatility. Such issues will be considered through the AEMC's upcoming consideration of the Reliability Standard and Settings Review (RSSR) rule change.

A more energy-limited power system

The NEM is transitioning from being a primarily capacity-limited thermal power system to being a high VRE, more energy-limited power system.

The Panel understands that thermal coal stockpiles at power stations had declined to very low levels prior to June 2022 due to a combination of tight supply, high prices, and thermal coal generators purchasing less coal given their declining role in dispatch. AEMO noted that participant energy limitation submissions to MT-PASA were slowly revised downwards, sometimes many weeks after actual limitations had been observed impacting operational timeframes.[20]

The need to manage energy limits was likely a factor incentivising generator withdrawal from the market. A large amount of thermal generation capacity was unavailable during the event due to planned and forced outages. To maintain reliability, available generators were being dispatched more than they had anticipated. The Panel understands that these generators hadn't planned coal purchases to cover this generation and needed to ration their operation to manage scarce fuel availability, particularly when faced with supplier non-delivery.

The combination of lower coal stocks and availability limits introduced significant energy-related risks for AEMO to manage during the market suspension. AEMO had to schedule across energy blocks contending with fuel delivery timelines, dispatch decisions, demand forecasts, battery storage and energy limits to maintain a reliable power system.[21] AEMO found it challenging to manage storage re-charging during this period. With high demand and low output from both thermal and VRE generators AEMO had to contend with storage windows as well as energy-limited thermal plants to ensure there was a continuous supply of energy to customers.

18 In addition, there were tight fuel supply conditions that required AEMO and NSW government intervention. AEMO invoked the Gas Supply Guarantee on 1 June 2022 due to limits in gas for electricity generation. The NSW government also passed special ministerial intervention powers to direct coal mines to supply coal for electricity generation.

19 Regulation 4 of the Essential Services Regulation (No 2) 2022 states that for the Essential Services Act 1988, section 9, the Minister for Energy is authorised to direct a person to do any act or thing to increase, or facilitate the increase of, the supply or distribution of coal to a power station.

20 AEMO note that since early July, the energy limits submitted by participants have been repeatedly revised down, better reflecting the levels of fuel availability and other operational challenges advised by participants. Furthermore, the AER notes there had been poor PASA compliance practices by some generators. For more information see https://www.aer.gov.au/system/files/AER%20June%202022%20Market%20Events%20Report-%20FINAL%20VERSION%20-%2014%20December%202022.pdf.

21 Raising the energy limit for a given day could mean that a lower limit would be necessary for the following day, requiring dispatch decisions to be made based on anticipated power system conditions. For example, on one occasion AEMO scheduled additional energy-limited coal generation when supply was tight due to lower forecast wind generation for the following day, on the basis that the forecast wind generation was significantly higher for the day after that.

The risks associated with a more energy-limited NEM are generally considered in terms of storage duration and the need to manage low VRE generation periods in a future high VRE NEM. By contrast thermal coal, and to a lesser degree gas, are not generally considered energy constrained, particularly in operational timescales. The June APP/market suspension illustrates that coal and gas may be more energy limited than previously appreciated which heightens the need to actively consider NEM energy limits in advance of thermal plant retirement. Such limits are considered proactively in the ESOO, published by AEMO.

Declining thermal generation availability

Physical thermal generator availability, as opposed to commercial availability, was a significant factor in the June APP/market suspension event. Planned maintenance and unscheduled outages of large generation capacity were at high levels in Q2 2022, having approached 8 GW in early May. Capacity was progressively returned to service up to 7 June, but a total of 2.8 GW of further forced outages at large generating units then occurred from 9 June to 13 June (Bayswater 2 & 4 totalling 1,320 MW, Callide C 3 430 MW, Gladstone unit 4 280 MW, and Yallourn units 1 and 4 totalling 740 MW). In total, approximately 6.6 GW of large generation capacity, corresponding to about 20% of winter maximum NEM demand, was offline by 14 June 2022.

Australia's thermal coal-fired generators are ageing and approaching the end of their technical lives. Thermal coal-fired power stations are therefore expected to suffer higher force outages and require additional maintenance as they approach retirement. These factors will limit thermal generator availability in the coming years potentially heightening reliability risk prior to their actual retirement dates. Section 3.2.1 discusses coal-fired generator retirements in further detail.

A more weather dependent power system

Weather-related risks were a material factor in the June APP/market suspension event. AEMO reported that:

- Weather leading up to 10 June 2022 was dominated by exceptionally cold early winter conditions from late May into early June. A series of cold fronts in early June that extended as far as north Queensland caused an increase in heating demand across the NEM. Cold winter conditions increased demand levels across the NEM between 7 June and 12 June 2022, with maximum NEM operational demands more than 1 GW higher on average than in the preceding week.
- The output from semi-scheduled generation was also low during this period. From mid to late-June average wind generation levels were at 23% in both Queensland and New South Wales and intermittently approaching 0% in both regions. Victoria, South Australia and Tasmania experienced very volatile generation levels, with Victoria recording sustained periods of extremely low wind generation from 13 to 17 June. Solar generation was also at minimum levels, which was not unexpected for this time of year. It offered minimal output during the morning and evening demand peak periods and was reflecting daytime generation levels of around 50-70% in Victoria, Queensland, New South Wales, and South Australia.

The NEM's transition to high penetrations of VRE will make it more weather dependent than it has historically been. The NEM has historically been more weather dependent on the demand side, compared to the supply side, given the relationship between temperature and heating/cooling demand. The large-scale uptake of VRE will change the NEM's reliability risk profile particularly given the inverse correlation between VRE generation and net demand. As an example, cloudy conditions will reduce transmission-connected PV generation while increasing net load given the reduction in DPV generation.

The June APP/market suspension period illustrated that weather-related risks on both the supply and demand side may be material already, particularly when combined with other reliability risks such as low thermal generator availability.

2.2.2 Issues with market frameworks

This section presents the issues with existing frameworks illustrated by events during the APP/market suspension. It identifies:

- The APP-related market price setting levels at the time of June 2022 were insufficient to cover the cost of some thermal generators and so may have exacerbated the events that occurred at the time.
- Given the infrequency of APPs historically, industry participants had limited previous experience with and understanding of the administered pricing compensation arrangements. Uncertainty about the scheme's operation may have weakened the incentive to provide services during the June APP.
- Gas and electricity market arrangements do not have price caps that are aligned in energy equivalent terms.

The APP-related market price settings applying at the time may have exacerbated the events that occurred

The Panel identifies a contributing factor behind the June APP/market suspension event was a set of market arrangements that were framed for a different time and designed to manage a different set of risks. The physical and market reliability risk profile has advanced ahead of the APP-related settings which were ultimately not fit for purpose given the circumstances that led to the June event.

- The level of the APC was no longer fit for purpose. The $300/MWh APC was too low for generators to recover their variable costs during the APP given the prevailing gas and coal prices. This may have been a factor in generators' decisions to withdraw capacity[22] from the market given that it was not economic to generate. The level of the APC had not been updated since its implementation and this was prior to the development of an LNG export industry and therefore set at a level that did not allow for the levels of fuel price volatility and geo-political event risk which is now part of the NEM's risk profile. Additionally, a $300/MWh APC did not provide with a price spread for storage charging and discharging.[23]

22 For more information see https://www.aer.gov.au/system/files/AER%20June%202022%20Market%20Events%20Report-%20FINAL%20VERSION%20-%2014%20December%202022.pdf.

- The APP-related market price settings, being the CPT and APC, are intended to manage systemic financial risk associated with short-duration extreme price periods occurring due to supply scarcity events. They were not designed to respond to chronically elevated average electricity market prices such as those observed in June 2022.

The Panel considers future administered pricing compensation, or other frameworks should be designed with a proactive view of possible future market and physical risks that could arise in the NEM. Further detail of ongoing changes are provided in Section 2.3 below.

Administered pricing compensation arrangements had only been experienced in limited form before, and so may have not been well understood

Administered pricing compensation is available to cover losses when the APC is applied with the aim of maintaining the incentive for generators to supply during an APP. The large-scale withdrawal of capacity in response to the APP raises the possibility that it was a lack of experience and understanding of the compensation arrangements which weakened this incentive.

The Panel observes that compensation arrangements in the NEM can be considered to be overlapping and potentially complex. Compensation is awarded through the following:

- APC compensation is awarded by the AEMC following an application and review process[24]
- AEMO intervention compensation is awarded based on review by AEMO and its Independent Expert.[25]
- Market suspension compensation is awarded by AEMO calculated based on a formula in clause 3.14.5A of the NER.[26]

The Panel notes that market participants are now more familiar with these arrangements, having observed their operation during and after June 2022, which partially mitigates this issue. The Panel supports consideration being given to commencing a review to determine opportunities for harmonisation and simplification of the compensation frameworks, as this is likely to make them more effective at providing the incentive to supply during any future APP event.

Gas and electricity market price caps are not aligned in energy equivalent terms

The electricity APP and gas market price caps do not have price caps were not aligned in energy equivalent terms during the 2022 APP/market suspension event. The gas market cap of $40/GJ which was imposed in the Declared Wholesale Gas Market (DWGM) and Short Term Trading Market (STTM), resulted in gas generator variable costs which were in many cases above the APC of $300/MWh. This meant many gas generators would incur losses while generating during the June event APP.

23 For more information see https://www.aemc.gov.au/sites/default/files/2022-11/Amending%20the%20administered%20price%20cap%20-%20Final%20Determination.pdf.

24 For more information see https://www.aemc.gov.au/our-work/apc-claims.

25 For more information see https://www.aemc.gov.au/rule-changes/application-compensation-relation-aemo-interventions.

26 For more information see https://www.aemc.gov.au/rule-changes/participant-compensation-following-market-suspension.

The gas market caps and APC are currently set via different processes through different bodies and frameworks. The STTM and DWGM APC is set via arrangements in the NGR and via AEMO Procedures which are both outside the Panel's remit.[27] AEMO's review of the STTM APC also occurs after the Panel's RSS review with gas market caps determined via a set of gas market-related considerations.[28]

There is currently no aligned holistic process that proactively considers risk across the entire fuel/electricity supply chain. The risks associated with international fuel market linkages and geo-political event risk on electricity market frameworks had not been pro-actively considered to inform the early adjustment of NEM arrangements which would have avoided the June event.

The Panel considers that further analysis may be needed to investigate aligning the gas and electricity governance frameworks as well as proactively identifying and managing risks across the whole supply chain.

2.3 Actions in response to this event

The Panel notes that there have been a number of processes, some of which are still underway, to address issues arising from the June APP/market suspension event.

These include the following Panel and AEMC reviews and rule changes:

- *Panel RSS review recommendations* — The Panel's 2022 RSS review recommended increasing the APC from $300/MWh to $500/MWh to prevent undue reliance on compensation during an APP given high fuel price conditions. The Panel also recommended increasing the CPT from its current level of $1,398,100 to $2,193,000 to be progressively phased between 1 July 2025 and 30 June 2028. This increase in the CPT will minimise the chance of high input fuel prices triggering a future APP. [29] The appropriate setting of the CPT will be considered in an upcoming AEMC rule change.
- *AEMC APC rule change* — On 17 November 2022 the AEMC made a final determination to raise the APC from $300/MWh to $600/MWh. The increase came into effect on 1 December 2022 and will apply until 30 June 2025.[30] This rule change reflects a temporary adjustment to the APC prior to a longer-term level. The longer-term level is planned to be applied between 1 July 2025 and 30 June 2028. Inputs to the adjustment will include the Panel's RSS review recommendations. Broader MPC and CPT arrangements are being considered through an upcoming AEMC rule change, that has been submitted by the Panel.
- *Review of the form of the reliability standard and APC* — The Panel is investigating possible longer-term changes to the form of the reliability standard and associated mechanisms. This review will consider different options for future APC including the

27 Rules 224 and 428 of the NGR.

28 Under rule 492 of the NGR, AEMO is required to review the STTM APC no later than six months after the completion of an RSS review and recommend a value that should apply to commence two years after the review is completed.

29 For more information see https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review

30 For more information see https://www.aemc.gov.au/rule-changes/amending-administered-price-cap.

option to dynamically link the level of the APC to gas prices. This review will be commencing shortly.

- *RSS review rule change* — The Panel's RSS review recommendations will be further considered in an AEMC rule change process to commence in 2023. [31]

AEMO has also identified a range of changes in response to learnings from its management of the power system during the APP/market suspension event. These include:

- *Energy adequacy assessment projection (EAAP) review* — AEMO is conducting a review of the EAAP guidelines. A review of the guidelines will assist AEMO to capture different scenarios reflective of the broad range of energy and information-gathering inadequacies the market may face. This includes consideration of fuel and energy quantity data, and regularly updated inputs into PASA metrics. The outcome of this review is expected to prevent some operational challenges from repeating in the future.
- *Gas market parameter review* — AEMO is also conducting a review of gas market prices/parameters as part of its gas market parameter review which has affirmed a $40/GJ gas market cap in the STTM and DWGM.[32] The cap is intended to avoid high prices flowing through to energy. AEMO's final determination is to not make any changes to the gas market parameters.[33]
- *General power system risk review* — AEMO is considering this series of events when developing the scope for the 2023 General Power System Risk Review.[34] Recommendations from the review includes measures to manage and mitigate future power system events.
- *Internal AEMO procedures* — To improve operational outcomes during an APP, AEMO has also indicated an intention to revise its internal procedures to include:
    - A plan for managing the transition to administered pricing when regional cumulative prices reach the CPT
    - Identifying tools and processes needed to cater for energy limitations.

2.4 Panel recommendations

The Panel notes the work that has been completed or is underway to address the reliability issues arising from the June APP/market suspension event. In addition, the Panel makes the following general recommendations:

- Review whether any reforms are required relating to integrating energy limit considerations. The June APP/market suspension event illustrates that energy limits will likely emerge as a material issue prior to significant additional thermal coal retirement

31 For more information see https://www.aemc.gov.au/rule-changes/amendment-market-price-cap-cumulative-price-threshold-and-administered-price-cap.

32 For more information see https://aemo.com.au/consultations/current-and-closed-consultations/gas-market-parameter-review-2022.

33 For more information see https://aemo.com.au/consultations/current-and-closed-consultations/gas-market-parameter-review-2022.

34 For more information see https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/general-power-system-risk-review.

rather than following. Robust operational processes for operating storage under supply scarcity conditions may be beneficial to develop.

- There is merit in considering how gas and electricity governance frameworks could be better aligned including:
  - Reviewing how gas and electricity systems are taken into account in the decisions made in each framework for example, market price caps.
  - Considering whether there would be merit in implementing a process to assess risk across the entire fuel and electricity supply chain, allowing full consideration of gas and electricity-related considerations for each system.
- The Panel supports a future review to determine opportunities for harmonisation and simplification of the compensation frameworks, and incorporate lessons learned from the June event.

3 RELIABILITY

BOX 2: PANEL OBSERVATIONS AND RECOMMENDATIONS

The Panel's assessment in this AMPR indicates that reliability in the NEM will be more challenging in the future than it has been in the past or is currently. The Panel identifies short-term reliability gaps are forecast in all mainland regions and additional challenges are likely in the medium to long-term, particularly if there is a material acceleration in the rate of thermal generator retirements.

The Panel's AMPR assessment identified:

- No breach in either the reliability standard or the interim reliability measure (IRM) for the period 2021-22.
- Near-term reliability in the NEM is expected to remain high given the February 2023 Electricity Statement of Opportunities (ESOO) indicates that levels of USE will be maintained within the reliability standard and interim reliability measure (IRM) on the basis of already committed developments.
- Medium-term reliability in the NEM will rely on significant levels of new investment to address already announced closures. Medium-term reliability risks are associated with the timely delivery of new investments and the potential for early thermal generator retirement. The ESOO forecasts breaches against the reliability standard in New South Wales from 2027-28, Victoria from 2028-29 and Queensland in 2029-30.
- The NEM's long-term reliability performance post-2030 is dependent on having fit-for-purpose frameworks to signal and appropriately incentivise the right level and mix of power system resources for a fundamentally weather-driven power system. The ESOO forecasts the reliability standard will be breached in South Australia in 2030-31.

The Panel notes the role of jurisdictional scheme delivery for addressing the reliability gap in different regions identified in AEMO's ESOO. The Panel's modelling of reliability for its 2022 RSS review identified investment under the NSW Roadmap would help to maintain reliability in NSW following Eraring's closure.

The continued growth in CER also represents an opportunity for the NEM to address future reliability needs. The significant growth in solar PV capacity continues, and while only minimal when compared to solar, 2021-22 saw the highest amount of batteries installed in the NEM since reporting began.

While current reliability performance remains acceptable and within both the IRM and reliability standard, there was a significant increase in low reserve conditions in the NEM during the review year. This significant increase was driven by winter-related reliability risk and may be becoming more attributable to forecast uncertainty than has been the case in previous years. The Panel notes that forecast uncertainty-related reliability risk is likely increasing in the NEM. Forecast uncertainty relates largely to weather-dependent energy such as wind and solar that can have net demand needs that vary significantly from what was signalled to market participants in pre-dispatch information. This is an issue that future AMPRs will consider.

Market price outcomes in the second half of the review year illustrate the circumstances that led to the June market suspension event as a confluence of high commodity prices, domestic market price caps, planned and unplanned outages of scheduled generating plant, low output from semi-scheduled generation, and high winter demand conditions led to unprecedented challenges operating the NEM and the suspension of the market. The Panel has identified the impacts of the Commonwealth imposed wholesale gas market price cap of $12/GJ on electricity market price outcomes as a potential issue for consideration in the next AMPR.

The Panel supports reform to existing NEM arrangements that provide for coordinated transmission and generation investment as the NEM transitions which enhances the long-term interests of consumers while also balancing efficient outcomes with providing appropriate levels of investor certainty.

The Panel will continue to monitor the penetration of CER on system load as it expects the impact to become more pronounced in the future.

A reliable power system has enough generation, demand response, and network capacity to supply consumers with the energy that they demand with a very high degree of confidence. Reliability events on the power system arise when there is a shortage of available generation and network capacity to meet end-user demand and customer load shedding is required.

This chapter sets out trends in, and risks to, the NEM's reliability performance. Reliability performance is considered for the reporting year FY2021-22 as well as on a forward-looking basis considering the new investment required given the timing of incumbent generator retirements.

The following is discussed:

- Current and historic NEM reliability performance
- Forward-looking reliability risks
- Review year reliability events and reserve levels
- AEMO interventions for reliability during the review year
- Market price signals and investment incentives.

This chapter makes reference to NEM frameworks the details of which are explained in the AMPR explanatory statement chapter 3.[35]

35 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

3.1 Current and historic NEM reliability performance

The Panel has considered the NEM's current and historic reliability performance to set out the status of reliability in the review year. The Panel considers:

- Actual levels of USE in the NEM
- Retirement and new entrant investment tracking.

This section sets out the Panel's understanding of the current status of reliability in the NEM to inform its opinion of whether reliability risks are building.

3.1.1 Actual USE in the NEM

The NEM's actual reliability performance is evaluated in terms of the level of unserved energy (USE) in a year and whether the reliability standard was satisfied. USE is the amount of end-user electrical energy (in MWh) for which there is an insufficient generation and inter-regional transmission capacity to supply.[36]

The reliability standard is a measure that expresses the efficient level of USE given the trade-off between the cost of investing in power system resources and the value of customer reliability. The current reliability standard targets a maximum expected USE in a region of 0.002% of the total energy demand in that region for a given year.[37]

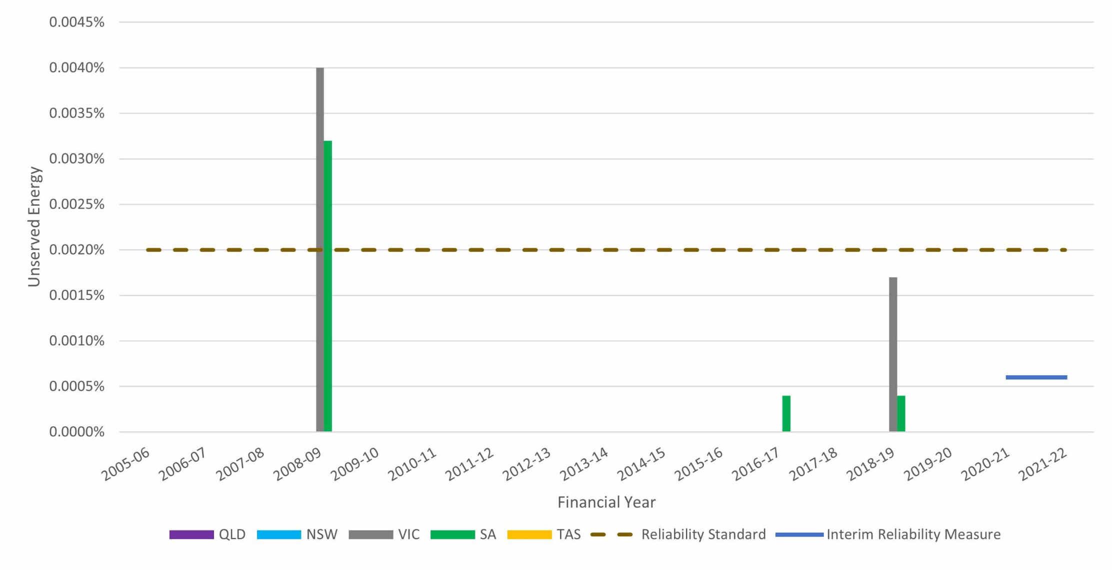
No actual USE was recorded in the NEM over the reporting year FY2021-22. This occurred despite multiple reliability-related events, including the June 2022 event when the supply/demand balance in the NEM was tight.

Figure 3.1 shows the NEM's historic levels of USE since 2005-6, represented as a percentage of total demand in a region, plotted against the reliability standard level. The last USE in the NEM occurred in 2019 in Victoria and South Australia and there was only one year (2008-9) in which the reliability standard was actually breached. This illustrates the historically high levels of reliability experienced in the NEM.

36 Under clause 3.9.3C(b)(2) of the NER, USE excludes power system security incidents caused by an event such as single or multiple non-credible contingency events, multiple credible contingency events, outages of transmission and distribution networks that do not significantly impact the ability to transfer power into the region, industrial action or acts of God.

37 Clause 3.9.3C(a) of the NER.

Figure 3.1: Actual USE



Source: Panel analysis of AEMO data

Stakeholders should note that actual levels of USE do not correspond to the total levels of lost load experienced by end-users.

The USE metric excludes distribution level and security events. For distribution metrics, System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) are used, which measure the number of minutes and average number of times customers experience interruptions respectively.[38]

While historic levels of USE in the NEM have been very low, the NEM is entering a period of heightened reliability risk as the incumbent thermal generating fleet retires. Forward-looking risks to reliability outcomes are discussed in Section 3.2 and considers the risk of higher levels of USE as the transition occurs.

3.1.2 Retirement and new entrant investment tracking

New investment is required to satisfy customer demand given incumbent generating system retirement. This section considers the status of retirement and new investment prior to, and during, the review period.

The Panel uses the trends in retirement and new-entrant investment outlined in this section to inform its understanding of progress in the transition to a high VRE power system. The Panel also considers whether current investment levels are likely to be sufficient on a forward-looking basis.

Retirement during the review period

38 SAIDI and SAIFI charts are provided in Appendix A.4.

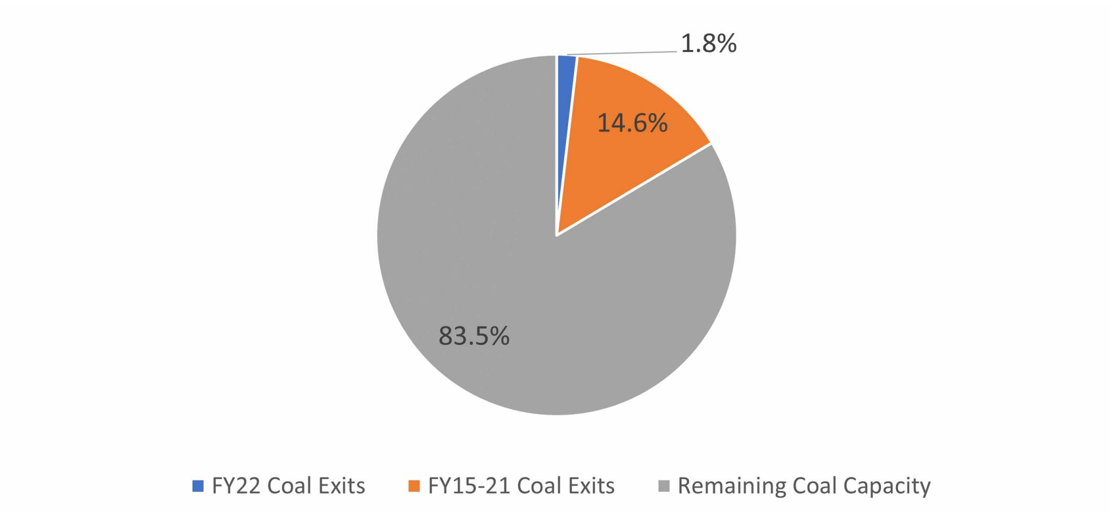
Thermal retirements in the NEM continued during the review period:

- A 500MW coal generator at Liddell Power Station retired
- A 120MW gas turbine at Torrens Island retired
- The 50MW turbine at Hunter Valley GT retired.

The remaining three Liddell units are due to retire in April 2023. Following Liddell, Eraring is the next large coal generator expected to retire in 2025, removing 2880MW of synchronous generation.[39]

The retirements seen during the review period continue the process of incumbent thermal generator retirement in the NEM. Figure 3.2 gives an indication of how far the NEM is through the transition at the end of the review period and shows that retirements in the period represent 1.8% of the incumbent thermal fleet with another 22.7GW still to retire. This indicates that the NEM is still in an early stage of the overall transition process with 83% of the incumbent coal-fired generating fleet yet to retire.

Figure 3.2: Coal Exit Proportions since FY15



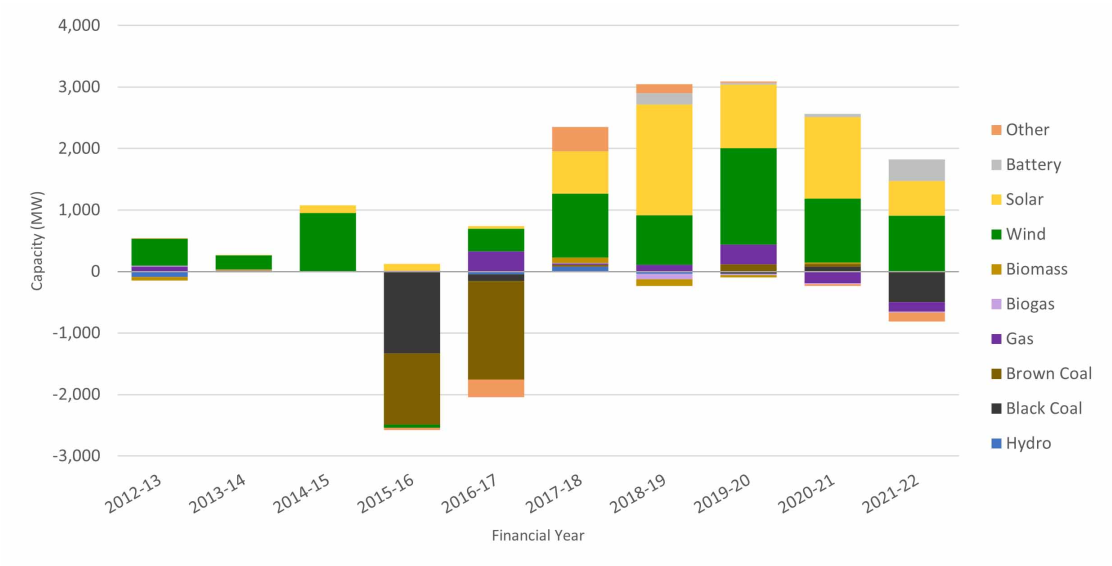
Source: Panel analysis of AEMO data
Note: Quantities are referenced against FY15

New generator entry during the review period

During the review period, 4 GW of new VRE generation entered the NEM. This includes 911 MW of new wind capacity, 562 MW of new grid-scale solar capacity, 350 MW of grid-scale battery capacity, and 2.4 GW of distributed solar capacity. Figure 3.3 shows the technology mix of new utility scale generation investment along with the generation retirement noted in the last section.

39 For more information see https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

Figure 3.3: NEM utility-scale Generator Entry & Exit



Source: Panel analysis of AEMO generator information survey data

Figure 3.3 shows the rate of new connections in the review period has declined from the peak rate observed in 2019-20 of 3,088MW of utility-scale capacity added to the NEM. In comparison, new utility-scale connection capacity in FY2021-22 was 1,824MW a decline of 1,264MW.

The Panel understands the increase in new connections following 2017 was significantly attributable to the financial incentives created by the end of the Commonwealth Renewable Energy Target (RET).[40] The end of the RET brought investment decisions forward as generators expedited development to capture the incentives. The decline in new connections observed in the review year therefore represents a natural lull associated with the generation investment brought forward.[41]

The Panel however identifies this decrease in new grid-connected investment as a risk for future reliability outcomes if sustained. The Panel identifies the rate of new connections should be monitored closely in future AMPRs and makes observations and recommendations on influential factors in further sections.

New project pipeline

40 The RET refers to the Commonwealth's scheme to reduce emissions by form of renewable energy certificates bought by energy retailers. For more information, see https://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target.

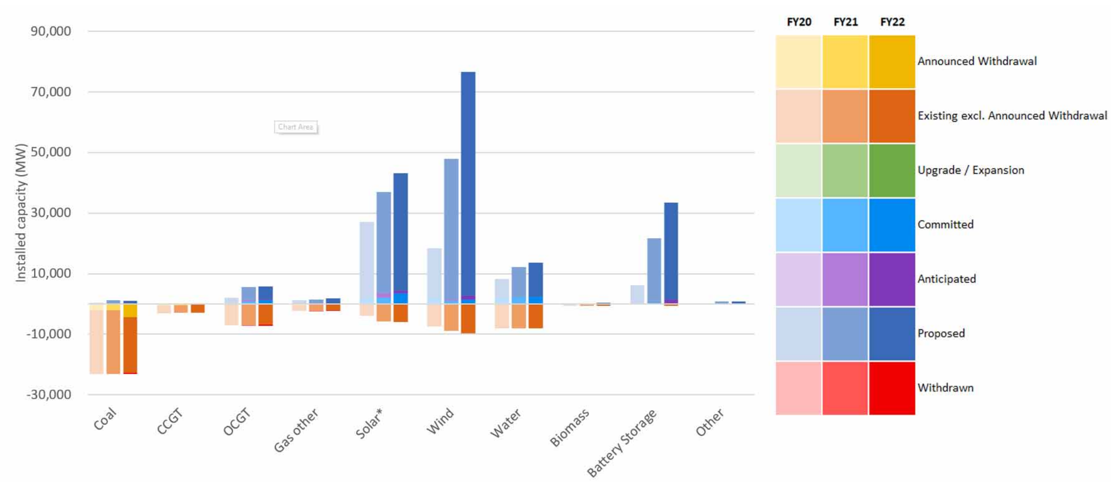
41 The scheme encouraged investment in large-scale renewable power stations to achieve 33,000 gigawatt hours of additional renewable electricity generation by 2020.

The pipeline of generation developments at various stages of connection is healthy, which is a positive indicator for future reliability. New generators can either be proposed, anticipated, or committed. A new generator is considered committed if it meets AEMO's five criteria.[42]

Figure 3.4 shows the generation project life cycle status (including retirements and committed, anticipated, and proposed new investment) and how this has evolved over the last three calendar years. This indicates the very healthy level of proposed solar, wind, and battery projects in the NEM that have yet to achieve anticipated or committed status. The project pipelines for wind and new battery development are observed to have grown since the last AMPR.

This pipeline suggests the lull in new connections observed during the review year may not be a sustained phenomenon that threatens future reliability. The extent to which the very large quantum of proposed projects transition to anticipated and committed status however will be monitored in future AMPRs.

