RELIABILITY
PANEL AEMC

REVIEW

Reliability Panel AEMC

FINAL REPORT

2020 ANNUAL MARKET PERFORMANCE REVIEW

20 MAY 2021

INQUIRIES

Reliability Panel
c/- Australian Energy Market Commission
GPO Box 2603
Sydney NSW 2000

E aemc@aemc.gov.au
T (02) 8296 7800

Reference: REL0081

CITATION

Reliability Panel, 2020 Annual Market Performance Review, Final report, 20 May 2021

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.

RELIABILITY PANEL MEMBERS

Charles Popple (Chairman), Chairman and AEMC Commissioner
Stephen Clark, Marinus Link Project Director, TasNetworks
Kathy Danaher, Chief Financial Officer and Executive Director, Sun Metals
Craig Memery, Director - Energy + Water Consumer's Advocacy Program, PIAC
Ken Harper, Group Manager Operational Support, AEMO
Keith Robertson, General Manager Regulatory Policy, Origin Energy
Ken Woolley, Executive Director Merchant Energy, Alinta Energy
John Titchen, Managing Director, Goldwind Australia
David Salisbury, Executive Manager Engineering, Essential Energy

FOREWORD

I am pleased to present this report setting out the findings of the Reliability Panel's (Panel) annual review of market performance, for the period 2019-20.

The Panel has reviewed the performance of the National Electricity Market (NEM) in terms of reliability, security and safety over the 2019-20 period, in accordance with the requirements of the National Electricity Rules (Rules or NER) and the terms of reference issued by the Australian Energy Market Commission (AEMC).

Security concerns the technical resilience of the power system itself and is primarily the responsibility of the Australian Energy Market Operator (AEMO); whereas reliability is about having sufficient capacity to meet customer demand for energy and is primarily driven by efficient market investment. The Panel has considered both historic trends and projections of the security and reliability of the NEM.

A number of trends were observed during the 2019-20 financial year. In particular:

- Despite there being no unserved energy, operational management of power system was challenging due to a combination of high peak demand and extreme environmental events (e.g. bushfires) impacting the power system. Increases in unexpected events occurring are presenting challenges for forecasting and operation of the power system, such as how such events are considered in future planning. Work is underway on these matters, but the Panel considers this is one area that will need to have continued focus given the potential impacts such events can have on reliability and security.
- Given the change in the generation mix that is occurring towards more diversified, variable resources, as well as changing market dynamics such as more volatile prices and higher incidences of low wholesale prices, the Panel considers that periods where the supply demand balance is tight may continue to occur at a higher rate in traditionally stable periods throughout the year, rather than just in the summer, e.g. during shoulder periods.
- The rapid uptake of distributed energy resources is leading to challenges in managing key elements of system security, including minimum system load, system strength, inertia and voltage control. It is also presenting challenges, similar to the increases in unexpected events, to accurately forecast supply and demand in the power system. The Panel notes that while these issues have been present for some time, the rate at which they are developing is providing challenges for the system operator, as well as networks in managing the system. The Panel notes that there is also some work underway to address these issues.

The Panel notes that there is currently a large body of work underway seeking to amend the regulatory framework to address some of the challenges outlined above. The Energy Security Board (ESB) is currently progressing into the final stage of the Post-2025 Market Design process, and the Panel is working closely to co-ordinate its work with that of the ESB.

The Panel has structured this report to enhance usefulness for different readers. An executive summary is provided for those readers seeking a high-level overview of the review and key trends. A data portal provides stakeholders with access to the data underlying the analysis in this review. Technical detail and background information about the regulatory framework and work underway to address challenges is available in appendices.

The preparation of this report could not have been completed without the assistance of the AEMO, the Australian Energy Regulator (AER), network service providers and state and territory government departments in providing relevant data and information. I acknowledge their efforts and thank them for their assistance.

Finally, the Panel commends the staff of the AEMC secretariat for their efforts in coordinating the collection and collation of information presented in this report, and for drafting the report for the Panel's consideration.

Charles Popple, Chairman, Reliability Panel,

Commissioner, AEMC

EXECUTIVE SUMMARY

1 This report sets out the findings of the Reliability Panel's 2020 Annual Market Performance Review (AMPR) as required by the National Electricity Rules. This review is conducted in accordance with the terms of reference issued by the AEMC.[1] The report covers the period from 1 July 2019 to 30 June 2020, and includes observations and commentary on the reliability, security and safety performance of the NEM primarily relating to that timeframe, but also comments on current and emerging trends and issues.

2 Most of the data included in this report is already publicly available in various reports. As per 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. As was the case in the 2019 AMPR, the Panel has developed a data portal so that stakeholders can use key data sets more easily.

3 The physical power system and the operating environment have changed materially in recent years, with changes to the generation mix and market dynamics, as well as numerous severe weather events and other global disruptions occurring. These changes have been happening at a rapid pace and these trends are likely to continue over the next two decades.

4 The NEM is at the global forefront of integrating non-synchronous generation capacity[2]. These changes represent new territory and so challenges and opportunities for those operating the market, and those operating within the market, given the system has historically been designed around the presence of large, centrally located synchronous machines, the majority of which are forecast to exit the market in the coming two decades. Demand-side trends are also changing as consumers continue to adopt distributed energy resources at a rapid pace, faster than many forecasts have predicted. This adoption has led to changes to intra-day demand, causing concern about how minimum system loads are managed. In addition to this, the impact of extreme environmental events was significant in 2019-20, with the significant bushfires, storms and extreme heat providing further challenges to maintaining security, safety and reliability due to rapid changes of these operating conditions.

5 2020 also saw the onset of the COVID-19 pandemic, which has led to changes in the way that people work and use electricity and changing consumption patterns on networks.

6 The Panel has noted a number of security, reliability and safety challenges and opportunities that are occurring or emerging due to the transition currently underway. As the NEM continues to move through this transition towards new operating modes and conditions, policy-makers and operators will need to focus on ensuring that the system is resilient in the face of increased levels of uncertainty and variability. The Panel considers that is it important that the NEM is resilient to future changes and the issues that they bring are thoroughly considered as the transition towards new operating modes and conditions continues over the

1 See Appendix A.

2 AEMO, Engineering Framework March 2021 report, https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/nem-engineering-framework-march-2021-report.pdf?la=en&hash=3B1283D31B542115CC56E0ECCDFB3D69

coming two decades. In particular, the Panel considers that the importance of forecasting accuracy will continue to grow in regard to management of increasing penetrations of variable generation capacity, as well as the management of extreme and unexpected events. The Panel notes that given the nature of the transition leading towards unfamiliar operating conditions, historic trends and information may not remain appropriate for understanding future scenarios.

7 The Panel notes that there is a large reform program underway to ensure the system is best able to manage the transition. The ESB is progressing its Post-2025 market design work to develop advice on reforms to the NEM to meet the needs of the transition and beyond 2025. In addition to this, the AEMC is progressing a suite of rule changes to address issues with security and reliability. The Panel is working closely with these bodies and has taken market developments into account when having regard to the assessment of reliability, security and safety performance.

8 Reliability

9 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.

10 What happened in 2019-20?

11 The Panel have found that the reliability performance of the NEM has been satisfactory during 2019-20. The regulatory framework, including the ability for AEMO to intervene in the market, were leveraged to support the reliable supply of electricity to consumers. The key reliability outcomes included that:

- The reliability standard of 0.002% unserved energy (USE) was not breached in any region, and there was no USE in any region across the NEM.
- AEMO has forecast that without additional action, the interim reliability measure (IRM) of 0.0006% USE would be breached in New South Wales in 2023-24, and that the reliability standard would be breached in New South Wales in 2029-30.
    - These issues are arising due to the forecast withdrawal of thermal generation capacity from the NEM over the next ten years.
    - AEMO have noted in the 2020 Integrated System Plan (ISP) that the completion of actionable ISP projects is likely to address some of these concerns.
- There were no reliability events (actual LOR3 conditions) where supply was interrupted due to a shortfall of available capacity and reserves.
- AEMO issued 17 actual lack of reserves (LOR) notices, and the number of LOR2 conditions increased significantly compared to historical trends. There was a higher concentration of forecast lack of reserve conditions in the shoulder periods.
- The Reliability and Emergency Reserve Trader (RERT) was activated on four occasions, and RERT costs were slightly higher in 2019-20, at $40.57 million, than in 2018-19 at $34.5 million.
- The cumulative price threshold was not breached for energy in 2019-20. The cumulative price threshold was breached once for Frequency Control Ancillary Services (FCAS) on 1

February 2020, leading to the administered price cap being introduced for approximately 10 days.

- AEMO issued six directions to market participants for reliability reasons, which was an increase from historical trends.
- The accuracy of forecasting for demand and intermittent generation was similarly accurate compared to 2018-19. Some participants in the NEM have begun self-forecasting.
- Transmission unsupplied minutes increased across all regions, and this increase was most notable in Victoria.

12 What are the implications?

13 The Panel notes that while the reliability standard was met in each region in 2019-20, the system operator faced significant challenges maintaining operational reliability during the reporting period. This was due to the number of extreme environmental events, such as the bushfires, that impacted the power system during this period. The difficulty in managing reliability is evidenced by the increased number of occasions when interventions were necessary, as well as the increase in actual LOR2 conditions in 2019-20. Furthermore, there was an increase in the number of tight supply-demand forecasts in non-peak periods that have traditionally not presented challenges of this manner.

14 The Panel notes that a large proportion of the significant trends in reliability metrics in 2019-20 were caused by extreme weather events such as storms, bushfires and extreme heat. These events may interrupt the normal functions of the market and present rapid changes to reliability performance. The impact that these events have on the power system will need to be considered in future planning and policy considerations as the power system operating environment continue to change, and the conditions that are conducive to these events arise more frequently. Additionally, as the NEM continues to transition to higher penetrations of variable generation capacity, the importance of forecasting will continue to grow in regard to managing reliability, both in relation to day-to-day management of variable generation. The Panel also considers that the increasing variability of supply and demand may be leading to changing reliability dynamics, with a higher concentration of low reserve conditions occurring in traditionally stable shoulder periods.

15 The Panel also believes that it is important to consider the impending challenges that are forecast to emerge in the coming two decades. The forecast exit of thermal generation capacity may lead to significant reliability challenges if steps are not taken to address this issue in a timely and coordinated manner. There is already work underway to address these issues by the ESB, however the Panel notes that this will be an important trend to monitor as thermal generation retirements continue to approach.

16 What work is being undertaken on reliability?

17 The Panel notes that there are a number of work programs that have been proposed or that are underway that are focused on ensuring that the frameworks that govern power system reliability will continue to provide good outcomes for consumers.

18 The Energy Security Board's Post 2025 Market Design work has a strong focus on power

system reliability, with workstreams dedicated to resource adequacy and demand-side participation. The Panel is working closely with the ESB to co-ordinate the work of the two bodies.

19 In addition, the Panel has reviewed the guidelines that it applies for the review of the Reliability Standard and Settings (RSSR) for the period of 2024-2028. The Panel considers that it is important for the guidelines to be updated in light of market changes and to be sufficiently broad so that they are applicable for future reliability standard and settings reviews. The Panel will be commencing the RSSR in mid 2021. This review will assess and examine the Reliability Standard and Settings in accordance with NER requirements and make recommendations to the AEMC for any changes that are necessary. The review must be completed by April 2022.

20 The Panel considers that an ongoing focus on power system resilience to extreme weather events should be taken in future regulatory reforms and planning work. This includes how such events change the examined trends and how these may be factored in decision-making. Market bodies are considering these issues. For example, such considerations have been taken in AEMO's Electricity Statement of Opportunities (ESOO) and Integrated System Plan documents. The Panel notes that a continued focus on these issues may lead to improved reliability outcomes in the future.

21 The Panel also notes that work is underway to improve the accuracy of forecasting in the NEM. AEMO have published self-assessments of forecasting performance in the ESOO to improve the process over time. In addition, the introduction of participant self-forecasting has led to improvements in generation forecasting. The Panel considers that these processes will continue to increase in importance as the variability of the power system operating environment continues to increase.

22 The Panel also notes that the AEMC is currently considering a rule change request from the former COAG Energy Council on Enhancing operational resilience in relation to indistinct events[3]. This proposes to put in place a framework to manage indistinct events, which are events that can impact multiple generators or transmission lines in an unpredictable and uncertain manner e.g. major storms, widespread fires. As power system technologies evolves and as storms and bushfires become more intense and frequent, these indistinct events are becoming an increasing threat to maintaining a secure supply of electricity to customers.

23 Security

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

<u>25 What happened in 2019-20?</u>

26 The Panel has noted security outcomes in 2019-20 are reflective of the increasing challenges

3 AEMC, *Enhancing operational resilience in relation to indistinct events,* https://www.aemc.gov.au/rule-changes/enhancing-operational-resilience-relation-indistinct-events#:~:text=The%20proposed%20rule%20change%20aims,for%20and%20manage%20indistinct%20events.

that AEMO are facing when managing power system security. As the power system continues to transition towards one characterised by smaller and more geographically dispersed generators with different characteristics to what the power was designed around, these challenges are likely to continue to occur.

27 Key security outcomes include:

- There were three incidents in which the power system was not in a secure operating state for more than 30 minutes in 2019-20. Two of these events were the result of bushfires, highlighting the challenges that the power system faces from extreme environmental events.
- There was an increase in the number of reviewable operating incidents in 2019-20 compared to 2018-19, however the amount of reviewable operating incidents was not unusually large compared to historical trends.
- There was a large increase in the number of directions issued by AEMO to manage power system security. The vast majority of these directions were issued in South Australia. The South Australian separation event in January 2020 contributed to this increase, however the high penetration of inverter-based generation in South Australia is also a factor.
- There were approximately 15,000 constraint changes in the NEM dispatch engine (NEMDE) in 2019-20. The number of constraint changes is likely to reflect the increasing complexity of power system management, and while 2019-20 saw a decrease compared to 2018-19, the number of constraint changes is higher than the historical average.
- Frequency performance of the NEM generally improved on both the mainland and in Tasmania in the 2019-20 financial year compared to 2018-19. AEMO remains concerned about increasing risks presented by aspects of frequency control that the frequency operating standard (FOS) does not directly address.
- There was an increase FCAS costs in 2019-20 compared to 2018-19. The South Australian separation event contributed to this increase. AEMO also implemented increases to the base volume of regulation FCAS procured in quarter two 2019 to improve frequency performance.

28 What are the implications?

29 The Panel notes that 2019-20 saw an increase in challenges and complexity in managing power system security. These security challenges were caused in part by extreme environmental events, and the rate at which the power system is undergoing the change to higher penetrations of inverter-based resources. The separation of South Australia from the remainder of the NEM in late January and February 2020 forced AEMO to operate the power system in an extended island formation what had not been done before.

30 As the power system continues to transition towards higher penetrations of inverter-based resources, the Panel expects many of the issues currently occurring, such as those created by minimum system load, to continue as operating techniques are adapted to the new operating conditions. Given the pace of change is faster than has previously been forecast, a number of security issues continue to present challenges for operating the power system. These include issues associated with minimum system load, such as system strength, inertia and voltage

control. Furthermore, these developments are contributing to increasing variability and frequency of minimum system load conditions. The ability for AEMO to accurately forecast and account for the increasing impact of rooftop PV will be an important issue as penetrations of rooftop PV continue to increase.

31 What work is being undertaken on security?

32 The Panel notes that there is a significant work program currently underway to address the management of system security through the transition. The ESB's Post 2025 Market Design work on essential system services and scheduling and ahead mechanisms is aimed at ensuring that the resources and services required to manage to complexity of dispatch and deliver secure supply to consumers are available when needed. This work encompasses frequency control, system strength, ramping services and inertia and is aiming to develop a long-term, fit-for-purpose market framework to support security and reliability that could apply from the mid-2020's.

33 In addition to this, the AEMC is currently considering a suite of system services rule changes addressing a number of important elements of system security, allowing the AEMC to advance issues that are urgent in nature. These rule changes include inertia, voltage control, system strength and frequency. This work allows the AEMC to complement the thinking and assessment done in the ESB work program and dovetail with the process being undertaken by the ESB.

34 Given the impact that extreme events had on the power system in 2019-20, the Panel believes that future planning and policy decisions should take into account the possibility of such events becoming more frequent over time and again how such events change historical trends.

35 As noted, the NEM is at the global forefront of dealing with these issues. The Panel notes however that the ability for frameworks to adapt to future outcomes and reforms to be implemented in a timely manner will be important as the power system continues to transition towards a new operating environment.

36 Safety

37 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.

38 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.

39 AEMO have noted that there were no incidents in 2019-20 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.

40 There were also no instances in 2019-20 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.

41 The Panel notes that there have been changes made in terms of safety in the NEM, both in terms of power system management and individual plant management, which may lead to improvements in safety outcomes moving forward.

CONTENTS

APPENDICES

TABLES

FIGURES

1 INTRODUCTION

This report has been prepared as part of the Reliability Panel's *Annual market performance review* of the National Electricity Market. It covers the 2019/20 financial year. The review is a requirement of the National Electricity Rules.

1.1 Background

The functions of the Panel are set out in section 38 of the National Electricity Law. 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; and
- At the request of the AEMC, to provide advice in relation to the safety, security and reliability of the national electricity system, and
- Any other functions and powers conferred on it under this Law and the Rules.

At the completion of a review, the Reliability Panel must give a report to the Australian Energy Market Commission. If requested to do so by the AEMC, the Reliability Panel must provide advice to the AEMC in relation to the safety, security and reliability of the national electricity system.[4]

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 under this clause by the end of 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[5]
- The policies and guidelines referred to in clause 8.8.1(a)(4) of the NER[6]
- The guidelines referred to in clause 8.8.1(a)(9) of the NER.[7]

The AEMC may provide, from time to time, the Reliability Panel with standing terms of reference in relation to the annual market performance report. A copy of the AEMC Terms of Reference are at Appendix A.