Figure 3.4: Changes in Planned Generation



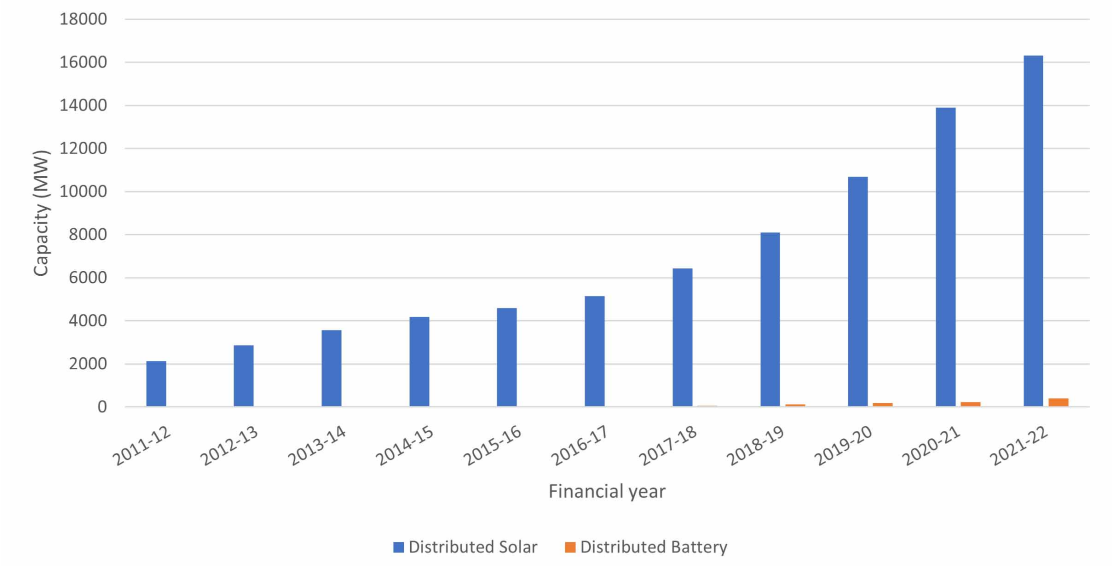
Source: Panel analysis of AEMO generator information survey data
Note: Positive figures represent the pipeline yet to be connected into the NEM. Solar excludes distributed (rooftop) solar installations

New Consumer Energy Resource connections

CER connections continued to grow strongly during the review period. Figure 3.5 shows the rate of behind the meter PV installation continuing the rate of growth observed since 2018-19 with a 17.5% increase since the last AMPR corresponding to an additional 2,430 MW of distributed PV over the review period.

42 AEMO considers a project to be committed if it has: acquired lease agreements, contracts for equipment supply, planning and other approvals, project finance and construction contracts in place. For more information see https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information

Figure 3.5: Installed CER Capacity



Source: Panel analysis of CEC installation data

The continued growth in CER also represents an opportunity for the NEM to address future reliability needs. The significance of the continuing growth in distributed solar is illustrated by AEMO's Integrated System Plan (ISP) step change projections that anticipate the additional DER capacity added to the NEM in 2034 will exceed new scheduled and semi-scheduled renewable capacity.[43]

The extent to which CER will contribute to future reliability outcomes will also depend on how that CER is beneficially integrated into the NEM including:

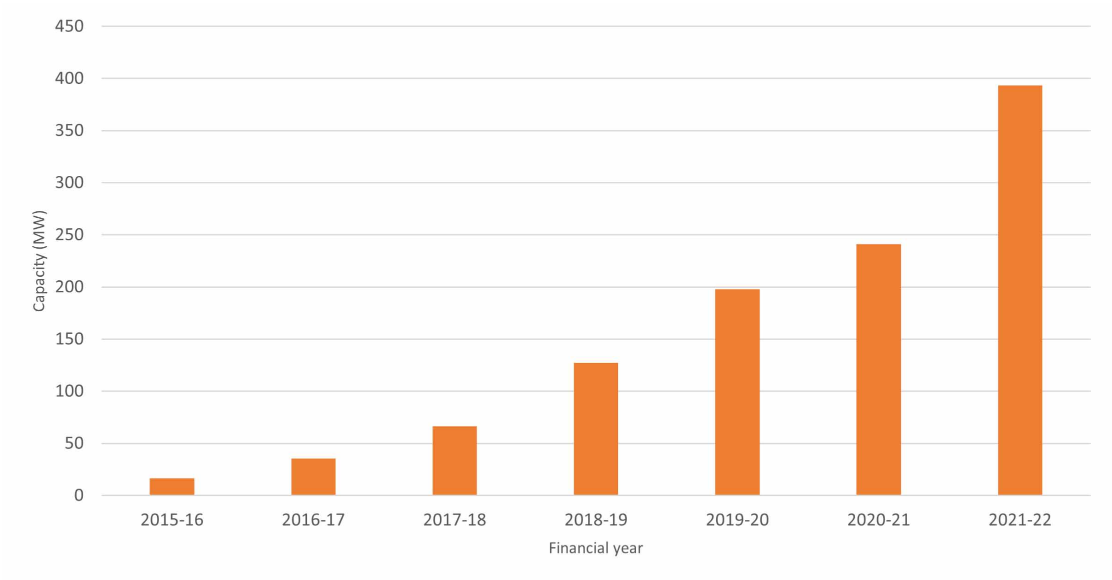
- Effects on minimum system demand and the associated system security issues
- Uptake of VPP and other forms of market participation
- Development of high CER penetration related system operating practices
- Implementation of CER related technical standards.

Figure 3.6 shows that distributed battery installation also increased 63% (241 MW to 393 MW) over the review period. While still only a fraction of installed PV capacity, the growth in distributed battery installation over the review period represents a substantial acceleration over the rate of growth seen prior to the review year and is the highest increase since the CEC's installation data began.

The Panel will continue to monitor the impact of CER on system load as it expects the impact to become more pronounced in the future.

43 For more information on AEMO's ISP see https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp

Figure 3.6: NEM Installed Distributed Battery Capacity



Source: Panel analysis of CEC installation data

3.2 Forward-looking reliability risks

The NEM's reliability performance to date reflects the historic investments made in thermal coal-fired power stations that still form the bulk of the NEM generating fleet. These generators connected in the 1970-80s and are approaching the end of their technical and commercial lives. Future reliability performance will depend on sufficient investment to address generator retirements and load growth.

Future reliability performance relies on new investment that is sufficient to replace the energy delivered by retiring generators and to meet load growth while still providing a sufficient reserve margin to manage power system security. Insufficient investment in generation and demand response capacity will increase USE beyond the level required by the reliability standard.

This section considers risk to reliability outcomes given retirement and new investment timing on a forward-looking basis. The Panel uses the risks identified here to inform its work program on NEM reliability. This chapter presents:

- Forward-looking retirement expectations and timing
- Reliability gap timing in different NEM regions as indicated by AEMO's February 2023 Update to the ESOO analysis
- The Panel's identified risks and recommendations on future reliability outcomes.

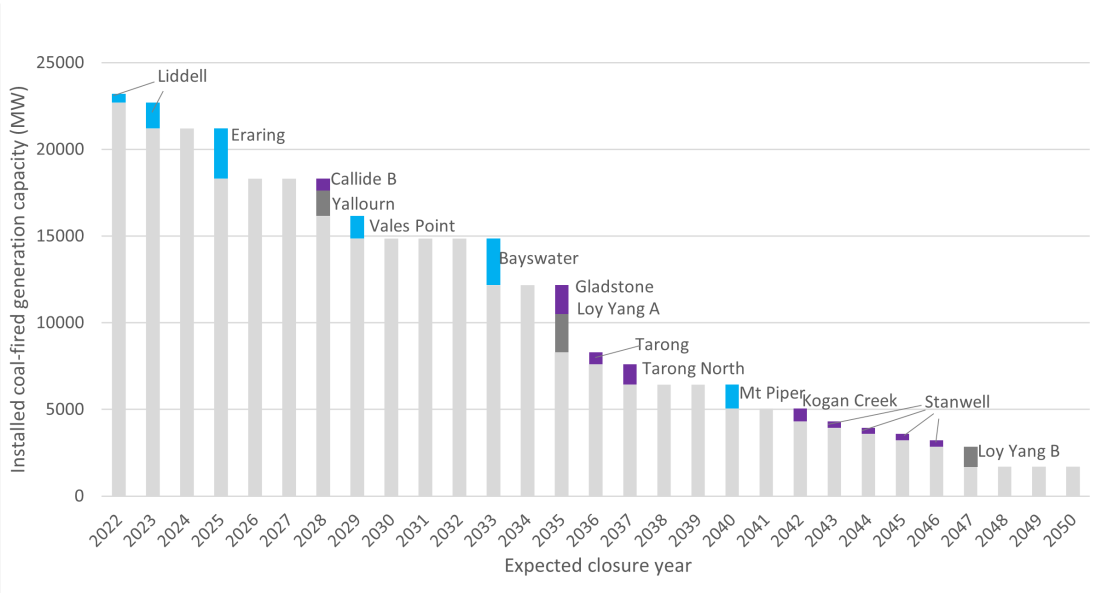
3.2.1 Retirement timing

As mentioned, the retirement of large coal-based generators signals a challenge for investment to fill the gap to maintain sufficient reliability. This section considers:

- The anticipated progress of thermal generator retirement in the NEM, based on currently announced retirement dates
- Risks to reliability from the early retirement of thermal generators as well as the deterioration in their performance as they approach retirement.

The process of thermal generator retirement is shown in Figure 3.7 on the basis of currently announced timing and indicates that 7,650 MW of dispatchable capacity is expected to retire by 2030 with 15,065 MW by 2040. The Panel notes that the Figure 3.7 does not take into account potentially earlier retirements, for example due to the impact of state government policies such as the QLD Energy and Jobs Plan.[44] By 2050, it is anticipated there will only be two coal power stations in a NEM.

Figure 3.7: Announced Coal Closures



Source: Panel analysis of AEMO data

The speed of retirements is not limited to the retirement dates as currently announced. The thermal generating fleet is ageing and progressively being displaced in dispatch by lower-cost, new entrant renewable generation. This results in declining revenue to support ongoing and periodic maintenance required to keep the generator in service to the end of its technical life. Retirement dates are therefore being advanced due to commercial as well as technical factors.

44 The QLD Energy and Jobs Plan notes all publicly owned coal-fired power stations as clean energy hubs by 2035. For more information see https://www.epw.qld.gov.au/energyandjobsplan

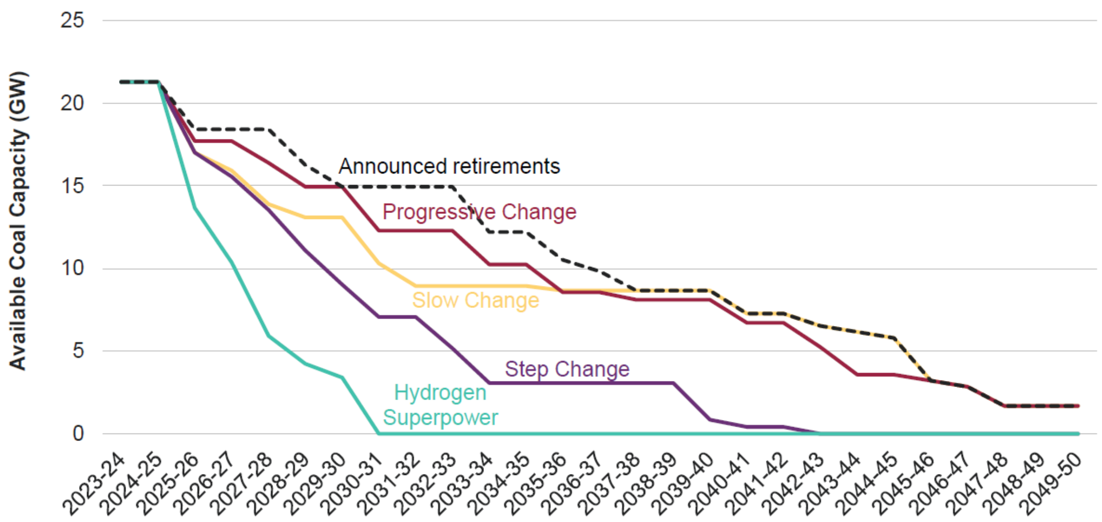
As an example, the following retirement decisions have been brought forward since the last AMPR:

- Torrens Island B Unit 1 will be mothballed until September 2024
- Loy Yang A closure was brought forward to 2035 from 2045.

A more complete list of early closure announcements is provided in Appendix B.6.

Figure 3.8 from AEMO's ISP indicates the risk of further acceleration in the rate of thermal generation retirements. No ISP scenario indicates a slower rate of thermal retirement anticipated that is currently announced. Under the ISP's step change scenario, an additional 5GW of coal-fired thermal generation is identified as closing relative to current announcements.

Figure 3.8: AEMO's ISP Forecast Coal Retirements



Source: Panel analysis of AEMO data

AEMO's ISP retirements incorporate the effects of possible future carbon budgets and carbon policy. Further details on AEMO's treatment of carbon budgets in modelling retirement in the ISP is provided in Section 2.2 of AEMO's 2022 ISP. The AEMC, through its Transmission Planning and Investment Review (TPIR), is also investigating how to incorporate carbon into the ISP going forward, with a final report expected in 2023.[45]

In addition to risk of accelerated retirement, the performance of thermal generators is likely to decline with more forced outages expected as generators approach the end of their technical lives.

Accelerated closure of large synchronous generators brings with it the further risk of a reliability shortfall if insufficient replacement generation is ready. Therefore, there is a challenge to determine the appropriate timing of replacement generation considering the

45 For more information visit https://www.aemc.gov.au/market-reviews-advice/transmission-planning-and-investment-review.

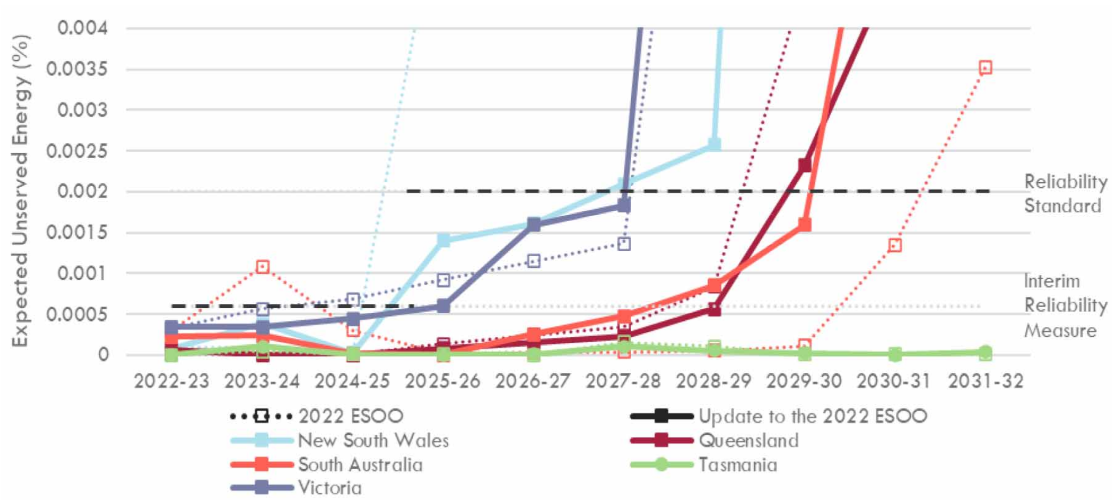
lead time of project development. The Panel notes the role of jurisdictional schemes in supporting new investment given this level of uncertainty. The Panel discusses the role of jurisdictional schemes further in Section 3.2.3.

3.2.2 Reliability gap requiring future investment

This section considers the future reliability gap created by currently announced thermal generator retirements.

This gap is annually forecast by AEMO in its ESOO report. The ESOO signals opportunities for new investment by indicating when USE is likely to exceed the reliability standard if new investment is limited to that already committed.[46] AEMO's ESOO assessment is not a forecast and should be interpreted as indicating worst-case reliability outcomes as the very large amount of new investment in the pipeline shown in Figure 3.9 is excluded from consideration within the ESOO.

Figure 3.9: Expected Unserved Energy - February 2023 Update to the 2022 ESOO



Source: AEMO's February 2023 Update to the 2022 ESOO

The Panel makes the following key observations from AEMO's February 2023 ESOO assessment.[47]

- New South Wales is expected to breach the reliability standard in 2027-28 following Eraring power station closure but delayed following the commitment of the Waratah Super Battery.[48]
- Victoria is expected to breach the reliability standard in 2028-29 following the closure of the Yallourn power station.

46 AEMO's ESOO also reports on USE outcomes which consider both committed and anticipated developments.

47 Note these observations are made in the absence commitments from any new investment.

48 While delays in commissioning to Kurri Kurri and Snowy 2.0 are forecast to marginally increase expected USE in the short term, NSW reliability performance will remain within both the IRM and Standard prior to 2025.

- Queensland is expected to breach the reliability standard in 2029-30 following the Callide B Power Station closure in Queensland and Vales Point Power Station closure in New South Wales, which will limit northward power flows across QNI to support Queensland reliability.
- South Australia is expected to breach the reliability standard from 2030-31 when numerous small gas generators are expected to retire.

As noted, AEMO's ESOO is a projection and not a forecast and so it does not capture the entire quantum of investment expected to address retirements. The Panel particularly notes that a significant amount of future investment is expected to be supported by state government schemes, such as the New South Wales Electricity Infrastructure Roadmap (NSW Roadmap).[49] Such investment has yet to achieve committed status and is therefore excluded from consideration in AEMO's ESOO.

The Panel's 2022 RSSR base case[50] identified the initial capacity under the NSW Roadmap (3 GW) in 2026 is not a one-to-one replacement for Eraring power station. This resulted in a small uplift in the expected USE, however by 2028, it is forecasted there is sufficient capacity (7 GW) to replace Eraring power station, resulting in a decrease in expected USE to 0.0003%. This outcome differed from the ESOO (in which a breach of the reliability standard was forecast following Eraring's closure) as the RSSR base case, in contrast to the ESOO, considers all investments under state government programs, including the full expected investment under the NSW Roadmap.

The Panel did not model the contribution to reliability from the other announced state government schemes and notes that some are more developed than others, but considers it likely these may also contribute to addressing the reliability gap identified in the ESOO, at least in the medium term, along with other investment occurring. The Panel considers future AMPRs should monitor the delivery of new investment through such schemes which are summarised below:

- In New South Wales, an expansion of the Snowy Mountains Hydroelectric Scheme, known as Snowy 2.0, is expected provide 6,100 MW of fast-start dispatchable generation capacity.[51]
- The Victorian renewable energy target is to achieve 50% of electricity to come from renewable sources by 2030. These include reviving the State Electricity Commission (SEC), with government commitments across clean energy, solar homes, state renewable energy, innovation, hydrogen and wind.[52]
- The Queensland renewable energy target includes capacity targets: 25 GW VRE (22 GW new) by 2035 including 7 GW pumped hydro, 3 GW low emissions gas generation, and 11 GW rooftop solar, 6 GW home and business batteries.[53]

49 The Roadmap is a plan to achieving a capacity of at least 12GW of renewable energy generation, and 2GW of long-duration storage by 2030. For more information, see https://www.energyco.nsw.gov.au/about-energyco/electricity-infrastructure-roadmap.

50 For more information see https://www.aemc.gov.au/sites/default/files/2022-09/2022%20RSS%20Review%20Final%20Report%20%281%29.pdf.

51 For more information see https://www.snowyhydro.com.au/snowy-20/about.

52 For more information see https://www.energy.vic.gov.au/renewable-energy/a-clean-energy-future.

53 For more information,see https://www.qld.gov.au/about/newsroom/queensland-energy-and-jobs-plan.

- Tasmanian Renewable Energy Action Plan to produce 200% renewable energy by 2040 double existing renewable capacity to 8GW by 2035.[54]
- The South Australian renewable energy target is to achieve 100% net renewables by 2030.[55]

Complementing these schemes is a range of initiatives to develop Renewable Energy Zones to provide connection opportunities supporting new investment.

3.2.3 Panel observations on risks to future reliability performance

The NEM has historically experienced very high levels of reliability.[56] The NEM is however entering a more challenging period from a reliability perspective. This section provides the Panel's observations on key issues and risks to the NEM's future reliability performance.

- **Near-term reliability in the NEM is expected to remain high**. The slowdown in investment during the review year identified in Section 3.1.2 is not expected to compromise near-term reliability outcomes (to 2025) given the ESOO indicates that levels of USE will be maintained within the reliability standard and IRM on the basis of already committed developments.
- **Medium-term reliability in the NEM will rely on significant levels of new investment to address already announced closures**. Medium-term reliability (to 2030) will be reliant on the delivery of significant levels of new investment to address already announced closures. This investment will be in part supported through state and commonwealth government schemes, the delivery of which will be important to medium-term reliability outcomes. Medium-term reliability risks are associated with the timely delivery of new investments and the potential for early thermal generator retirement.
- **The NEM's long-term reliability performance post-2030 is dependent on having fit-for-purpose frameworks to signal the right level and mix of power system resources.** Reliability uncertainty is not limited to the timing of thermal retirements and new investments but also involves the type of investment required to address risk in a high VRE power system that is more reliant on energy-limited storage for reliability outcomes. Fit-for-purpose frameworks will be required to signal and appropriately incentivise the right level and mix of power system resources for a fundamentally weather-driven power system.

The Panel considers the pipeline of proposed generation projects in the NEM will be sufficient to provide for acceptable short and medium-term reliability outcomes in the NEM. There is large interest in new renewable energy developments. Future reliability outcomes however rely on a sufficient number of these projects proceeding to committed status, and ultimately connecting to the NEM. The Panel identifies a set of factors that it considers will be important for the timely progression of these projects including:

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54 For more information see https://www.premier.tas.gov.au/site_resources_2015/additional_releases/renewable_energy_target_to_deliver_for_tasmania.

55 For more information see https://www.safa.sa.gov.au/environmental-s-governance/energy.

56 Please note that the Panel monitors reliability with regard to the value of customer reliability (VCR). The VCR balances the need to deliver secure and reliable electricity supplies and maintain reasonable costs for electricity consumers.

- **Ability to secure system parts and components in a supply-constrained global manufacturing supply chain**. International energy development support programs in the US and Europe[57] are strongly subsidising renewable energy investment which is expected to place further pressure on global equipment supply chains possibly leading to equipment delivery delays.
- **Sufficient physical connection opportunities**. The development of additional network capacity in areas with high-quality renewable resources such as, but not limited to, declared Renewable Energy Zones will be critical to supporting additional large-scale investment in the medium term. This includes sufficient system security-related investments in system strength and other system services. Slow development and deployment of necessary investments may create a barrier to sufficient medium-term investment.
- **A connection process that provides investor confidence**. Negotiating technical performance standards and other connection-related negotiations can introduce risk that is significant to the project investment case. The challenges of negotiating technical performance requirements can be challenging in an environment with rapidly changing physical power system characteristics and numerous generators seeking to connect in proximity. The Panel notes that AEMO and the renewable energy industry are seeking to address these issues through the Connections Reform Initiatives (CRI).[58]
- **Jurisdictional support schemes that are designed to maximise transparency and private investment opportunities.** Transparency in government scheme operation and support that focuses on enabling investment will maximise investor confidence.

The Panel is currently considering longer-term reliability risk through its upcoming review of the form of the reliability standard. This review is considering whether the existing form of the reliability standard is fit-for-purpose in a future NEM given its transition from a primarily capacity-limited thermal power system to a more energy-limited high VRE power system. This review will specifically consider new reliability risks from a range of sources including energy storage limits and the potential for extended low VRE (dark doldrum) events. A significant challenge in a low carbon high VRE NEM will be to signal appropriate investment levels of capacity and storage resources with sufficient durations. These resources are needed to limit USE from extended low VRE events and return the system to efficient levels.

This review arises out of a recommendation made in the Panel's final 2022 RSS review report.[59]

3.3 NEM Reserve level events and constraint impacts

Reliability events occur when there is insufficient generation response, demand response, or interconnector capacity to meet consumer demand leading to USE. In addition to reliability

57 Such as those associated with the Inflation Reduction Act in the United States and the Green Deal Industrial Plan in Europe.

58 For more information, see https://aemo.com.au/consultations/industry-forums-and-working-groups/list-of-industry-forums-and-working-groups/connections-reform-initiative.

59 For more information see https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review.

events involving USE, low reserve levels can also indicate periods of reliability stress that, while being short of USE, signals building reliability risk.[60] Further, constraints reflect the physical capabilities of the system, which impact the amount of dispatchable reliability at a given time.

This section considers NEM reliability events and reserve-level outcomes. It includes the following:

- LOR notices and low reserve periods during the review period
- NEM constraint impacts.

3.3.1 LOR notices and low reserve conditions

AEMO provides advanced warning to the market of reliability issues on operational timescales by forecasting and then declaring actual LOR conditions. LOR notices are published to elicit a market response to address a possible reliability issue prior to AEMO intervening in the market to maintain reliability.[61]

As noted in Section 3.1.1, there were no USE events in 2021-22.[62] While there were no actual LOR 3 events during 2021-22, there were sustained periods of reliability risks as reflected by a large quantity of actual LOR 1 and LOR 2 notices with LOR 3 (load shedding) forecast on several occasions.

The number of LOR notices in each year since 2008-9 is shown in Figure 3.10. LOR notices issued in June 2022 have been removed from this figure to indicate underlying trends.[63]

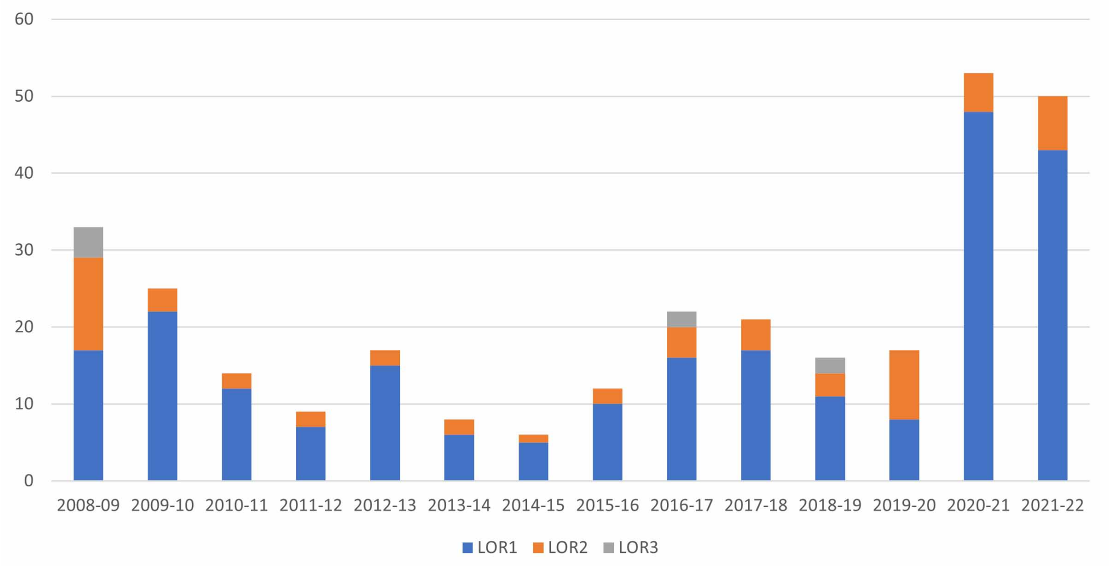
60 Market reserve levels refer to the amount of spare capacity available given the amount of generation, demand and demand response at any point in time. The reserve level represents the amount of generation available to the NEM, however has not been dispatched. For more information see chapter 3 of the explanatory statement https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

61 See clause 4.8.4 of the NER and chapter 3 of the AMPR explanatory statement.

62 These conditions in the system are also referred to as a LOR 3.

63 Detail of the June market suspension event is discussed in Chapter 2.

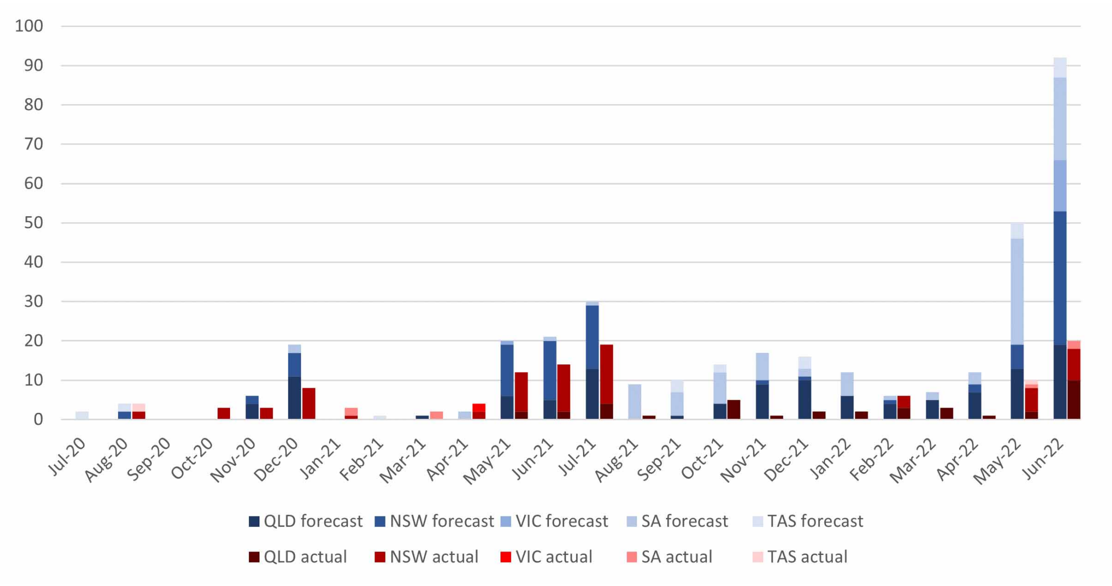
Figure 3.10: Number of Actual LOR Notices



Source: Panel analysis of AEMO data
Note: 2021-22 data excludes June-22 notices

There were 50 actual LOR notices issued in 2021-22. This included 43 LOR 1 and 7 LOR 2 notices. This represents a significant increase from historically observed levels of LOR conditions in the NEM. The Panel however notes this significant increase in LOR 1 and LOR 2 conditions has not translated to a corresponding increase in actual reliability events indicated by LOR 3 notices. While this suggests the market is responding to avoid the need for load shedding, the Panel also considers LOR notice trends signal the changing risk profile of the system.

Figure 3.11: Number of LOR Notices by Month (FY21, FY22)



Source: Panel analysis of AEMO data

Figure 3.11 shows the number of LOR notices by month which indicates a relative dominance of reliability risk during winter rather than summer, in particular in New South Wales, and a relatively limited number of forecast LOR conditions that become actual conditions. This result may be a function of the relatively cool summers that have been experienced over the last 3 years as well as changing underlying reliability risk drivers associated with forecast uncertainty.[64] LOR 1 and 2 notices can be triggered by either capacity reserve margin declining below the largest 1 or 2 credible risks, or forecast uncertainty (assessed under the 'forecast uncertainty measure', otherwise known as the FUM) rising beyond acceptable thresholds. The FUM assesses the impact of forecast uncertainty on reliability risk and is used in conjunction with the largest and second largest contingency in the NEM to determine LOR 1 and LOR 2 triggers.[65]

3.3.2 NEM constraints

The NEM is maintained in a secure state through the use of constraints within the national electricity market dispatch engine (NEMDE). Constraint inputs to NEMDE ensures market solutions are within the physical capabilities of the system and prevent vulnerability of supply disruptions in response to a credible contingency. Constraints are broadly grouped into types

64 Historically, changes in net demand have been relatively easy to foresee. Underlying demand has been largely predictable and the proportion of VRE generation was relatively smaller than today. However, as more VRE generation enters the system, forecasts of net demand will be subject to greater uncertainty. VRE generation, particularly from large-scale wind and solar, is weather dependent and can vary significantly from the net demand needs that were signalled to market participants in pre-dispatch information.

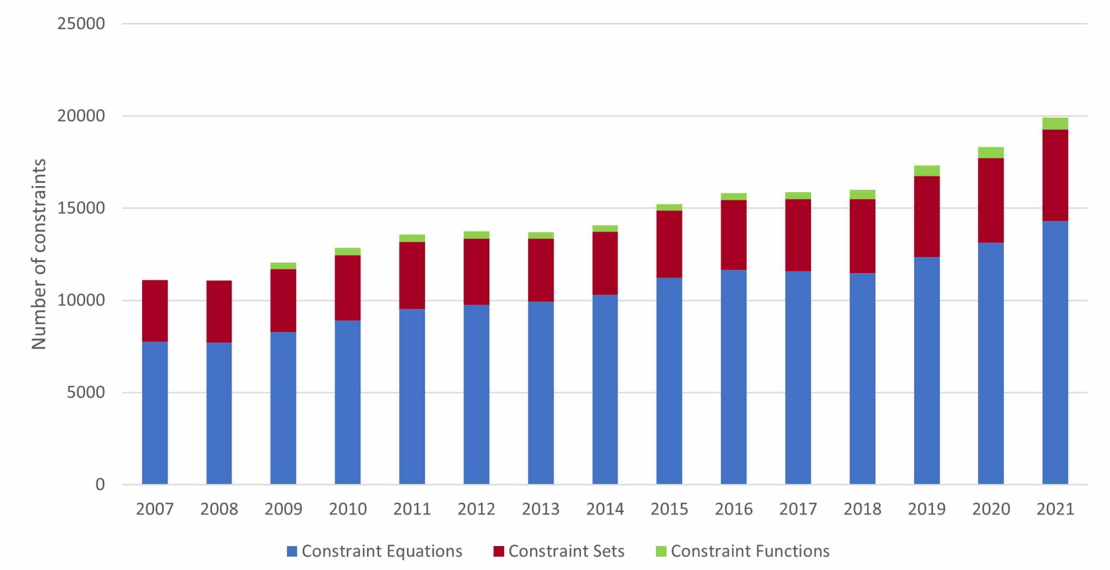
65 The FUM utilises a Bayesian belief network to convert forecast uncertainty to a MW level of reliability risk. More information can be found in AEMO's reserve level declaration guidelines: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Reserve-Level-Declaration-Guidelines.pdf.

such as voltage stability, thermal, network support, and others. When a constraint becomes the limiting factor to power flow, it is considered binding.[66]

Under regular operation, in congested areas, generation is curtailed based on network constraints. Constraints limit the amount of power that can be transferred between generation and load centres and also between regions of the NEM. An example is when voltage stability constraints affect the limits on interconnectors. Some top New South Wales constraints impact interconnector flows between regions.[67]

Figure 3.12 shows the total number of constraints in the NEM is increasing with 19,911 active in 2021 up from 18,318 in 2020, and 17,323 in 2019. The total number of constraints has been trending up over the last decade.[68] This increase is attributable to a more complex NEM. As the power system transitions from one dominated by a small number of large synchronous generating systems, located in areas with strong transmission connections, to a system dominated by inverter-connected renewable generators connecting in weaker parts of the network, the number of constraint changes is likely to increase to reflect this complexity.