4 Division 3 section 38 (1) - (4) of the NEL.

5 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.

6 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

7 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.

1.2 Purpose of the report

The purpose of this report is to set out the Panel's findings for its annual market performance review for 2019-20. It includes observations and commentary on the reliability, security and safety performance of the power system.

The report also provides an opportunity for the Panel to consolidate information related to the performance of the power system in a single publication for the purpose of informing stakeholders. Among other things, this may assist governments, policymakers and market institutions to monitor the performance of the power system, and to identify the likely need for improvements to the various measures available for delivering reliability, security and safety.

For this review, the Panel has:

- Only considered publicly available information as well as information obtained directly from relevant stakeholders and market participants that can be shared publicly.[8]
- Collated and interpreted this information to inform its assessments of what is happening across the power system and market and identify future trends that may require management.
- Set up a data portal so that stakeholders can use key data sets more easily. The portal has been updated to reflect the findings from this 2019-20 report.

This report has considered in more detail the key issues identified in the Panel's first Market Performance Update[9] published in December 2020. The Reliability Panel's Market Performance Updates were introduced in 2020 to provide market participants more timely information about power system performance and about emerging trends in the areas of security, reliability and safety as early as possible.

1.3 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.[10]

The AEMC requested that the Panel review the performance of the market in terms of reliability, security and safety of the power system. The Panel has also had regard to the matters outlined in the AEMC Terms of Reference and those considered in the Panel's first market update.

In this report, the Panel has considered reliability and security in terms of:

- A secure system is one that is 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.

8 Data is obtained from AEMO in relation to unserved energy, directions and instructions, reviewable operating incidents, frequency, market reserves, network constraints, market notices and forecasting.

9 Reliability Panel, Annual Performance Market Update, January - June 2020, December 2020, https://www.google.com/search?q=ampr+2020&rlz=1C1GCEB_enAU908AU908&oq=ampr+2020&aqs=chrome.0.69i59j0i22i30l2j0i10i22i30j0i22i30j69i60l3.1310j0j4&sourceid=chrome&ie=UTF-8

10 See Appendix A.

- A reliable power system has enough generation, demand response and network capacity to supply customers with energy that they demand with a very high degree of confidence. A reliable power system will also be a secure power system, however the opposite is not necessarily true; a power system can be secure even when it is not reliable.

The two concepts are closely related operationally and it is not always simple to separate them. For consumers, the final result of either a reliability event or a security event may be indistinguishable given both may result in an outage for a customer.

The Panel considers it important to clearly describe and identify how these two aspects of power supply work, and the extent to which each is responsible for final interruptions to consumers. This is because each is managed through the use of different tools and regulatory frameworks, and where further actions may be needed to improve outcomes for consumers, it is helpful to know which parts of the framework to focus on.

For this review, the matters considered included:

- **Key market trends:** The Panel has considered some trends occurring in the NEM, and how these may be impacting power system reliability and security. These are specifically related to:
  - Supply side trends, including new generation entry and withdrawals
  - Demand side trends, including the continued uptake of Distributed Energy Resources (DER)
  - Wholesale market trends, including price outcomes, and
  - Network trends, including supply interruptions and the impact of COVID-19.
- **Power system resilience:** The Panel has considered the importance of power system resilience as an important emerging trend in 2019-20. During 2019-20, the power system was subject to more frequent and extreme events, including bushfires and storms. In examining power system resilience, the Panel has looked at:
  - The impact of extreme weather events
  - The impact of COVID-19, and
  - The current response to such events
- **Reliability performance of the NEM:** The Panel has reviewed the reliability performance of generation and bulk transmission (i.e. interconnection). In doing so, it has considered:
  - Actual levels of unserved energy in 2019-20.
  - Actual and forecast supply and demand conditions including an assessment of lack of reserves notices in order to form a view on whether any underlying changes to reliability performance have occurred, or are expected to occur, and
  - AEMO's use of the reliability safety net mechanisms in 2019-20, including incidents, and reasons for, the use of directions and instructions, and the Reliability and Emergency Reserve Trader mechanism.

- **Security performance of the NEM:** The Panel has reviewed performance of the power system against the relevant technical standards. In particular, the Panel has had regard to:
  - Frequency operating standards, voltage limits, interconnector secure limits and system stability, and
  - AEMO's use of the security safety net mechanisms in 2019-20, including incidents of, and reasons for, the use of directions and instructions or other mechanisms to ensure power system security.
- **Safety performance of the NEM:** The National Electricity Law and rules 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. However, the rules do not specify additional requirements in relation to safety performance monitoring.[11] However, the Panel also has the function of advising in relation to the safety of the national electricity system at the request of the AEMC.[12]

The Reliability Standard and Settings Review will commence in mid-2021, following the completion of the current review of the Guidelines which guide the review. This review must be undertaken in accordance with the requirements under the NER[13] and completed by April 2022. The RSS review will consider and provide an in-depth assessment of reliability outcomes in the NEM. Given the Panel's review of the reliability standard and settings, the 2019-20 AMPR final report focuses more on power system security challenges and other emerging issues, such as decreasing minimum demand.

1.4 Linkages to other work and reforms

2021 Reliability Standard and Settings Review

The Reliability Panel is required to conduct a review of the reliability standard and settings every four years under the NER.[14] The next review must be completed by April 2022.

In undertaking the review, the Panel must comply with the reliability standard and settings guidelines. These guidelines set out the principles and assumptions the Panel must use when undertaking the reliability standard and settings review. The Reliability Panel is currently reviewing these guidelines, with a final decision expected shortly.

The guidelines are being amended to take account of the changes that are occurring in the market and the evolving power system. This is because for the 2021 RSSR and reviews going forward, it will be important and necessary to undertake the RSSR in a comprehensive and holistic manner. That is the Panel is able to consider the existing requirements, including

11 Instead, the functions of the Reliability Panel under clause 8.8.1 of the Rules provide that the functions of the Panel is to, among other things, monitor, review and report on the performance of the market in terms of reliability of the power system, report to the AEMC and jurisdictions on overall power system reliability matters and undertake a number of functions relating to the security of the power system. The reliability and security focus of the Panel under the Rules is reflected in the scope of the annual market performance review that the Panel is required to undertake under clause 8.8.3(b) of the NER.

12 If the AEMC requests such advice, the Panel is required to provide it (section 38(4) of the NEL).

13 Clause 3.9.3A(d) of the NER

14 NER cl 3.9.3A(d).

the purpose, form and level of the Reliability Standard and Settings and whether these are fit for purpose going forward.

The Panel will also work closely with the ESB during the review in order to take into account the direction of the ESB's 2025 market design work (discussed below). The Panel, will, where necessary have regard to the policy proposals put forward in the context of the outcomes for reliability and impact on the reliability standard and settings.

Energy Security Board Post 2025 market design

The Energy Security Board (ESB) is advising the Energy Ministers on a long-term reform package with the focus on reviewing the market design of the NEM. The ESB is developing advice on alternative, long-term, fit for purpose market design options that could apply from the mid-2020s. The ESB has released its April 2021 options paper[15] that provides details of design of each of its options outlined in the January 2020 paper. A summary of the ESB's key proposals are outlined in section 2.4. There are four key workstreams in this, of particular relevance to AMPR are those relating to resource adequacy mechanisms and essential system services.

The Panel will consider as part of its work program the ESB reform proposals, in particular, in the context of reliability and security and future operation of the power system.

AEMC system security work program

The AEMC has a substantial system security work program, comprising around 11 rule change requests. The AEMC is working closely with the ESB and the other market bodies, particularly AEMO, on these rule change requests given that these rule change requests dovetail with this other work. The rule change requests complement and are interdependent with the work of the ESB in its 2025 project. The rule changes provide us with an opportunity to complement some of the thinking and assessment done in the ESB work program, as well as technical input from AEMO through its *Renewable Integration Study*. It allows us to address the issues in a cohesive way, as well as addressing system security issues that are more urgent in nature.

The Panel has had regard to these and relevance to assessment of reliability, security and safety performance review. A detailed outlined of the relevant work and reforms is provided at Appendix B.

1.5 Structure of this report

The report is structured as follows:

- *Market Trends.* This chapter outlines some key trends and challenges occurring in the NEM, and how these may be impacting power system reliability and security.
- *Reliability.* This chapter considers the reliability performance of the NEM against key metrics including actual unserved energy, market reserve levels and use of interventions.

15 ESB, Options paper April 2021, https://esb-post2025-market-design.aemc.gov.au/options-paper

- *Security.* This chapter considers the security performance of the NEM against key metrics including use of interventions and frequency performance.
- *Safety Assessment.* This chapter considers the safety performance of the NEM.
- Appendix A. The Terms of Reference provided by the AEMC to the Panel for this report.
- Appendix B. Summary of reforms and other work underway related to reliability, security and safety.

2 MARKET TRENDS

2.1 Outline

This chapter outlines some key trends and challenges occurring in the NEM, and how these may be impacting power system reliability and security. This chapter also outlines a number of the key outcomes for the NEM that occurred in 2019-20. These are specifically related to:

- Supply side trends, including new generation entry and withdrawals
- Demand side trends, including continued uptake of distributed energy resources (DER)
- Wholesale market trends, including price outcomes, and
- Network trends, including supply interruptions and the impact of COVID.

Box 1 provides a summary of these outcomes.

BOX 1: SUMMARY OF MARKET TRENDS IN 2019/20

- **Power system resilience**: During 2019-20, the power system was subject to more frequent and extreme events. This included bushfires, storms and the COVID-19 pandemic. These events had material impacts on the operation of the power system and highlight the importance having the appropriate measures in place so that the power system continues to be resilient to such events in the long term. It is noted that there are a range of reforms underway or have been completed that seek to address some of the challenges arising from more frequent and extreme weather events.
- **Market reforms:** There is a significant range of reforms that have been introduced or will be introduced over the next few years that are aimed at supporting the transition occurring in the NEM. Of particular relevance are those reforms related to the post 2025 market design that are being progressed by the ESB.
- **Supply-side trends**: The expected retirement of thermal generation capacity presents a potential challenge for reliability. The market is seeing increasing investment in battery storage capacity compared to OCGT, changing the way that the wholesale market response to peak market events in times of temporary scarcity and very high prices.
- **Demand-side trends**: Intra-day minimum system load issues are currently an important issue in the NEM. AEMO is forecasting that minimum system load levels will become negative in some regions within the next five years, increasing the existing operational challenges for power system security and network stability. Rates of deployment of rooftop PV over 2020 continue to be high, and are higher than forecast, leading to changes in market dynamics.
- **Wholesale market trends**: Wholesale prices declined in the 2019-20 financial year, with increased shared of intermittent renewable generation continuing to impact the intra-day price profile observed across the NEM. There are also increasing levels of volatility in wholesale prices across multiple regions in the NEM.

- **Network trends**: COVID-19 has affected the use of distribution networks, with shifts away from traditional load centres, such as central business districts, with the increase of people working from home. This has the potential to impact network planning and operation. A more diverse range of services and operations will be necessary to continue to integrate DER into the NEM. Minimum system load may present some challenges for network stability.

Panel insights

- The Panel notes that the transition in the NEM towards a system with more intermittent, inverter-based generation, retirement of ageing thermal generation and installation of dispatchable generation (storage) and use of demand response may present challenges - but also opportunities - for security and reliability. Australia is at the global forefront of managing the power system with high penetrations of inverter-based generation.
- In addition to this transition, the power system was exposed to multiple extreme weather events, such as from bushfires, in 2019-20, causing challenges for the system operator for forecasting and operation of the power system. The Panel considers that the future occurrences of high impact low probability events should be considered in planning for future management of reliability and security in the NEM.
- The Panel notes that while there is a large program of reform work to transition the NEM, monitoring of power system resilience and operation of the power generally will be a key issue in the future as the system operator, policy-makers and the market more generally adapt to the rapid changes.

2.2 NEM in transition

The physical power system is undergoing a period of material change[16]. The generation mix of the NEM is changing and there have also been changes to market dynamics. In 2019-20, the NEM experienced multiple severe weather events and other global disruptions.[17]

Over time, there has been:

- Significant increases in inverter based generation, such as variable, renewable wind and solar units at both the transmission and distribution level, as well as increased storage capacity
- Exit of thermal, synchronous generation, especially coal-fired capacity
- An increase in demand-side participation, including demand response
- Increasing price volatility affecting market dynamics for investors and generators
- Increasing congestion on the transmission network
- Proposals for increased interconnection

16 AEMC, Transitioning to a lower emissions power system, https://www.aemc.gov.au/our-work/our-forward-looking-work-program/system-security/lower-emissions

17 Reliability Panel *Review of Reliability Standard and Settings Review Guideline Consultation Paper*, March 2021.

- Continued uncertainty in relation to emissions policy, and
- Jurisdictional government policies that incentivise new investment into the system.

These changes have been happening rapidly, and may continue over the next two decades. Each has affected the supply and demand-side of the wholesale market, affecting the power system in different ways.[18]

As noted, there are also significant reforms currently being considered, including by those by ESB. The range of ESB reforms are discussed in Section 2.4.

The 2019-20 financial year has seen the power system operate in the presence of numerous extreme events, including large-scale bushfires, storms and the advent of the COVID-19 pandemic. These events have presented challenges for reliability and security, while COVID-19 has introduced some additional uncertainty for investors and changed the demand mix between industrial/commercial and residential sectors as more people work from home.[19] This brings new challenges in determining future trends for the market in terms of demand and consumption patterns, such as what future intra-day demand will be, and whether increased residential demand will be a permanent feature.

AEMO have noted in the 2020 ISP that it will continue to advance consideration for climate risks in decision-making to ensure outcomes are as robust as possible[20]. Steps taken as part of this process include collaboration with the BOM and CSIRO on the Electricity Sector Climate Information (ESCI) Project, and the introduction of the climate vulnerability scan to identify vulnerabilities of the energy system to climate factors such as heat, bushfires, wind, rainfall, coastal inundation and compound extreme events.[21].

2.3 Power system resilience to more extreme and frequent events

The Panel considers that power system resilience is becoming increasingly important in the face of changes to underlying environmental and other conditions. Power system resilience, in this context, refers to the ability of the power system to remain in a secure and reliable state in the face of credible and non-credible contingencies.[22]

As operating conditions and trends change away from those seen in the past, the ability of the system to remain secure and reliable in the face of more extreme and frequent events is critical.

In 2019-20, there were several events that have had or may have an impact on power system operation. Most notable among these were the:

18 Reliability Panel, *Review of the Reliability Standard and Settings Guidelines, Consultation Paper,* March 2021, p.9.

19 Reliability Panel, *Annual Market Performance Market Update,* January-June 2020, December 2020.

20 AEMO, Integrated System Plan 2020, Appendix 8, https://aemo.com.au/-/media/files/major-publications/isp/2020/appendix--8.pdf

21 Climate Change in Australia, Electricity Sector Climate Information Project, https://www.climatechangeinaustralia.gov.au/en/projects/esci/

22 Credible contingency events are events that AEMO considers to be reasonably possible to occur and have the potential for a significant impact on the power system. A non-credible contingency event are events other than credible contingency events. These are generally considered to be events that are rare in occurrence, such as the combination of a number of credible contingency events occurring at the same time. AEMO can re-classify non-credible events as credible when the risk of rare events more becomes likely, including during extreme weather such as bushfires or storms. *See: https://www.aemc.gov.au/energy-system/electricity/electricity-system/security.*

- Bushfires over the summer of 2019-20,[23]
- Storms, such as the extreme wind event in Victoria on 31 January 2020,[24], and
- The advent of the COVID-19 (COVID) pandemic.

The 2019-20 bushfires resulted in over 17 million hectares being burned across NSW, Victoria, Queensland, ACT, Western Australia and South Australia[25]. Bushfires threaten to degrade transmission and generation infrastructure, as well as create forecasting challenges as fire, smoke, ash and haze impact transmission networks and solar output[26].

The 2019-20 bushfires led to incidents including the declaration of lack of reserve 2 conditions (LOR2). To address reserve shortfalls, the RERT was activated on more occasions in 2019-20 than in 2018-19, however each event required less of a response and not all available RERT was activated as these events did not progress to LOR3 declarations. These incidents are described in more detail in Chapter 3.3.4.

Severe storms also had significant impacts on the operation of the power system in 2019-20. For example, there was the convective downdraft event that resulted in the collapse of seven transmission towers along the Moorabool - Mortlake and the Moorabool - Haunted Gully 500 kilovolt (kV) transmission line.

The resulting outages led to the separation of the South Australia region and part of western Victoria from the rest of the NEM, including leaving the Alcoa Portland (APD) aluminium smelter and generation at Mortlake Power Station and the Portland and Macarthur wind farms connected to South Australia but disconnected from the rest of Victoria. In total, South Australia was islanded from the rest of the NEM between 31 January and 17 February 2020.

AEMO was able to manage the power system in this 'extended island' configuration, however the management of the situation required significant intervention compared to normal market operation.

The impact of extreme events such as the bushfires and storms is reflected in metrics such as RERT activation events, reviewable operating incidents, FCAS costs and directions. Increases in these metrics highlight the challenges facing AEMO in the role of maintaining the system in a secure and reliable state. There has been an increase in frequency of extreme heat events and extreme fire conditions over time in Australia. Given the impact that these conditions may have on power system operation, the Panel considers that it is important that

23 Parliament of Australia, 2019-20 Australian bushfires, https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1920/Quick_Guides/AustralianBushfires

24 AEMO, Final report - Victoria and South Australia separation event on 31 January 2020, https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/final-report-vic-sa-separation-31-jan--2020.pdf?la=en

25 Parliament of Australia, 2019-20 Australian bushfires, https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1920/Quick_Guides/AustralianBushfires

26 AEMO, 2019-20 summer operations review, https://aemo.com.au/en/newsroom/media-release/2019-20-summer-operations-review

these events and the responses to them are being factored into the ongoing planning and future approaches to maintaining power system resilience[27].