Figure 3.12: Total Number of Constraints



Source: AEMO's NEM Constraint Report 2021 summary data

In addition to a more constrained NEM, constraints are binding more frequently, including under system normal conditions. This indicates more network congestion. This increase in

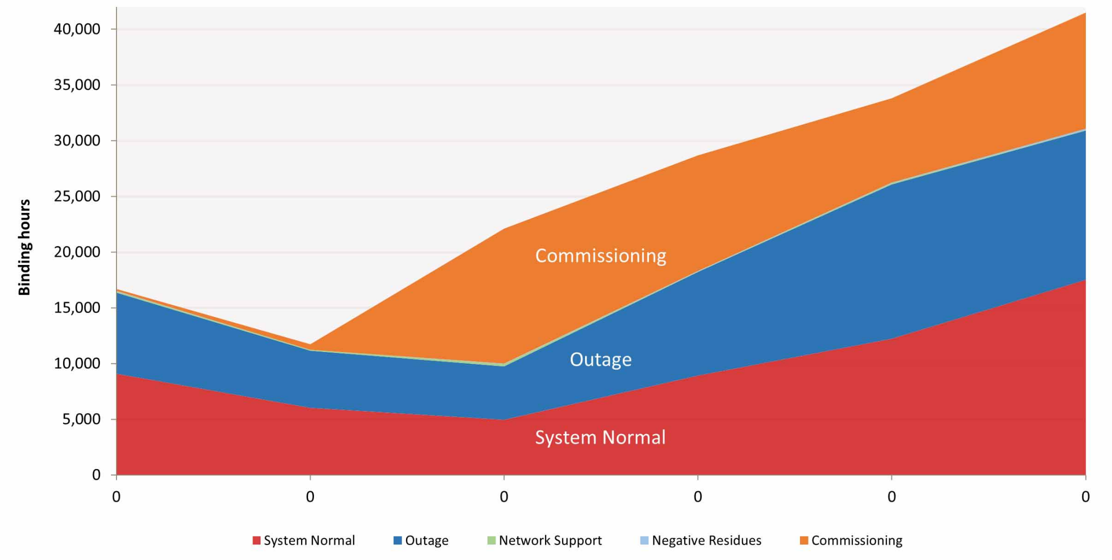
66 Network constraints are derived from TNSP advice to AEMO about the technical limits of plant and are used by AEMO in the NEM dispatch process.

67 For more information, see https://www.transgrid.com.au/media/jn4klv4s/tgr12164-tapr-2022-v5-4-final.pdf or AEMO's NEM Constraint Report 2021.

68 Constraint equations are changed or added to for a number of reasons including: new advice from the TNSP; an item of plant (such as a generator) was commissioned or decommissioned; adjustments were made to improve the performance of the constraint equation; power system studies identified a new condition that needs to be managed by a constraint equation; a new FCAS requirement was identified.

congestion is associated with VRE generation connecting outside of traditional generation centres to take advantage of quality renewable resources.[69] Multiple renewable generators also seek to connect in regions with quality renewable resources. The development of multiple projects in proximity adds to congestion and often requires AEMO to perform curtailment. An example of this is New South Wales' Parkes-Orange-Molong area which currently experiences thermal constraints with potential further connections.

Figure 3.13: Binding Hours of System Normal and Outage Constraints



Source: AEMO's NEM Constraint Report 2021 summary data

Figure 3.13 indicates the increasingly constrained nature of the NEM by showing the number of binding constraint hours in the NEM since 2016. The Panel notes the increasingly constrained nature of the NEM and that a significant amount of work is underway on the NEM's transmission access and pricing arrangements, as well as work to develop frameworks for delivering future transmission capacity. The work includes:

- The ESB's transmission access reform workstream. On 24 February, Ministers agreed a way forward on the complex issue of transmission access reform, with Ministers requesting the Energy Security Board (ESB) to work with Senior Officials and stakeholders to develop the voluntary Congestion Relief Market (CRM) and the priority access model and to bring forward a detailed design for consideration by the Energy and Climate Change Ministerial Council (ECMC) in mid-2023. Ministers decided not to further develop or consider the congestion management model and congestion fee options, ruling out any models using locational marginal pricing.[70]

69 Good geographical renewable resource quality does not always correspond to areas of the network with sufficient transmission or system strength.

70 For more information see https://esb-post2025-market-design.aemc.gov.au/transmission-and-access.

- The AEMC's review on transmission planning and investment which is considering multiple issues relating to the planning and delivery of transmission infrastructure goes to the overarching objective of obtaining the right balance between time and efficiency to support the transition to net zero.[71]

The Panel supports the ongoing work considering enhancements to existing arrangements that provide for coordinated transmission and generation investment as the NEM transitions. Such arrangements should enhance the long-term interests of consumers while also balancing efficient outcomes with providing appropriate levels of investor certainty.

3.4 AEMO interventions for reliability and RERT

The NEM's reliability framework is based on market prices providing incentives for investment supporting efficient reliability outcomes. AEMO also publishes significant levels of information to inform market operational and investment decisions that support reliability. As effective as information processes and market incentives can be in delivering the desired reliability outcomes, they may not always deliver the required outcome. If the market fails to respond to the financial market incentives and the information AEMO publishes, AEMO may have no other choice but to intervene in the market more directly. Under the NER, the intervention mechanisms to maintain the power system in a reliable state are through the use of the RERT.[72] [73]

This section considers AEMO's reliability interventions during the review period including:

- RERT activation and procurement
- AEMO's use of reliability directions.

AEMO issued instructions in response to forecast LOR 3 conditions to prevent load-shedding during the review period.

3.4.1 Reliability and emergency reserve trader

The RERT is an intervention function to manage reliability shortfalls and limit USE. AEMO procures RERT from out-of-market generation and demand response resources to manage circumstances where the market has not delivered reliability outcomes consistent with the reliability standard or IRM.[74]

RERT was utilised five times in the review period. Once in February 2022 and four times to manage the June 2022 APP/market suspension event, the details of which are summarised in Table 3.1.

71 For more information see https://www.aemc.gov.au/market-reviews-advice/transmission-planning-and-investment-review.

72 See rule 3.20 of the NER and clause 4.8.9 directions and instructions.

73 AEMO also take a range of additional measures to address reliability issues including deferring network maintenance; intervening in the fuel supply chain; bringing reactive and other network assets back into service.

74 Further explanation of the RERT and reliability directions is provided in the AMPR explanatory statement in chapter 3 https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

Table 3.1: FY22 RERT Uses

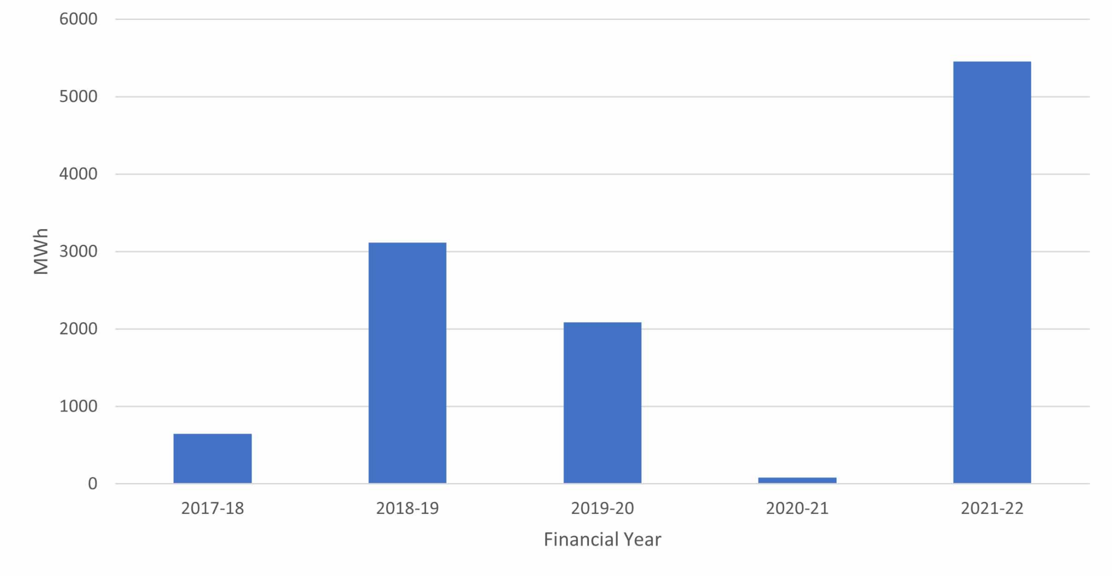
DATE	RE-GIO N	QUANTITY	DETAIL
1-Feb-22	QLD	323MW, 1415MWh	Dispatched in response to LOR 2 and LOR 3 conditions (hot weather in QLD coupled with generator outages led to a reliability shortfall. RERT resulted in temporarily lifting environmental caps).
14-Jun-22	NSW	300MW, 900MWh	June event: Dispatched in response to a forecast LOR 3 condition.
15-June-22	NSW	489MW, 1483MWh	June event: Dispatched in response to a forecast LOR 3 condition.
15-June-22	QLD	51MW, 241MWh	June event: Dispatched in response to forecast LOR 2 and LOR 3 conditions.
17-June-22	NSW	463MW, 1417MWh	June event: Dispatched in response to a forecast LOR 2 condition, later increased by 200MW

Source: AEMO NEM Event — Directions Report 1 February 2022 (https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/market_event_reports/2022/nem-event-direction-to-queensland-generators-1-february-2022.pdf?la=en) and AEMO NEM market suspension and operational challenges in June 2022 (https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/market_event_reports/2022/nem-market-suspension-and-operational-challenges-in-june-2022.pdf

The amount of RERT activated in the review period was a record for the NEM although RERT was only activated once outside the June market suspension/APP period. This occurred in Queensland in February 2022 and was caused by increased demand driven by hot and humid weather conditions, and generator outages resulting in insufficient reserves. Activation in June was during the market suspension event.[75]

75 For more information on the June events see Chapter 2.

Figure 3.14: RERT Reserves Activated



Source: Panel analysis of AEMO data

The RERT guidelines specify three types of RERT based on how much time AEMO has in which to procure the RERT prior to the projected reserve shortfall occurring:

- Long-notice RERT – At least ten weeks' notice of a projected reserve shortfall.
- Medium-notice RERT – Between one and ten weeks' notice of a projected reserve shortfall
- Short-notice RERT – Between three hours and seven days' notice of a projected reserve shortfall.

AEMO has not forecast any reliability gap relative to the IRM or reliability standard in the next three years and has therefore not entered into any new long-notice RERT contracts in the review period. The Panel has observed a trend of increased use of short notice RERT and direction by AEMO. However, net of the June event, there is no clear trend of RERT activated.[76]

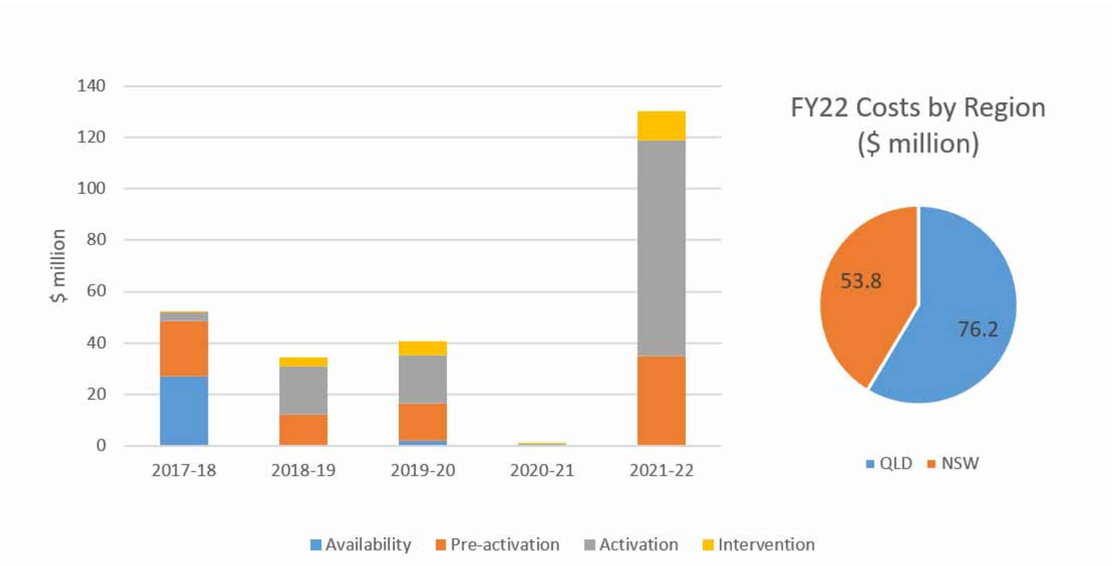
RERT Costs

RERT is procured as an out-of-market resource with costs that generally lie between the market price cap and the value of customer reliability. RERT is therefore a more expensive option for reliability than energy provided through the market with consequentially higher costs for consumers and is therefore treated as a last resort option.

76 Although, this does not discount the learnings from the June event, particularly signals around energy limitations within the NEM and internationally linked fuel markets.

Figure 3.15 shows RERT costs in each year since 2017-18. Total costs in the review year was $130,079,017 which represents a significant increase on historic levels which can be attributed to dispatch during the June APP/market suspension event.

Figure 3.15: RERT Costs



Source: Panel analysis of AEMO data

The average MWh cost of RERT during the review year was $22,500/MWh. The Panel notes that care should be taken when comparing RERT activation costs with energy costs or the value of customer reliability. This is because the activation of RERT does not necessarily avoid system outcomes such as load shedding. Rather, RERT is used to ensure appropriate reserve buffers to reduce the probability that load shedding could result from reliability or security events.[77]

No clear RERT cost trends are noted when measuring costs in the financial year on a $/MWh basis. The $/MWh cost of RERT is highly variable with costs per event presented in AEMO's RERT reporting.[78]

3.4.2 AEMO directions for reliability

In addition to RERT, AEMO is also able to direct participants to maintain reliability. Reliability directions are issued to maintain the power system in a reliable operating state. Historically, AEMO has rarely used directions to manage reliability-related events. Over the last five years, the vast majority (99%) of directions have been issued for security-related events.

Reliability directions are not frequently used as reliability events generally occur when market prices are high providing a strong financial incentive for generators to make themselves

77 For more information see https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review.

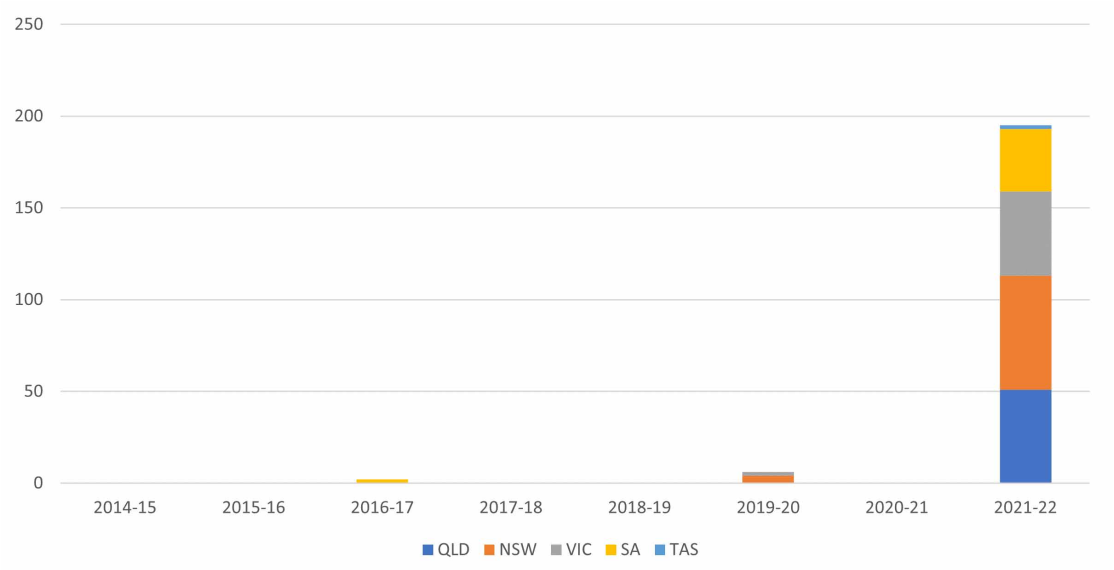
78 For more information see https://aemo.com.au/en/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert/rert-reporting.

available for dispatch. AEMO would only direct for reliability when there is technically available generation that is not bidding in.

Significant directions for reliability were issued by AEMO during the review year to manage the June APP/market suspension event. During this event technically available generation withdrew from the market in response to high input fuel costs, limited energy availability, and the APC which at that time was $300/MWh. This resulted in AEMO directing generators on to manage reliability.

Figure 3.16 shows the number of reliability directions issued by AEMO since 2015-16. Prior to the review year there were only two periods in the NEM where AEMO directed for reliability. In contrast, there were 195 directions for reliability during the review year attributable to the June event.[79]

Figure 3.16: Number of Reliability Directions issued by AEMO



Source: Panel Analysis of AEMO Data

The Panel notes that RERT activation and directions for reliability during the review year were dominated by circumstances around the June APP/market suspension event and net of this particular event does not indicate observable trends. The Panel however notes that RERT and AEMO's powers to direct for reliability were critical in managing the June APP/market suspension event in a way that resulted in no load shedding.

79 For more information on the June events see chapter 2 of this report.

3.5 Market price signals and investment incentives

Reliability frameworks in the NEM rely on market incentives to deliver reliability. Market prices determine the extent to which market revenue is sufficient to financially incentivise new entrant investment consistent with achieving the reliability standard.

The Panel considers trends in market price outcomes when assessing the investment environment in the NEM and the adequacy of the market price settings. Through the 2022 RSS Review, the Panel recommended the MPC and CPT be set at a level to enable the market to achieve and send efficient price signals, and support the efficient operation of, and investment in electricity services over the long-run, while also limiting market participant exposure to price risk.[80]

This section provides the Panel's consideration of market price outcomes in terms of their impact on investment decisions and future NEM reliability. This includes:

- Wholesale market price trends
- Market price cap/floor event frequency
- Contract market price outcomes.

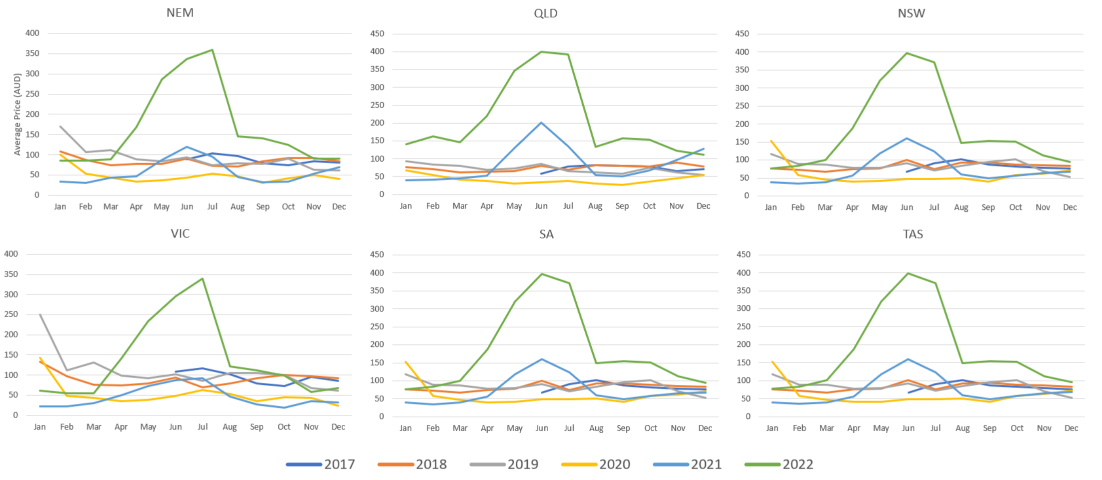
3.5.1 Average wholesale market price trends

Expectations on average wholesale market prices inform inputs to investment decisions and impact a potential developer's risk appetite when determining whether to proceed with development of a new project. Average market price movements are also particularly relevant to consumer electricity bill costs. For these reasons the Panel considers average wholesale market price trends when considering the investment environment in the NEM.

The Panel observes significant levels of variation in average price outcomes observed during the review year and understands that uncertainty in the direction of future prices remains. Figure 3.17 shows the monthly average dispatch prices in each region of the NEM all showing a significant peak over winter in 2022 corresponding to historically high input fuel prices. By contrast, average market prices in the second half of the calendar year 2021 were depressed in each region of the NEM at levels that were some of the lowest seen since 2017. This divergent average price outcome is compounded by recent price declines in the second half of 2022.

80 For more information see https://www.aemc.gov.au/sites/default/files/2022-09/2022%20RSS%20Review%20Final%20Report%20%281%29.pdf.

Figure 3.17: Monthly Average Dispatch Prices



Source: Panel Analysis of AEMO Data
Note: Sorted by Calendar Year

The development of a large LNG export industry has coupled Australian and international gas markets in a way that makes uncertainty in input fuel costs associated with international factors a driver of domestic average electricity market prices. The Panel, therefore, considers that fuel costs for Australian electricity generation will remain at elevated levels in the absence of policy intervention to cap prices or reserve domestic fuel for domestic use.

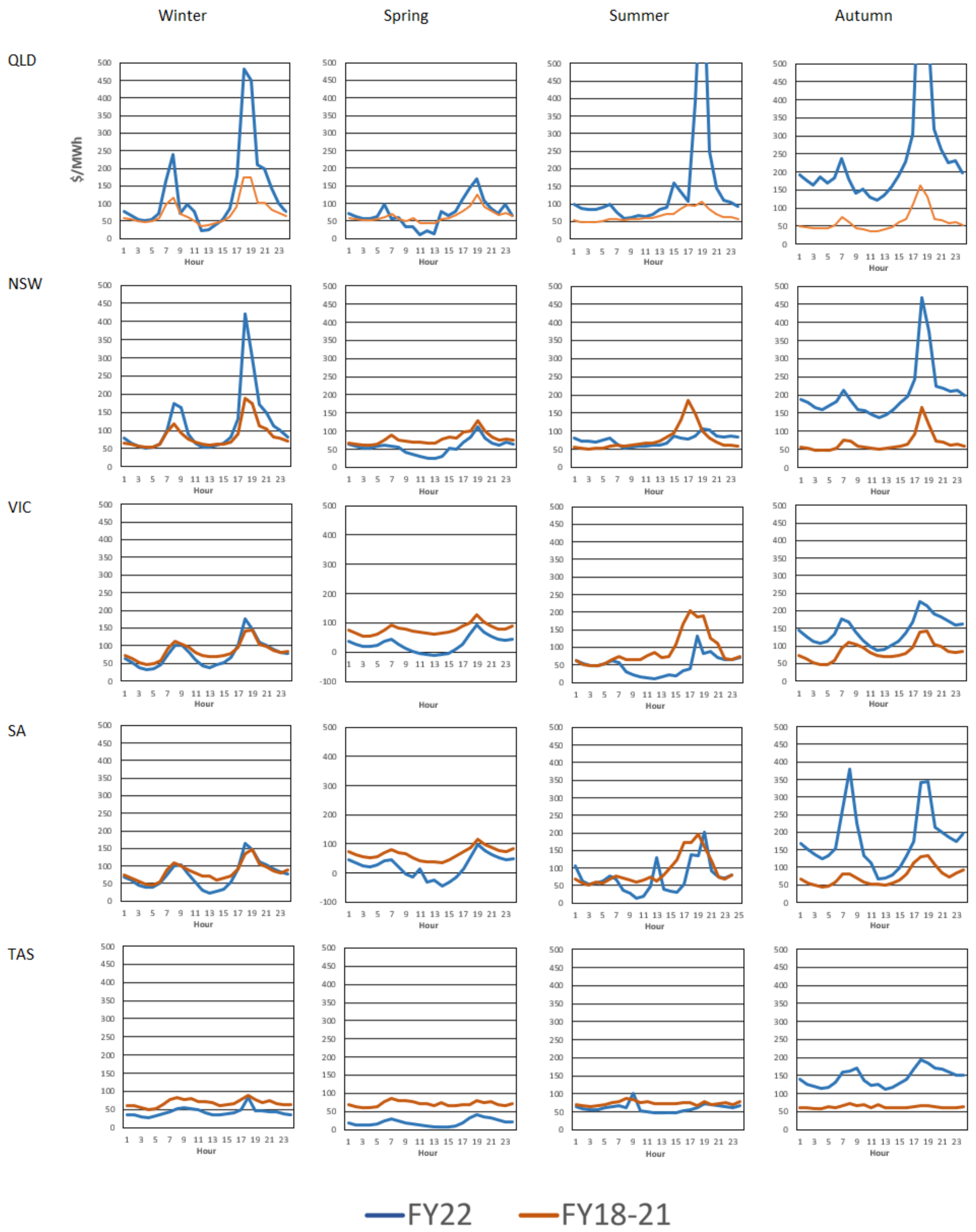
In this regard, the Panel notes the Commonwealth's decision to impose a temporary price cap on east coast gas as a suite of measures that includes reform of the Australian Domestic Gas Security Mechanism.[81] The price cap is in place for a period of 12 months in which the wholesale gas contract will be capped at $12/GJ. However, wholesale gas is contracted for delivery beyond 2023 and as such, producers will be required to offer reasonable prices consistent with the mandatory code to be overseen by the ACCC.

These changes do not affect price outcomes during the review year but the Panel is likely to consider the effect of the price cap on domestic wholesale electricity market prices in the next AMPR as price caps may have implications on the investment and operational signals in the NEM, leading to potential impacts on the reliability standard.

Another facet of a project's development is the diurnal profile of prices. The diurnal profile of prices can inform the revenues expected from certain renewable generation technologies and inform the business case for investment in firming storage. Figure 3.18 shows the change in seasonal diurnal wholesale electricity market prices in each region of the NEM during the review year and the average of the period 2018 to 2021.

81 For more information see https://www.industry.gov.au/mining-oil-and-gas/oil-and-gas/securing-australian-domestic-gas-supply.

Figure 3.18: Diurnal Price Profiles



Source: Panel analysis of AEMO data
Note: ''FY22' covers the period 1 Jun 2021 to 31 May 2022 to ensure the seasons are contiguous. The same was not done for FY18-21 due to the larger sample size.

The Panel identifies a general trend of increasing variations with a larger afternoon price ramp in all regions except Tasmania. This involves higher afternoon and early evening prices and lower daily prices. This reflects the influence of solar PV generation during the day and the transition to thermal power in the later afternoon and early evening as the sun goes down and underlying demand increases around dinner time.

These dynamics provide several important signals for investment and operations including:

- Value in intra-day storage investment to shift lower value solar PV generation during the day into the afternoon/evening period
- The low daytime prices disincentivise thermal generators that are required for security reasons or to meet the afternoon net load ramp from committing in the morning and running throughout the day (given the minimum up time/down time and minimum stable generation level constraints that apply to these generators).

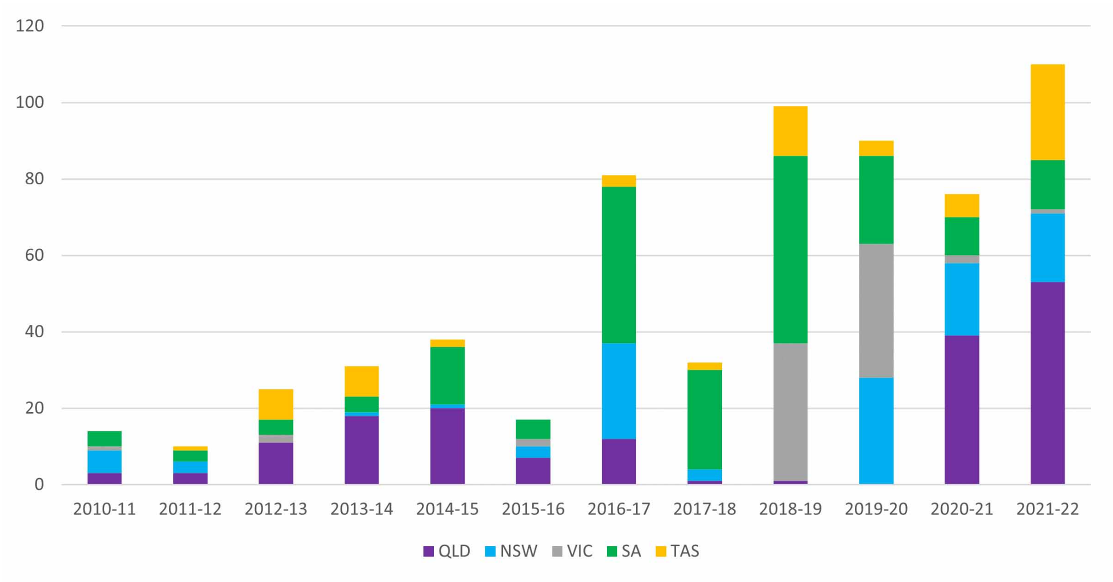
3.5.2 Market price cap events and frequency

The level of the MPC balances economically efficient dispatch outcomes with the need to minimise the chance of systemic financial risk associated with unbounded high market prices. An increase in the frequency in which the MPC is binding in the NEM indicates a reduction in the market's opportunity to clear at an efficient level reflecting the actual value of generation under supply scarcity conditions.

Figure 3.19 shows the number of MPC events in the NEM over the period since 2010-11. During the review year, MPC events mostly occurred during summer and winter corresponding with periods of reliability stress and high demand conditions. The total number of MPC events for Victoria, New South Wales and South Australia remained relatively consistent with the previous year. However, there was a large increase in MPC events for Queensland and Tasmania in 2021-22. The Panel observes that increase is related to the June market suspension.

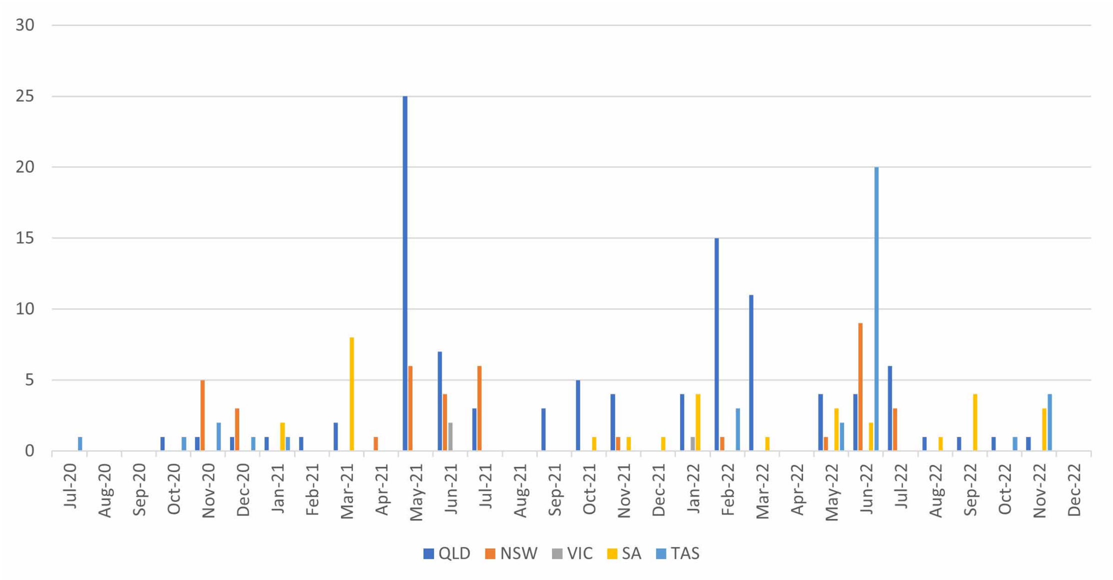
While the regional breakdown in MPC events is variable, the total number of MPC events across the NEM is observed to have increased relative to 2010-11. In its 2022 RSS review, the Panel considered an increase in the frequency of MPC events in the NEM supported its recommendation to increase the MPC over the period 1 July 2025 to 30 June 2028 to allow additional revenue supporting new entrant investment.

Figure 3.19: Market Price Cap Events



Source: Panel analysis of AEMO data

Figure 3.20: Market Price Cap Events by Month



Source: Panel analysis of AEMO data

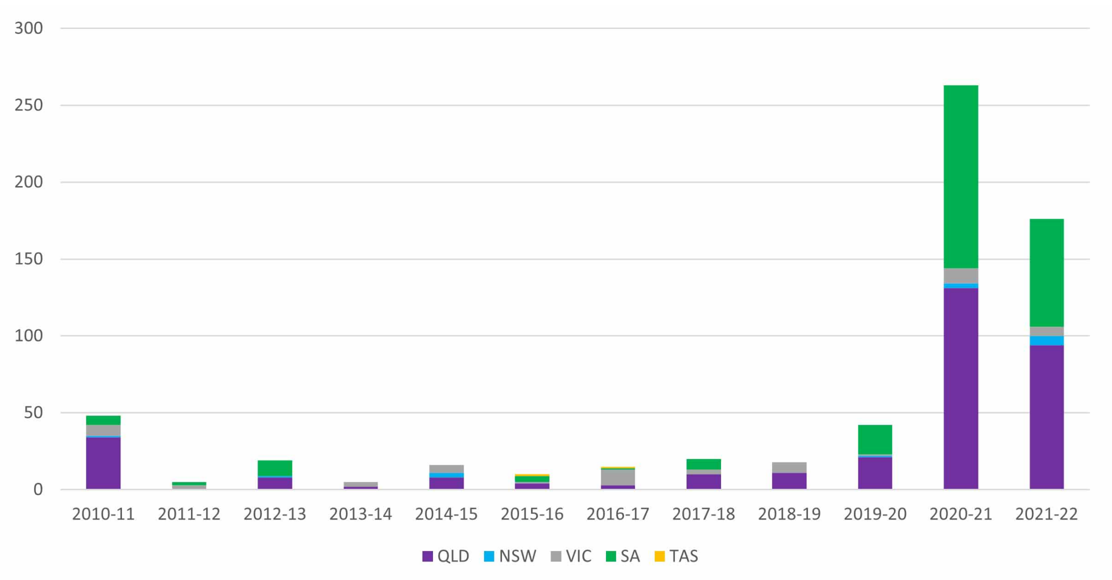
In general, low price events are expected at times when there is an abundance of generation relative to demand. During such periods, negative prices assist power system operations by creating an incentive to reduce generation.

Negative bids reflect the amount a generator is willing to pay to remain dispatched to a certain level. Less flexible generators subject to high start-up costs and technical unit commitment constraints, such as minimum up-time requirements, place a significant value on remaining dispatched at their minimum load level in the event of negative prices. In contrast, highly flexible generation, which can start or cease generation easily and at a low cost, will reduce generation and de-commit if necessary in response to negative pricing.

Figure 3.21 shows the increase in MFP events that have been observed in the NEM over the period from 2010-11. The substantial increase in recent years was considered to indicate a need to decrease the MFP to a more negative level. The Panel notes anecdotal evidence in South Australia of "race to the floor" bidding due to limits on VRE for system strength that may be driving some of the MFP events shown in Figure 3.21.

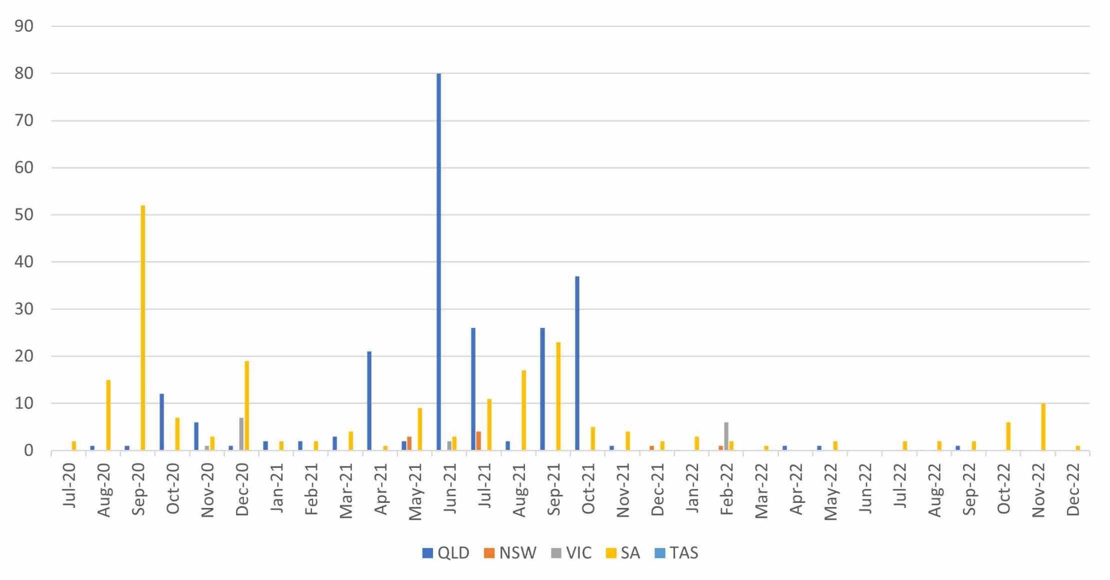
Following the commencement of the 5-minute settlement and semi-scheduled dispatch obligations Rule in October 2021, there has been a sustained decline in MFP events observed in the NEM. In its 2022 RSS review, the Panel elected to retain the MFP at -$1000/MWh as there was no longer an indication that the market was failing to clear at the current MFP. The Panel will continue to monitor MFP events in future AMPRs to provide useful input into future RSS reviews, particularly in relation to MFP considerations.

Figure 3.21: Market Floor Price Events



Source: Panel analysis of AEMO data

Figure 3.22: Market Floor Price Events by Month



Source: Panel analysis of AEMO data

3.5.3 Contract market price trends

Wholesale market participants enter into various wholesale hedging contracts to manage financial risks and increase certainty over their wholesale energy costs. Both buyers and sellers in the wholesale market are exposed to variations in the spot price in the wholesale market. They appreciate that large swings in spot prices have a similar but opposite effect on their costs and revenue and consequently their profits. This encourages both buyers and sellers to agree to contracts that convert volatile spot revenues and costs to a more certain cash flow which can also help underwrite further investment in both generation and retail assets. These are generally expensive, long-term investments in a more uncertain investment environment.

While the primary role of entering into these contracts is to manage risk and cash-flows, contracts can be considered as another means of expressing the price of the same underlying product, meaning that the spot and contract prices are intrinsically linked. The price of hedging contracts reflects the balance of expectations as to the level and volatility of future wholesale spot price outcomes and therefore supports reliability by informing both investment and operational decisions.

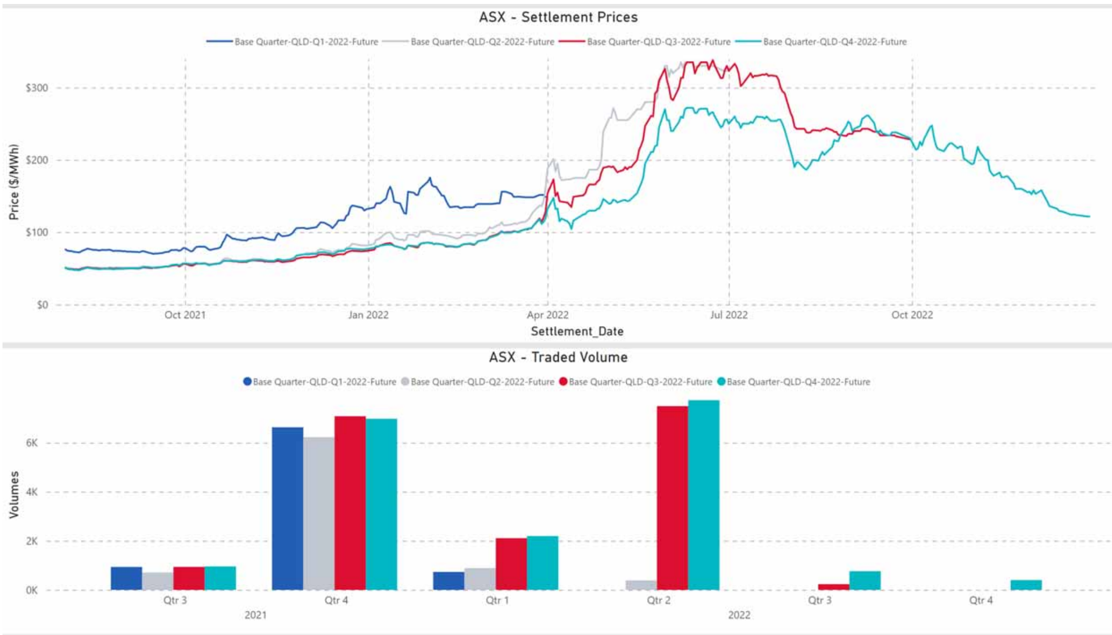
Contracts for the NEM are traded either on the ASX, FEX or bilaterally. ASX futures prices for Queensland is shown in Figure 3.23 and other states in Appendix B. It is observed that trends were similar across states.

On analysis of the figures, the Panel notes:

- Tightening fuel and energy markets internationally pushed up future contract prices leading up to and proceeding the June event.
- A milder than expected winter in Europe and federal gas cap announcements have since settled prices.
- In late December 2022, the Federal Government announced a price cap of $12 GJ to apply to new domestic wholesale gas contracts by east coast producers for gas to be supplied over the next 12 months from development fields. Initial data shows future contract market price trends have settled.[82].

The Panel will continue to monitor the impact of the price cap on wholesale prices.

Figure 3.23: ASX QLD Quarterly Futures



Source: Panel analysis of AEMO data

82 For more information see https://www.accc.gov.au/regulated-infrastructure/energy/gas-price-cap

4 SECURITY

BOX 3: SUMMARY OF PANEL OBSERVATIONS

The Panel notes that system security outcomes in the NEM were mostly acceptable during the review year, driven by:

- The sustained improvement in NEM frequency performance following the introduction of mandatory primary frequency response.
- A reduction in the number of security directions in South Australia following commissioning of the four synchronous condensers that have addressed the system strength gap in that region.
- Generally stable levels of reviewable operating incidents and reclassifications.
- A decrease in system restart ancillary services (SRAS) costs following the merger of the two Queensland sub-regions.
- AEMO's extensive analysis of system security risks through its Power System Frequency Risk Review (PSFRR), which has informed its practical operation of the system and its collaboration with NSPs.

While overall security outcomes were good in 2021-22, there are some areas of concern arising from the security events that occurred during the review year. The Panel particularly notes:

- Protection and control system mal-operation remains the greatest source of reviewable operating incidents, with the use of more special protection schemes (SPS) in response to an increasingly complex system. Whilst such schemes have the potential to mitigate the effect of high-impact, low probability events, there are potentially severe security risks associated with mal-operation and potential adverse interactions between protection systems. These are partially mitigated by SPS design in accordance with remedial action scheme (RAS) guidelines.
- Gaps in existing NER frameworks relevant to defining acceptable limits to sub-synchronous power system oscillations in the NEM and acceptable generator performance in such events. The Panel considers learnings from AEMO's work on the Connections Reform Initiative in response to the oscillations observed in the West Murray Zone (WMZ) should be considered further given the likely re-occurrence of such issues as IBR penetrations increase and levels of system strength decline.
- Multiple incidents of synchronous condensers tripping in New South Wales illustrate the need to explore and assess the technical performance of the synchronous condensers due to how their performance standards are defined.
- The amount of load under the control of under-frequency relays in South Australia, Queensland, Victoria and New South Wales is now well below the levels anticipated in the

NER when there are high levels of Distributed PV (DPV) operating. The Panel notes that the effectiveness of under-frequency load shedding (UFLS) systems in response to the Callide event were undermined by increasing penetrations of DPV. While sufficient UFLS was available in this event to maintain Queensland frequency within the extreme frequency tolerance band of 47 Hz, the Panel is concerned that the risks of a black system event are rising. The Panel considers further review be progressed and any changes to the framework be implemented via the rule change process if required.

In response to these outcomes and events, the Panel recommends the following:

- Continue investigations to understand the root cause of voltage oscillations in the WMZ region and explore enhancing NER frameworks to define acceptable limits of sub-synchronous power system oscillations in the NEM and acceptable generator performance in such events.
- Explore whether there is benefit in establishing principles as part of the NER for performance standards and compliance monitoring for system strength services.
- Monitor the load under the control of under-frequency relays in South Australia, Queensland, Victoria and New South Wales as it is now well below the levels anticipated in the NER when there are high levels of DPV operating.

One of the Panel's key responsibilities is to monitor, review and report on the security of the national power system.[83] System security relates to the power system's ability to remain stable and continue supplying load given credible and non-credible disturbances that may occur.[84] This chapter considers the security performance of the NEM in respect to the frameworks explained in chapter 4 of the AMPR's explanatory statement[85] over the reporting period 2021-2022 financial year.

The following are assessed:

- Power system security incidents/risk management
- Frequency performance
- AEMO interventions for security
- System services procurement and use.

The Panel plays an important role in determining standards that are required to deliver a secure, reliable, and safe power system in the most efficient way in order to minimise costs for consumers. The Panel's findings and considerations set out in this chapter will inform its future standard development work program.

83 Section 38(2) of the NEL.

84 Chapter 10 of the NER defines power system security as the safe scheduling, operation and control of the power system on a continuous basis.

85 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

4.1 Power system security incidents/risk management

Power system security frameworks are in place to maintain power system stability following a disturbance.[86] This section presents major power system security incidents that occurred during the reporting year along with AEMO's use of NER frameworks to manage the risk of such incidents.

The observations made in this section inform the Panel's appreciation of the NEM's system security risk profile and whether existing security arrangements and standards are sufficient to manage such risk.

This section presents:

- The number and type of reviewable operating incidents during the review year
- Details of major security incidents during the reporting year.

4.1.1 Reviewable power system operating incidents

Reviewable operating incidents are defined in clause 4.8.15(a) of the NER to mean, amongst other things, an incident identified to be of significance in the operation of the power system or a significant deviation from normal operating conditions.[87]

AEMO's reviewable operating incident reviews are opportunities to publicly assess and report on the adequacy of systems and responses to address significant incidents and abnormal operating conditions. These reports represent a valuable source of information for the Panel to understand the system security events that have occurred in a review year.[88]

Number of reviewable operating incidents

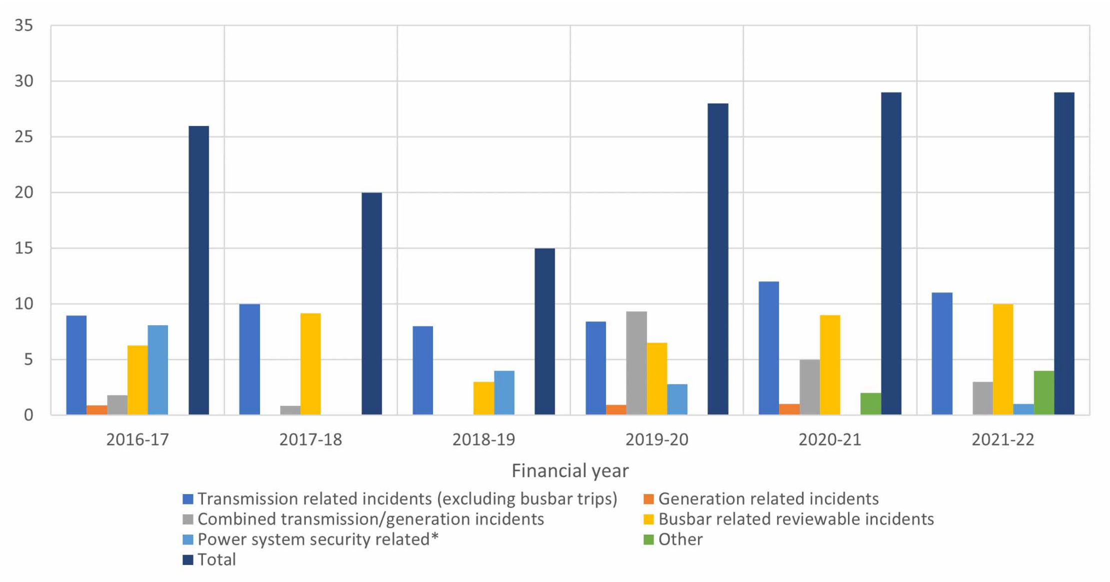
Figure 4.2 shows there were 29 reviewable operating incidents in the reporting year. This is the same number as in the previous year.

86 Power system disturbances are referred to as contingency events. See clause 4.2.3 of the NER for the definition of a contingency event.

87 This is in accordance with guidelines determined by the Panel under rule 8.8 of the NER.

88 Further details on AEMO's reviewable operating incident reporting obligations are outlined in section 4.1.4 of the explanatory statement that can be accessed at https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

Figure 4.1: Number of reviewable operating incidents



Source: Panel analysis of AEMO data
Note: * Insecure/non-satisfactory related **Multiple categories of incident can occur during the same event and are double-counted, so the sum of all categories does not necessarily equal the total.

While the Panel observes an increase in the total number of reviewable operating incidents since 2018-19, the total number during this review period is only marginally above the 6-year average level of 25 incidents. The increase in this review period, over the 6-year average, can be attributed to marginally higher numbers of transmission-related incidents, busbar-related events, and other events.[89]

The Panel has not identified any specific concerns associated with the number of reviewable operating incidents during the reporting year, except to note:

- The 'other' category of reviewable operating incidents has been growing over the last two review years. Three events were categorised as 'other' in the reporting year compared to no events categorised as 'other' having occurred prior to 2020-21. 'Other' events as described in the chart above are defined by the equipment involved and include stability or supervisory data acquisition and control (SCADA) related reviewable operating events. The most significant 'other' event that occurred during the reporting year involves sub-synchronous voltage oscillations that were observed in the West Murray region. Further discussion of these oscillations is provided in Section 4.1.4.

There was only one period where the power system was not in a secure state for more than 30 minutes during the review period. This is up from zero instances in 2020-21 but down

89 The complete list of reviewable operating incidents is available in Appendix C with more information available from https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/power-system-operating-incident-reports#:~:text=AEMO%20conducts%20investigations%20of%20'unusual,the%20operation%20of%20the%20NEM.

from three instances in 2019-20. This instance occurred during the June market suspension event and is summarised below:

- On 13 June 2022 active power transfer on Queensland — New South Wales Interconnector (QNI) exceeded the actual secure limit which resulted in the power system not operating in a secure state for approximately 60 minutes. This breach of secure limits occurred after the unexpected withdrawal of generation capacity in Queensland and New South Wales following the commencement of the APPs. The generation AEMO directed on in response was unexpectedly slow to ramp up and follow dispatch targets resulting in QNI flows above secure limits for greater than 30 minutes. AEMO considered load shedding to maintain the power system in a secure state, however, identified the time required to affect load shedding would have been too great to address the additional 30 minutes insecure state.

The Panel notes the unexpected nature of the generator withdrawal leading to the insecure state and highly uncertain operating conditions that applied at that time. The Panel recognises that AEMO has identified strategies that could assist faster response by directed generation in future circumstances.[90] This event is discussed in further detail in Section 4.1.4.

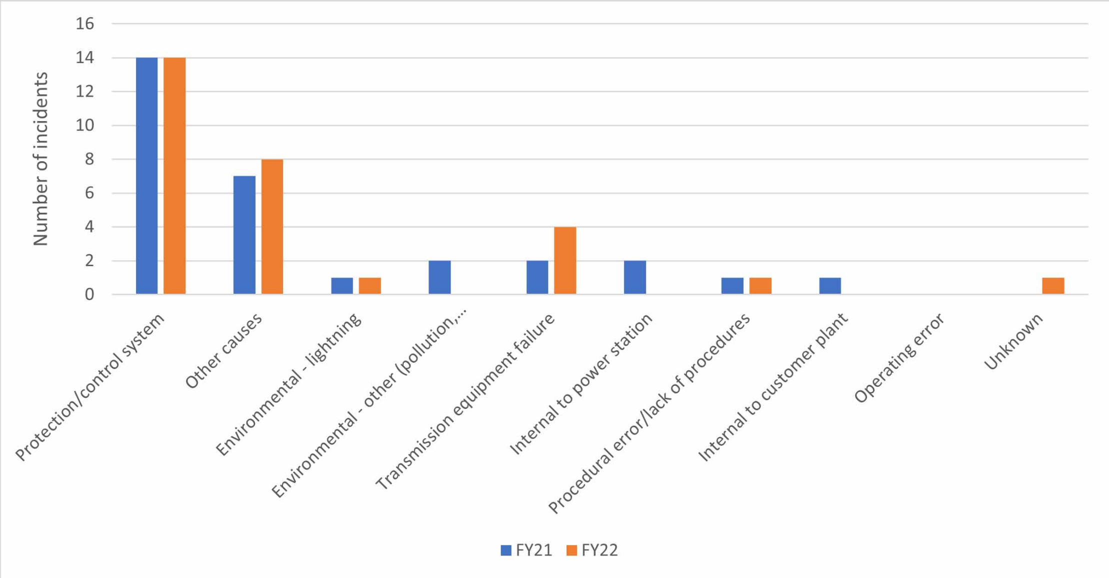
Type of reviewable operating incidents

Reviewable operating incidents that occurred in the last two reporting years are broken down by type in Figure 4.1. Protection/control system related events are observed to be the most frequent type of reviewable operating incident over the last two years followed by reviewable operating incidents associated with 'other causes'.[91] The Panel observes the number of each type of reviewable operating incident are substantially similar over the last two years.

90 For more information see https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/market_event_reports/2022/nem-market-suspension-and-operational-challenges-in-june-2022.pdf.

91 Note the 'other causes' described in Figure 4.1 differ from Figure 4.2 due to the differences in AEMO and AEMC categories. AEMO describe the cause of the incident whereas AEMC categories describe the equipment involved. In both figures, the total incidents remain at 31.

Figure 4.2: Reviewable operating incidents by type



Source: Panel analysis of AEMO data

Incidents involving protection and control system mal-operation can represent a significant risk to power system security and safety. The Panel considers protection/control system mal-operation may lead to potentially severe system security outcomes as the NEM continues its transition to higher penetrations of IBR. There is an increasing reliance on Special Protection Schemes (SPSs), also known as Remedial Action Schemes (RAS), to improve asset utilisation, network access for generating systems, integrated resource systems and loads, reduce the impact and severity of events, and aid with recovery from such events.

The RAS guidelines provide a reference for good industry practice to help ensure schemes are appropriately designed. The RAS has the potential to improve security by mitigating risks associated with non-credible events.[92] The Panel also notes that new obligations on NSPs require priority schemes be reviewed in association with the General Power System Risk Review rule change.[93]

While these schemes are important for the secure operation of the NEM as it transitions to higher IBR penetrations, the Panel is aware of the potential for mal-operation of these schemes that lead to adverse system impacts, including cascading events and supply disruptions. In the context of the transforming power system and changing operational conditions, the Panel considers it crucial that existing schemes are reviewed to ensure they remain effective and continue to meet their design and performance requirements and that

92 For more information see https://www.aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/publication-of-remedial-action-scheme-guidelines/further-information/final-remedial-action-scheme-guidelines.pdf?la=en.

93 Clause 5.12.1(b)(7) of the NER.

any new schemes are implemented carefully to minimise the potential for new system security risks from undesirable scheme interactions.

The Panel notes that AEMO has been reviewing existing and proposed SPSs in its power system frequency review report (PSFRR) and also published a RAS guideline to define good electricity industry practice for the design, modelling and review of such protection schemes critical to the operation of the NEM as it transitions to higher penetrations of IBR.[94]

The second highest reviewable operating incident category for 2021-22 is "other"[95] which involves SCADA and oscillatory stability events. There were two oscillatory stability issues[96] that occurred during the reporting year. One incident involves sub-synchronous voltage oscillations in the WMZ. The cause of the second oscillatory issue in South Australia was the result of human error. Panel observations on the WMZ oscillation issue are provided in the following section.

4.1.2 Major power system security events during the reporting period

In addition to the June APP/market suspension event, which is discussed in detail in the 'key events chapter', the Panel has identified major power system security events that either occurred in the reporting year or had their reviewable operating incident report published during the reporting year. These are:

- WMZ oscillations
- Multiple separate incidents involving Buronga synchronous condensers
- The Callide event

These events are summarised in the following sections along with the Panel's observations.

West Murray Zone oscillations

The WMZ is an area of the NEM with low system strength, extending across parts of Victoria and New South Wales.[97] This area has attracted significant investment in grid-scale solar and wind generation in the past three years. The scale and rapid pace of IBR generator connections have resulted in new technical challenges in this zone, impacting grid performance and operational stability.

On 16 November 2021, sub-synchronous power system oscillations were observed with a maximum peak-to-peak root-mean-square (RMS) voltage magnitude of up to 17% and a

94 For more information see https://www.aemo.com.au/consultations/current-and-closed-consultations/publication-of-draft-remedial-action-scheme-guidelines.

95 Note the 'other causes' described in Figure 4.1 differ from Figure 4.2 due to the differences in AEMO and AEMC categories. AEMO describe the cause of the incident whereas AEMC categories describe the equipment involved. In both figures, the total incidents remain at 31.

96 AEMO define oscillatory stability as: small-signal rotor angle stability, which is the ability of the power system to maintain synchronism after being subjected to a small pertubation without application of a contingency event. With this form of stability, the perturbations are considered to be sufficiently small that linearisation of system equations, or operationally, liner mathematical techniques, are permissible for the purposes of analysis. Instability is characterised by sustained or growing oscillations in active power, reactive power, voltage magnitude or frequency in linearised calculation.

97 The WMZ spans parts of the interconnected networks in south-west New South Wales and north-west Victoria bounded by Ballarat, Dederang, and Darlington Point.

frequency of 19 Hz.[98] These oscillations persisted for approximately 37 minutes and led to 35 MW of generation disconnecting.[99] There have been a total of five instances of the WMZ region sub-synchronous oscillation events identified and analysed by AEMO.[100] WMZ oscillations were the subject of a separate incident in 2020 which required significant power system security constraints that curtailed wind and solar in the area [101] While no oscillations were observed outside the WMZ and no wider risks to system security were identified by AEMO, AEMO considered the event to be of significance to the operation of the power system and therefore require a reviewable operating incident report.

The Panel identifies the following key observations on this event for power system security:

- AEMO was unable to identify the root cause of, or individual contributions to, the oscillations. The Panel considers it important to understand the root cause of such events given the repeated events of this type in the WMZ, as well as their likely significance in other zones of the NEM as the power system transitions to higher IBR penetrations and lower levels of system strength. The Panel notes the planned roll out of additional high-speed monitoring improvements will assist AEMO with root cause analysis of similar future power system incidents.
- Existing NER frameworks do not specifically address these types of sub-synchronous voltage oscillations or define acceptable limits for such events.
  - The system standard for stability, set out in clause S5.1.8 of the NER, requires power system oscillations to be adequately damped but does not define an operational limit which can be used to identify the background-level power system oscillation that is acceptable.
  - The current generator technical performance standard regarding protection to trip for unstable operation, as set out in clause S5.2.5.10 of the NER, does not provide sufficient requirements on acceptable generator performance given such events.

The Panel notes that AEMO is requesting the Power System Security Working Group (PSSWG) work with NSPs to define a level of power system oscillations that may be considered acceptable on operational time-frames and is also currently consulting with industry on guidelines for how generators can best comply with S5.2.5.10 for asynchronous generators. However, it observes that a gap in NER frameworks currently exists and considers further review be progressed with any changes to the framework implemented via a rule change process if needed.

98 The 19 Hz oscillation frequency mentioned in this document refers to the RMS aliased frequency as measured in the phasor variables measurement points. The Fast Fourier Transform (FFT) of the instantaneous three-phase voltages and currents would indicate the actual frequency components to be modulated as 50 Hz +/- the measured RMS frequency of 19 Hz. For more information see Appendix A1 of the West Murray Zone Power System Oscillations 2020-21 at https://aemo.com.au/energysystems/electricity/national-electricity-market-nem/system-operations/power-system-oscillation.

99 During the incident, 35 of the 39 inverters at Wemen Solar Farm (SF) tripped, causing approximately 35 MW of generation to disconnect.

100 For more information see https://aemo.com.au/-/media/files/electricity/nem/network_connections/west-murray/high-level-summary-of-wmz-subsynchronous-oscillations.pdf?la=en.

101 Sub-synchronous power system oscillations in the range of 15-20 Hz lasting from a few seconds to several minutes have been observed in the WMZ on various occasions, since first identified on 20 August 2019. The power system oscillations seem to occur both with and without any obvious network disturbances.

The Panel also recommends investigation into the oscillations to continue to understand the root cause of the events. As noted above, high-speed monitoring improvements may assist AEMO in their understanding of the oscillation's origin.

Multiple separate incidents involving Buronga synchronous condensers

Between 11 November 2020 and 30 March 2022 there were 20 events where Buronga synchronous condensers tripped, along with the associated solar farms for which the synchronous condensers were providing system strength remediation. The events involved Buronga No. 1, No. 2, and No. 3 synchronous condensers located in New South Wales.

AEMO considered these recurring incidents may involve systemic issues of significance to overall power system operation and conducted a review to identify the root causes of the trips.[102] AEMO concluded multiple causes of the trips including faulty logic in the control program and protection mal-operation relating to stator differential protection and vibration protection.

Through these events, AEMO also identified issues with assessing the technical performance of the synchronous condensers due to how their performance standards are defined. AEMO is currently reviewing how best to define performance standards for new synchronous condenser connections as part of the current access standard review.[103]

The Panel considers that there may be merit in exploring whether there is benefit in establishing principles as part of the NER for performance standards and compliance monitoring for system strength services.

Callide event[104]

On 25 May 2021 multiple generators and high voltage transmission lines tripped in Queensland following an initial event at CS Energy's Callide C Power Station (Callide)[105]

Following the loss of DC and AC station supplies, Callide unit C4 boiler and turbine tripped, and the unit ceased exporting active power but remained electrically connected to the power system. This resulted in the generator motoring asynchronously on the power system, drawing power from the system for about 20 minutes and subsequently a catastrophic fault.[106]

102 For more information see https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2022/multiple-separate-incidents-involving-buronga-synchronous-condensers.pdf?la=en.

103 See Clause 5.2.6A(a) of the NER.

104 The Callide event occurred outside the Panel's reporting requirement for this financial year period. However, due to the timing of the event, a number of the learnings were not known during the previous reporting period and were not included in the FY2020-2021 AMPR. Given the scale and relevance of the Callide event to security outcomes in the NEM in relation to mal-operation of protection systems with the increase of IBR penetration in the system, the Panel considers it appropriate to review and report on it in this AMPR.

105 Callide Power Station (Callide) is a thermal power plant in central Queensland consisting of two 350 MW generating units at Callide B (B1 and B2) and 466 MW and 420 MW generating units at Callide C (C3 and C4 respectively). Callide B is owned by CS Energy and Callide C by a joint venture of CS Energy and Intergen. Both are operated by CS Energy.

106 SCADA data provided through AEMO's Energy Management System (EMS) indicated that Callide C4 was absorbing continuously around 50 MW and 300 MVAr for 20 minutes, as it motored asynchronously. This is a serious condition for a turbo-generator, particularly when combined with the loss of auxiliary AC supplies and where the motoring continues for a sustained period.

The loss of DC supply meant that internal Callide protection systems and backup protection systems on the feeder linking Callide C4 to the Calvale substation failed to isolate the faulted unit from the wider power system. This resulted in a severe and extended voltage disturbance in Central Queensland which was not cleared until zone 2 protection systems operated on the six 275 kV lines exiting the Calvale substation 400ms later. There was a rapid sequence of events that followed including the loss of nine major generating units in Queensland.

QNI flows rapidly increased following the loss of major Queensland generators before tripping. After QNI tripped, resulting in synchronous separation between Queensland and the rest of the NEM, the frequency in Queensland dropped to approximately 48.53 Hz. This low frequency caused UFLS relays to operate automatically, disconnecting load in Queensland to arrest the frequency decline. Approximately 2,276 MW in Queensland and 25 MW of load was lost in New South Wales primarily through the action of UFLS relays. QNI auto-reclosed approximately 16 seconds later re-establishing a synchronous connection with the rest of the NEM.

At 1410 hrs AEMO gave permission to commence restoration of load interrupted by the UFLS operation and commenced the load and generation restoration process.

The Panel makes the following key power system security related observations in respect of the Callide event:

- The serious nature of the issue developing at Callide Power Station was not fully appreciated by AEMO, the Transmission Network Service Provider (TNSP) and the power station staff given inconsistent observation and interpretation of the situation. The event illustrates the significant importance of protection system design and coordination as internal Callide protection systems were relied upon for power system security.
- UFLS systems operated as designed to prevent Queensland frequency from declining to the extreme frequency tolerance band of 47 Hz. The significant amount of distributed solar PV in Queensland however compromised the effectiveness of the UFLS system. While sufficient UFLS was available in this case, higher DPV penetrations, without subsequent changes to UFLS arrangements, may increase the chance of a black system event occurring in response to a similar future event.