The 2019-20 financial year saw the advent of the COVID-19 pandemic in Australia. The response to the pandemic caused significant changes in lifestyle for large proportions of the population over the course of 2019-20, continuing into 2020-21.[28]This has led to changes in electricity consumption patterns, as well as introducing uncertainty about future trends for operating the power system. Additionally, COVID has created some further uncertainty around project timelines and investment for developers. This uncertainty is related to maintenance and construction delays due to workforce shortages.

The impacts of COVID are noticeable in changes in distribution network usage, as well as solar uptake in particular areas. These impacts are discussed in more detail in 2.7.1 and 2.6.4 respectively.

Power system resilience will also be important in the face of variability in operating conditions and outage management of generation and transmission, as well as minimum system load phenomena. These factors may cause the system to be vulnerable to unexpected events a larger proportion of the time.

The Panel considers that improved methods for assessing and measuring power system resilience are important to addressing the increasing risk and uncertainty associated with higher levels of volatility and uncertainty for power system operation. The Panel notes that power system resilience was taken into account in AEMO's 2020 Integrated System Plan, and was considered in two main ways[29]:

- Risk analysis and evaluation: Where possible, risk analysis considers both the impact of acute and chronic hazards. Where captured, these risks contribute to the estimation of system reliability, security and calculated project market benefits. Efforts have been taken to improve risk analysis and evaluation to capture resilience, however many acute hazards remain excluded.
- Planning standards: Planning standards consider climate and resilience when developing physical designs and technology solutions.

The AEMC is currently considering the Enhancing operational resilience in relation to indistinct events rule change[30]. The purpose of this rule change is to amend the NER to introduce a framework to manage indistinct events. This follows a recommendation made by the AEMC in its mechanisms to enhance resilience in the power system - review of the South Australian black system event.

27 Bureau of Meteorology, State of the Climate 2020, http://www.bom.gov.au/state-of-the-climate/documents/State-of-the-Climate-2020.pdf

28 AEMO, 2020 Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en

29 AEMO, 2020 Integrated System Plan, https://aemo.com.au/-/media/files/major-publications/isp/2020/appendix--8.pdf

30 AEMC, *Enhancing operational resilience in relation to indistinct events,* https://www.aemc.gov.au/rule-changes/enhancing-operational-resilience-relation-indistinct-events#:~:text=The%20proposed%20rule%20change%20aims,for%20and%20manage%20indistinct%20events.

2.4 Market reforms

There are a range of reforms that are underway. Of particular relevance are those related to the ESB post 2025 market design and the AEMC system security work program. These are discussed below.

2.4.1 ESB market reforms

As noted, the ESB have has been developing a number of policy initiatives for a post 2025 market design.

The ESB post 2025 market design key focus areas outlined in the April 2021 options paper include:

- Resource adequacy mechanisms
- Essential system services and scheduling and ahead mechanisms
- Integration of distributed energy resources and flexible demand
- Transmission and access.

The ESB has noted that an any new design would not be introduced at a single point in time, rather introduced over time.

A number of reform pathways have been set out and fall into three categories, immediate reforms to be done now, initial reforms to be developed and implemented in the near term, and next reforms which are longer term and depend on developments in the industry including technical changes.[31]

A brief explanation of each work stream and linkages to operation of power system in relation to reliability and security is provided below. The suite of other reforms occurring in the NEM are outlined in Appendix B.

Resource adequacy mechanisms

The ESB for this reform area is focuses on facilitating the timely entry of new generation, storage and firming capacity, and an orderly retirement of ageing thermal generation.[32]

The measures set out in the options paper include immediate measures that include:

- The provision of additional two-way advice to jurisdictions on what dispatchable resources will be needed in a jurisdiction in future years, given anticipated development.
- Principles and practical contract structures to inform the design of government long-duration contract schemes and to incentivise investment in classes of resources. Both are intended to facilitate such potential government intervention being at least cost to consumers.
- Development of three proposed exit mechanisms. As prudent backstops implemented immediately, they can address reliability risks that might arise with exits that occur before

31 Energy Security Board, Post 2025 Market Design Options - A paper for consultation, April 2021,

32 Energy Security Board, Post-2025 Market Design Options, a paper for consultation, Part A, April 2021

the 42-month notice of closure expires. Options for actions to manage early closure, including possible intervention, can then be examined.

Initial reform steps to be implemented in the near term on the proposed transition pathway, and focus on the spot and contract markets. These include:

- Modifying the Retailer Reliability Obligation (RRO). Two options for modifying the RRO are being developed:
  - Removing the T-3 trigger from the existing RRO to promote and increase the duration of the price signal for investment and a higher level of enduring contracting by retailers.
  - Changing the definition of qualifying contracts to newly created physical certificates that provides a more direct link to a physical resource. It is proposed that this could encourage more timely and earlier contracting. The ESB note that the design choices for such a physical RRO can either replace the current market signals for reliability investment or work in parallel with them.

The ESB is also considering an operating reserve in the Essential System Services and Ahead Scheduling workstream. Depending on its design, an operating reserve could provide a positive externality for resource adequacy. The interactions between an operating reserve and its contribution as a resource adequacy mechanism will continue to be investigated.

Essential system services and scheduling and ahead mechanisms

The essential system services and ahead scheduling workstream is aiming to ensure that essential system services required to maintain system security are available when they are needed. These system services are:

- Frequency control,
- Operating reserves,
- Inertia, and
- System strength.

The ESB have noted that the growing role of renewable generation and battery storage in the power system will increase the need for these services. This will be exacerbated by the retirement over time of ageing thermal generators who provide many of these services. The ESB considers that it is necessary to specify and value those essential system services and efficiently procure them, including procurement from non-traditional and new sources. The approach proposed is to use co-optimised market-based procurement where possible and, where not possible, structured procurement approaches.

The arrangements need to not only ensure that the range of essential system services are available, but also that they are effectively used in a more complex operating environment. The AEMC's package of rule change on system strength is coordinating with this work, allowing system security issues that are more urgent in nature to be addressed.

Integration of distributed energy resources and demand side participation

These reforms are aimed at providing clarity and direction on roles and responsibilities for various actors in the system and how they may evolve. Further, to reward customers for their flexible demand, enabling access to products and services that innovation offers, and managing risks to consumers through the right protections, regardless of how consumers choose to use or receive energy, or their level of engagement. The second element is to integrate flexible DER and demand-based assets into the market at all levels, safely and effectively.

The ESB is considering immediate reforms, which include a customer protections risk assessment tool that helps to assess whether customer protections may be needed with the expansion of new forms of energy services, as well as opportunities to streamline and increase easy customer participation. Options to include the appropriate technical standards, and arrangements to address minimum demand on the networks so that security and power quality is maintained are also being considered.

Initial reforms are focused on:

- Options for rewarding customers for their flexible demand and increasing value to the system for flexible resources.
- Changes needed to make it easier for innovative new retailers and service providers to enter the market enabling customers to benefit from greater choice and competition. Customers will continue to interface with retailers and aggregators, but retailers and aggregators will have new opportunities to engage in the market and offer different choices to customers.

ESB will consider priority issues for DER integration and deliver and inform the detailed design consistent with directions on future roles and responsibilities over the short to longer term.

Transmission and access

The transmission and access workstream is aiming to reconfigure the transmission system so that new renewable generation and large-scale storage can connect and be dispatched to meet customers' demand. The ESB propose a range of measures to ensure that much needed transmission investment is delivered in a timely and efficient manner, and options to ensure that market design promotes a targeted set of supply-side investments that delivers the energy transition at least cost. It is also important to ensure that these investments, once made, are used in an efficient manner.

Key elements of this workstream include:

- Actioning the ISP
- The development of Renewable Energy Zones (REZs).
- Improving access arrangements for connecting generators.
- Investigating methods for real time congestion management in the grid.

2.4.2 AEMC system security work program

The AEMC is considering numerous rule change requests that form part of the ESB's post-2025 work program, in particular the essential system services workstream. The AEMC is working closely with the ESB and the other market bodies, particularly AEMO, on these rule change requests given that these rule change requests dovetail with this other work. The rule change requests complement and are interdependent with the work of the ESB in its 2025 project. The rule changes provide the AEMC with an opportunity to complement some of the thinking and assessment done in the ESB work program, as well as technical input from AEMO through its *Renewable Integration Study*. It allows the AEMC to address the issues in a cohesive way, as well as addressing system security issues that are more urgent in nature.

These rule changes relate to the following four workstreams:

- **Operating reserves -** The AEMC is considering two rule change requests (one from Infigen, one from Delta Electricity) that relate to operating reserves. Both rule changes are aimed at addressing the power system needs and how the increased uncertainty and decreased ramping availability may manifest in failures of the current market to meet these needs without intervention. A directions paper was published on these rule changes in January, with a draft determination due by June 2021.
- **Frequency control.** The AEMC is considering two frequency control rule changes, targeting different areas of the service:
  - Fast frequency response market ancillary service, submitted by Infigen which proposes the introduction of new ancillary service markets for fast frequency response to efficiently manage power system risks associated with reducing system inertia. A draft determination was published in April 2021, with draft rules to implement a fast frequency response market.
  - Primary frequency response incentive arrangements, submitted by AEMO which proposes way to incentivise the provision of primary frequency response during normal operation. A draft determination is due in September 2021.
- **System strength.** The AEMC is considering a rule change request from TransGrid that is seeking to amend the existing arrangements regarding the provision of system strength in the NEM. A draft determination was published in April 2021, with draft rules evolving the current system strength framework to be more forward-looking.
- **Synchronous Services.** The AEMC is considering two synchronous services rule changes (one from Delta Electricity, and one from Hydro Tasmania) that are both aimed at making sure there are mechanisms to value and procure specific system services in the NEM, as the system transitions. These are necessary in order to maintain the system within its operational limits. Updates on these are due in June 2021.

2.5 Supply side trends

This section highlights the important trends in the supply of electricity over the 2019-20 financial year, and the implications of these for power system security and reliability, including:

- The change in generation capacity
- Entry and exit trends of generation
- The change in generation output
- Investment environment

2.5.1 Change in generation capacity

There have a been a number of key changes in the installed generation capacity in the NEM over the last decade with increasing large and small-scale intermittent generation, retirement of ageing thermal generation and installation of dispatchable generation (storage) and use of demand response. In 2019-20, the key changes included:

- The entry of approximately 5600 MW of generation capacity, including 926 MW of gas and other fuels,[33] 1,340 MW of wind, and 763 MW of large-scale or utility solar.[34]
- Large plant entries included:
  - Cherry Tree Wind Farm (56.7 MW)
  - Dundonnel Wind Farm (168 MW)
  - Elaine Wind Farm (83.6 MW)
  - Oakey 2 Solar Farm (55.64 MW)
  - Barker Inlet Power Station (210 MW)
  - Finley Solar Farm (162.36 MW) and
  - Limondale Solar Farm 2 (28.98 MW).

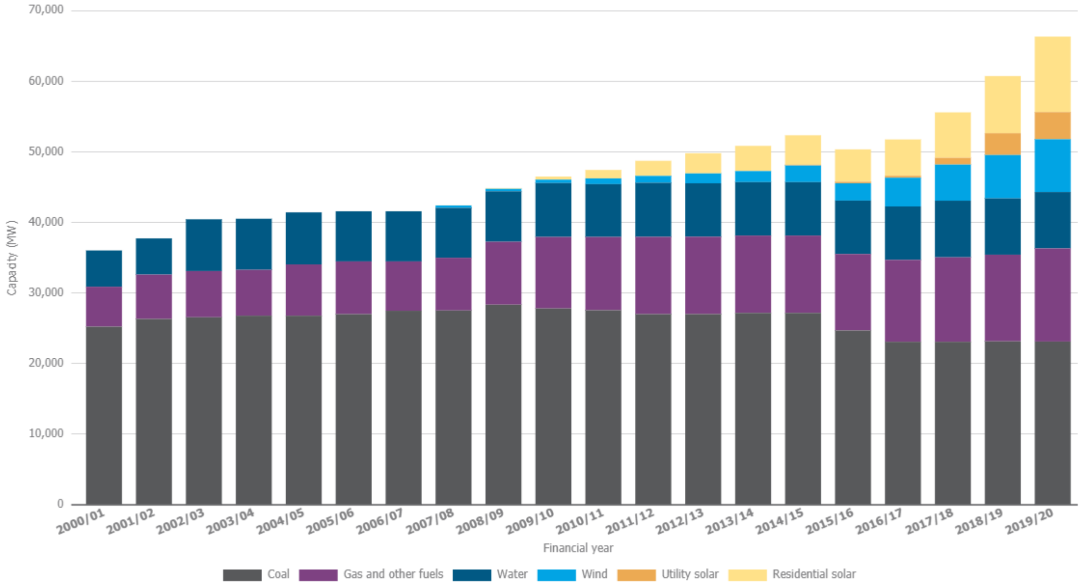
These trends are illustrated in Figure 2.1, which shows the total installed generation capacity in the NEM. There has been an upwards trend in NEM generation capacity since 2017 as more large-scale wind and solar projects connect to the power system. AEMO have also noted that a total of 342 proposed generators are currently in various stages of connecting and registering across all NEM regions[35].

33 Gas and other fuels includes bagasse, biogas, coal seam methane, diesel, fuel oil, gaseous fossil fuels - other, green or air dried wood, landfill gas, landfill methane/landfill gas, municipal solid waste, natural gas, natural gas pipeline, waste coal mine gas and wood waste.

34 Reliability Panel analysis of data from AEMO Generation information 29 July 2020 v2, https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information, Clean Energy Regulator, Postcode data for small-scale installations, http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations.

35 AEMO, State of the System November 2020, https://aemo.com.au/en/newsroom/news-updates/state-of-the-system-update-feb-2021

Figure 2.1: NEM generation capacity (installed megawatts) by fuel type 2001-2020



Source: Reliability Panel analysis of AEMO Generation Information data, as well as Clean Energy Regulator small-scale solar installation data
Note: The data for this chart is available in the AMPR data portal.

Generation exit and entry

A key trend in the supply side of the NEM is the expected exit of a significant proportion of the existing large synchronous thermal generation fleet[36]. This process has already begun, with the exit of Hazelwood power station in Victoria, the announced closure of Liddell power station in New South Wales in 2023, and the (more recent announcement, outside the reporting period of) Yallourn power station in Victoria[37]. These closures are forecast to continue to occur at a consistent rate over the next 2-3 decades.[38] The exit of synchronous thermal generation is expected to be offset by the entry of large and small-scale intermittent renewable generation. This trend continued in 2019-20 with the entry of 763 MW of utility scale solar capacity and 1340 MW of wind capacity. The Panel also notes the addition of 75 MW of storage capacity added in 2019/20. Battery storage is likely to continue to increase in capacity as the NEM transitions towards higher penetrations of intermittent renewables.[39]

36 AEMO, Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

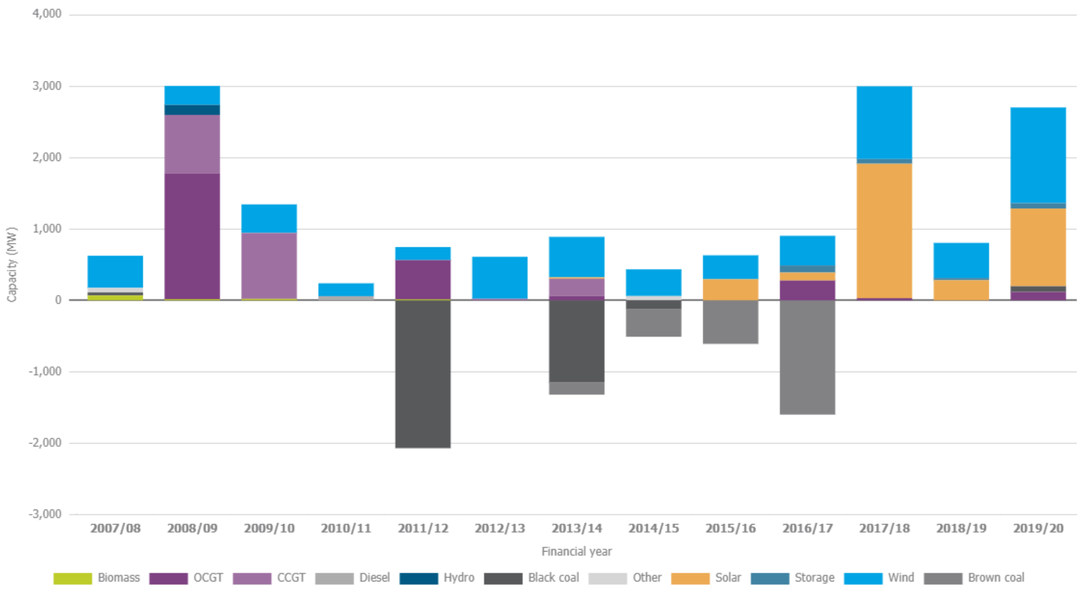
37 EnergyAustralia, EnergyAustralia powers ahead with energy transition, https://www.energyaustralia.com.au/about-us/energy-generation/yallourn-power-station/energy-transition, https://www.energyaustralia.com.au/about-us/energy-generation/yallourn-power-station/energy-transition

38 AEMO, Electricity Statement of Opportunities 2020.

39 AEMO, Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en

Figure 2.2 illustrates the entry and exit of generation in the NEM by technology type since 2007-08.[40]

Figure 2.2: Entry and exit of generation (installed megawatts) by fuel type - 2007-2020



Source: Reliability Panel analysis of AEMO Generation Information data.
Note: The data for this chart is available in the AMPR data portal.

Figure 2.2 highlights the variability of annual capacity changes in the NEM and also conveys the challenges associated with planning for the exit of large amounts of capacity.

The most recent retirement of large scale capacity was the Hazelwood brown coal power station in 2016-17. As can be seen, the exit of a single power station can lead to significant withdrawals of capacity at a single time. If the exit of such large amounts of capacity are not expected and planned for, this may affect security and reliability.[41]. There are currently notice provisions in the NER that require generators to give at least 42 months notice of their closure. Recent announcements by EnergyAustralia and AGL about Yallourn and Liddell respectively were all longer than this timeframe.

A number of reforms to address the challenges associated with exit of ageing thermal plant are discussed below in Section 2.5.3 and outlined in Appendix B.

The Panel notes that there have been some recent developments post the reporting period in generator exit and entry that may affect future investment and reliability outcomes in the NEM, which are summarised here. These will be looked at more comprehensively in the next AMPR.

40 Difference between 29 July 2019 and 29 July 2020, as per AEMO's generator information page

41 AEMO, Integrated System Plan 2020, https://www.aemo.com.au/-/media/files/major-publications/isp/2020/final-2020-integrated-system-plan.pdf

Firstly, the New South Wales government has been progressing plans for the Central-West Orana Renewable Energy Zone (REZ) as part of its wider REZ program.[42] The Central-West Orana REZ is expected to deliver up to 3000 MW of new generation capacity by the mid-2020's, with construction on new generation plant expected to begin by the end of 2022. AEMO have noted that the impact of the Central-West Orana REZ transmission link was not included in the 2020 ESOO when assessing the benefits of actionable ISP projects on future reliability outcomes[43]. This was because the augmentation is designed for VRE capacity that is not committed by investors. The Panel therefore notes that the effect of the NEW REZ on reliability outcomes will be important to consider going forward.

Secondly, EnergyAustralia has reached an agreement with the Victorian government to deliver an orderly retirement of the Yallourn power station[44]. Under the agreement, EnergyAustralia will retire Yallourn in mid-2028 and build new storage capacity through a 350 MW, four-hour, utility scale battery project that will be completed by 2026. This brings the closure date of Yallourn forward by four years, as it was originally expected to close in 2032. The Victorian energy minister stated that the agreement with EnergyAustralia is about "ensuring there is sufficient power supply in the system".[45]

Change in generation output

Figure 2.3 shows the proportion of electricity demand that was met by each technology type per year. Wind (9.5 per cent) and solar (3.1 per cent) have increased as a proportion of electricity generated over 2019-20. The proportion of demand met by coal (70.7 per cent) has decreased compared to 2018-19 from 74 per cent, although it still represents the greatest proportion of electricity generated by a significant margin[46]. Hydro-powered generation contributed approximately 7.6 per cent of electricity generated and gas-fired generation contributed approximately 9 per cent.

Outcomes from 2019-20 reflect that VRE continues to become an increasingly significant contributor of the total electricity generated in the NEM. Including hydro, renewables contributed 20.2 per cent of all output generated in 2019-20, increasing from approximately 17.5 per cent in 2018-19. This trend is expected to continue, particularly as the cost of VRE falls and efficiency of generation continues to increase.[47].

42 New South Wales Department of Planning, Industry and Environment, Renewable Energy Zones, https://energy.nsw.gov.au/renewables/renewable-energy-zones#-what-is-a-renewable-energy-zone-

43 AEMO, 2020 Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

44 EnergyAustralia, EnergyAustralia powers ahead with energy transition, https://www.energyaustralia.com.au/about-us/energy-generation/yallourn-power-station/energy-transition, https://www.energyaustralia.com.au/about-us/energy-generation/yallourn-power-station/energy-transition

45 Parliament of Victoria, Assembly questions without notice and ministers statements 16 March 2021, https://hansard.parliament.vic.gov.au/isysquery/5927b583-49dc-4ae7-b76a-9b669d195edd/12/doc/

46 Reliability Panel, Annual Market Performance Review 2019, https://www.aemc.gov.au/sites/default/files/2020-04/2019%20AMPR%20final%20report%20-%20republished%20with%20minor%20amendments%20in%20April%202020.PDF

47 AEMO, Integrated System Plan 2020, https://aemo.com.au/en/newsroom/media-release/isp-2020

Higher levels of VRE output pose challenges for the system operator in relation to managing system security and reliability. AEMO is investigating this through its Engineering Framework[48], which aims to:

- Facilitate a discussion to identify possible future operational conditions for the power system
- Consolidate a common view of the current work underway to adapt the system and existing avenues for engagement
- Collaborate on identifying where increased industry focus is needed to bridge the gap between current work and future operational conditions.

The lack of synchronous generators has implications for system operations due to the inability of non-synchronous generators to provide the same additional services such as system inertia and system strength[49]. The AEMC's consideration of reforms to the existing system strength framework will help to overcome these concerns.[50]

Additionally, the variable nature of renewable resources, particularly solar, is already creating issues with intra-day ramping and minimum system load, which will continue to develop as more of these resources connect to the grid[51]. The AEMC is currently considering the introduction of an operating reserve market, as well as a ramping service, both of which are relevant to the discussion of managing increasing variability and volatility in power supply in the NEM[52].

48 AEMO, Engineering Framework, https://aemo.com.au/en/initiatives/major-programs/engineering-framework

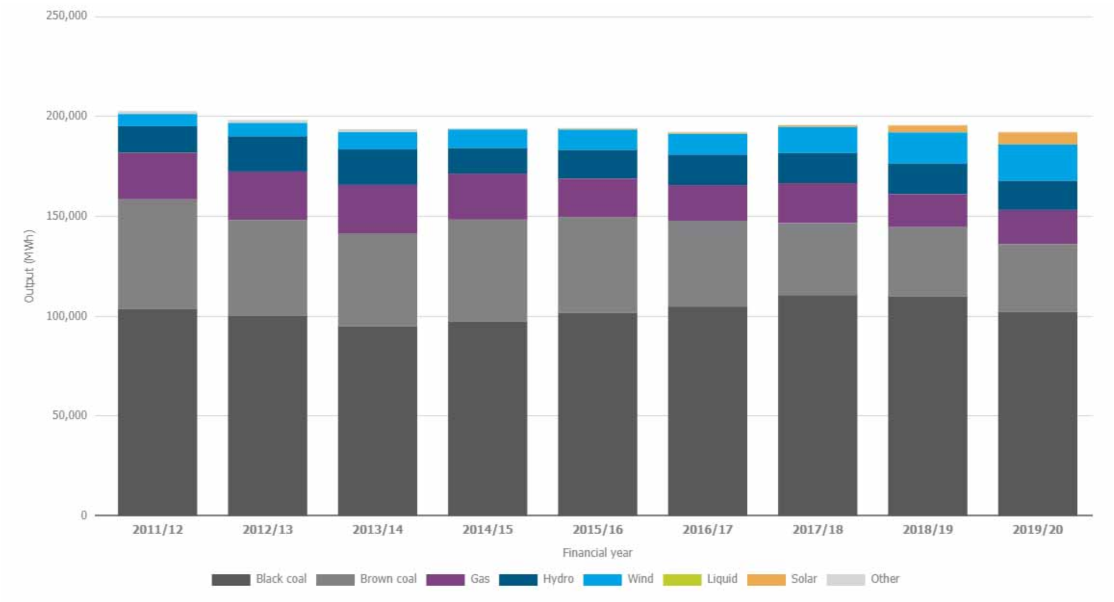
49 https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/Operability/2020/2020-System-Strength-and-Inertia-Report

50 AEMC, Efficient management of system strength on the power system, https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system

51 AEMO, South Australian electricity report 2019, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/sa_advisory/2020/2020-south-australian-electricity-report.pdf?la=en

52 AEMC, Reserve Services Directions Paper, https://www.aemc.gov.au/sites/default/files/2021-01/Reserve%20services%20directions%20paper%20-%205.01.2021%20-%20FINAL.pdf

Figure 2.3: NEM generation output (gigawatt hours) by fuel type 2011 - 2020



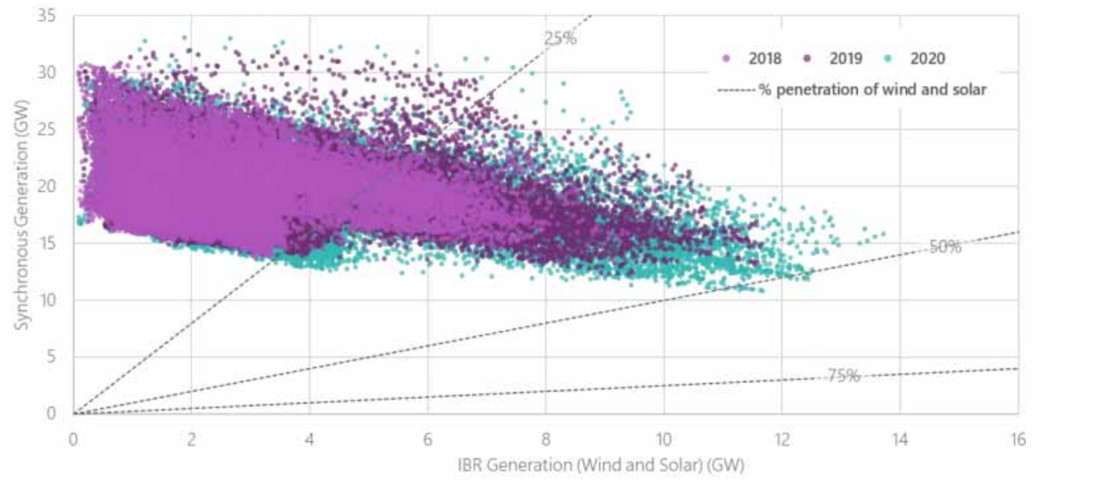
Source: Reliability Panel analysis of AEMO MMS data.
Note: The data for this chart is available in the AMPR data portal.

Changes in operating conditions

The Panel notes that the NEM is approaching uncharted territory internationally in terms of operating the power system with above 75 per cent and towards 100 per cent wind and solar penetration[53]. AEMO's NEM Engineering Framework report states that the NEM has reached 30 minute dispatch intervals with greater than 50 per cent wind and solar penetration, as reflected in Figure 2.4 below.

53 AEMO, NEM Engineering Framework Report, https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/nem-engineering-framework-march-2021-report.pdf?la=en&hash=3B1283D31B542115CC56E0ECCDFB3D69

Figure 2.4: Dispatch intervals with penetrations of inverter-based generation



Source: AEMO Engineering Framework March 2021 Report, page 10.

The unprecedented nature of these operating conditions may present challenges in managing power system security and reliability in both the short and long-term as market operators, policymakers and participants adapt to new operating methods and conditions.

2.5.2 Investment environment

Large amounts of investment in additional capacity will be necessary to ensure that the NEM remains secure and reliable throughout the transition towards higher penetrations of VRE.[54] Whilst this is the case, market participants have noted that there is some investment uncertainty which is inhibiting further investment in generation capacity.[55] COVID has made things more uncertain, however the Panel notes that there was a level of investment uncertainty before the beginning of 2020.

The rapid change of conditions in Australia in the first half of 2020 due to COVID-19 presented a number of issues to the electricity market, including:

- Significant reduction in overseas travel, leading to issues with labour resources for construction and maintenance of projects
- Increase in hardship customers and issues with bad debt for retailers, and
- Changing demand patterns with changing consumer preferences and choices[56].

The impact that COVID had on the outlook for investment may be indicated in Table 2.1, which shows the differences in capacity at different stages of the generator development

54 AEMO, Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

55 Reliability Panel, Annual Market Performance Review - Market Performance Update, https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2020

56 This is addressed in more detail in Section 6

process between January and June 2020, the period when disruptions from COVID were at their peak. A figure to note is the change in publicly announced capacity, which saw a decrease of 1610.9 MW over this period.

Table 2.1: **Impact of COVID on investment**

UNIT STATUS	DIFFERENCE FROM JANUARY - JUNE 2020 (MW)
Committed	-69.7
Emerging	-626.6
In Commissioning	346.8
In Service	900.9
Announced Withdrawal	214
Maturing	-481.3
Publicly Announced	-1610.9
Upgrade	20

Source: Reliability Panel analysis of AEMO generation information data

As noted, there were other causes of uncertainty before the COVID pandemic. These factors include:

- Growing regulatory risk given increasing intervention and proposed reforms
- Curtailment risks increasing due to low demand
- Continued low wholesale prices and contract prices.[57] This is addressed in more detail in 2.8.1.

The Panel notes that it is important that the market is conducive to new investment for reliability and security of the NEM. The conclusion of the ESB post-2025 process and the finalisation of recommendations to the Energy Ministers Meeting are intended to reduce risks around regulatory uncertainty, and will provide more certainty about the direction of the market over coming years.

The Panel notes initiatives underway to reduce curtailment risk. These include:

- The development of REZs and the frameworks that govern these developments to ensure that efficient levels of access are provided for participants[58].
- The efficient management of system strength on the power system rule change, which is intended to provide system strength in a more proactive manner to maintain a secure

57 Reliability Panel, Annual Market Performance Review, Market performance update, https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2020

58 Energy Security Board, Renewable Energy Zones consultation paper, https://esb-post2025-market-design.aemc.gov.au/32572/1608712510-esb-interim-rez-framework-stage-2-consultation-paper-final.pdf

power system and to provide additional levels of system strength to streamline the connection of new non-synchronous generators[59].

2.5.3 Expected generator retirements

As noted above, the timing of the retirement of large thermal generators from the NEM will be of significant importance for security and reliability outcomes over the period of transition towards a higher penetration of VRE.

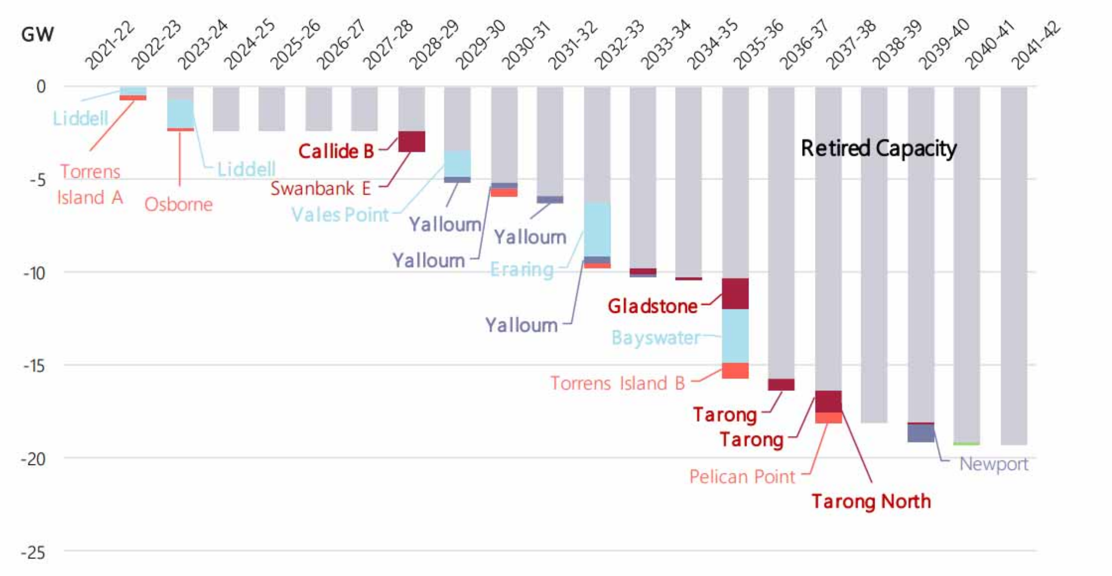
The regulatory arrangements associated with this require AEMO to maintain an up to date list of expected closure dates for generating units on its website. In the 2020 ISP, AEMO outlined the expected generation retirement dates of coal-fired and gas-power generation plant as indicated by participants in February 2020.

As seen in Figure 2.4, the retirement of significant thermal generation capacity begins cascading in 2030[60]. The Panel notes that this period may provide significant challenges for security and reliability outcomes in the NEM, and it is important that the appropriate steps are taken to prepare for this period.

As noted above, the ESB is considering this issue in the April options paper, particularly through the resource adequacy mechanisms workstream.

The Panel will also continue to consider how retirements will affect reliability and security in its work. This includes the upcoming 2021 RSSR.