The Panel considers the Callide event illustrates the risks to power system security associated with declining UFLS effectiveness. The Panel makes additional observations on UFLS effectiveness in Section 4.2.2

4.2 Management of power system security risks

AEMO maintains the power system in a secure state by defining a technical envelope such that the power system remains stable without the loss of customer load for any credible contingency event.[107]

107 A contingency event is an event affecting the power system that AEMO expects would likely involve the failure or removal from operational service of one or more generating units and/or transmission elements.

Credible contingency events are those that AEMO considers reasonably possible, such as the unexpected disconnection of one operating generating unit. Non-credible contingency events are those that AEMO considers not reasonably possible given prevailing conditions, such as multiple generating unit failures.[108]

AEMO does not maintain the power system in a secure state for non-credible contingencies. AEMO has additional powers to manage non-credible power system security risks through reclassification and protected events, which are discussed further below. This section considers the management of power system security risks during the review year through the following frameworks:

- **AEMO reclassification decisions:** Reclassification decisions provide insight into the power system security risks associated with abnormal conditions and whether there are trends in the types of conditions leading to reclassification decisions. The Panel considers AEMO's reclassification decisions to identify whether there are trends or particular emerging risks requiring reclassification during the review year.
- **Protected events and power system risks identified in the PSFRR:** The Panel's understanding of frequency-related power system security risk is informed by the risks AEMO identifies through its PSFRR and protected events applications.

Additional explanation on the NER frameworks for managing power system security risks is provided in chapter 4 of the AMPR's explanatory statement.[109]

4.2.1 AEMO reclassification decisions

Under abnormal conditions, certain normal non-credible contingencies can become credible. The NER requires AEMO to 'reclassify' these normally non-credible contingency events to be credible, adjust the technical envelope accordingly, and notify the market.[110] AEMO applies a set of criteria when making reclassification decisions which are set out in AEMO's power system security guidelines. AEMO publishes its criteria in its power system security guidelines which are also subject to periodic review.[111]

From 1 May 2021 to 30 April 2022[112]there were a total of 936 reclassified events, most of which were caused by lightning (865), a smaller number by severe weather (39) and the remaining classified as "other" (32).[113] The Panel notes that not all reclassification decisions affect market dispatch with 39 of these reclassified events resulting in binding constraint equations[114] with the remaining 897 constraints not affecting dispatch outcomes.[115]

108 Clause 4.2.3(b), (e) of the NER.

109 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

110 Clause 4.2.3A of the NER.

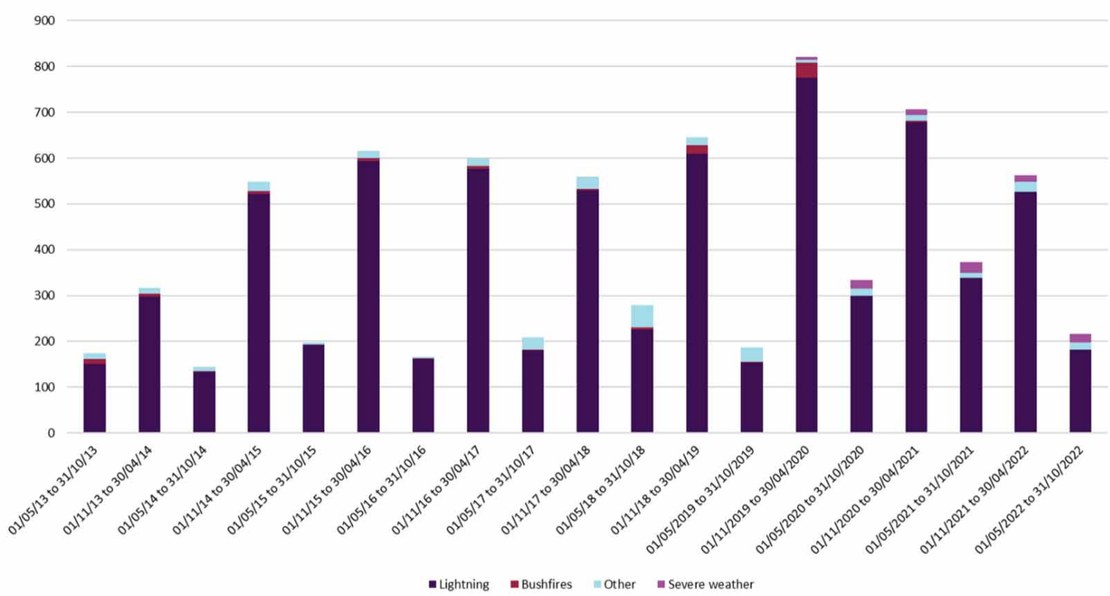
111 For more information see https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3715%20Power-System-Security-Guidelines.pdf.

112 This is AEMO's reporting period for reclassification events which differs from the Panel's review year.

113 For more information see https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/power-system-reclassification-events.

114 A constraint equation is binding when the dispatch engine targets the summation of the Left Hand Side (LHS) terms to be equal with the constraint Right Hand Side (RHS) value. For network constraint equations this indicates the power system is being operated near or at a design limit (e.g. thermal, voltage stability or transient stability). Occasionally, a constraint equation will bind and then not bind. This indicates that something has changed in the power system that changes the inputs to the limit

Figure 4.3: Historic reclassification events 2012/13 to 2022



Source: AEMO's Review of Reclassification Events Report

Note: It does not include 'severe weather' for reclassification periods prior to 1 November 2019 as it was previously included in the 'other' category. 'Severe weather' became a new category and was only included from the report covering 1 November 2019 to 30 April 2020.

Figure 4.3 shows the number of summer and winter reclassifications since 2012. Although there has been an increase in the total number of reclassifications since 2012, the Panel notes the number of reclassified events during the period was similar to historical averages. While the number of summer reclassifications in the review period has declined since 2019-20 there has been an increase in winter re-classifications over the same time-frame.

Lightning-related reclassification is the key driver of reclassification events. While lightning dominates the number of reclassifications, the Panel does not consider trends in the number of lightning-related reclassifications to materially indicate changes in the NEM's power system security risk profile.[116] The Panel's view is informed by there having only been one lightning-relating reviewable operating incident during the review period. This indicates lightning-related security risk is well managed by AEMO's reclassification decisions.

The 36 events reclassified under 'severe weather' and 'other' criteria were reclassified due to either:

equation e.g. a generator tripped or demand changed.

115 For more information see https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/reclassification-events/reclassification-report-may-2021-to-oct-2021.pdf?la=en and https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/reclassification-events/reclassification-report-nov-2021-to-apr-2022.pdf?la=en.

116 Under normal conditions, the simultaneous trip of both circuits of a double-circuit transmission line would be considered a non-credible contingency event. During lightning storms, however, the trip of multiple circuits on certain transmission lines becomes reasonably possible and therefore credible.

- Forecast abnormal weather conditions (such as severe weather warnings due to high wind or cyclones), or
- Occurrence of a non-credible contingency event following which AEMO considered there was a reasonable possibility of re-occurrence.

There were no bushfire reclassification events during the reporting year. Bushfire reclassifications last occurred during the fires of 2019-20.

While the Panel does not identify particular concerns from the number and type of reclassification events during the review period, it notes that AEMO's reclassification criteria will be expanded prior to the next AMPR to include criteria to manage a range of 'indistinct events'. Given the indistinct event criteria, the Panel intends to monitor the reclassification outcomes closely in future AMPRs. Further discussion on indistinct events is provided in chapter 4 of the AMPR explanatory statement[117] and Appendix C.

4.2.2 Protected events and the PSFRR

Protected events are an additional mechanism available to manage the power system security risks from certain non-credible contingency events. AEMO is able to request the Panel declare a non-credible contingency event it has identified in its PSFRR to be a protected event. If the Panel declares a protected event, AEMO can take additional approved steps to proactively manage the risk.[118]

The PSFRR identifies non-credible contingency events that have the potential to involve uncontrolled increases or decreases in frequency (alone or in combination) leading to cascading outages, or major supply disruptions. The PSFRR, therefore, provides details on the specific events AEMO considers requires management through a number of mechanisms including, but not limited to, declaration as a protected event.

The Panel has considered AEMO's 2022 PSFRR in terms of intentions on:

- Existing protected events
- Future protected event applications
- Other major (non-protected event related) risks requiring management.

<u>Existing protected event</u>

At present, only one protected event has been declared. This protected event is to manage the loss of multiple transmission elements causing generation disconnection in the South Australia region during periods where destructive wind conditions are forecast by the Bureau of Meteorology.[119] The Panel approved a 250 MW limit on the Heywood interconnector during forecast destructive winds in South Australia and implementation of a system integrity

117 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

118 Clause 8.8.4 of the NER. Management of actions include those which can cost-effectively address the chance of cascading failures and major supply disruption from the event's occurrence. AEMO does not maintain the power system in a secure state for protected events.

119 For more information see https://www.aemc.gov.au/sites/default/files/2019-06/Final%20determination%20-%20AEMO%20request%20for%20declaration%20of%20protected%20event.pdf.

protection scheme (SIPS) to manage these risks as it considered the benefits from management exceeded management costs.[120]

AEMO has invoked the 250 MW import constraint to manage a protected event twice during the review period on 11 January and 26 January 2022. In both instances, Heywood Interconnector flows into South Australia were reduced to 250 MW, causing more expensive South Australian generation to be dispatched than would otherwise have been the case. AEMO reported an additional $118,000 of costs were incurred associated with these management actions during the review period.[121]

AEMO is considering changes to this protected event following the commissioning of project energy connect (PEC) stage 1.[122] In addition, AEMO is also considering whether to request the Panel revoke the existing protected event following the AEMC final rule on enhancing operational resilience in relation to indistinct events that commenced in March 2023. [123] This rule will provide AEMO with scope to determine criteria to manage destructive wind conditions in South Australia through reclassification.

Future protected event applications

AEMO made no new protected event applications during the reporting period, however has identified priority non-credible contingency events in the 2022 PSFRR which could be the subject of a future protected event application to the Panel.[124] The following two risks are identified:

- Separation of South Australia through loss of the Heywood — South East 275 kilovolts (kV) lines considering potential operation with fewer than two synchronous generators prior to delivery of PEC stage 2. This possible future protected event is proposed to apply to a separation of South Australia from the rest of the NEM, including separation at Heywood interconnector or at various points in the Victorian 500 kV network. Based on events during the past decade, this type of event is anticipated to occur approximately once a year.[125] AEMO is progressing with the technical feasibility and the costs and

120 SIPS will be upgraded to a new more effective scheme (WAPS), planned for implementation in early 2023. WAPS will further lower the risk of South Australia islanding (and subsequent black system) due to trip of multiple South Australian generators when South Australia is importing.

121 For more information see https://www.aemc.gov.au/sites/default/files/2019-06/Final%20determination%20-%20AEMO%20request%20for%20declaration%20of%20protected%20event.pdf.

122 Preliminary studies indicate that losing 500 MW of generation during maximum import could lead to issues including thermal overload of PEC Stage 1 plant. This could lead to a trip of PEC Stage 1, and a cascading trip of the Heywood interconnector, islanding South Australia and leading to a black system. ElectraNet is in the process of designing modifications to WAPS to be applied post PEC Stage 1 to mitigate these risks and minimise their economic impact. AEMO calculates that constraining Heywood import to 430 MW and PEC stage 1 import to 70 MW should be sufficient to prevent either of the interconnectors exceeding satisfactory limits.

123 National Electricity Amendment (Enhancing operational resilience in relation to indistinct events) Rule 2022 No. 1. The rule required AEMO to update the reclassification criteria by 9 March 2023 to reflect the broadened definition of 'contingency event' and other changes made by the rule, to better accommodate the reclassification and management of possible widespread contingency events in abnormal conditions. In the course of consultation on the reclassification criteria, AEMO will consider whether and to what extent the existing protected event could, in future, be best managed under the new reclassification framework rather than the protected event framework.

124 In accordance with rule 5.20A of the NER, AEMO is required to undertake a GPSRR at least annually and publish a GPSRR report for the NEM setting out its findings and recommendations. From 2023, the GPSRR replaces and expands on the scope of the previous PSFRR.

125 This event relates to the frequency arrest period and the subsequent frequency recovery period (up to 10 minutes after separation).

benefits of each approach for development of a submission to the Panel. AEMO has noted its intention to provide a submission to the Panel in late 2022 on this issue.[126]

- Possible future protected event associated with QNI instability given interconnector contingencies in other parts of the NEM. PSFRR historic and future scenario studies indicate that QNI could lose stability following the loss of other interconnectors, such as Heywood interconnector or PEC, and this could lead to multiple line and generation losses and the formation of synchronous islands. AEMO intends to conduct further investigation and studies to inform whether to apply for a protected event along with other measures, such as installation of an appropriate SPS to manage this issue.[127]

Other major identified risks

AEMO has also identified a number of other risks which are not necessarily related to specific existing or future protected events. The Panel has identified several key risks from the list compiled by AEMO. These are:

- Risks associated with the efficacy and adequacy of UFLS that, as noted in Section 4.1.2, is reduced by increasing levels of DPV. AEMO's analysis indicates that the amount of load under the control of under-frequency relays in South Australia, Queensland, Victoria and New South Wales is now well below the levels anticipated in clause 4.3.1(k) of the NER when there are high levels of DPV operating and considers that this is likely to deteriorate further in the coming years. AEMO specifically notes the risk to frequency collapse in Queensland following separation when QNI is importing due to insufficient UFLS during periods of high DPV generation in this regard. AEMO is collaborating with NSPs on strategies to manage risks to UFLS effectiveness.
- Risks associated with large net generation ramping events given the anti-correlation between DPV and transmission-connected IBR in response to changes in South Australian weather conditions. AEMO has identified ramping events in South Australia in 2021 where the combined DPV and IBR generator output reduced by over 1,750 MW over 2.5 hours. After its review is complete, AEMO plans to explore options to forecast and manage future NEM ramping events.
- Management of Queensland over frequency conditions following the loss of QNI. Frequency in Queensland could rise above 52 Hz following the loss of QNI when exporting. To regulate Queensland frequency to meet the Frequency Operating Standard (FOS), AEMO plans to collaborate with Powerlink to develop an over-frequency generation shedding (OFGS) scheme for Queensland to manage over-frequency during separation.
- Future scenarios indicate that with projected inertia levels, excessive OFGS and UFLS action can occur during high rate of change of frequency (RoCoF) events. AEMO will continue to monitor this in future general power system risk reviews and reviews of OFGS/UFLS settings, if required.

126 For more information see https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/psfrr/2022-final-report—-power-system-frequency-risk-review.pdf?la=en.

127 For more information see https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/psfrr/2022-final-report—-power-system-frequency-risk-review.pdf?la=en.

4.3 Frequency performance

Controlling or maintaining frequency is a key element of power system security.[128] A contingency event that leads to an imbalance in active power supply and demand will result in a frequency deviation that, if sufficiently large, may result in cascading failure and major supply disruption possibly including a black system event.

The Panel considers the NEM's frequency performance against the requirements set out in the FOS which the Panel is responsible for developing.[129] The purpose of the FOS is to define the range of allowable power system frequencies under different conditions, including normal operation and following contingencies. Generator, network and end-user equipment must be capable of operating within the range of frequencies defined by the FOS, while AEMO is responsible for maintaining the frequency within the ranges defined by these standards.[130] The Panel is currently in the process of reviewing the FOS in light of the ongoing energy market transformation, as conventional synchronous generation leaves the market and inverter-based technologies such as wind, solar and batteries enter the market. This is discussed further in Section 4.3.1 below.

This section considers:

- Frequency performance in 2021-22
- Trends in frequency performance across the frequency distribution in the NEM.

Additional explanation of frequency control-related frameworks and policy measures relevant to frequency control of frequency in the NEM is provided in chapter 4 of the AMPR explanatory statement.[131]

4.3.1 Frequency observations in 2021-22

The Panel observed an acceptable frequency performance in the NEM during the reporting year although notes a significant number of FOS breaches in Tasmania.

128 All generation, transmission, distribution, and load components connected to the power system are standardised to operate at a normal system frequency of 50 Hz.

129 Clause S5.1a.2 of the NER.

130 See clauses 4.4.1(a) and S5.3a.13(a) of the NER. AEMO has arrangements for a range of ancillary services to respond to minor or larger variations in frequency to ensure a deviation beyond the normal operating frequency band (NOFB) does not result in a system-wide event. In addition, there are emergencies under frequency control schemes (UFCS) that automatically respond as a last line of defence to prevent a severe frequency deviation cascading to a black system event.

131 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

Table 4.1: Frequency operating standard exceedance 2021-22

QUARTER	TIME FOS EXCEEDED	
	Mainland	**Tasmania**
2021 Q3	0	7
2021 Q4	0	56
2022 Q1	0	20
2022 Q2	0	31

Source: AEMO frequency and time error monitoring

The Panel notes:

- There were no times on the mainland where FOS was exceeded, down from 5 in 2020-21. This is consistent with the NEM's generally improved frequency performance observed below.
- The FOS was exceeded 114 times in Tasmania in 2021-22, down from 158 in 2020-21. The higher number of FOS exceedances in Tasmania highlights the inherent nature of the smaller power system that is not AC-interconnected with the mainland.

The Panel understands that the majority of FOS breaches in Tasmania occurred during periods when the Basslink interconnector was out of service and are characteristic of the frequency performance for the small Tasmanian system in the absence of the Basslink frequency controller.[132] The Panel has published a draft determination on a change to the FOS for Tasmania to better reflect the size of events that qualify as contingency events.[133] This change is likely to reduce the breaches of the FOS in Tasmania in future review years.[134]

4.3.2 Trends in NEM frequency performance

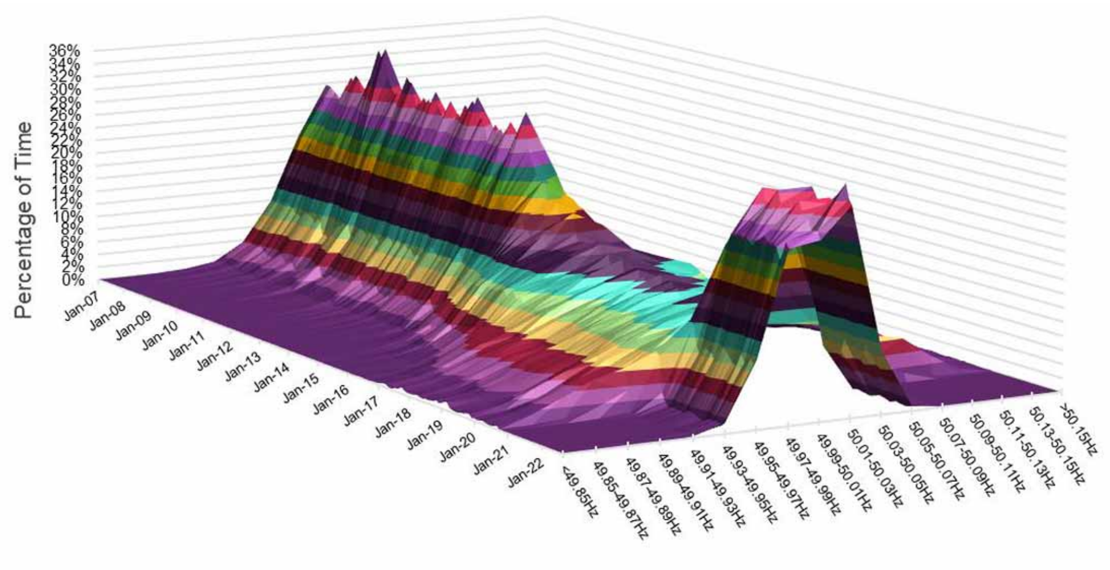
The Panel notes that frequency performance has significantly improved after a period of poor performance from 2015 to 2020. This degradation of frequency performance is shown in Figure 4.4 as a widening of the distribution of frequency during normal operation. The Panel understands this deterioration was attributable to the de-tuning of the generator governor response and exclusively relying on regulation FCAS, using a 4-second automatic generator control (AGC) signal for frequency control. The improvement in frequency outcomes was the result of the AEMC making a rule to put in place mandatory provisions for generators to provide primary frequency response.

132 For more information see https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/frequency-and-time-error-reports/quarterly-reports/2022/frequency-and-time-error-monitoring-q3-2022.pdf?la=en.

133 Extension of the existing 144MW limit for generation events in Tasmania to also apply for load and network events. This change would reflect the challenge associated with operating the Tasmanian power system including the expected interest in the connection of large commercial and industrial loads such as hydrogen electrolysers and data centres.

134 For more information see https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022.

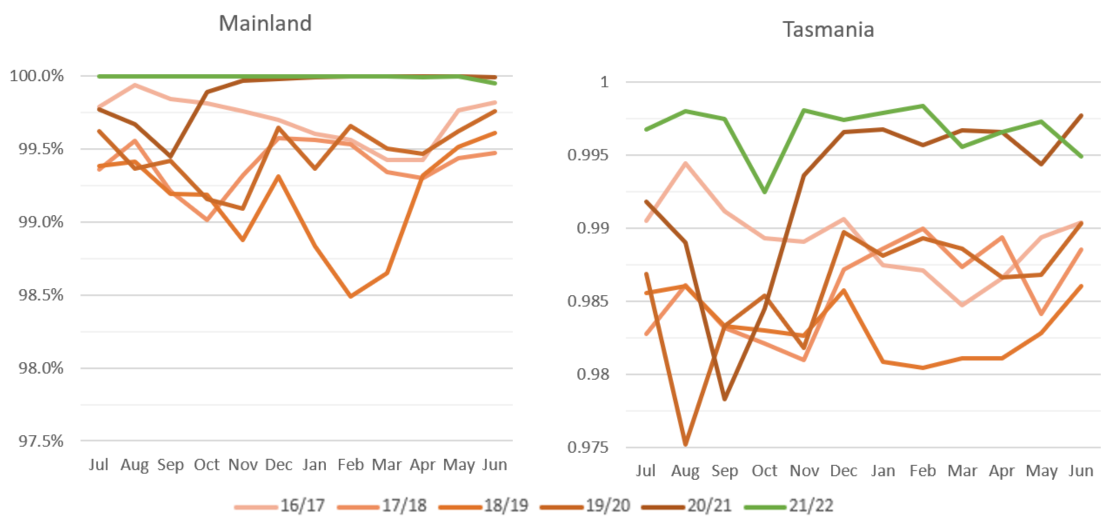
Figure 4.4: Monthly frequency distribution



Source: AEMO frequency and time error monitoring

This improvement can be further observed from Figure 4.5 which shows the percentage of time the mainland and Tasmanian frequency is within the normal operating frequency band (NOFB). Figure 4.5 shows time in the NOFB on the mainland is now close to 100% instead of the low point observed in 2018-19 where time in the NOFB was as low as 98.5%. Time in the NOFB in Tasmania is generally around 99.5%.

Figure 4.5: Proportion of time in normal operating frequency band



Source: Panel analysis of AEMO data

Frequency distribution has tightened around 50 Hz from September 2020 across both the mainland and Tasmania, following the roll-out of mandatory primary frequency response (MPFR). The AEMC final rule regarding MPFR[135] requires all scheduled and semi-scheduled generators in the NEM to support the secure operation of the power system by responding automatically to changes in power system frequency.[136] Since the implementation of the MPFR, there has been a significant reduction in the number and length of frequency excursions from the NOFB and a corresponding increase in time spent within the NOFB.

The Panel considers this improvement in frequency control indicates an improvement in the resilience of the power system to non-credible contingency events and a generally more secure power system as when contingency events do occur, frequency will be contained earlier or recovered to the NOFB faster than experienced during similar events prior to the mandatory primary frequency control implementation.

Building on MPFR arrangements, the AEMC also made a final rule that put in place incentives to further reward and encourage primary frequency response.[137] The Panel notes the value of primary frequency response incentive arrangements to remunerate and encourage generators to behave in a way that enhances frequency performance. The Panel intends to continue to monitor frequency performance and related developments through future AMPRs. In particular, the Panel intends to monitor and report on:

- Frequency performance with respect to the new system limit on RoCoF following contingency events
- Regulatory and procedural developments that relate to RoCoF, including the outcomes from the *AEMO review of the technical requirements for connection* with respect to RoCoF and any related future rule changes, and developments through the *Efficient provision of inertia* rule change
- Frequency performance during normal operation and the interaction with aggregate frequency responsiveness.

4.4 AEMO interventions for security

AEMO is responsible for operating the power system in a secure state.[138] At times, AEMO may need to intervene in the power system to ensure it remains secure. AEMO also intervenes to return the power system to a secure state following a contingency.[139] AEMO may use the following intervention mechanisms for this purpose:

- Power system directions
- Instructions

135 For more information see https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response.

136 Primary frequency response provides the initial response to frequency disturbances caused by power supply-demand imbalances. It reacts automatically and almost instantaneously to locally measured changes in system frequency outside predetermined set points. PFR involves an automatic change in active power generated (or consumed) by a generator (or load) in response to a locally measured change in system frequency.

137 For more information see https://www.aemc.gov.au/rule-changes/primary-frequency-response-incentive-arrangements.

138 Clause 4.3.1 of the NER.

139 Clause 4.2.6(b) of the NER.

- RERT dispatch for security.[140]

RERT was not dispatched for security during the reporting year and AEMO did not issue any security-related instructions. There was however extensive use of power system security directions, predominately in South Australia.

This section reports on AEMO's use of power system directions for security and considers the market notices it issued in respect of system security matters during the review period. This informs the Panel of the extent to which the power system is physically able to remain secure through market processes.

While there was no time in 2021-22 when AEMO issued load-shedding instructions to maintain security, AEMO issued instructions for distributed PV to be curtailed in South Australia in November 2022 for security reasons.[141] This represents only the second time AEMO has used instructions for PV curtailment to maintain system security.[142] While the Panel notes this intervention, it did not occur within the AMPR FY2021-22 reporting period. The Panel will report in detail on this event in the subsequent AMPR and how it may impact the future management of system security risks.

4.4.1 Power system directions

AEMO may issue directions to participants to maintain or re-establish the power system to a secure operating state, particularly within the 30 minutes following a contingency event.

Currently in the NEM, the majority of security directions are made by AEMO to synchronous gas-fired generators in South Australia. This trend started in December 2016 when AEMO announced that at least two large synchronous generating units should be online at all times in South Australia.[143]

Figure 4.6 shows that the number of security directions has increased significantly. During FY2021-22, AEMO issued 183 power system directions, an increase from 157 the previous year. All security directions were in South Australia, there were no other states where AEMO issued directions for security.

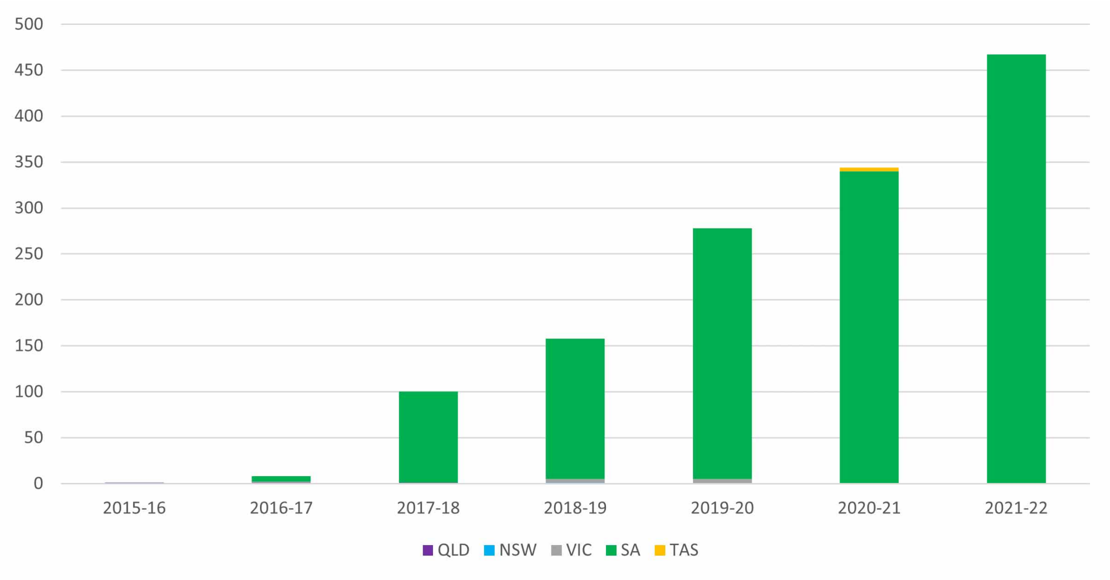
140 Clause 4.8.9 of the NER.

141 These instructions were issued to manage South Australian frequency following separation from Victoria.

142 The first occasion was on 14 March 2021.

143 This is based on specific system configurations identified by AEMO that represent a secure technical operating envelope within which a secure power system can be modelled and operated. These system configurations are predefined combinations of units that collectively are known to correspond to a secure power system. It is these system configurations that inform AEMO's direction of generators to maintain system security.

Figure 4.6: Directions for Security



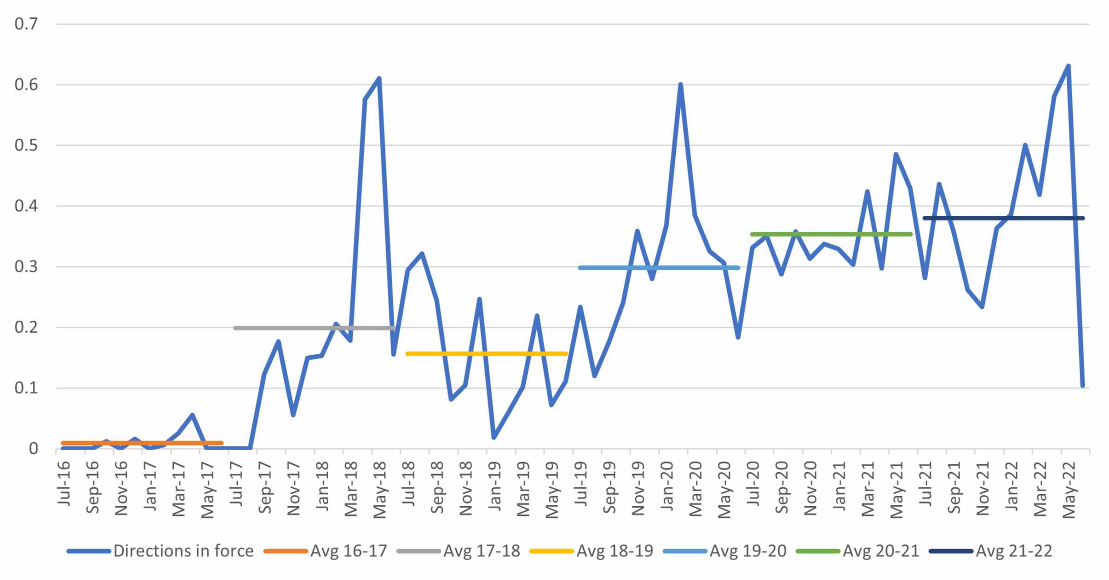
Source: Panel analysis of AEMO data

South Australia generates almost 70% of its energy by wind and solar, supported by battery storage technologies and gas. The shift away from synchronous generating units has created a shortfall in system strength[144] and inertia[145], both of which are needed to ensure a secure power system. The directions issued by AEMO for South Australia are to maintain a minimum number of synchronous machines online to provide a sufficient amount of both to avoid risk of system instability and supply interruptions following contingency events.

144 System strength relates to the ability of a power system to manage minor fluctuations in supply or demand while maintaining stable voltage levels, ensuring stable and secure supply for customers.

145 Inertia relates to the ability of a power system to manage fluctuations in supply or demand while maintaining stable system frequency. It is mostly provided by large rotating electrical machines that help to maintain the frequency of the power system.