Figure 2.5: **Coal-fired generation and GPG retirements**



Source: AEMO 2020 Integrated System Plan, page 44

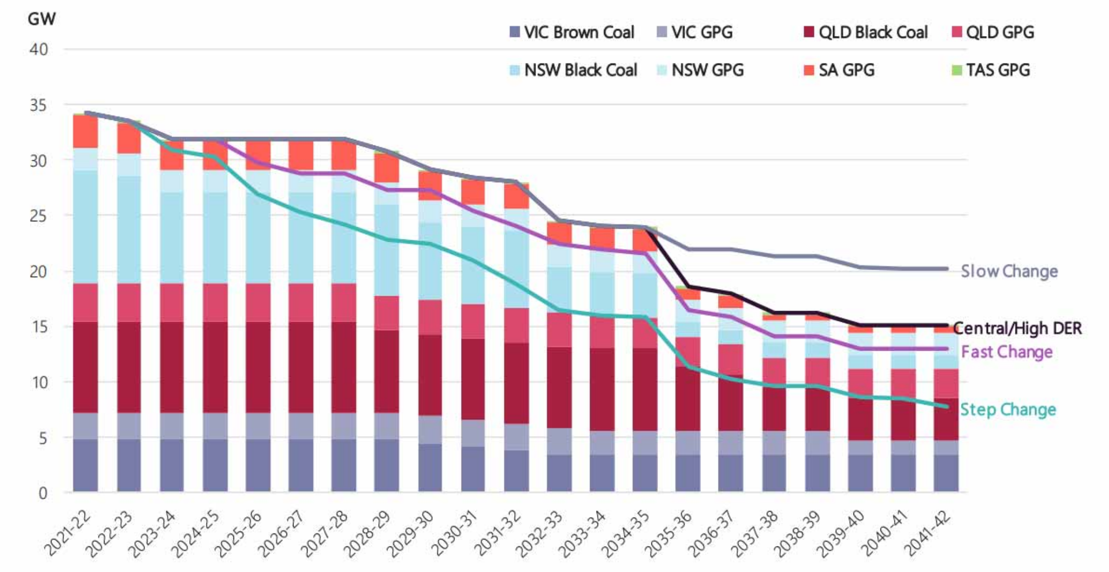
59 AEMC, Efficient management of system strength on the power system, https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system

60 On 10/03/2021, EnergyAustralia announced that the closure date of Yallourn had been brought forward from 2032 to 2028

The Panel notes that as the penetration of low cost VRE generation continues to grow in the NEM, the commercial outcomes for large, inflexible thermal generators may deteriorate. This may influence the decision of large thermal plant to exit the market.

This impact can be displayed in Figure 2.6 from AEMO's 2020 ISP, showing the expected closure of coal-fired and gas-power generation plant as indicated by participants in February 2020 subject to the different scenarios outlined in the 2020 ISP, ranging from slow change, with minimal additions of VRE to step change, with significant increases of VRE capacity.

Figure 2.6: Coal-fired generation and GPG



Source: AEMO 2020 Integrated System Plan, page 44

The Panel notes that the "Step Change" scenario would see a significantly faster retirement of large-scale thermal capacity than any other scenario. The Panel is of the view that it is necessary for participants, policymakers and operators to consider each of the scenarios occurring, and to have the ability to respond to a faster than expected withdrawal of large-scale thermal capacity.

The Panel will continue to consider how retirements will affect reliability and security in its work. This includes the upcoming 2021 RSSR.[61]

2.5.4 Impact of extreme events - supply side

Extreme weather events had a significant impact on the ability of generators to supply electricity to the market on a number of occasions in 2019-20. As noted, extreme heat, bushfires and storms required AEMO to intervene in the market to keep the power system in

61 Reliability Panel, Review of the reliability standard and settings guidelines, https://www.aemc.gov.au/market-reviews-advice/review-reliability-standard-and-settings-guidelines-0

a secure and reliable state. Extreme events that required AEMO to intervene in the NEM by activating RERT include:

- 30 December 2019: Actual LOR2 declared in Victoria due to network constraints associated with unplanned transmission outages caused by bushfires.
- 4 January 2020: Actual LOR2 declared in New South Wales due to network constraints associated with unplanned outages of 330 kV transmission lines in the Snowy Mountains area. There were also extreme temperatures in Sydney, with temperatures reaching 47 degrees Celsius at Bankstown.
- 23 January 2020: Actual LOR2 declared in New South Wales due to existing limitations on transmission equipment from the events of 4 January 2020. There were also extreme temperatures in Sydney, with temperatures reaching 41.8 degrees Celsius at Bankstown
- 31 January 2020: Actual LOR2 declared in Victoria and South Australia disconnected from the NEM due to a severe convective downdraft event resulting from thunderstorm activity. There was also very high demand forecast for this day due to extreme heat, with temperatures reaching 43.6 degrees Celcius at Melbourne Airport.

These events are discussed in more detail in Chapters 3.3.4 and 4.3.1.

The Panel notes that a number of changes have been made following previous incidents to enable the power system to remain resilient to extreme events. These events include the 2016 South Australia black system event[62] and the 2018 Queensland and South Australia system separation event[63]. The learnings and changes arising from these events are discussed in more detail in Chapter 4.3.1, which will explore the South Australian separation event in more detail.

2.6 Demand side trends

Demand side trends refer to the changes in electricity consumption over time in the NEM. Electricity consumption habits have the potential to impact system security and reliability outcomes. As the NEM continues to transition towards high penetrations of VRE generation, there are a number of demand side trends that the Panel considers important to security and reliability outcomes, including:

- Intra-day demand trends
- Total electricity demand (operational and demand forecasts), and
- Uptake of Distributed Energy Resources
- Impact of COVID-19 on demand

62 AEMO, Integrated Final Report - SA Black System 28 September 2016, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf

63 AEMO, Final Report - Queensland and South Australia system separation on 25 August 2018, https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2018/qld---sa-separation-25-august-2018-incident-report.pdf?la=en&hash=49B5296CF683E6748DD8D05E012E901C

The Panel also notes that COVID has led to changes in electricity consumption that have impacted the management of the network, and will continue to do so while more people work from home[64].

Energy use can be considered in terms of the total amount of energy consumed over a period of time (i.e. energy consumption), or in terms of the rate at which energy is used at a single point in time (i.e. energy demand).[65] Both of these measures are important to consider when examining demand side trends. For example, energy consumption trends are relevant to assessing how much bulk energy supply is needed in the NEM over a period of time to ensure the system is reliable. Changes in patterns of minimum system load are relevant to in assessing ways in which generation and load need to behave to ensure system security and reliability. This section will examine both of these elements.

2.6.1 Intra-day demand trends

Minimum system load is emerging as an important issue for the NEM. Particularly in South Australia, the prevalence of VRE generation, notably utility and rooftop solar, is causing significant reduction of demand in the middle of the day. While South Australia is approaching negative minimum system load more quickly than other jurisdictions in the NEM, the impact of VRE on intra-day demand trends is still significant across all regions of the NEM, and presents issues with ramping capabilities of existing generators, as well as system strength issues due to lack of synchronous generation, often leading to AEMO intervention in the market.[66]

Over 2019-20, South Australia reached record low levels of demand on a number of occasions.[67] This low demand in the middle of the day is due to the increased prevalence of solar generation in South Australia, and the correlation of solar generation profiles.

Figure 2.7 shows the reduction of demand is significant when averaged over a month.[68], with a difference of approximately 600 MW between the lowest and highest levels of demand within the day.

This effect is highlighted on days such 13 September 2020, where there is a difference of approximately 500 MW between the peak and trough. As can be seen in Figure 2.8, this trend is not limited to South Australia, but is prevalent across other regions of the NEM, although minimum system load is not expected to be an issue in other jurisdictions as soon as South Australia.

64 Australian Bureau of Statistics, Household impacts of COVID-19 survey, https://www.abs.gov.au/statistics/people/people-and-communities/household-impacts-covid-19-survey/latest-release

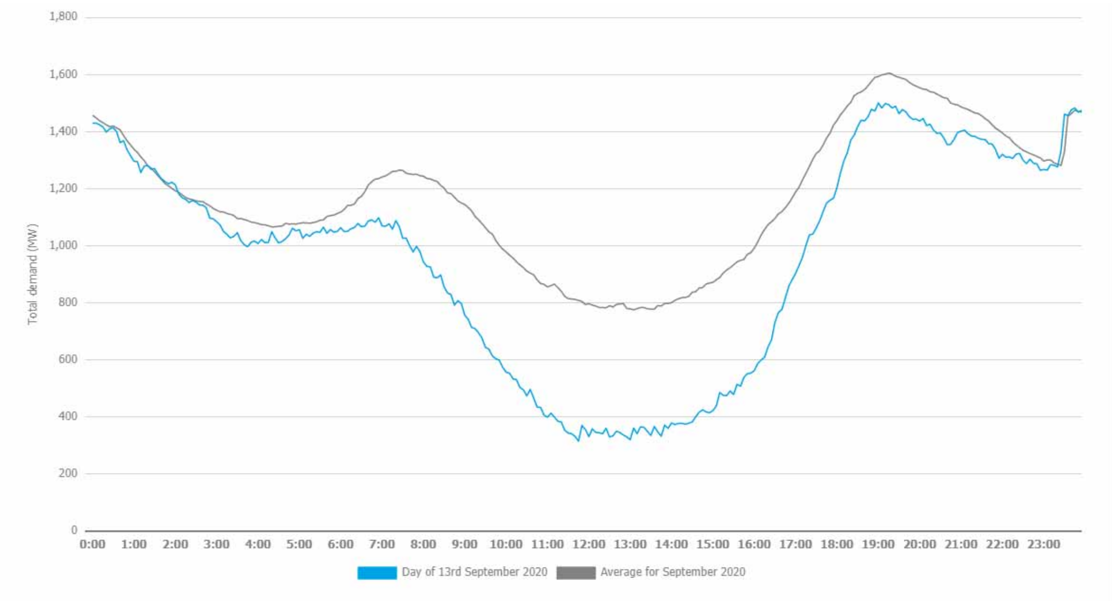
65 Reliability Panel, Annual market performance review 2019, https://www.aemc.gov.au/sites/default/files/2020-04/2019%20AMPR%20final%20report%20-%20republished%20with%20minor%20amendments%20in%20April%202020.PDF

66 AEMO, Minimum operational demand thresholds in South Australia review, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2020/Minimum-Operational-Demand-Thresholds-in-South-Australia-Review

67 It should be noted that this trend has continued at a rapid rate in 2020-21.

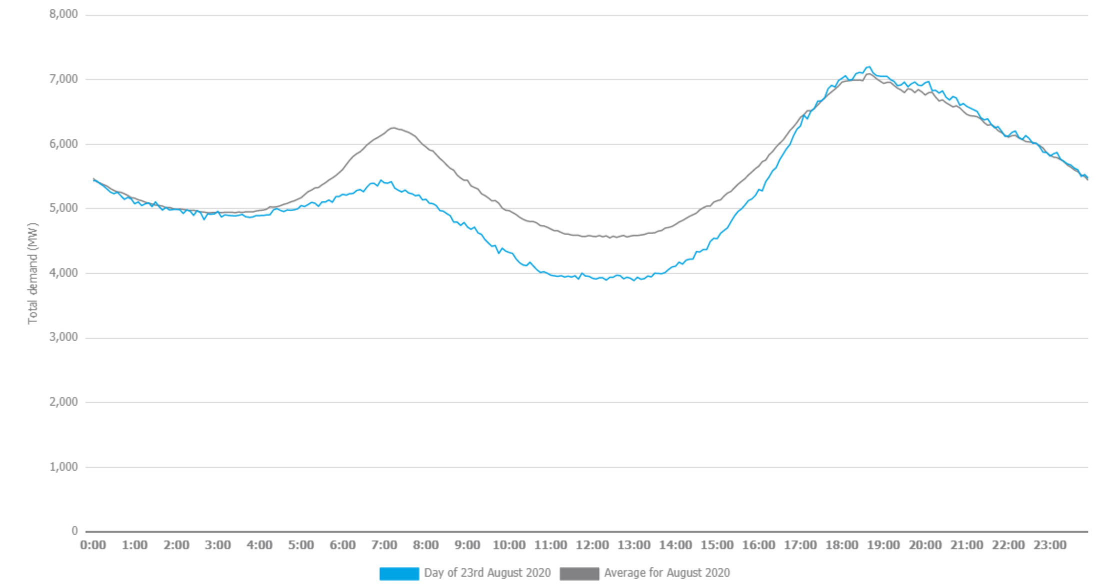
68 The month in which the low demand event occurred has been averaged for comparison.

Figure 2.7: South Australia intra-day total demand - September 2020 and 13/09/2020



Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

Figure 2.8: Queensland intra-day total demand - August 2020 and 29/08/2020



Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

As mentioned above, this daily trough is likely to place pressure on inflexible thermal generation due to the slow ramp rates, or the inability to quickly change the level of output[69].

The Panel notes that attempts to increase the amount of ramping that occurs over the course of the day are likely to have adverse impacts on the longevity of thermal generation plant, as well as potential impacts on the safe operation of the system[70].

A second issue arising from such low levels of demand is the lack of system strength, inertia and other power system characteristics that are inherent with synchronous machines in periods of very low demand[71].

System strength and inertia are requirements for a secure power system.[72] A minimum level of system strength is required for the power system to remain stable, particularly for stability of the voltage waveform. Inertia in conjunction with frequency control services are needed for maintaining the power system frequency within limits.

AEMO has noted in it's 2020 System Strength and Inertia report that the commissioning of new utility-scale generation resources continues at a high pace, and at the same time, due to increases in installations of distributed PV generation, record minimum system load has been observed in several regions, most notably South Australia[73].

A situation of very low, zero or negative demand would mean that synchronous generators operating at minimum generation to provide system strength would lead to over-supply of energy in the power system.[74]. If no synchronous generators were dispatched, however, the lack of synchronous generation would mean that system strength would be below the minimum specified level to ensure the power system is secured.

AEMO notes that there is growing evidence that the combination of new generation capacity and low demand will result in changes to the operation of existing large scale synchronous generating units, including decommitment, and where feasible, more flexible operations[75]. Recently announced jurisdictional energy infrastructure policies are intended to support increasing introduction of new renewable generation, which could accelerate changes in the operation of existing thermal generation.[76]

AEMO have also identified that declining minimum system load is creating voltage management issues, and on some occasions has resulted in AEMO switching out transmission

69 AEMO, Integrated system plan, appendix 6, https://aemo.com.au/-/media/files/major-publications/isp/2020/appendix--6.pdf?la=en

70 AEMO, Integrated System Plan 2020, https://www.aemo.com.au/-/media/files/major-publications/isp/2020/final-2020-integrated-system-plan.pdf

71 AEMO, Minimum operational demand thresholds in South Australia review, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2020/Minimum-Operational-Demand-Thresholds-in-South-Australia-Review

72 https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/Operability/2020/2020-System-Strength-and-Inertia-Report.

73 AEMO, 2020 System Strength and Inertia Report, https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/Operability/2020/2020-System-Strength-and-Inertia-Report

74 For definition of system strength, please see https://aemo.com.au/-/media/files/electricity/nem/system-strength-explained.pdf

75 AEMO, System strength and inertia report, https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/Operability/2020/2020-System-Strength-and-Inertia-Report

76 AEMO, Integrated System Plan 2020 Appendix 6, https://aemo.com.au/-/media/files/major-publications/isp/2020/appendix--6.pdf?la=en

lines for voltage management purposes. AEMO are finalising a set of transmission outage guidelines for TNSPs that address the voltage management issues arising during low demand periods.

These issues will require management at the distribution level to effectively integrate DER but may continue to provide challenges at the transmission level as higher quantities of VRE and DER continue to connect to the NEM.[77] Therefore, the Panel believes that consideration should be given to any ongoing impacts this will have to security and reliability outcomes, as well as any changes to the market framework that could improve the efficiency of solutions.

2.6.2 Demand forecasts

AEMO forecasts the maximum and minimum annual demand as part of its ESOO report.[78]

Maximum annual demands are strongly driven by weather, and depending on the State or Territory can occur at different times of year. This is generally dependent on whether the State is likely to experience extreme heat, such as Queensland, or extreme cold, such as Victoria and Tasmania.[79]

Minimum system load forecasts are increasingly reflecting the high rate of VRE penetration in the NEM, with zero minimum system load forecast to occur within the NEM before 2026[80].

Maximum operational demand forecasts

Figure 2.9 shows the maximum operational demand forecast based on the 2020 ESOO Central scenario. The forecast highlights that there is not expected to be a dramatic increase in maximum demand across any of the regions of the NEM.

Although this is the case, there is still expected to be increases of approximately 2 GW from 2021 to 2040 in New South Wales, Queensland and Victoria, highlighting the need for additional investment in generation capacity to be made[81].

Given the time-scale involved, the Panel notes that increases in maximum demand on their own are not expected to lead to significant issues with power system security and reliability over the forecast horizon[82].

77 AEMO is currently addressing system strength shortfalls in Queensland, South Australia and Victoria, with the potential for shortfalls at several nodes in Tasmania. AEMO has declared an inertia shortfall in South Australia and a potential shortfall in Tasmania. https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/Operability/2020/2020-System-Strength-and-Inertia-Report

78 AEMO, Electricity Statement of Opportunities 2020, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

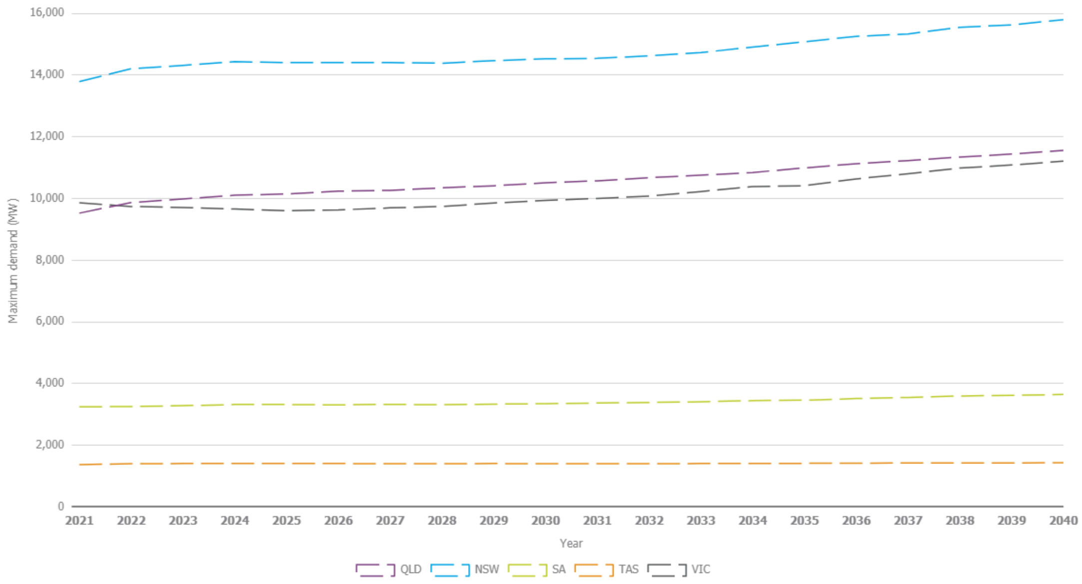
79 AEMO, Forecast accuracy report 2020, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/accuracy-report/forecast-accuracy-report-2020.pdf?la=en

80 AEMO, Forecast accuracy report 2020, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/accuracy-report/forecast-accuracy-report-2020.pdf?la=en

81 AEMO, Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

82 AEMO, Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

Figure 2.9: Maximum operational demand forecast - ESOO Central scenario, Summer



Source: Reliability Panel analysis of AEMO ESOO data.
Note: The data for this chart is available in the AMPR data portal.