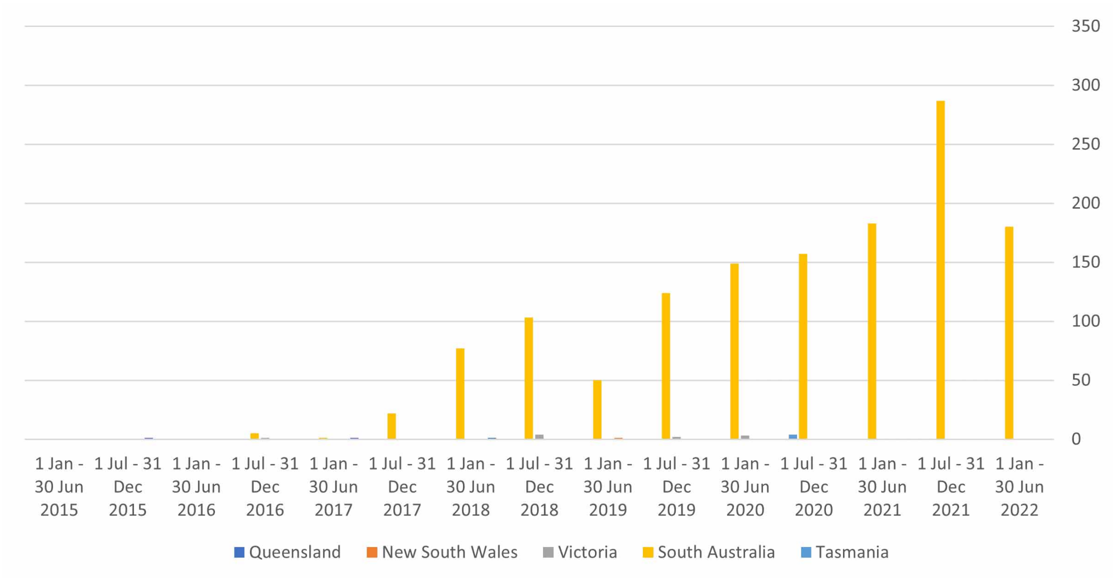
Figure 4.7: Percentage of time NEM under direction



Source: Panel analysis of AEMO data

Figure 4.7 shows that the amount of time security directions are in force in the NEM has been increasing since 2016 reaching approximately 38% of the time during the reporting year. Despite this increase, in security directions both annually and as a percentage of time across the NEM, the Panel observes recent declines in the number of security directions over the 6 months to 30 June 2022.

Figure 4.8: Directions for security — 6 month basis



Source: Panel analysis of AEMO data

Figure 4.8 shows that the first half of the reporting year (1 July 2021 to 31 December 2021) saw a significant increase in AEMO security directions in South Australia. This was due to a reduction in spot prices, low operational demand and high gas prices leading to gas powered generators decommitment. AEMO was then required to direct them to operate to maintain system security.[146]

In contrast, a reduction in AEMO security directions was observed in the second half of the reporting year. This reduction can be attributed to higher gas prices, making it more economic for gas power generators to remain online, and also the four synchronous condensers in South Australia coming into service on 25 November 2021.[147]

Integrating South Australia synchronous condensers

In 2017/2018, AEMO announced shortfalls of both system strength and inertia in South Australia which were addressed through the procurement of four synchronous condensers. These four synchronous condensers became fully operational on 25 November 2021, following which AEMO updated its system strength limit advice to reduce the minimum number of gas generation units required to ensure power system security from the equivalent of four large units to two under most operating conditions, as well as allowing for an increased nominal limit on non-synchronous generation in the state.[148]

146 For more information see https://aemo.com.au/-/media/files/major-publications/qed/2021/q3-report.pdf?la=en and https://aemo.com.au/-/media/files/major-publications/qed/2021/q4-report.pdf?la=en.

147 For more information see https://aemo.com.au/-/media/files/major-publications/qed/2022/qed-q1-report.pdf?la=en and https://aemo.com.au/-/media/files/major-publications/qed/2022/qed-q2-2022.pdf?la=en.

148 For more information see https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/related-resources/operation-of-davenport-and-robertstown-synchronous-condensers and AEMO Market Notice 92718.

The reduction in the number of synchronous generators required online, and the increased nominal limit of non-synchronous generation resources, will act to reduce the number of directions for security required in South Australia. The synchronous condensers will likely not, however, eliminate the need for security directions (at least at this point in time).

While the four synchronous condensers have addressed the shortfall in system strength in South Australia,[149] AEMO has advised that currently at least two large synchronous thermal generators are still required online to provide essential system support that may not otherwise be available in the South Australian system.

The Panel will continue to monitor the use of synchronous condensers in South Australia and whether it has an impact on the number of directions in subsequent years when greater engineering knowledge on a high VRE and non-synchronous power system is developed.

4.5 System services procurement and use

System ancillary services are used by AEMO to ensure the system remains secure to credible contingencies and re-energise the power system if there is a black system event. These services maintain key technical characteristics of the system, including standards for frequency, voltage, network loading, and system restart processes.[150] System ancillary services are procured to:

- Maintain power system frequency
- Have services available to restart the power system if needed
- Provide emergency reserves for maintaining power system reliability and security
- Provide other services needed to maintain power system performance in line with system standards.

AEMO operates eight separate markets for the delivery of frequency control ancillary services (FCAS), and purchases network support and control ancillary services (NSCAS) and system restart ancillary services (SRAS) under agreements with service providers.[151] The Panel monitors AEMO's procurement and use of these services to indicate power system security performance and signal issues arising. This section presents Panel considerations on costs and procurement of:

- FCAS
- NSCAS
- SRAS
- System strength.

Further explanation on the specific services considered in this section is provided in chapter 4 of the AMPR explanatory statement.[152]

149 With the full operation of the four synchronous condensers allowing dispatch of up to 2,500 MW of online inverter-based resources.

150 See clause 4.8.12 and schedule 5.1a of the NER.

151 Clause 3.11.2(a) of the NER.

152 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

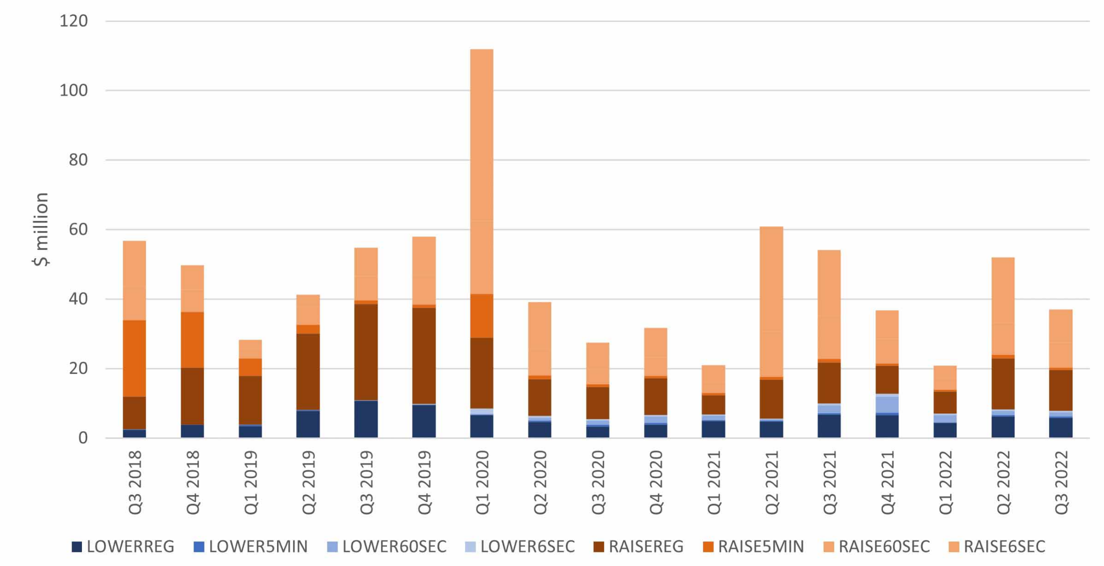
On 15 July 2021, the Commission published a final determination and final rule to introduce two new market ancillary services to help control system frequency and keep the future electricity system secure.[153] The markets will commence on 9 October 2023 and the Panel will report on the impact of these markets in subsequent AMPRs.

4.5.1 Frequency Control Ancillary Services

FCAS services are used to raise system frequency if it has fallen (by increasing generation or reducing load) and to lower system frequency if it has risen (by decreasing generation or increasing load) above acceptable bounds.

There are eight FCAS markets which are co-optimised with energy market dispatch. The different FCAS types are intended to work together to maintain a steady frequency during normal operation and to stabilise and restore the frequency by reacting quickly and smoothly to contingency events that cause frequency deviations.

Figure 4.9: Global NEM FCAS costs by quarter

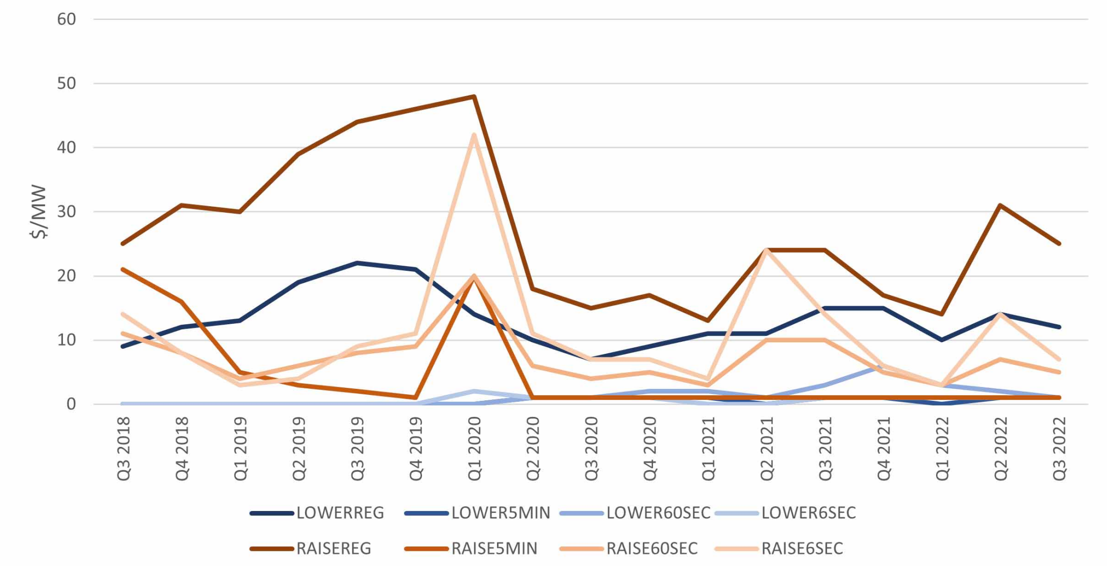


Source: Panel analysis of AER data

The AER monitors FCAS prices to understand the impact that the use of these services has on the total cost of running the power system. The Panel observes that the FCAS market costs have risen since 2020-21. Overall, FCAS costs were $163.6 million in 2020-21, an increase from $140.9 million in 2020-21.

153 For more information see https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service.

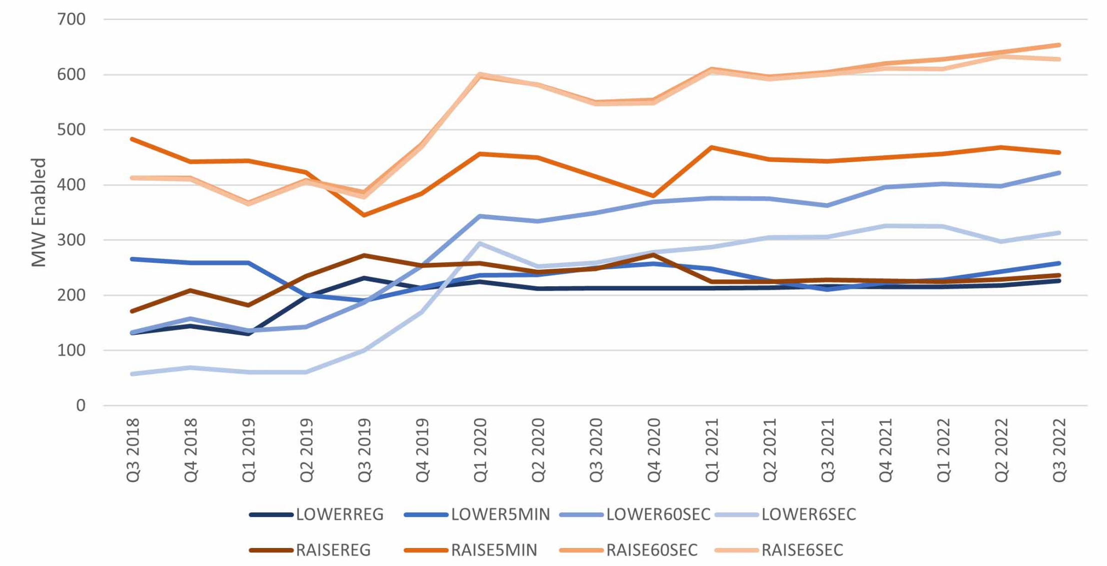
Figure 4.10: NEM FCAS prices by quarter



Source: Panel analysis of AER data

While there were some changes throughout 2021-22 in the volume of FCAS services procured due to varying power system operating conditions, the variation in most services was relatively small. This is illustrated in Figure 4.11 below.

Figure 4.11: NEM FCAS enablement



Source: Panel analysis of AER data

From the figures above, the Panel notes that:

- Raise regulation prices are up from 2020-21, averaging $22/MW in 2021-22, compared to $17/MW in 2019-20
- Lower regulation prices have also increased, averaging $13/MW in 2021-22, compared to $10/MW in the previous year
- Contingency raise prices are similar for 2020-21 to the previous period and contingency lower prices remain near zero, reflecting the low cost of supplying it for most generating units.

The Panel understands that the increase in FCAS prices may be reflecting the retirement of synchronous generators which previously were able to provide FCAS at a low cost via the marginal costs. As more VRE enters the power system, technologies such as batteries have to reserve headroom to provide FCAS and therefore may charge more to reflect the opportunity cost. The Panel acknowledges this risk, particularly in regard to regulation FCAS prices, as the power system transitions away from units that historically provided these services at very low cost. The Panel will closely monitor any upward trend in FCAS prices in subsequent AMPRs.

4.5.2 Network Service Control Ancillary Services

NSCAS are non-market ancillary services that may be procured by AEMO to maintain power system security and reliability and to maintain or increase the power transfer capability of the transmission network.[154] AEMO has defined the types of NSCAS according to the needs that would be primarily addressed — that is, maintaining system security and reliability, and increasing net market benefits. As such, AEMO has divided NSCAS into the following types:

- Reliability and Security Ancillary Service (RSAS)
- Market Benefit Ancillary Service (MBAS).

The Panel's consideration of NSCAS in this AMPR is limited to RSAS.

AEMO assesses NSCAS needs in the NEM on a five-year assessment cycle. When AEMO identifies an NSCAS gap, the NER gives TNSPs the primary responsibility for putting arrangements in place to address the gap.[155] AEMO will be required to acquire NSCAS only to ensure power system security and reliability if the NSCAS gap remains unmet after the TNSP's attempt to procure services.[156]

AEMO has not declared any new NSCAS gaps in their 2022 NSCAS Report (time-frame is Dec 2022 to Dec 2027).[157] This is because announced transmission, generation, battery and system strength projects are expected to provide a range of essential system security services. However, any delays to major projects could expose system security gaps,

154 See Chapter 10 of the NER for definition of "NSCAS" and "NSCAS need".

155 Clause 3.11.3(a) of the NER.

156 Clause 3.11.3(c)(3) of the NER.

157 For more information see https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-nscas-report.pdf?la=en.

particularly in Queensland, New South Wales and Victoria. In its 2022 NSCAS Report, AEMO confirmed the status of the following NSCAS gaps:[158]

- Voltage control gap at Coleambally — AEMO has confirmed the RSAS gap of 2 megavolt amperes reactive (MVAr) reactive power absorption in the Coleambally region declared in the 2021 System Security Report. Transgrid currently has operational measures in place to manage this issue and AEMO will continue to receive updates from Transgrid on the resolution of this matter.
- Voltage control gap in southern Queensland — AEMO has confirmed the RSAS gap of 120 MVAr reactive power absorption in Southern Queensland declared in the 2021 System Security Report. Powerlink is finalising a near-term solution for this gap.[159]

AEMO is also considering future NSCAS gaps in particular to manage South Australian voltages given declining minimum demand. AEMO has identified that under low demand conditions voltage challenges may exist in the distribution network which would have a flow-on impact on the ability to adjust voltage control set points in the transmission network.[160] ElectraNet and SA Power Networks are investigating measures to control voltages across the distribution and transmission systems, including proposed installation of reactors.[161]

The Panel will continue to monitor the risk of an NSCAS gap emerging in Queensland, New South Wales and Victoria in light of any delays to major projects in subsequent AMPRs. In addition, the Panel will also report on potential NSCAS gaps in South Australia due to declining minimum demand forecasts.

4.5.3 System Restart Ancillary Services

SRAS enable the recovery of the power system following a major disturbance, where large parts of the power system have collapsed to a "black system" condition.[162] SRAS is currently provided by generators with the capability to start or remain in service without electricity being provided from the grid.

For 2021-22, AEMO procured 11 SRAS contracts, down from 12 the previous year. This was due to 1 less contract procured in Queensland following the merger of the Queensland-north and Queensland-south sub-network. For this period the sub-networks are:

- Queensland
- New South Wales

158 For more information seehttps://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-nscas-report.pdf?la=en.

159 For the latter end of the five-year NSCAS assessment period, AEMO is not declaring a gap. However, re-assessment may be needed in 2023 as more information becomes available. Committed and anticipated generation and storage projects are expected to provide reactive support, along with Powerlink's ongoing project to manage voltages in South East Queensland, but uncertainty remains about the impact of synchronous generation dispatch and system strength services. AEMO will continue to receive updates from Powerlink on this matter, and Powerlink is continuing to pursue measures to maintain voltages in southern Queensland.

160 For more information see https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-nscas-report.pdf?la=en.

161 For more information see https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-nscas-report.pdf?la=ena.

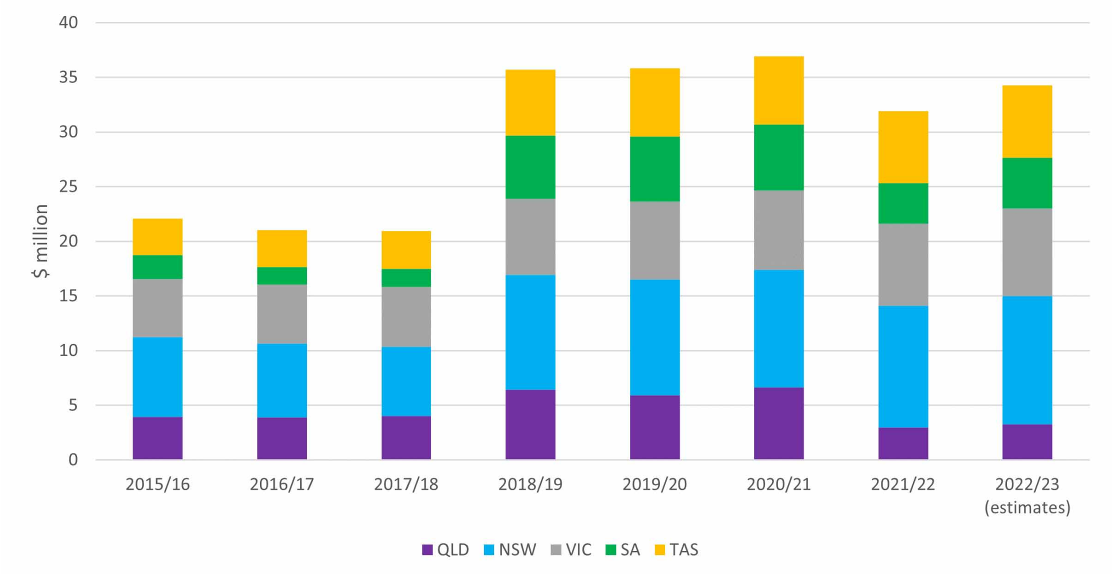
162 A black system condition is defined in Chapter 10 of the NER as the absence of voltage on all or a significant part of the transmission system or within a region during a major supply disruption affecting a significant number of customers.

- Victoria
- South Australia
- Tasmania.

The total cost of SRAS in 2021-22 was $31.9 million, a decrease of approximately $5 million from the previous year.

The Panel notes the decrease in SRAS costs are largely driven by a decrease in costs for the Queensland sub-region. The Panel understands this may be due to AEMO's decision to combine north and south Queensland sub-networks into a single sub-region in October 2020 for the purposes of SRAS procurement.[163] As noted above, this change resulted in 1 less SRAS contract procured for Queensland and a reduction in SRAS costs by $3.7 million for this region.

Figure 4.12: SRAS costs by sub-network



Source: Panel analysis of AEMO data

While the Panel notes SRAS procurement costs remain largely consistent with costs since 2018, the Panel is also aware of future challenges to SRAS posed by the synchronous generator retirement. SRAS 'black start' service availability is limited by the existing plant available with that capability. A sufficient supply of future SRAS, will require investment in new capability in IBR plant that has not historically been SRAS capable, once incumbent SRAS capable thermal generation retire.

163 On 16 October 2020, AEMO made a determination to combine the existing north and south Queensland sub-networks into a single sub-network for Queensland. The single sub-network aligns with the NEM regional boundary for Queensland. Following this, the Panel then published a final report on the System Restart Standard on 28 January 2021 for the combined region. For further information see https://www.aemc.gov.au/market-reviews-advice/review-system-restart-standard-2020.

Although the retirement of existing SRAS capable plant is not a threat to the availability of sufficient SRAS at this time, the Panel notes that future AEMO SRAS procurement rounds may be more challenging with higher prices demanded by a smaller pool of SRAS capable generation.

The Panel is considering a review into the system restart standard, ahead of AEMO's upcoming SRAS procurement around. If such a review is initiated, a key aspect will be considering how best to signal for new investment in SRAS capable plant. If such a review was to commence, it would occur in late 2023.

4.5.4 System Strength

System strength can be understood as the ability of the power system to maintain and control the voltage wave form at any given location in the power system, both during steady state operation and following a disturbance. A smooth, consistent and predictable voltage waveform is critical to the power system's voltage remaining within the parameters required for a safe and secure transfer of energy from generators to consumers.[164]

AEMO is responsible for setting and reviewing the minimum fault levels needed to maintain power system security across the NEM.[165] AEMO considers the system strength gaps in the NEM in its system strength reports and the Panel has considered AEMO's 2022 System Strength Report.[166]

System strength provision is particularly pressured in the context of low demand on the power system and decline of available sources of traditional service provision such as synchronous generators. AEMO has maintained existing minimum fault level requirements across all the NEM states, including South Australia where no shortfalls were identified as the four synchronous condensers are delivering sufficient system strength for this region.

The Panel will continue to monitor system strength in the power system and will report in subsequent AMPRs whether there is an emerging risk for NSPs to meet their system strength obligation under the new system strength framework.

AEMO has not declared any new system strength shortfalls before 2025. However, based on its 2022 assessment, it has identified seven adjustments to existing shortfalls. These shortfalls are based in Tasmania, New South Wales and Queensland and are summarised in the table below.

For Tasmania, AEMO confirms that the system strength shortfall based on its 2019 assessment remains unchanged and will re-emerge when the current contracts with Hydro Tasmania expire in 2024 as there is insufficient generation in place in the market to address these gaps. TasNetworks will investigate options to alleviate this shortfall prior to the expiration of these contracts in April 2024.[167]

164 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

165 Clause 4.4.5 of the NER.

166 For more information see https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-system-strength-report.pdf?la=en.

167 For more information see https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-system-strength-report.pdf?la=en.

The existing shortfalls in New South Wales and Queensland have been slightly lowered in AEMO's 2022 assessment. Both shortfalls are due to the projected decline in the number of synchronous machines online.[168]Transgrid and Powerlink are continuing to progress its consideration of how to provide services to address the shortfalls.[169]

Table 4.2: Summary of 2022 system strength shortfalls in the NEM

SYSTEM STRENGTH NODES	FAULT LEVEL SHORTFALL DECLARED BEFORE DECEMBER 2025 (MVA)
New South Wales	
Armidale	No shortfall
Buronga	No shortfall
Darlington Point	No shortfall
Newcastle	A shortfall of 711 MVA is declared from 1 July 2025 to 1 December 2025. This is an adjustment to the existing shortfall declared in May 2022. AEMO will request that Transgrid provide system strength services to address the shortfall by 1 July 2025.
Sydney West	A shortfall of 314 MVA is declared from 1 July 2025 to 1 December 2025. This is an adjustment to the existing shortfall declared in May 2022. AEMO has requested that services be available from 1 July 2025.
Wellington	No shortfall
Queensland	
Gin Gin	A shortfall of up to 64 MVA is declared until from this present year until 1 December 2025. This is an adjustment to the existing shortfall declared in May 2022. Powerlink is currently preparing to make services available. AEMO has requested that services be available from 31 March 2023.
Greenbank	No shortfall
Lilyvale	No shortfall
Ross	No shortfall
Western Downs	No shortfall
South Australia	

168 For more information see https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-system-strength-report.pdf?la=en.

169 For more information see https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-system-strength-report.pdf?la=en.

SYSTEM STRENGTH NODES	FAULT LEVEL SHORTFALL DECLARED BEFORE DECEMBER 2025 (MVA)
Davenport	No shortfall
Para	No shortfall
Robertstown	No shortfall
Tasmania	
Burnie	A shortfall range of 374 to 423 MVA is declared for 15 April 2024 to 1 December 2025. This is an adjustment to the existing shortfall declared in December 2021. AEMO has requested that services be available from 15 April 2024.
George Town	A shortfall range of 717 to 827 MVA is declared for 15 April 2024 to 1 December 2025. This is an adjustment to the existing shortfall declared in December 2021. AEMO has requested that services be available from 15 April 2024.
Risdon	A shortfall range of 403 to 511 MVA is declared for 15 April 2024 to 1 December 2025. This is an adjustment to the existing shortfall declared in December 2021. AEMO has requested that services be available from 15 April 2024.
Waddamana	A shortfall range of 440 to 594 MVA is declared for 15 April 2024 to 1 December 2025. This is an adjustment to the existing shortfall declared in December 2021. AEMO has requested that services be available from 15 April 2024.
Victoria	
Dederang	No shortfall
Hazelwood	No shortfall
Moorabool	No shortfall
Red Cliffs	No shortfall
Thomastown	No shortfall

Source: AEMO's 2022 System Strength Report, December 2022

4.5.5 Total costs of operating the system

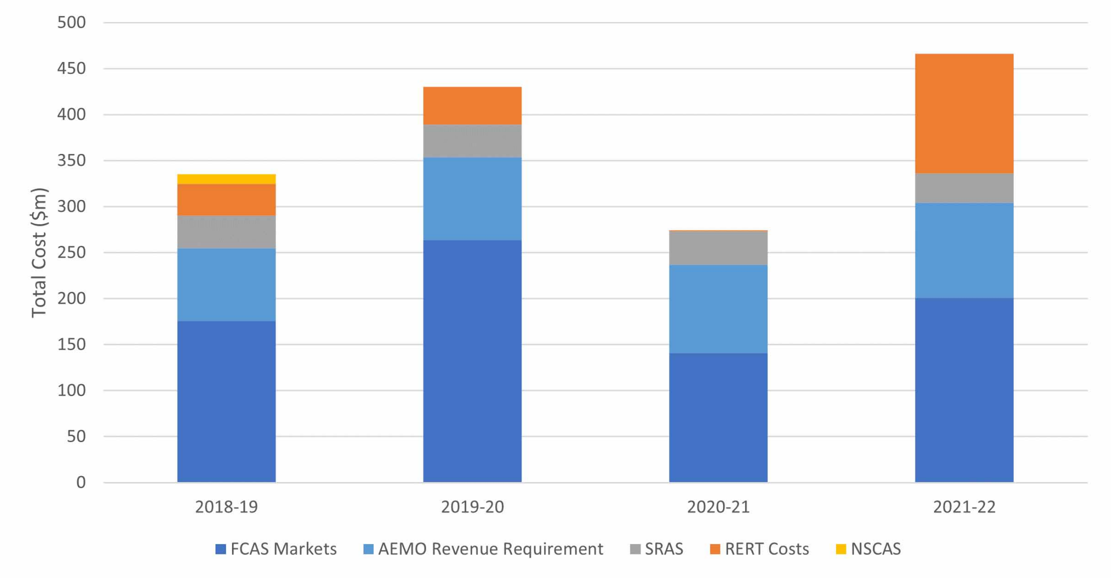
The costs of operating the system increased by approximate $192 million in 2021-22 compared to the previous year. This was largely the result of RERT costs that were dispatched for reliability during the June 2022 events. Total RERT costs for this period increased by around $130 million. FCAS costs also increased (discussed in Section 4.5.1) whereas in contract, SRAS costs decreased for the 2021-22 year (discussed in Section 4.5.3).

In 2021-22:

- Just over $200 million was paid out through FCAS markets, up from $140 million in 2020-21
- Total RERT costs were $130 million, an increase from $0.66 million in 2020-21
- SRAS costs were $31.9 million, a slight decrease from $36.9 million in 2020-21.

The Panel observes that the annual system costs vary year-on-year and it is difficult to draw a definitive trend on whether overall we are likely to see the costs for ancillary services increase or decrease in the coming years. The Panel will continue to closely monitor the total system costs in subsequent AMPRs, particularly with the commencement of the fast frequency response market in October 2023, noting that the introduction of FFR is designed to be a more cost-effective way of maintaining security in the system.

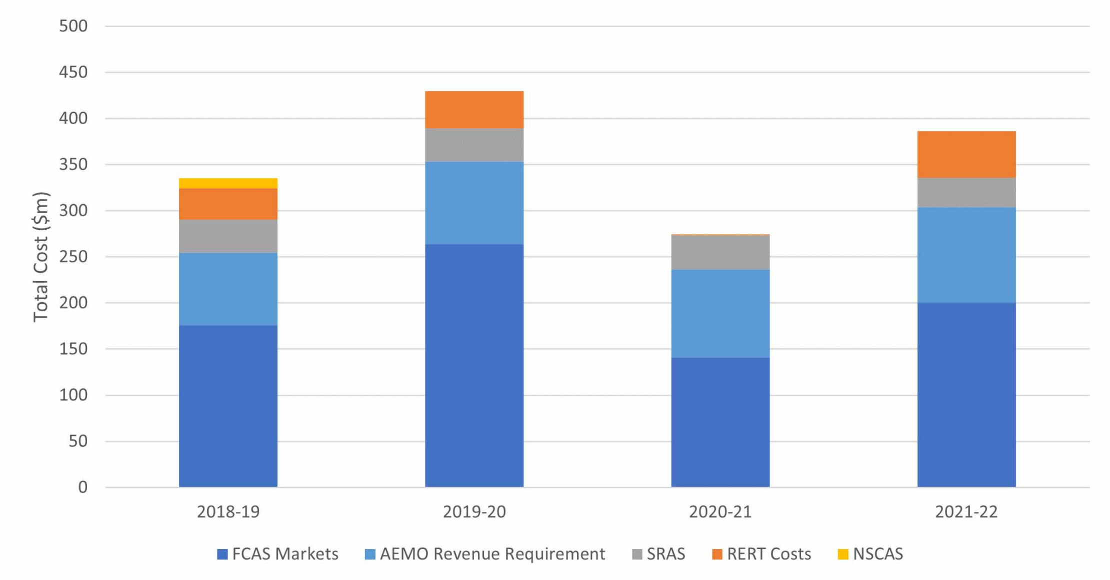
Figure 4.13: Costs of operating the system



Source: Panel analysis of AEMO and AER data

The Panel observes that without the RERT costs associated with the events of June 2022, the total system costs for 2021-22 remains higher than the previous year. This is due to the increase in FCAS costs (discussed further in Section 4.5.1).

Figure 4.14: Costs of operating the system (excl. June 2022)



Source: Panel analysis of AEMO and AER data

5 SAFETY

5.1 Safety performance of the power system

This chapter covers the Panel's assessment of safety of the power system in FY2021-22.

The Panel notes that its role regarding safety for the purposes of this report relates primarily to the operation of assets and equipment within their technical limits.

This chapter sets out:

- The definition of power safety for the purposes of this review
- Safety performance of the NEM in FY2021-22.

This chapter makes reference to NEM safety frameworks the details of which are explained in chapter 5 of the AMPR explanatory statement.[170]

5.2 Overview of safety

The safety of the power system and associated equipment, power system personnel and the public is covered in general terms under the NEL. However, there is no national safety regulator specifically for electricity. Instead, state and territory legislation governs safety generally, which includes the safe supply of electricity and the broader safety requirements associated with electricity use in households and businesses.

As discussed in the accompanying explanatory statement, the Panel's role in relation to safety for the purposes of the AMPR is narrow and relates primarily to the operation of assets and equipment within their technical limits and not to the broader safety requirements governed by jurisdictional legislation.

5.3 Safety performance of the power system in 2021-22

The Panel has reviewed AEMO's power system incident reports and consulted with AEMO to understand if there were any instances where actions to maintain the power system within relevant standards and technical limits resulted in technical safety issues. The Panel is not aware of any incidents during the FY2021-22 reporting period where AEMO's management of power system security has resulted in a safety issue.

The Panel also notes that there were no instances in FY2021-22 where AEMO issued a direction and the directed participant did not comply on the grounds that complying with the direction would be a hazard to public safety, or materially risk damaging equipment or contravene any other law.