Minimum operation demand forecasts

Figure 2.10 shows the minimum operational demand forecast from AEMO's 2020 ESOO report[83].

This chart shows results in the shoulder period, which occurs between summer and winter, and is generally when demand for electricity is the lowest due to ambient temperatures. This chart also includes both the Central and High DER scenarios.

Minimum system load is projected to decline at differing rates across the NEM regions, with large differences between the rates depending on the rate of DER uptake. This trend is best conveyed by the difference between the Central and High DER scenarios in New South Wales and Queensland, where High DER uptake increases the rate of decline by a significant margin.

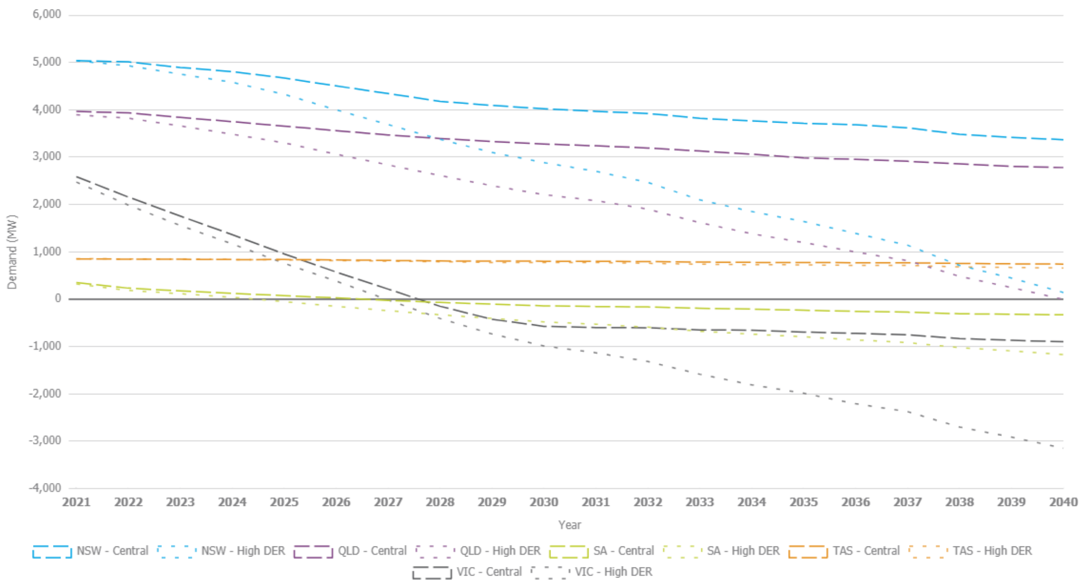
The Panel emphasises that the situation in Victoria and South Australia is a key concern for security and reliability outcomes in the NEM. As alluded to in Section 2.6.1, South Australia is approaching negative minimum system load, with AEMO forecasting this to occur in 2026 under the Central scenario, and as early as 2024 under the High DER scenario. Victorian is also approaching negative minimum system load, and continues on a sharp trajectory under the High DER scenario.

83 AEMO, Electricity Statement of Opportunities 2020, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

As noted, low demand situations are currently handled through a range of operational measures, including curtailment of VRE during critical periods to ensure that the power system remains secure. The introduction of synchronous condensers are also expected to alleviate the issues.

The Panel notes that it is important to consider the potential cost of such methods to keep the power system secure, particularly as the NEM experiences levels of negative demand into the negative thousands. The Panel considers that it is important for policy-makers and market operators to consider the full extent of reliability and security issues that are going to arise from the advent of negative minimum system load, and that all solution to these issues be kept in consideration. The Panel notes that the current ESB work will aim to address some of these issues.

Figure 2.10: Minimum operational demand forecast - ESOO Central and High DER scenario, Shoulder



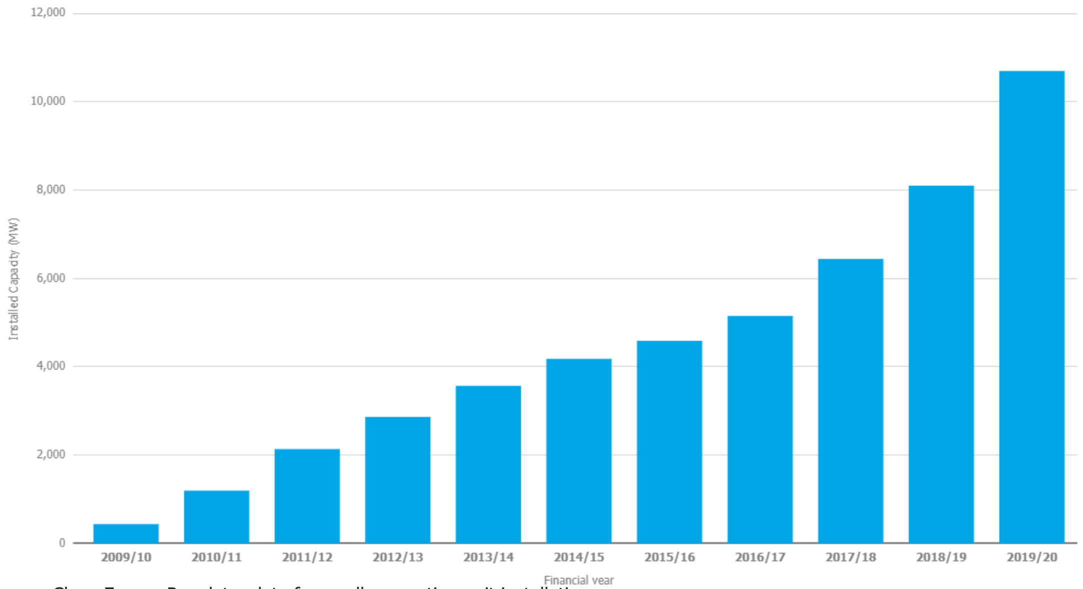
Source: Reliability Panel analysis of AEMO ESOO data.
Note: The data for this chart is available on the AMPR data portal.

2.6.3 Uptake of distributed energy resources

The upwards trend of rooftop solar PV uptake has continued over the 2019/20 financial year with COVID having a relatively minor impact on this in most cases. The continued uptake of rooftop PV systems is likely to continue to accelerate power system security and reliability concerns associated with high penetrations of DER, such as inertia and voltage issues, ramp rates and the need for emergency controls and critical load[84].

84 AEMO, 2020 system strength and inertia report, https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/Operability/2020/2020-System-Strength-and-Inertia-Report

Figure 2.11: Rooftop PV installed capacity



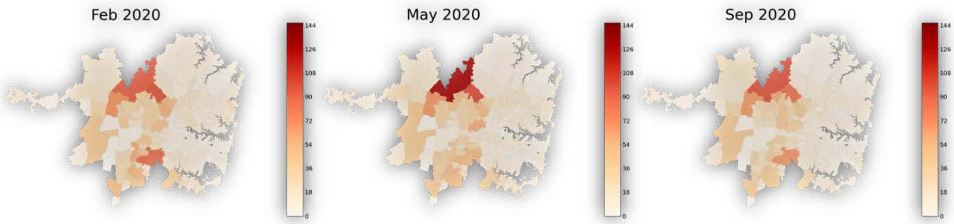
Source: Clean Energy Regulator data for small generation unit installations.
Note: The data for this chart is available in the AMPR data portal.

Figure 2.11 shows the estimated PV installed capacity in the NEM by year. There has been a strong upwards trend since 2010, and the trend has continued with approximately 2.5 GW of rooftop PV capacity estimated to have been installed in 2019-20. This is a significant increase in the space of a year, and it means that rooftop PV capacity now has approximately the same capacity as one fifth of all utility scale generation plant in the NEM.

Increases in this trend are likely to see intra-day demand issues continue to occur as the output profile of this capacity is correlated. The Panel notes that the strong upward trend of rooftop PV uptake is a key point of importance regarding the management of power system security in the short term.

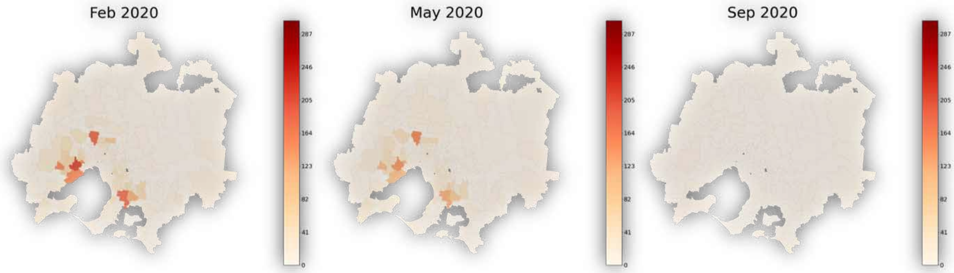
The strong trend in rooftop PV uptake continued in spite of COVID-19. As shown in Figure 2.12, Sydney did not see a decrease in rooftop PV installations over 2020 during the disruptions caused by the pandemic. Melbourne, on the other hand, saw levels of rooftop PV installations decrease significantly as the second lock down took place. This suggests that the results for 2019-20 could have been even larger if it weren't for the pandemic. The Panel notes that this is important to acknowledge when considering the future impact of rooftop PV installations on security and reliability outcomes.

Figure 2.12: Rooftop PV uptake in Sydney during COVID



Source: Clean Energy Regulator data for small generation unit installations.

Figure 2.13: Rooftop PV uptake in Melbourne during COVID



Source: Clean Energy Regulator data for small generation unit installations.

The Panel notes that rate of rooftop PV installations has continued to increase at a higher rate than has previously been forecast. The 2020 ESOO rooftop PV forecasts, released in August 2020, assume that rooftop PV installations, over the period of 2020-21 to 20203-24, grow at a rate of approximately 1000 MW per year in the central scenario, and at a rate of approximately 1500 MW per year in the step change scenario[85]. The Clean Energy Regulator (CER) however, in its Quarterly Carbon Market Report for Quarter 4 2020, noted that approximately 3000 MW of rooftop solar PV was installed in 2020 under the small-scale renewable energy scheme (SRES). The CER also expects between 3000 and 4000 MW to be installed in 2021[86]. The Panel notes that these installations are larger than those forecast in

85 AEMO, Current inputs, assumptions and scenarios, https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios

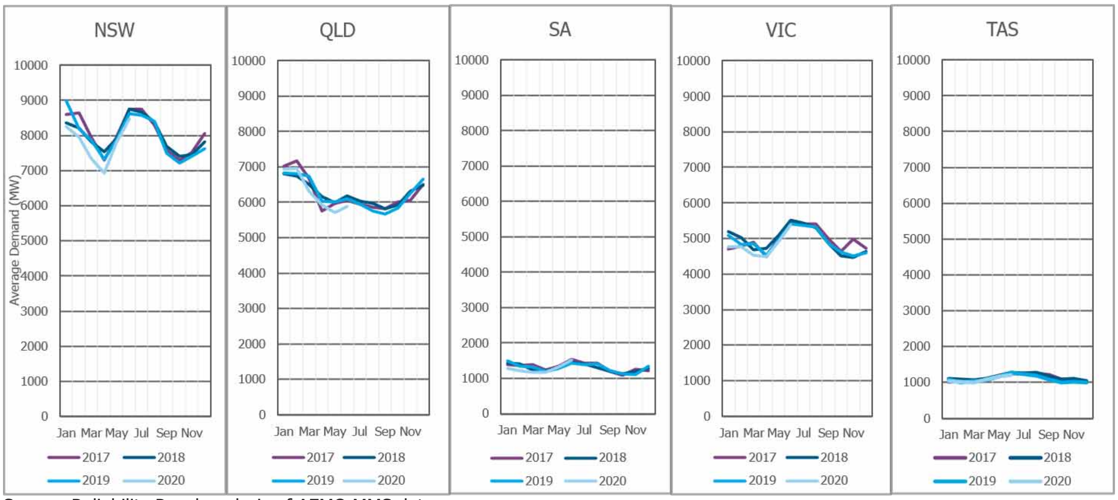
86 Clean Energy Regulator, Quarterly Carbon Market Report Quarter 4 2020, http://www.cleanenergyregulator.gov.au/DocumentAssets/Documents/Quarterly%20Carbon%20Market%20Report%20-%20Quarter%204%20December%202020.pdf

the 2020 ESOO, and that issues associated with large penetration of rooftop PV could be approaching more quickly than has been stated in the past. This particularly relates to issues discussed in Section 2.6.1.

2.6.4 Impact of COVID on demand

Overall demand for electricity was not significantly impacted by the COVID-19 pandemic. There was a slight decrease in demand across all regions except Tasmania at different points of the year, however demand trends are mostly consistent with previous years. There has been a change in the demand mix, with the decrease in commercial and industrial demand being offset by increases in residential demand.

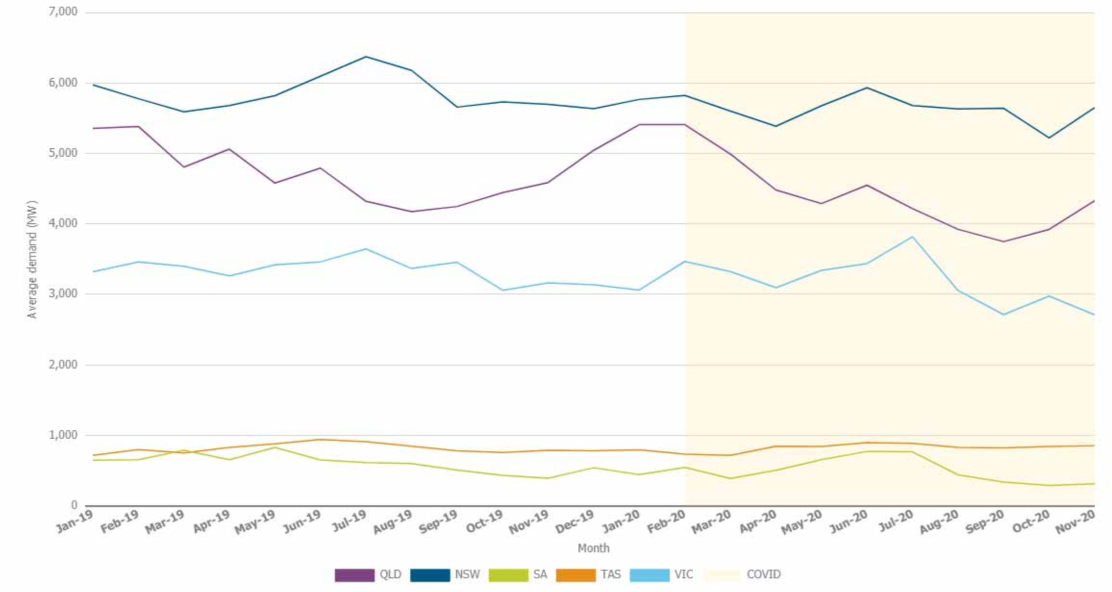
Figure 2.14: Average monthly overall demand



Source: Reliability Panel analysis of AEMO MMS data
Note: The information for this chart is available in the AMPR data portal.

Figure 2.14 showcases the trends in monthly overall demand across the NEM. As stated above, the impact of COVID on overall demand trends has been minimal over the first six months of 2020. Furthermore, the Panel notes that it is not necessarily accurate to attribute any changes in demand entirely to COVID, as other factors, including rooftop PV installations, have been contributing to this downward trend over time.

Figure 2.15: Monthly minimum total demand in 2019-20



Source: Reliability Panel analysis of AEMO MMS data.
Note: The data for this chart is available in the AMPR data portal.

Figure 2.15 shows that there was also no discernible impact of COVID-19 on minimum system load levels across the NEM. Over the course of 2020 minimum system load trends generally continued to follow seasonal patterns, and did not appear to be affected by the impact of COVID. The Panel notes that while COVID did not impact the power system greatly in terms of negative demand, this is an area where the power system is vulnerable to extreme or unlikely events such as unexpected ambient conditions in terms of security and reliability. It is important to consider how recent and future trends in demand are taken into account when understanding risks to power system security and reliability in the short term.