170 For more information see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

ABBREVIATIONS

AC	Alternating Current
ACCC	Australian Competition and Consumer Commission
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AGC	Automatic Generator Control
APC	Administered Price Cap
APP	Administered Price Period
ARENA	Australian Renewable Energy Agency
ASX	Australian Securities Exchange
CBD	Central Business District
CEC	Clean Energy Council
CER	Consumer Energy Resources
Commission	See AEMC
CPT	Cumulative Price Threshold
CRI	Connections Reform Initiatives
DC	Direct Current
DNSP	Distribution Network Service Provider
DPV	Distributed PV
DWGM	Declared Wholesale Gas Market
EAAP	Energy Adequacy Assessment Projection
ECMC	Energy and Climate Change Ministerial Council
EMS	Energy Management System
ESB	Energy Security Board
ESOO	Electricity Statement of Opportunities
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
FOS	Frequency Operating Standard
FUM	Forecast Uncertainty Measure
GPSRR	General Power System Risk Review
IBR	Inverter Based Resources
IRM	Interim Reliability Measure
ISP	Integrated System Plan
LNG	Liquified Natural Gas
LOR	Lack of Reserve
MBAS	Market Benerfit Ancillary Service
MCE	Ministerial Council on Energy

MFP	Market Floor Price
MPC	Market Price Cap
MPFR	Mandatory Primary Frequency Response
MSPS	Market Suspension Pricing Schedule
MT-PASA	Medium Term-Projected Assessment of System Adequacy
NEL	National Electricity Law
NEMDE	NEM Dispatch Engine
NEO	National Electricity Objective
NER	National Energy Rules
NERL	National Energy Retail Law
NERO	National Energy Retail Pbjective
NGL	National Gas Law
NGO	National Gas Objective
NOFB	Normal Operating Frequency Band
NSCAS	Network Support and Control Ancillary Services
OCD	Over-constrained Dispatch
OFGS	Over Frequency Generation Shedding
PEC	Project Energy Connect
PFR	Primary Frequency Response
PSFRR	Power System Frequency Risk Review
PV	Photovoltaics
QED	Quarterly Energy Dynamics
QNI	Queensland - New South Wales Interconnector
RAS	Remedial Action Schemes
RERT	Reliability and Emergency Reserve Trader
RET	Renewable Energy Target
RMS	Root Mean Square
RoCoF	Rate of Change of Frequency
RSAS	Reliability and Security Ancillary Service
RSS(R)	Reliability Standard and Settings (Review)
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SEC	State Electricity Commission
SIPS	System Integrity Protection Scheme
SPS	Special Proctection Scheme
SRAS	System Restart Ancillary Services
ST-PASA	Short Term-Projected Assessment of System Adequacy

STTM	Short Term Trading Market
TNSP	Transmission Network Service Provider
TPIR	Transmission Planning and Investment Review
UFCS	Under Frequency Control Scheme
UFLS	Under Frequency Load Shedding
USE	Unserved Energy
VCR	Value of Customer Reliability
VNI	Victoria - New South Wales Interconnector
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
WAPS	Wide Area Protection Scheme
WMZ	West Murray Zone

GLOSSARY

Available capacity	The total MW capacity available for dispatch by a scheduled generating unit or scheduled load (i.e. maximum plant availability) or, in relation to a specified price band, the MW capacity within that price band available for dispatch (i.e. availability at each price band).
Busbar	A busbar is an electrical conductor in the transmission system that is maintained at a specific voltage. It is capable of carrying a high current and is normally used to make a common connection between several circuits within the transmission system. The rules define busbar as 'a common connection point in a power station switchyard or a transmission network substation'.
Cascading outage	The occurrence of a succession of outages, each of which is initiated by conditions (e.g. instability or overloading) arising or made worse as a result of the event preceding it.
Contingency events	These are events that affect the power system's operation, such as the failure or removal from operational service of a generating unit or transmission element. There are several categories of contingency event, as described below: • credible contingency event is a contingency event whose occurrence is considered "reasonably possible" in the circumstances. For example: the unexpected disconnection or unplanned reduction in capacity of one operating generating unit; or the unexpected disconnection of one major item of transmission plant • non-credible contingency event is a contingency event whose occurrence is not considered "reasonably possible" in the circumstances. Typically a non-credible contingency event involves simultaneous multiple disruptions, such

	as the failure of several generating units at the same time.
Customer average interruption duration index (CAIDI)	The sum of the duration of each sustained customer interruption (in minutes) divided by the total number of sustained customer interruptions (SAIDI divided by SAIFI). CAIDI excludes momentary interruptions (one minute or less duration).
Directions	Under s. 116 of the NEL, AEMO may issue directions. Section 116 directions may include directions as issued under clause 4.8.9 of the NER (e.g. directing a scheduled generator to increase output) or clause 4.8.9 instructions (e.g. instructing a network service provider to load shed). AEMO directs or instructs participants to take action to maintain or re-establish the power system to a secure operating state, a satisfactory operating state, or a reliable operating state.
Dispatch	The act of initiating or enabling all or part of the response specified in a dispatch bid, dispatch offer or market ancillary service offer in respect of a scheduled generating unit, a scheduled load, a scheduled network service, an ancillary service generating unit or an ancillary service load in accordance with NER rule 3.8, or a direction or operation of capacity the subject of a reserve contract as appropriate.
Distribution network	The apparatus, equipment, plant and buildings (including the connection assets) used to convey and control the conveyance of electricity to consumers from the network and which is not a transmission network.
Distribution network service provider (DNSP)	A person who engages in the activity of owning, controlling, or operating a distribution network.
Frequency control ancillary services (FCAS)	Those ancillary services concerned with balancing, over short intervals, the power supplied by generators with the power consumed by loads (throughout the power system). Imbalances cause the frequency to deviate from 50 Hz.

Interconnector	A transmission line or group of transmission lines that connect the transmission networks in adjacent regions.
Jurisdictional planning body	The transmission network service provider responsible for planning a NEM jurisdiction's transmission network.
Lack of reserve	This is when reserves are below specified reporting levels.
Load	A connection point (or defined set of connection points) at which electrical power is delivered, or the amount of electrical power delivered at a defined instant at a connection point (or aggregated over a defined set of connection points).
Load event	In the context of frequency control ancillary services, a load event: involves a disconnection or a sudden reduction in the amount of power consumed at a connection point and results in an overall excess of supply.
Load shedding	Reducing or disconnecting load from the power system either by automatic control systems or under instructions from AEMO. Load shedding will cause interruptions to some energy consumers' supplies.
Low reserve condition (LRC)	This is when reserves are below the minimum reserve level.
Momentary average interruption frequency index (MAIFI)	The total number of customer interruptions of one minute or less duration, divided by the total number of distribution customers.
Medium term projected assessment of system (MT PASA) (also see ST PASA)	A comprehensive programme of information collection, analysis and disclosure of medium-term power system reliability prospects. This assessment covers a period of 24 months and enables market participants to make decisions concerning supply, demand and outages. It must be issued weekly by AEMO.
Minimum reserve level (MRL)	The minimum reserve margin calculated by AEMO to meet the reliability standard.
Ministerial Council on Energy (MCE)	The MCE is the national policy and governance body for the Australian energy market, including for electricity and gas, as

	outlined in the COAG Australian Energy Market Agreement of 30 June 2004.
National Electricity Code	The National Electricity Code was replaced by the National Electricity Rules on 1 July 2005.
National electricity market (NEM)	The NEM is a wholesale exchange for the supply of electricity to retailers and consumers. It commenced on 13 December 1998, and now includes Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia, and Tasmania.
National Electricity Law (NEL)	The NEL is contained in a schedule to the National Electricity (South Australia) Act 1996. The NEL is applied as law in each participating jurisdiction of the NEM by the application statutes.
National Electricity Rules (NER)	The NER came into effect on 1 July 2005, replacing the National Electricity Code.
Network	The apparatus, equipment and buildings used to convey and control the conveyance of electricity. This applies to both transmission and distribution networks.
Network capability	The capability of a network or part of a network to transfer electricity from one location to another.
Network control ancillary services (NCAS)	Ancillary services concerned with maintaining and extending the operational efficiency and capability of the network within secure operating limits.
Network event	In the context of frequency control ancillary services, the tripping of a network resulting in a generation event or load event.
Network service providers	An entity that operates as either a transmission network service provider (TNSP) or a distribution network service provider (DNSP).
Network services	The services (provided by a TNSP or DNSP) associated with conveying electricity and which also include entry, exit, and use-of-system services.
Operating state	The operating state of the power system is defined as satisfactory, secure or reliable, as described below.

	The power system is in a **satisfactory** operating state when: • it is operating within its technical limits (i.e. frequency, voltage, current etc are within the relevant standards and ratings) • the severity of any potential fault is within the capability of circuit breakers to disconnect the faulted circuit or equipment. The power system is in a **secure** operating state when: • it is in a satisfactory operating state • it will return to a satisfactory operating state following a single credible contingency event. The power system is in a **reliable** operating state when: • AEMO has not disconnected, and does not expect to disconnect, any points of load connection under NER clause 4.8.9 • no load shedding is occurring or expected to occur anywhere on the power system under NER clause 4.8.9 • in AEMO's reasonable opinion the levels of short term and medium term capacity reserves available to the power system are at least equal to the required levels determined in accordance with the power system security and reliability standards.
Participant	An entity that participates in the national electricity market.
Plant capability	The maximum MW output which an item of electrical equipment is capable of achieving for a given period.
Power system reliability	The measure of the power system's ability to supply adequate power to satisfy demand, allowing for unplanned losses of generation capacity.
Power system security	The safe scheduling, operation and control of the power system on a continuous basis.

Probability of exceedance (POE)	POE relates to the weather/temperature dependence of the maximum demand in a region. A detailed description is given in the AEMO ESOO.
Reliable operating state	Refer to operating state.
Reliability of supply	The likelihood of having sufficient capacity (generation or demand-side response) to meet demand (the consumer load).
Reliability standard	The Reliability Panel's current standard for reliability is that there should be sufficient generation and bulk transmission capacity so that the maximum expected unserved energy is 0.002 per cent.
Reserve	The amount of supply (including available generation capability, demand side participation and interconnector capability) in excess of the demand forecast for a particular period.
Reserve margin	The difference between reserve and the projected demand for electricity, where: Reserve margin = (generation capability + interconnection reserve sharing) – peak demand + demand-side participation.
System average interruption duration index (SAIDI)	The sum of the duration of each sustained customer interruption (in minutes), divided by the total number of distribution customers. SAIDI excludes momentary interruptions (one minute or less duration).
System average interruption frequency index (SAIFI)	The total number of sustained customer interruptions, divided by the total number of distribution customers. SAIFI excludes momentary interruptions (one minute or less duration).
Satisfactory operating state	Refer to operating state.
Scheduled load	A market load which has been classified by AEMO as a scheduled load at the market customer's request. A market customer may submit dispatch bids in relation to scheduled loads.
Secure operating state	Refer to operating state.
Separation event	In the context of frequency control ancillary services, this describes the electrical

	separation of one or more NEM regions from the others, thereby preventing frequency control ancillary services being transferred from one region to another.
Short term projected assessment of system adequacy (ST PASA) (also see MT PASA)	The PASA in respect of the period from two days after the current trading day to the end of the seventh day after the current trading day inclusive in respect of each trading interval in that period.
Spot market	Wholesale trading in electricity is conducted as a spot market. The spot market allows instantaneous matching of supply against demand. The spot market trades from an electricity pool, and is effectively a set of rules and procedures (not a physical location) managed by AEMO (in conjunction with market participants and regulatory agencies) that are set out in the NER.
Supply-demand balance	A calculation of the reserve margin for a given set of demand conditions, which is used to minimise reserve deficits by making use of available interconnector capabilities.
Technical envelope	The power system's technical boundary limits for achieving and maintaining a secure operating state for a given demand and power system scenario.
Transmission network	The high-voltage transmission assets that transport electricity between generators and distribution networks. Transmission networks do not include connection assets, which form part of a transmission system.
Transmission network service provider (TNSP)	An entity that owns operates and/or controls a transmission network.
Unserved energy (USE)	The amount of energy that is required (or demanded) by consumers but which is not supplied due to a shortage of generation or interconnection capacity. Unserved energy does not include interruptions to consumer supply that are caused by outages of local transmission or distribution elements that do not significantly impact the ability to transfer power into a region.

A KEY EVENTS

A.1 Timeline of events leading to the APP and market suspension

The table below outlines the timeline of events leading to the APP and market suspension in June 2022. For a detailed overview of these events as well as observations made by the Panel, see Chapter 2 of the final report.

Table A.1: Summary of Events

TIME	EVENT
12 June 2022 18:55	Queensland APP commenced
13 June 2022 06:30	QNI secure limit exceeded for 1 hour
13 June 2022 18:35	New South Wales APP commenced
13 June 2022 22:00	South Australia APP commenced
13 June 2022 22:05	Victoria APP commenced
15 June 2022 14:05	AEMO suspends the spot market Market Suspension Pricing Schedule (MSPS) applied
17 June 2022 17:20	Period of low frequency analysis
22 June 2022 04:00	South Australia APP ended
23 June 2022 04:00	Queensland, New South Wales, Victoria APP ended AEMO ends MSPS Dispatch pricing resumed
24 June 2022 14:00	Market suspension ends Spot market resumed in the NEM

Source: Panel analysis of AEMO's market suspension report

B RELIABILITY

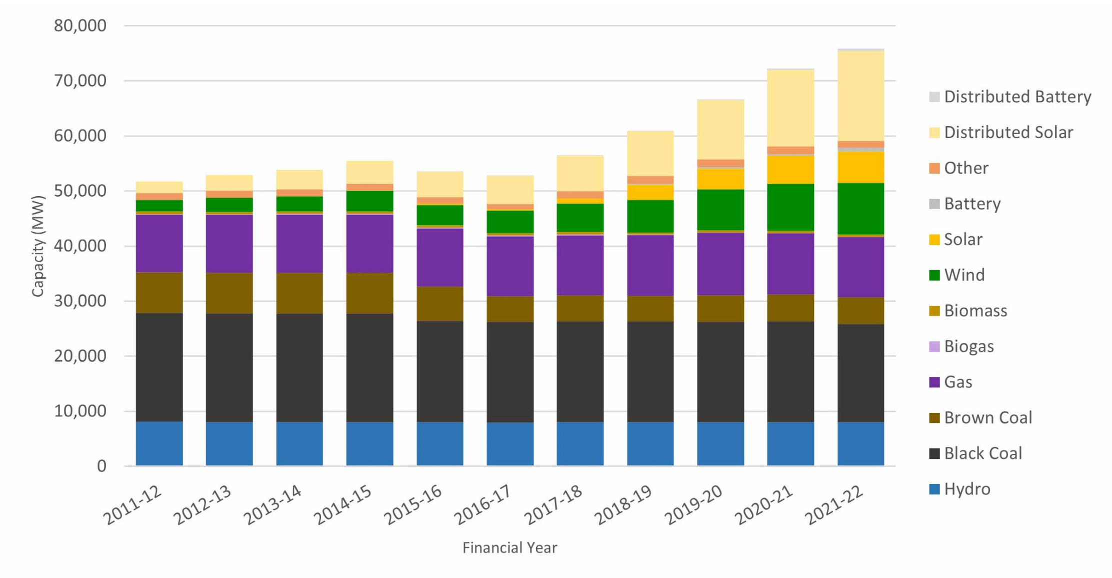
B.1 Introduction

This appendix outlines the complete set of charts relating to reliability outcomes in the NEM, in addition to those provided in Chapter 3 of the final report. The Panel does not make any recommendations in relation to the charts below but provides commentary on the trends observed throughout FY2021-22 reporting period.

B.2 NEM Installed Capacity

The generation mix in the NEM continues to evolve with significant new unit entries and units reaching their end-of-life or being retired early for economic reasons. Recent years has seen significant connections of new VRE generation, primarily wind and solar. While still small, the amount of grid-scale storage is increasing and is expected to play a significant role in reliability.

Figure B.1: NEM Installed Capacity



Source: Panel analysis of AEMO data

B.3 NEM Energy Output

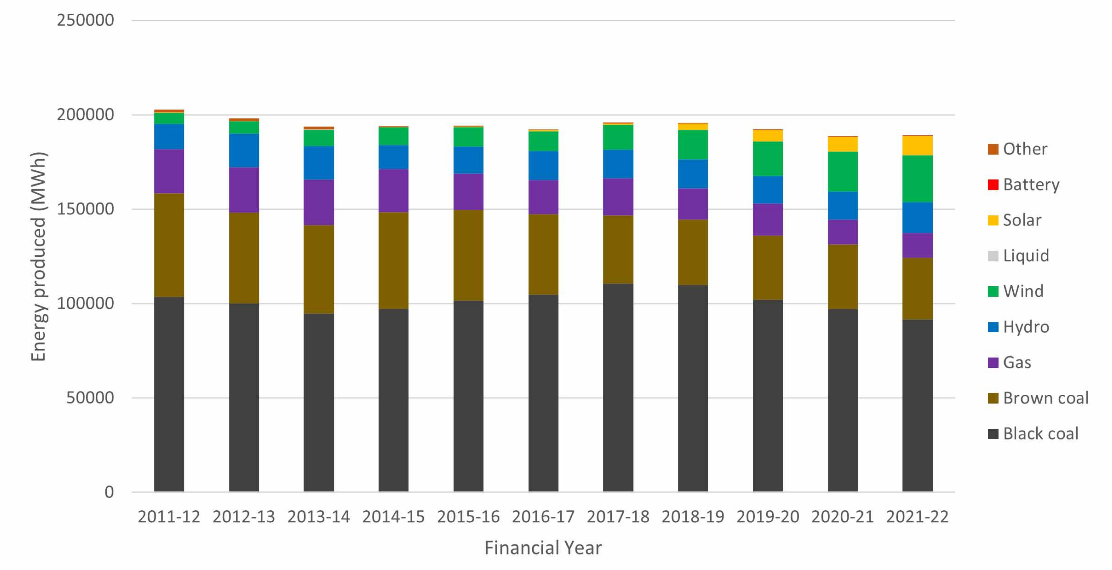
FY2021-22 saw the continuation of several trends in energy generation illustrative of a system trending towards higher VRE penetrations.

The following key changes in energy sources since 2020-22 are:

- Coal-fired generators — decreased by 5.4%
- Gas-fired generators — decreased by 0.1%
- Grid-scale sources (all generation) — increased by 0.3%

- Wind generators — increased by 16.8%
- Grid-scale solar generators — increased by 29.1%.

Figure B.2: Energy produced by grid-scale generation technology



Source: Panel analysis of AEMO data
Note: Data does not include output of distributed energy resources

B.4 Distribution Network Performance

The performance of distribution networks, and the reliability standards that must be met, fall within the responsibility of each jurisdiction. All jurisdictions have their own monitoring and reporting frameworks for the reliability of distribution network service providers (DNSPs).[171]

Two important indicators of distribution network reliability are:

- System average interruption duration index (SAIDI)
- System average interruption frequency index (SAIFI).

SAIDI indicates the average number of minutes of outages that each customer served by the DNSPs experienced. More specifically, it is the sum of the duration of each sustained customer interruption, divided by the number of customers excluding certain events that are not within the control of the distribution network. Momentary interruptions of three minutes or less are excluded from the calculation.

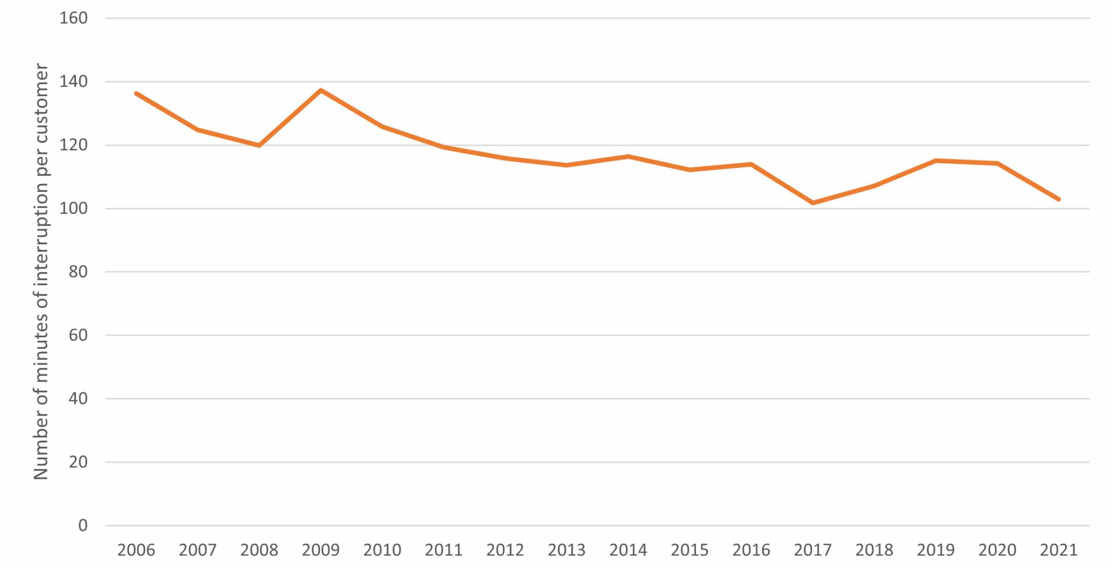
Network reliability standards are often measured in terms of the SAIDI. It is calculated for different parts of each DNSP's network, and for example, the reliability on long rural lines is

171 The Panel observes the following but makes no explicit recommendation to the performance of DNSPs in relation to Clause 8.8.1(b) of the NER.

calculated differently to the reliability on CBD networks. The reliability targets for these different parts of the network are also different.

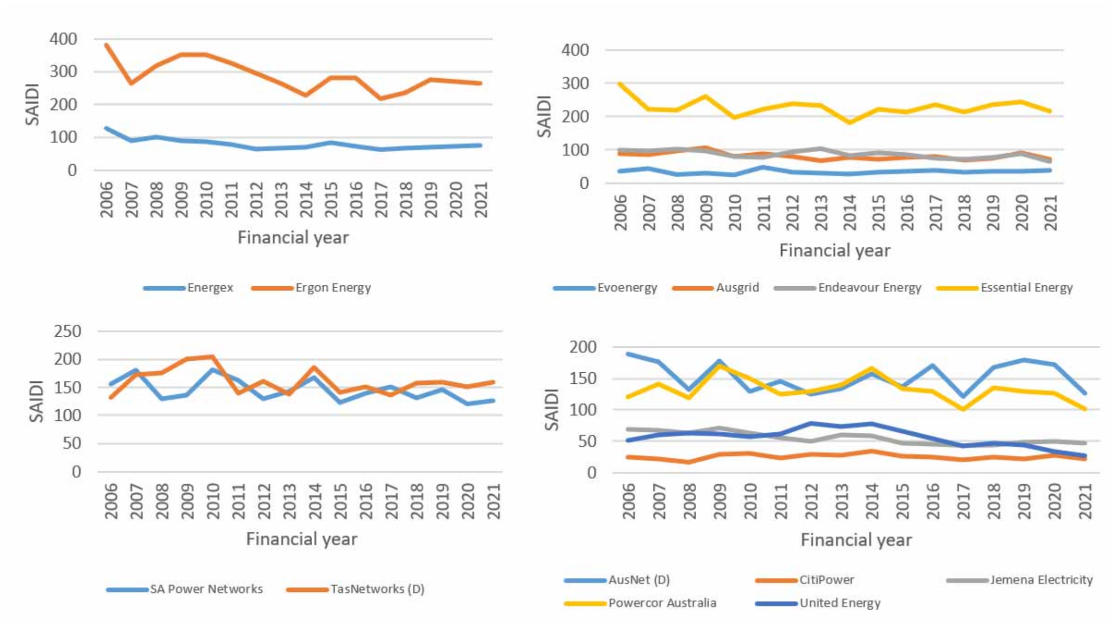
SAIDI outcomes over the previous financial year is shown in Figure B.3 and Figure B.4. As shown in the figures, SAIDI has been trending down over the long term.

Figure B.3: SAIDI - All Regions Average



Source: Distributed Network Service Provider Data

Figure B.4: SAIDI - All Regions

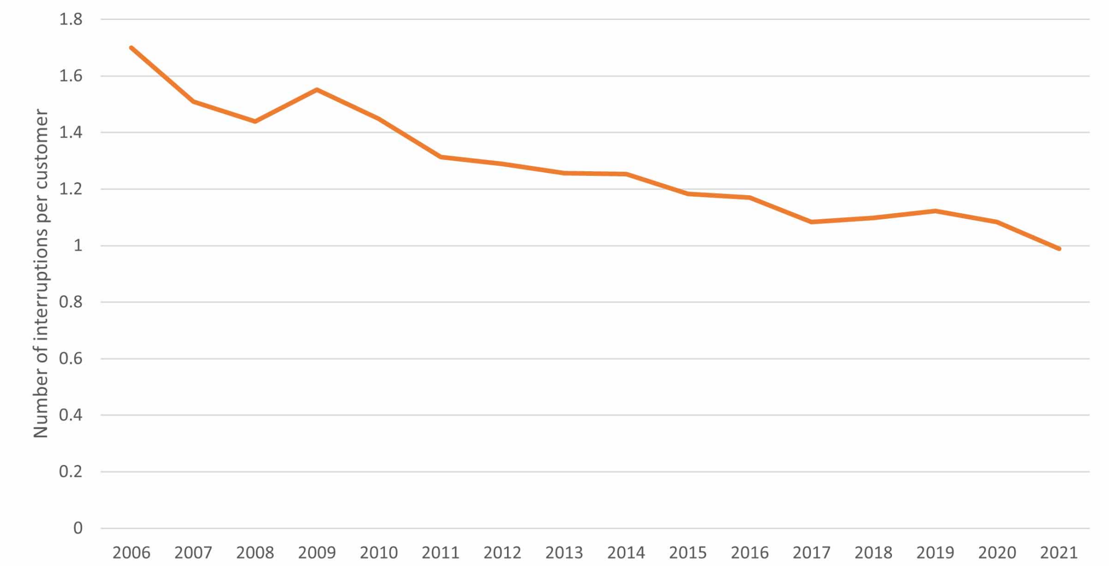


Source: Distributed Network Service Provider Data
Note: SAIDI refers to System Average Interruption Duration Index

SAIFI indicates the average number of outages for each customer served by the DNSP. More specifically, it is the total number of sustained customer interruptions, divided by the number of customers excluding certain events that are not within the control of the distribution network. Momentary interruptions of three minutes or less are excluded from the calculation.

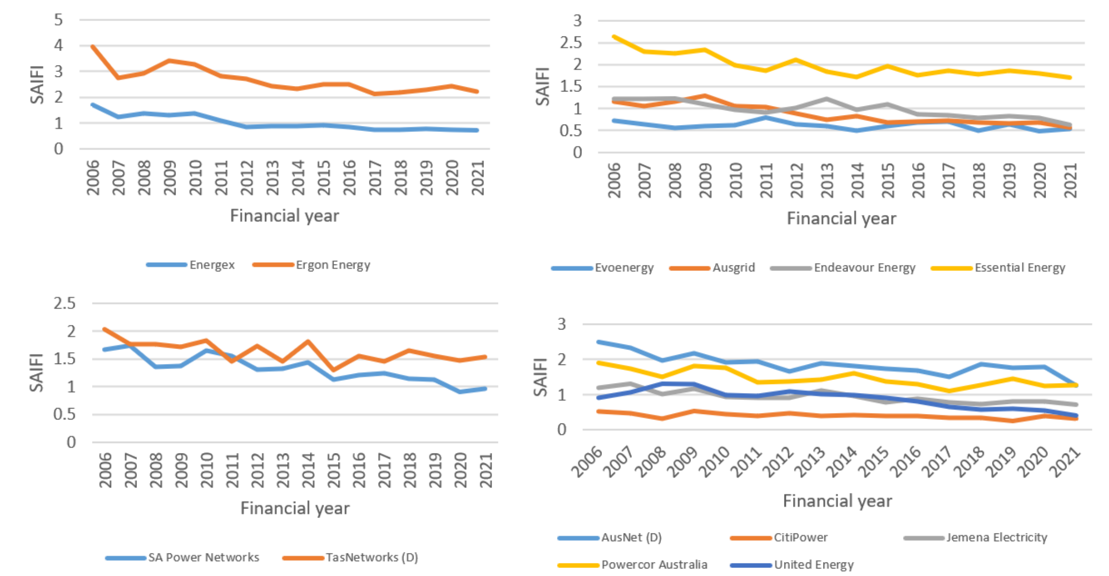
Figures B.5 and Figure B.6 show the SAIFI outcomes over the previous financial year. As shown in the figures, SAIFI has been trending down over the long term.

Figure B.5: SAIFI - All Regions Average



Source: Distributed Network Service Provider Data
Note: SAIFI refers to System Average Interruption Frequency Index

Figure B.6: SAIFI - All Regions



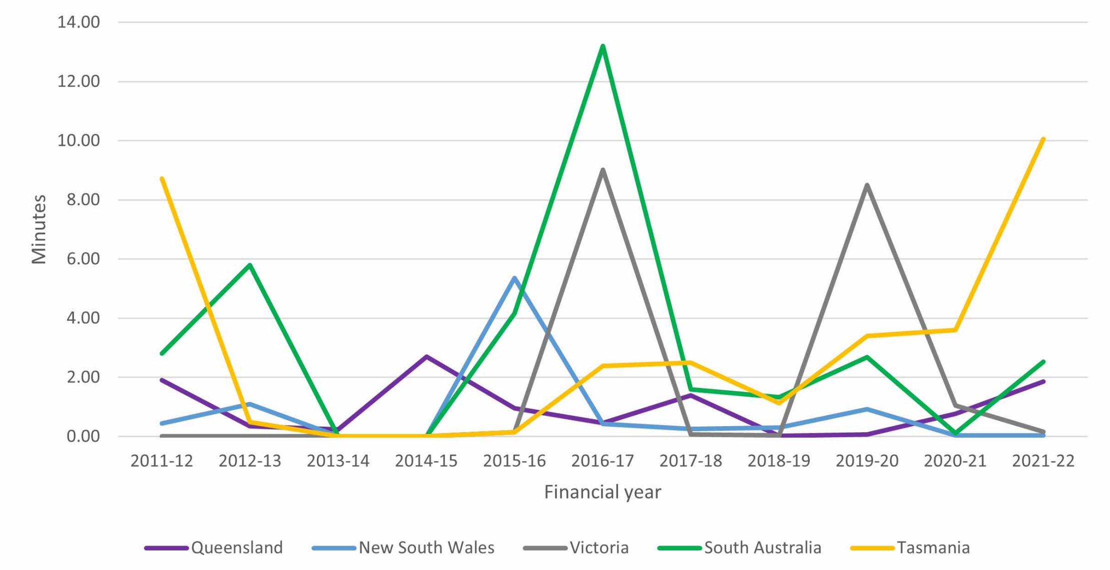
Source: Distributed Network Service Provider Data
Note: SAIFI refers to System Average Inerruption Frequency Index

B.5 TNSP Unsupplied Minutes

Unplanned network outages result in lost load that is not counted towards USE for the purposes of the reliability standard. This is because USE is only calculated based on demand that is not met due to insufficient generation and bulk transfer, which does not include interruptions to supply caused by disturbances on intra-regional transmission and distribution networks.

Figure B.7 below shows transmission unsupplied minutes rose in Tasmania while other states remained relatively low.

Figure B.7: TNSP Unsupplied Minutes



Source: Requested from TNSPs

B.6 Retirement timing

Table B.1 shows the announced timings of large coal generator closures. The Panel note that Liddell Unit 3 has closed as of April 2022.