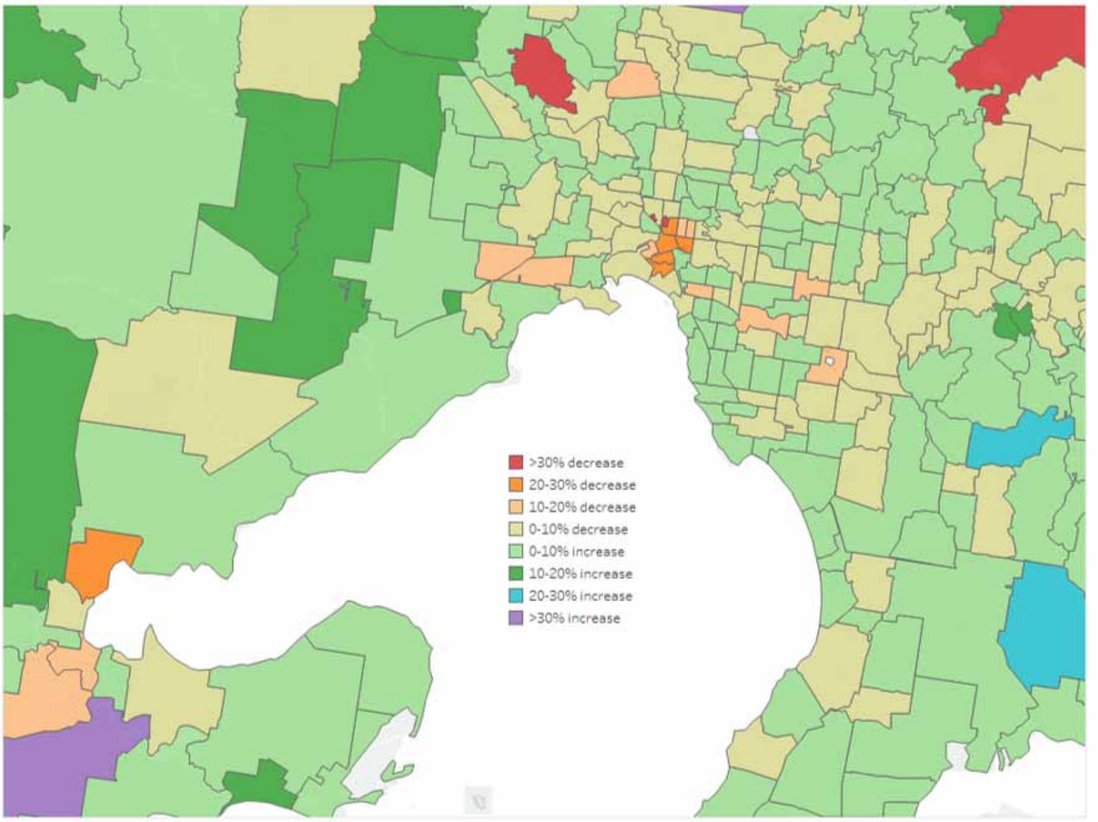
2.7 Network trends

The performance of transmission and distribution networks are important for reliability and security outcomes in the power system. 2019-20 led to changes to the operation of distribution networks given changes in people's behaviour during the COVID-19 pandemic. These changes may have implication for power system security and reliability in the future.

2.7.1 Impact of COVID-19 on network operation

COVID-19 led to people staying at home more, and in particular, working from home. Given changes in where people worked, there was a large change in the electricity consumption mix in large load centres, with residential demand increasing and commercial and industrial demand decreasing. The operation of distribution networks also changed to deal with increased consumption from people's homes. As noted in Section 2.6.4, the net impact of this change on overall demand was minimal, with total demand levels remaining largely steady, however the changing load profile and increases in residential demand away from historic norms may have implications for the power system, mainly how networks are built and managed going forward.

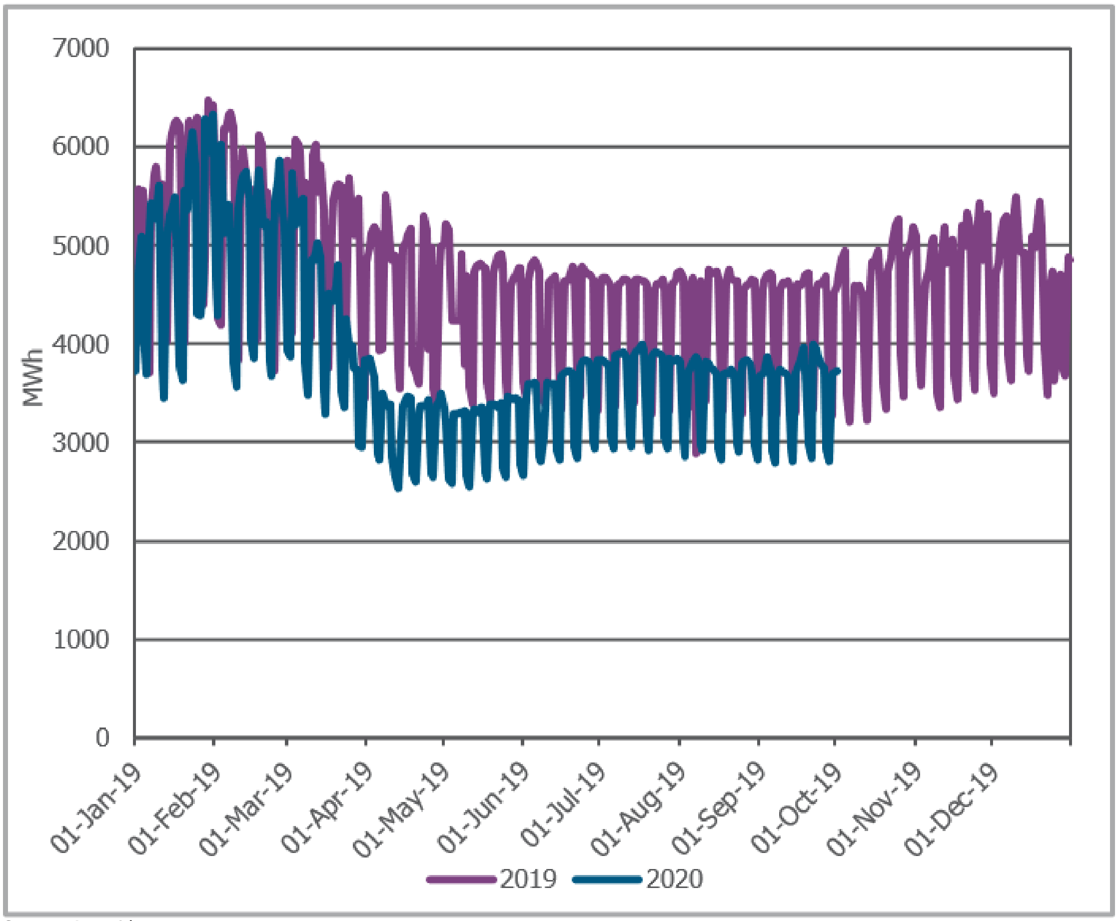
Figure 2.16: Shifting load profiles in Melbourne during COVID - net change in consumption from April - October, 2019 compared to 2020



Source: Powercor

Figure 2.16 highlights the change in network operation that was induced by COVID. In Melbourne, there was a large decrease in electricity consumption in the historically high consumption area around the CBD, offset by smaller increases across the residential suburbs. Figure 2.17 highlights that similar trends were occurring in Sydney due to the large and sudden increase in the amount of people working from home.

Figure 2.17: **Shifting load profiles in Sydney CBD during COVID**



Source: Ausgrid

This trend suggests that changes to network operation could be significant if working from home continues to take place post COVID. The Panel notes that it will be important for network operators and policy-makers to consider these changes when planning network build-out and maintenance into the future.

A failure to consider these new conditions may have adverse impacts on power system reliability with outages having a proportionally larger impact due to the increased concentrations of load in residential areas.

In addition, the Panel notes that the COVID pandemic has seen internal migration of people away from cities towards regional areas[87]. This is a relatively new trend being faced by distribution networks, and the increased load in traditionally lower demand areas may lead to changes in network operation and maintenance. Furthermore, the increased installation of

87 ABS, Regional internal migration estimates, provisional, https://www.abs.gov.au/statistics/people/population/regional-internal-migration-estimates-provisional/sep-2020

rooftop PV in regional areas may expose sections of the network that are underdeveloped relative to the influx of new users. It remains to be seen whether there is an enduring change not. The Panel will continue to monitor these effects.

2.7.2 Integration of DER

As mentioned in Section 2.6.3, there is an upwards trend of DER uptake currently occurring in the NEM. Given that this uptake is forecast to continue to increase, AEMO have noted that it is critical to understand the opportunities that are likely to emerge and the power system challenges that will need to be addressed as the power system transitions to higher penetrations of VRE generation, including DER. The Panel notes that a range diverse services and operations will be necessary to better integrate the increasing capacity of DER.[88]

2.8 Wholesale market trends

The wholesale, or spot market is the mechanism that AEMO uses to match the supply of electricity from power stations with real-time consumption by households and businesses. Electricity in the spot market is bought and sold at the spot price, which generally reflects the demand and supply balance in the power system at the time of purchase; high prices reflect scarcity of supply, and low prices reflect abundance of supply. These prices indicate to generators how much electricity the market needs at any moment in time to keep the physical power system in balance.

As has been described above, the NEM is undergoing a period of transition towards higher penetrations of VRE generation, with the expected retirement of ageing thermal generation. Flexible generation technologies with the ability to ramp up and down quickly are expected to play an increasingly important role in supporting the intermittent output of VRE generation[89]. As described in Section 2.4 demand side flexibility is also expected to play an important role in managing periods of high demand and high spot prices on the network.

Wholesale market outcomes impact the financial viability of existing market participants and the business case for new investment in the market. These trends therefore have the potential to influence security and reliability outcomes in the NEM.

This section outlines of the key trends related to:

- Wholesale spot prices
- Contract prices
- Price banding

88 AEMO, 2020 South Australian electricity report, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/sa_advisory/2020/2020-south-australian-electricity-report.pdf?la=en&hash=E323BB3271C041904CF0D0334F5511C8

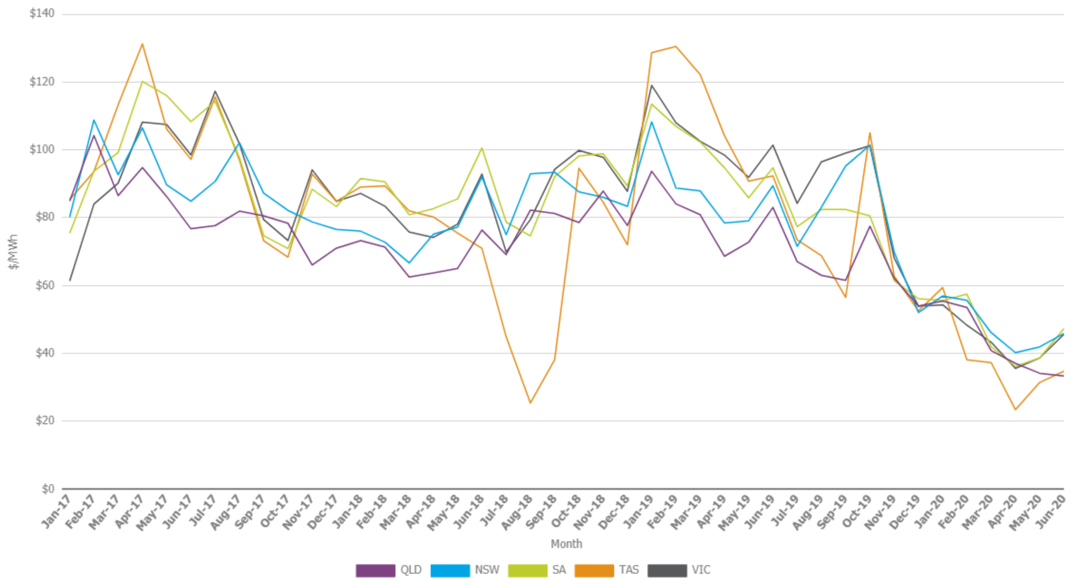
89 AEMO, Renewable integration study Appendix C, https://www.aemo.com.au/-/media/files/major-publications/ris/2020/ris-stage-1-appendix-c.pdf?la=en

2.8.1 Trends in wholesale spot prices

Wholesale prices saw a sharp decline in the 2019-20 financial year, following an extended period of relatively high prices between 2015-16 and 2018-19. Monthly average wholesale prices [90]across the NEM have declined from between \$80/MWh and \$100/MWh to between \$30/MWh and \$50/MWh between September 2019 and June 2020.

The Panel notes that this decline has been largely linked to falling gas prices during this period[91]. It is also possible that COVID has had an impact on this trend, although the Panel notes that the downward trend began in September 2019 before the disruptions caused by the pandemic began.

Figure 2.18: Monthly average wholesale prices



Source: Reliability Panel analysis of AEMO MMS data.
Note: The data for this chart is available in the AMPR data portal.

The Panel notes that although falling gas prices have been attributed to the decline in prices, the increasing penetration of VRE is likely to continue to lead to lower wholesale prices in the longer-term, particularly as more essential system services are 'unbundled' from the energy market. Given that many VRE generators can operate with very low of zero short run marginal costs, it is likely that as the generation share of VRE increases, the spot market may experience more periods of low prices.[92].

90 Prices below \$0 and above \$300 removed to show underlying trends

91 ACCC, Impact of gas prices on wholesale market outcomes, https://www.accc.gov.au/system/files/Appendix%208%20-%20HoustonKemp%20-%20Impact%20of%20gas%20powered%20generation%20on%20wholesale....pdf

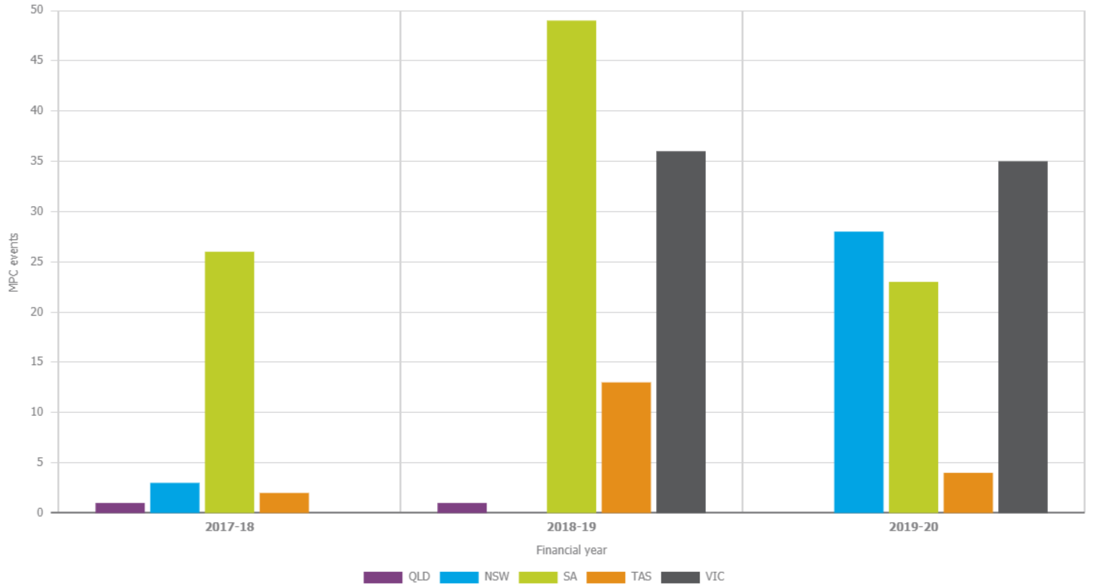
92 AER, State of the energy market 2020 Market overview, https://www.aer.gov.au/system/files/State%20of%20the%20energy%20market%202020%20-%20Market%20overview%20A3%20spread.pdf

The Panel notes that this trend will be important to monitor as it will likely have a significant impact the profitability and longevity of existing thermal generation, as well as the entry of new generation to the market[93]. An inability to decommit and recommit will leave inflexible generators exposed to increasing periods of low or negative prices, and this could lead to changes in forecast closure dates[94] or operational decisions, such as seasonal closures or mothballing. Withdrawal of large-scale thermal capacity could have a negative impact on the power system in terms of both reliability and security, described in Section 2.5.

The Panel has also observed that the volatility of wholesale price outcomes has been increasing in recent years. An indication of this is the number of market price cap (MPC) and market floor price (MFP) events that occur in the financial year.

The MPC and MFP are two of the reliability settings that are considered by the Panel in the recurring Reliability Standard and Settings Review. In 2019-20, the MPC was $14,700/MWh and the MFP was -$1,000/MWh[95]. When wholesale prices in a region reach these levels, it indicates that there is extreme scarcity (MPC) or extreme abundance (MFP) of supply.

Figure 2.19: Market price cap events



Source: Reliability Panel analysis of AEMO MMS data
Note: Based on 5-minute dispatch intervals, rather than 30-minute trading intervals.
Note: The data for this chart is available in the AMPR data portal.