Table B.1: Announced Coal Closures

SITE NAME	REGION	CAPACITY (MW)	ANNOUNCED DATE OF CLOSURE
Liddell Unit 3	NSW	500	2022
Liddell Units 1, 2 & 4	NSW	1500	2023
Eraring	NSW	2880	2025
Callide B	QLD	700	2028
Yallourn	VIC	1450	2028

SITE NAME	REGION	CAPACITY (MW)	ANNOUNCED DATE OF CLOSURE
Vales Point B	NSW	1320	2029
Bayswater	NSW	2665	2033
Gladstone	QLD	1680	2035
Loy Yang A Power Station	VIC	2210	2035
Tarong (Unit 1 & 2)	QLD	700	2036
Tarong (Unit 3 & 4)	QLD	700	2037
Tarong North	QLD	450	2037
Mt Piper	NSW	1390	2040
Kogan Creek	QLD	744	2042
Stanwell (Unit 1)	QLD	365	2043
Stanwell (Unit 2)	QLD	365	2044
Stanwell (Unit 3)	QLD	365	2045
Stanwell (Unit 4)	QLD	365	2046
Loy Yang B	VIC	1160	2047
Callide C	QLD	840	2051
Millmerran	QLD	852	2051

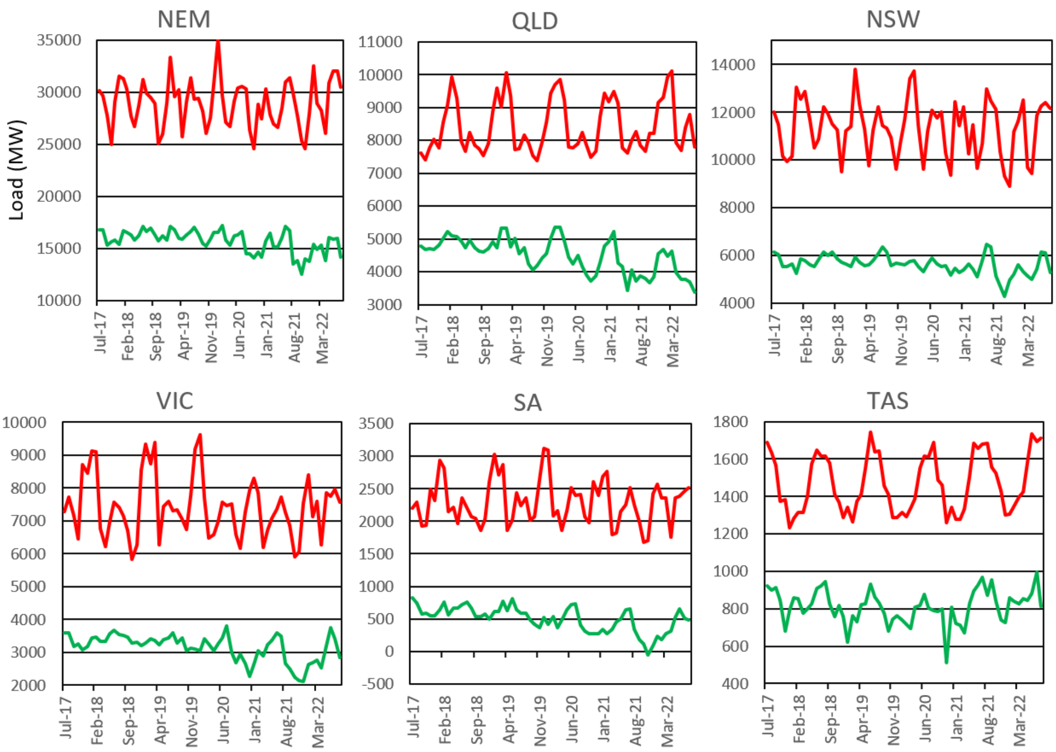
Source: Panel analysis of AEMO data

B.7 Minimum and Maximum System Load

Maximum and minimum system load are important parameters for the operation and planning of the power system. They represent the edges of the technical envelope in terms of system load, and the system needs to be optimised around the values that are expected into the future. System load refers to the load that is met by scheduled and semi-scheduled generators, meaning distributed energy resources influence system load. Monthly minimum system load is shown below for each NEM region as well as the system as a whole.

Figure B.8 shows minimum system load continues to trend down in all states in the long term. Consumer behaviours are playing a significant role in load trends. Factors such as electrification, distributed solar and batteries, and electric vehicles are expected through demand side response to play a role in the future energy system. In the previous financial year, South Australia experienced negative system load that presented challenges to the NEM requiring changes to the NEM framework. Since, South Australia had not experienced another day of negative system load, however the Panel will continue to monitor the impacts of high VRE and distributed resource penetrations on the NEM.

Figure B.8: Minimum and Maximum System Load (MW)



Source: Panel analysis of AEMO data

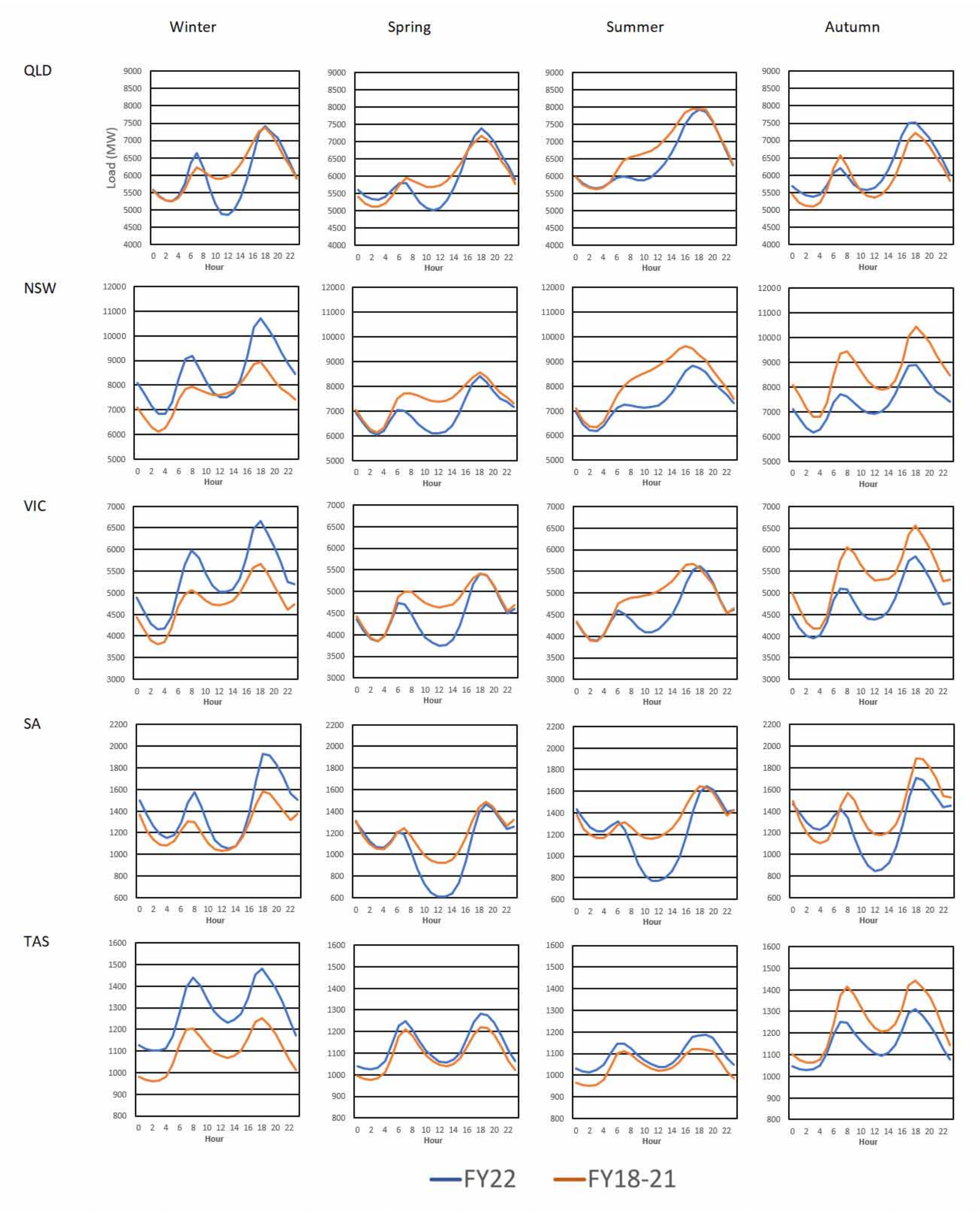
B.8 Diurnal System Load Profiles

Diurnal system load profiles represent the average system load at various points across the day - in this case, each hour -. Figure B.9 compares the average diurnal profile for each season for FY2021-22, with the combined profile from financial years 2018-2021.

The variability of system load across the day continues to increase as the installed capacity of distributed PV increases. This is resulting in increased ramping requirements in the evening period when solar PV generation is tapering off and evening load is peaking.

The Panel observes that in FY2021-22, winter loads increased and autumn loads decreased in all states except Queensland. Furthermore, spring and summer loads decreased in all states but Tasmania. System load trends have been observed to be inherently linked to weather patterns, with early onset winter conditions and a mild summer experienced in the financial year. The variability of diurnal system load continues to be impacted by the impact of distributed solar resources.

Figure B.9: Diurnal System Load Profiles



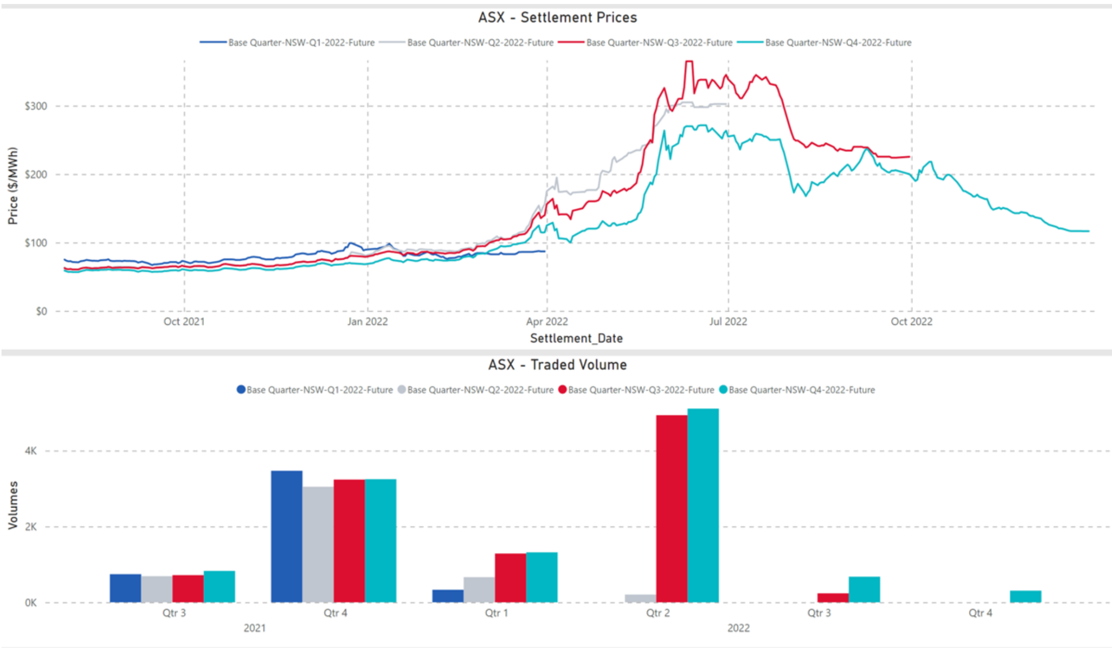
Source: Panel analysis of AEMO data
Note: "FY22" covers the period 1 Jun 2021 to 31 May 2022 to ensure the seasons are contiguous. The same was not done for FY18-20 due to the larger sample size

B.9 Contract Prices

Contracts for the NEM are traded either on the ASX or bilaterally. ASX futures prices for New South Wales, Queensland, South Australia and Victoria over the FY2021-22 are shown in Figure B.10 to Figure B.12.

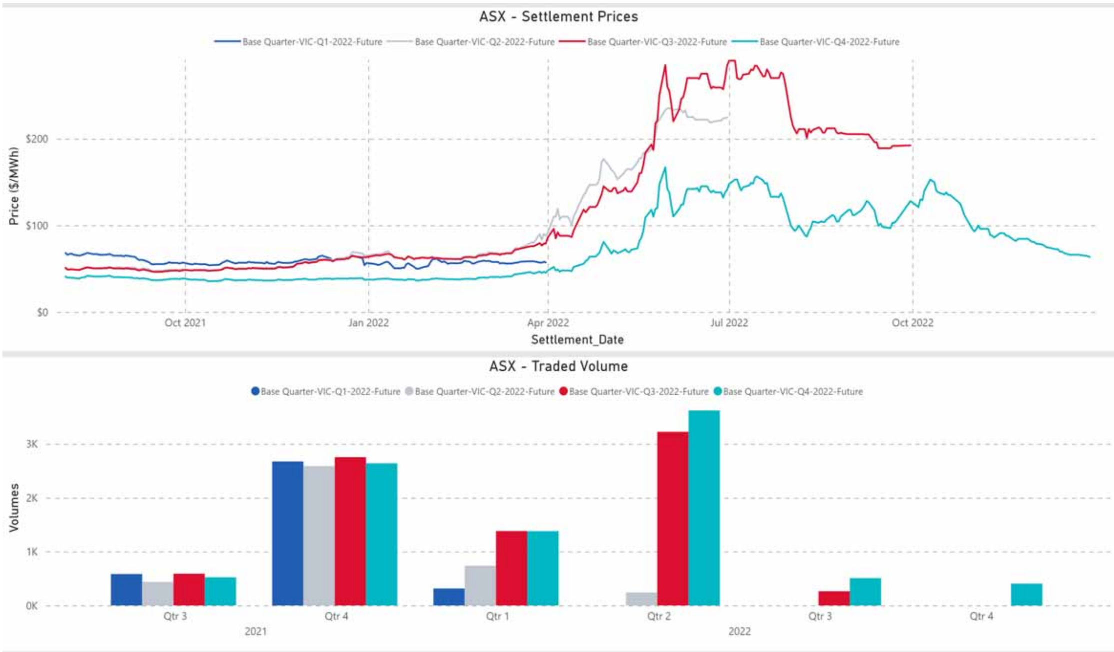
Macro trends of price and volume are generally aligned between states. However, South Australia has a lower level of liquidity in its futures market, which is likely related to the lower volume of energy consumed and the concentration of ownership of baseload generation in the state. Pricing commentary has been provided in Section 3.5.3 of the report.

Figure B.10: ASX NSW Quarterly Futures



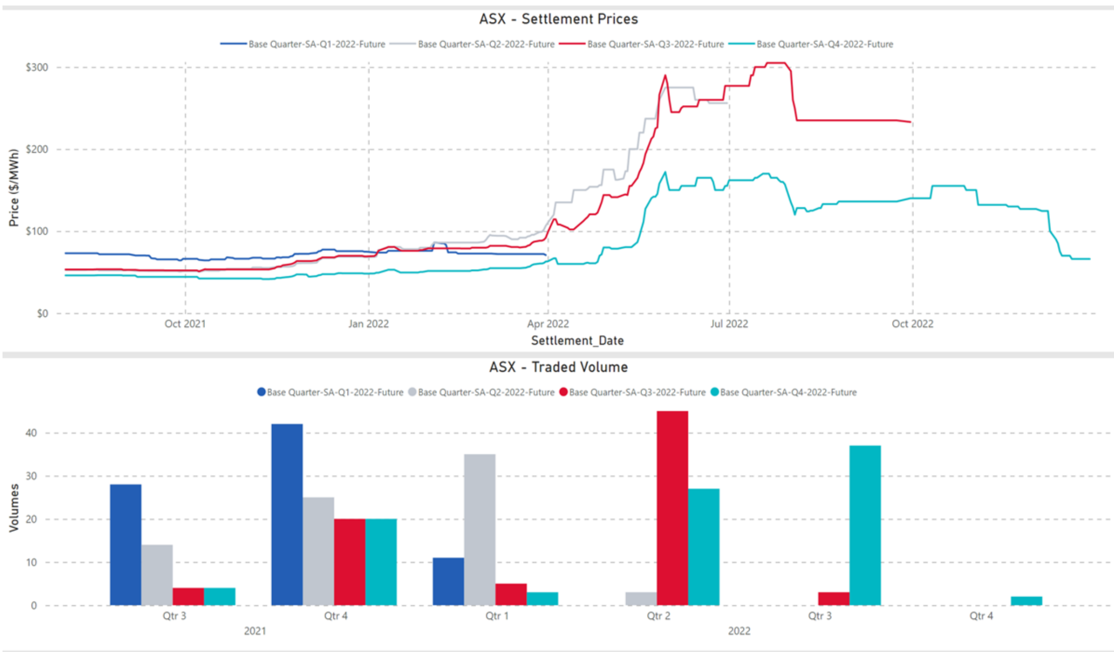
Source: Panel Analysis of AEMO data

Figure B.11: ASX VIC Quarterly Futures



Source: Panel Analysis of AEMO data

Figure B.12: ASX SA Quarterly Futures

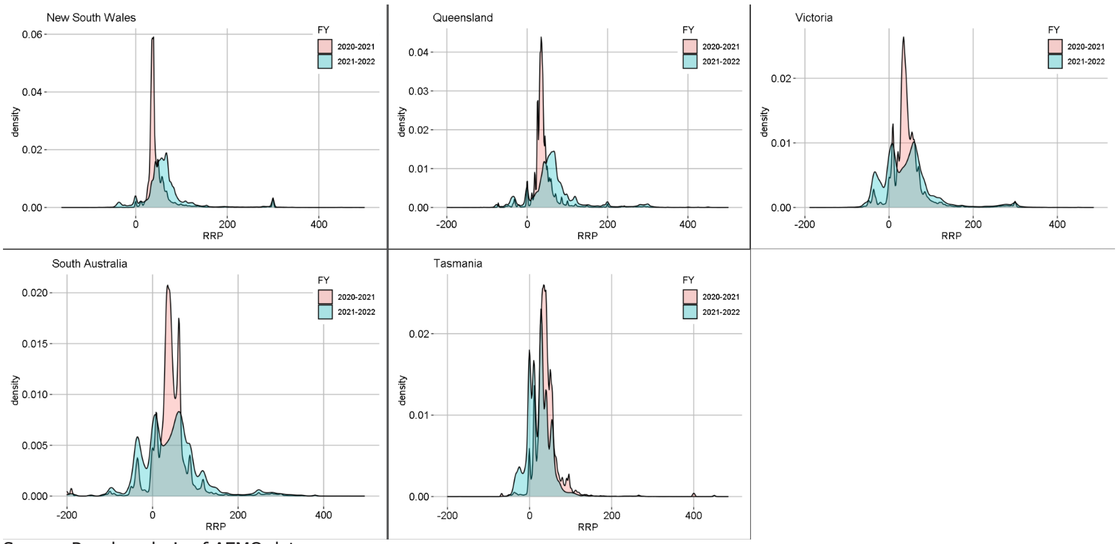


Source: Panel Analysis of AEMO data

B.10 Wholesale Prices

Figure B.13 below shows the wholesale price distribution from FY2020-22. On average, wholesale prices in every state are less centred around previous years' means, resulting in a broader distribution. In Victoria and South Australia, there appears to be a second negative price peak in FY2021-22. The Panel will continue to monitor wholesale price trends.

Figure B.13: NEM Wholesale Price Distribution FY2020-22



Source: Panel analysis of AEMO data

Note: No points have been included for this figure because it is a distribution and as such has too many data points to include in this file

C SECURITY

C.1 Introduction

This appendix outlines the complete set of charts relating to security outcomes in the NEM, in addition to those provided in the Section 4 of the final report. The Panel does not make any recommendations in relation to the charts below but provides commentary on the trends observed throughout FY2021-22 reporting period. This appendix also outlines changes to security frameworks that may impact future AMPRs.

C.2 Reviewable operating incidents

The Panel's observations on the reviewable power system operating incidents for FY2021-22 are outlined in Section 4.1.1. In addition, the table below lists the full list of incidents for this reporting period.[172]

Table C.1: Reviewable operating incidents for 2021-22

DATE	INCIDENT
10/08/2021	5A3 line and Bayswater unit 4 trip
31/08/2021	Eraring 500 kV main busbar trip
9/09/2021	Gordon Power Station B 220 kV Busbar Trip
20/12/2021	Operation of Frequency Control Special Protection Scheme in Tasmania
30/11/2021	Trip of Alcoa Portland No1 220 kV Busbar
5/07/2021	Trip of Armidale Sapphire WF 8E line
28/09/2021	Trip of Broken Hill Silverton X6 220 kV line Silverton Wind Farm and Broken Hill Solar Farm
12/09/2021	Trip of Canowie 275 kV Circuit Breakers
27/10/2021	Trip of Dederang - Wodonga 330 kV line
21/12/2021	Trip of Heywood Alcoa Portland 500 kV line
16/07/2021	Trip of Multiple Cherry Gardens Lines
28/09/2021	Trip of multiple transmission elements at Davenport 275 kV substation
13/07/2021	Trip of Muswellbrook-Tamworth 88 line
30/12/2021	Trip of Rowville Terminal Station - Yallourn Power Station No8 220 kV line
6/01/2022	Trip of Rowville Terminal Station - Yallourn Power Station No8 220 kV line
22/09/2021	Trip of South East Substation No 1 and No 2 Static Var Compensators
22/09/2021	Trip of Torrens Island 66 kV East busbar
17/07/2021	Multiple separate incidents involving Buronga Synchronous Condensers
12/06/2022	NEM market suspension and operational challenges in June 2022
2/03/2022	The trip of Hazelwood Cranbourne No 4 500 kV line

172 The report for each incident can be found at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/power-system-operating-incident-reports.

DATE	INCIDENT
1/01/2022	Trip of Bell Bay No 3 and No 4 Potlines
11/02/2022	Trip of Davenport and Bungama Blyth West 275275 kV lines
27/01/2022	Trip of Eildon Power Eildon Power Station No 2
17/02/2022	Trip of George Town Hadspen 220 kV line
1/03/2022	Trip of Red Cliffs Kiamal 220 kV line
10/02/2022	Trip of Sydney North 330-132 kV Transformer and 132 kV busbar
10/05/2022	Trip of Terang No 2 220 kV Busbar
25/05/2022	Trip of Waratah West B 330 kV Busbar
26/04/2022	Trip of Woree No1 132 kV busbar and No1 Transformer
16/11/2021	Northwest Victoria power system oscillations reviewable incident - cause unknown
23/06/2022	SA power system oscillations incident – Cause - Other causes – human error

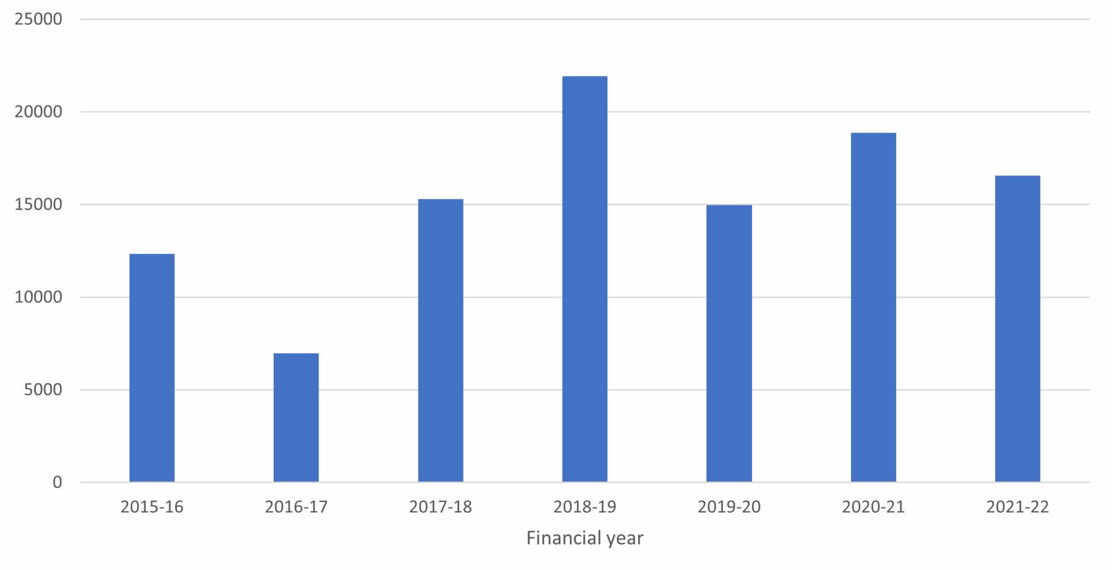
Source: AEMO

C.3 Constraint changes

Network constraints are derived from TNSP advice to AEMO about the technical limits of plant and are used by AEMO in the NEM dispatch process. This is done to ensure that plant remains within its technical rating and power transfers remain within stability limits, ensuring the power system is in a secure operating state.

In 2021-22, there were 16,571 constraint changes. This is a decrease from the 18,870 from 2020-21. The high number of constraint changes is typical of recent years and are symptomatic of the increasing complexity of operating the NEM power system.

Figure C.1: Number of constraint changes



Source: Panel analysis of AEMO data

C.4 Interventions for security

At times, AEMO may need to intervene in the power system to ensure it remains secure. AEMO may also intervene to return the power system to a secure state following a contingency event.[173]

In addition to the observations discussed in Section 4.4, the Panel also makes observations on:

- RERT dispatched to maintain security
- Market notices for security.

C.4.1 RERT security dispatch

If there is sufficient notice, AEMO may dispatch or activate suitable reserve contracts to address a power system security event, if the reserves have already been contracted for reliability reasons.[174] There was no event in 2021-22 where RERT was dispatched to manage security outcomes in the NEM. This is a decrease from 1 event the previous year, related to the Callide event discussed in Section 4.1.2.

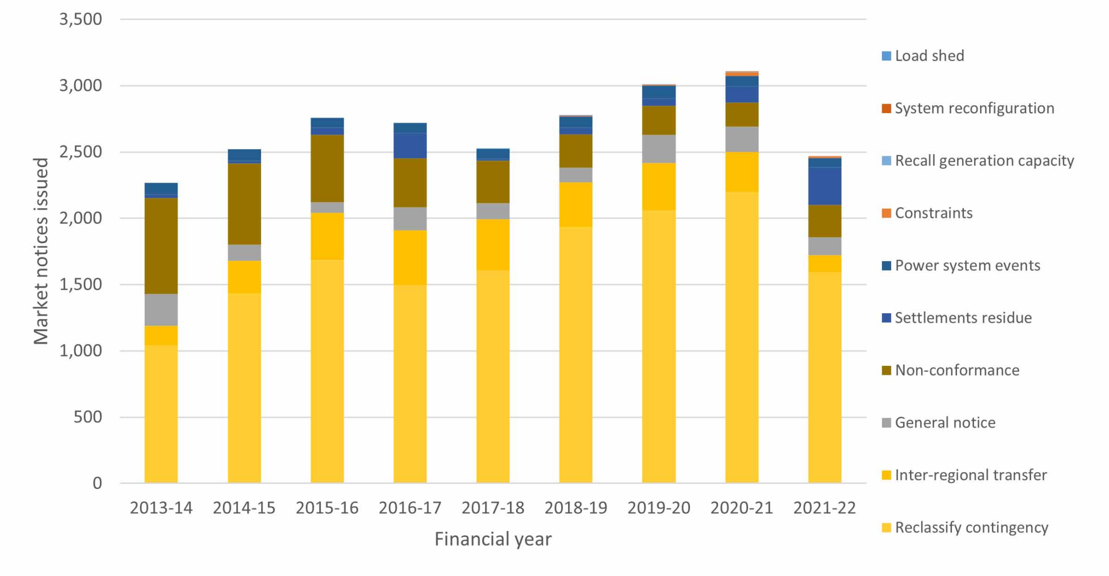
C.4.2 Market notices for security

AEMO issues market notices to communicate to participants events that impact the market, including interventions and power system events.

173 Clause 4.2.6(b) of the NER.
174 Rule 3.20 of the NER.

The chart below shows the number of security related market notices issued by AEMO over the last nine years.[175] The Panel observes that market notices for security have decreased in 2021-22 when compared to the previous year. This decline is driven largely in a reduction in reclassify contingency, down from 2,199 in 2020-21 to 1,591 in 2021-22. As discussed in Section 4.2.1, this is due to a reduction in the number of lightning re-classifications in this reporting period.

Figure C.2: Market notices for security



Source: Panel analysis of AEMO data

C.5 Changes to security frameworks

As the way energy is generated and consumed in the NEM continues to evolve, the security frameworks must also evolve to ensure a secure system now and into the future. Recent or upcoming changes to the security frameworks are:

- Indistinct events
- General power system risk review
- Review of the FOS
- Mandatory primary frequency response
- Fast frequency response ancillary services
- Operational security mechanism
- Efficient management of system strength on the power system.

175 Note this is intended to show a general trend and not an exact number. There may be overlap between the categories.

C.5.1 Indistinct events

On 3 March 2022 the AEMC made a final rule to expand the contingency event framework to allow AEMO to manage the risk of events that are uncertain, unpredictable and can impact multiple power system elements (indistinct events).[176] The final rule provides AEMO with the flexibility to manage threats to power system security which are unpredictable and uncertain and can impact multiple power system elements (indistinct events), while minimising costs to consumers. In early 2023, AEMO updated its Power System Security Guidelines to implement criteria for how it will undertake reclassification decisions for indistinct events.[177]

C.5.2 General power system risk review

On 3 June 2021 the AEMC made a final determination to introduce an annual GPSRR to replace the current PSFRR.[178] The first review will be published in 2023, following the final PSFRR in 2022. The GPSRR will provide a greater breadth of analysis than the PSFRR by considering all events that AEMO expects would likely to lead to major supply disruptions and increase the scope of risks considered beyond frequency. A number of priority risks will be identified by AEMO and then reviewed through the GPSRR process, in cooperation with NSPs. The GPSRR will also formally include DNSPs and integrate the review with other AEMO and NSPs planning process. The Panel will monitor the risks identified in the GPSRR in subsequent AMPR reports.

C.5.3 Review of the FOS

The Panel is currently reviewing the FOS to ensure the appropriateness of settings in the standard in light of the ongoing energy market transformation, as conventional synchronous generation leaves the market and inverter-based technologies such as wind, solar and batteries enter the market.[179]

The Panel also considers it timely to review the FOS given the recent regulatory reform work including the MPFR and incentive arrangements. While the FOS currently includes a number of criteria relating to frequency performance, including defining the boundaries for performance under NOFB, it does not currently define acceptable frequency performance within these boundaries. There is an opportunity to amend the FOS to better specify frequency performance requirements under normal conditions. This will help the effectiveness of PFR frameworks over-time to be understood and evaluated, bench-marked against actual frequency performance. This will be increasingly important as the power system transitions and new operational conditions emerge over time.

Within its current review, the Panel is also considering the timing for a subsequent future review of the FOS which will allow for settings in the FOS, including those that relate to MPFR, to be further reviewed following a sufficient period of operational experience with the new frequency performance payments in effect.

176 For more information see https://www.aemc.gov.au/rule-changes/enhancing-operational-resilience-relation-indistinct-events.

177 For more information see https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/power-system-reclassification-events/contingency-event-reclassification-criteria-review-targeted-consultation-update.

178 For more information see https://www.aemc.gov.au/rule-changes/implementing-general-power-system-risk-review.

179 For more information see https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022.

The purpose of the FOS is to define the range of allowable frequencies for the electricity power system under different conditions, including normal operation and following contingencies. Generator, network and end-user equipment must be capable of operating within the range of frequencies defined by the FOS, while AEMO is responsible for maintaining the frequency within the ranges defined by these standards. The Panel published a draft determination on 8 December 2022 and the final determination will be published in April 2023.[180]

C.5.4 Mandatory primary frequency response

The MMPFR rule change requires all scheduled and semi-scheduled generators in the NEM to support the secure operation of the power system by responding automatically to changes in power system frequency.[181] The final determination identified that changes to the existing frameworks were required to support effective frequency control in the national electricity system, particularly as it shifts toward more variable sources of electricity generation and consumption. This shift has difficulties in predicting variability, increasing the potential for imbalances between supply and demand that can cause frequency disturbances.[182] Further detail on how this rule change impacted the frequency performance of the NEM is discussed in Section 4.3.

Primary frequency response incentive arrangements

Building on mandated regulatory requirements, the Commission also made a final determination that put in place incentives to further reward and encourage PFR.[183]

The final rule, published 8 September 2022, specifies that MPFR will be enduring for all scheduled and semi-scheduled generators beyond 4 June 2023 and introduces frequency performance payments to incentive generators to operate their plant in a way that helps control power system frequency. The new frequency performance payments transactions as set out in the final rule will commence on 8 June 2025.

C.5.5 Fast Frequency Response Market Ancillary Services

On 15 July 2021 the AEMC published a final determination and a final rule to introduce two new market ancillary services to help control system frequency and keep the future electricity system secure.[184] The new markets for fast frequency response (FFR) will operate similar to the existing market arrangements for FCAS. It introduces two new market ancillary service categories in the NER for:

- The very fast raise service
- The very fast lower service.

180 For more information visit https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022

181 Primary frequency response provides the initial response to frequency disturbances caused by power supply-demand imbalances. It reacts automatically and almost instantaneously to locally measured changes in system frequency outside predetermined set points. PFR involves an automatic change in active power generated (or consumed) by a generator (or load) in response to a locally measured change in system frequency.

182 For more information see https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response.

183 For more information see https://www.aemc.gov.au/rule-changes/primary-frequency-response-incentive-arrangements.

184 For more information see https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service.

The markets will commence on 9 October 2023.

C.5.6 Operational security mechanism

The AEMC is considering options for the scheduling and provision of security services to ensure the power system remains secure in response to two rule change requests. A draft determination was released on 21 September 2022, with the final determination expected to be published later this year.[185]

C.5.7 Efficient management of system strength on the power system

On October 2021 the AEMC made its final determination on *the Efficient Management of System Strength on the Power System* rule change.[186] This rule evolves the existing system strength provision framework, that was reactive in nature, to a more proactive framework. The evolved framework requires TNSPs to procure system strength services to meet a forecast produced by AEMO. To coordinate demand with supply, connecting generators can choose to pay a charge representing the marginal cost of system strength they demand, or to remediate their own impact. The rule commenced in two stages:

- 1 Dec 2022 — The TNSP system strength planning and procurement (supply side) provisions commenced.
- 15 March 2023 — The system strength mitigation requirement (coordination) and new access standards (demand side) for connecting generators commenced.

As a result, from December 2022 onward:

- AEMO has set the system strength standard for each system strength node, including a three-phase fault level required for a secure system and a forecast of future inverter-based connections at the node, and
- Responsible TNSPs must use reasonable endeavours to plan system strength services to meet the standard at each node.

185 For more information see https://www.aemc.gov.au/rule-changes/operational-security-mechanism.

186 For more information see https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.