93 AEMO, Integrated System Plan 2020, https://www.aemo.com.au/-/media/files/major-publications/isp/2020/final-2020-integrated-system-plan.pdf

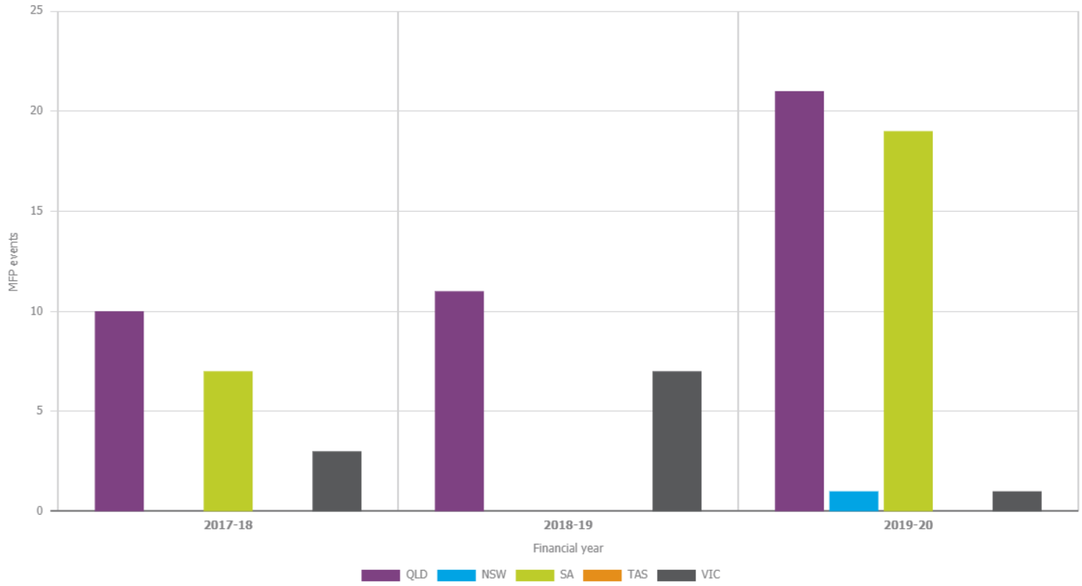
94 EnergyAustralia recently announced that the closure date of the Yallourn power station in Victoria has been moved forward from 2032 to 2028

95 AEMC, AEMC publishes the schedule of reliability settings for 2019-20, https://www.aemc.gov.au/news-centre/media-releases/aemc-publishes-schedule-reliability-settings-2019-20

Figure 2.19 shows the number of 5-minute dispatch interval MPC prices for each state. There was a decrease in MPC dispatch prices in NSW in 2019-20; from 99 total in 2018-19 to 90 total in 2019-20. There was a change in the distribution of MPC dispatch prices, with NSW experiencing significantly more than 2018-19. A contributing factor to this change was the separation of New South Wales and Victoria on 4 January 2020. This event was caused by a major bushfire event in the Snowy Mountains area, resulting in a reduction of approximately 2,267 MW of generation capacity.[96]

Victoria recorded a similar number of MPC events compared to 2018-19, and South Australia and Tasmania both had decreases in the number of MPC dispatch prices. South Australia had 23 MPC dispatch prices in 2019-20, compared to 49 in 2018-19, and Tasmania had 4 MPC dispatch prices in 2019-20, compared to 13 in 2018-19. It is important to note that as can be seen in Figure 2.19, prices in South Australia are still highly volatile, despite the decline in MPC dispatch prices, as is reflected in the increase of MFP dispatch prices.

Figure 2.20: Market floor price events



Source: Reliability Panel analysis of AEMO MMS data.
Note: Based on 5-minute dispatch intervals, rather than 30-minute trading intervals.
Note: The data for this chart is available in the AMPR data portal.

Figure 2.20 shows the number of MFP dispatch prices for each state. There were large increases in MFP events in Queensland, from 11 to 21, and South Australia, from 0 to 19, in 2019-20. Increasing penetrations of utility-scale VRE as well as DER could be playing a significant role in these trends.

96 AEMO Final report - New South Wales and Victoria Separation Event on 4 January 2020, https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/final-report-nsw-and-victoria-separation-event-4-jan-2020.pdf?la=en

A significant contributor to the increase in MFP events in South Australia was the South Australian separation event in late January and February 2020. This event, further detailed in Chapter 4.3.1, left South Australia disconnected from the rest of the NEM for a large part of February, and therefore reduced the export capacity from South Australia to Victoria to zero.

The lack of export capacity led to an abundance of supply, particularly in the middle of the day due to the correlation of solar output profiles. The Panel notes that sustained levels of low prices may have implications investment in the NEM, as well as for the retirement of the existing fleet of thermal generators.

2.8.2 Trends in contract prices

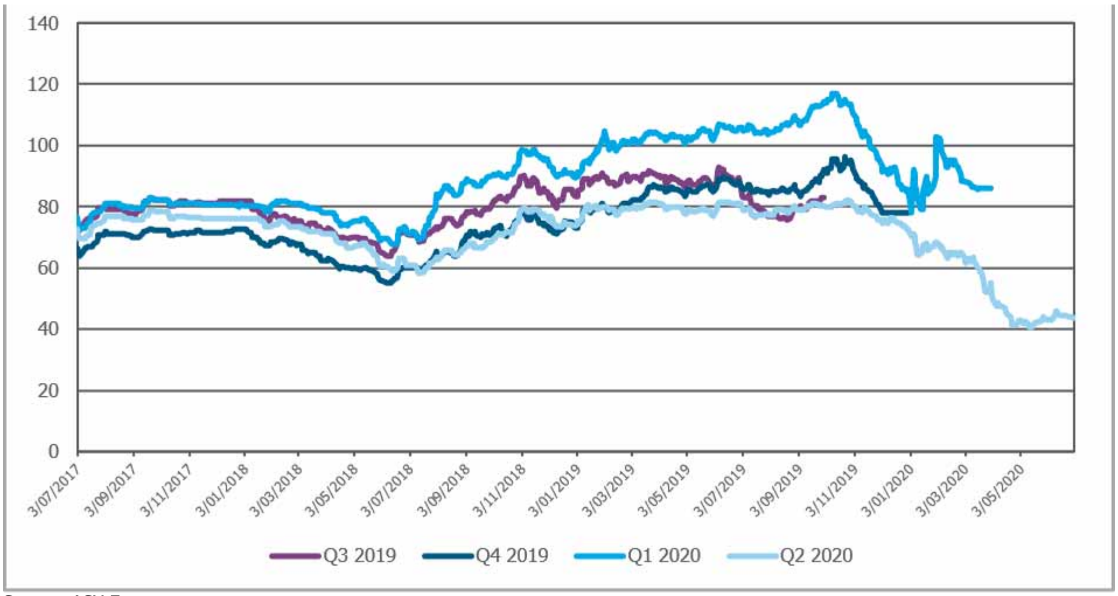
Wholesale market participants enter into various wholesale hedging contracts to manage financial risks and increase certainty over wholesale energy costs.

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 and share price. This encourages both buyers and sellers to agree to contracts that convert volatile spot revenues and costs to a more certain cash flow, or to help underwrite further investment in both generation and retail assets, which 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 simply 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 or bilaterally, and their prices for New South Wales, Queensland, South Australia and Victoria over the 2019-20 financial year are shown in Figures 2.21 to 2.24 respectively.

Figure 2.21: ASX settlement prices of 2019-20 base load futures - New South Wales

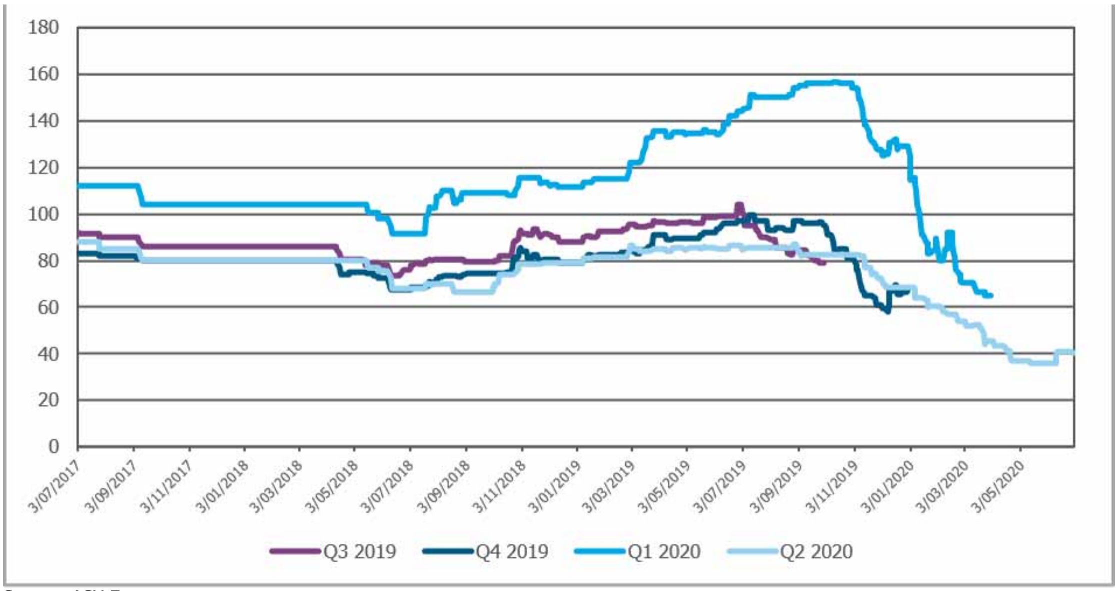


Source: ASX Energy

Figure 2.22: ASX settlement prices of 2019-20 base load futures - Queensland

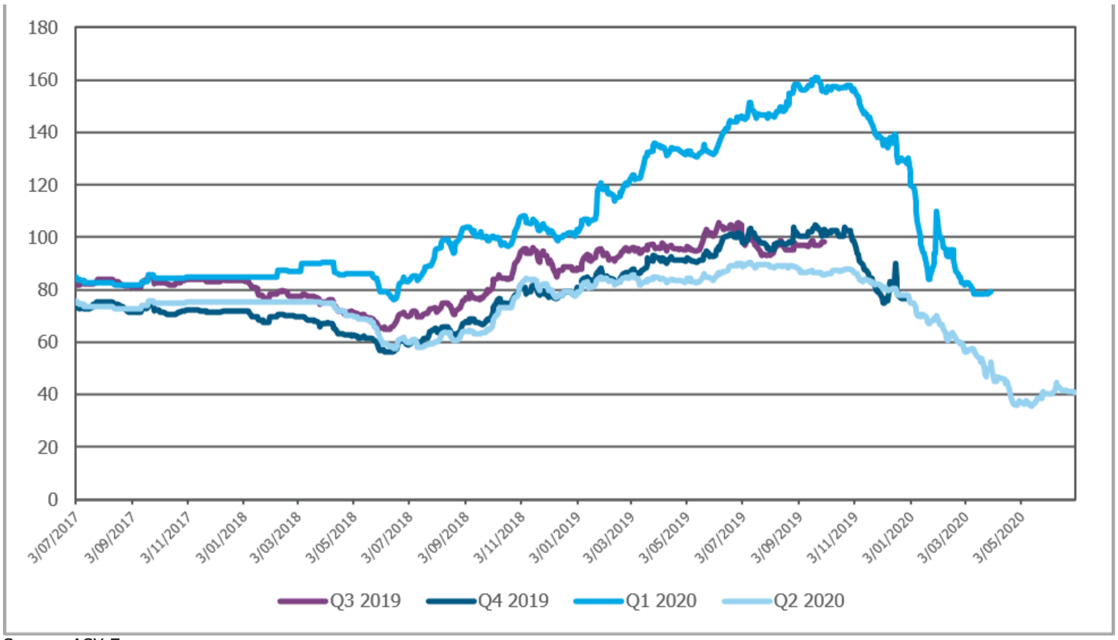
Source: ASX Energy

Figure 2.23: ASX settlement prices of 2019-20 base load futures - South Australia



Source: ASX Energy

Figure 2.24: ASX settlement prices of 2019-20 base load futures - Victoria



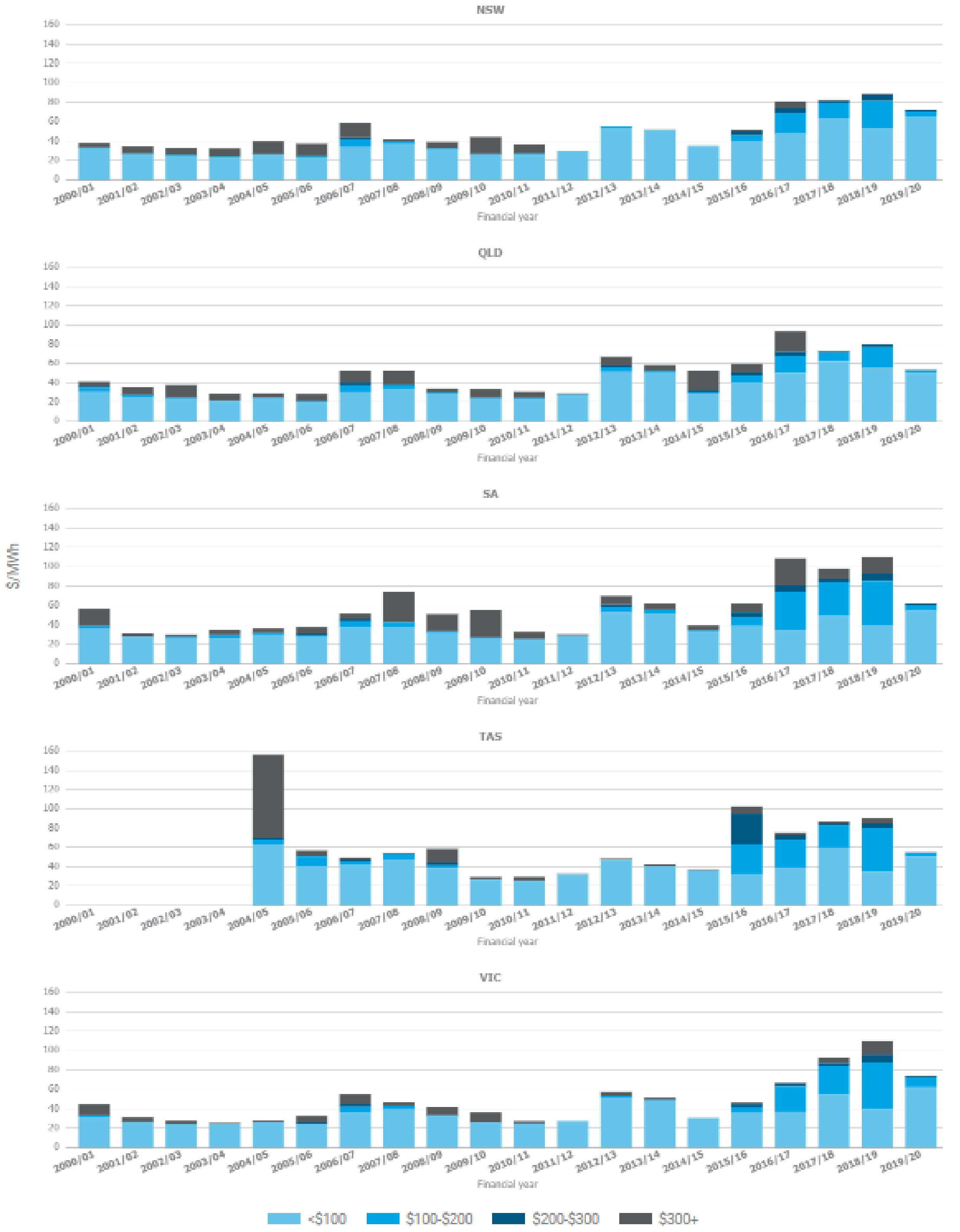
Source: ASX Energy

These figures illustrate that prices rose from July 2018 onward, particularly for quarter 1 of 2020. This could have been reflective of the expectation of a tight supply-demand balance in the summer of 2020. The impact of the South Australian separation event in late January 2020 can be seen with spikes in prices across all regions, particularly in Victoria, given the lack of exports from South Australia.

2.8.3 Trends in price banding

Wholesale prices fell across all regions in 2019-20 compared to 2018-19. As can be seen in Figure 2.25, there was an increase in the proportion of wholesale prices lower than $100/MWh in 2019-20. This is reflective of the overall decrease in wholesale prices in this period. As noted in Section 2.8.1, falling gas prices and increasing penetrations of renewable generation may have contributed to this outcome.

Figure 2.25: Price band contribution to spot prices from 2000-01 to 2019-20



Source: Reliability Panel analysis of AEMO MMS data.
Note: The data for this chart is available in the AMPR data portal.

2.9 Costs of operating the system

In order to keep the power system in a secure and reliable state, a number of additional costs are incurred, including but not limited to:

- Maintaining power system frequency
- Having services available to restart the power system if needed
- Emergency reserves for maintaining power system reliability
- Other services needed to maintain the secure operation of the power system
- Costs incurred from intervening in the market, including costs of compensating affected participants, and
- Costs of running and administering the market.

In the 2019/20 financial year:

- $263.8 million was paid through FCAS markets. ($176 million in 2018-19).
- $35.9 million was paid for the provision of system restart ancillary services. ($35.7 million in 2018-19).
- $40.6 million was paid following the exercise of the RERT. ($34.2 million in 2018-19).
- There were no costs paid for network support and control ancillary services. ($10.6 million in 2018-19).

These costs are relatively small compared to the total value transacted through the wholesale market, however they still represent costs that are recovered from market participants, and ultimately consumers.

The Panel notes that increase in key metrics, such as FCAS payments and RERT costs highlight the increasing volatility of the power system and, as noted, the increasing challenge that AEMO is facing to keep the power system in a secure and reliable state.

3 RELIABILITY

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.[97] A reliable power system requires the following:

- A well-functioning electricity spot and contract market that provides clear price signals, along with forecasts and notices from the system operator, AEMO, backed up by policy certainty from governments. This combination of features gives market participants incentives and information to supply generation and demand response when and where it is needed. In addition to this, a sufficient level of reserve or buffer is necessary to ensure that demand and supply can be kept in balance in the face of external shocks.
- A reliable transmission and distribution network.
- The system being in a secure operating state, meaning that it is able to withstand shocks to its technical equilibrium.

As outlined in Chapter 1, one of the key responsibilities of the Panel that is set out in the NEL[98] is to monitor, review and report on the reliability of the national electricity system and provide advice in relation to the reliability of the national electricity system at the request of the AEMC. This chapter considers the reliability performance of the NEM over the 2019-20 financial year in line with the Panel's obligations and the review's Terms of Reference.

This chapter sets out:

- What is reliability and how is it delivered?
- The reliability performance of the NEM in 2019-20.
- Panel insights: challenges to reliability and the work underway to address these.

The Panel plays an important role in determining the standard and settings to deliver a reliable power system in the most efficient way to minimise costs for consumers. The Panel as outlined in Chapter 1, will be undertaking the review of the reliability standard and settings this year. The Panel will consider and examine the reliability standard and each of the market settings, that include:

- The Market Price Cap
- The Cumulative Price Threshold
- The Administered Price Cap, and
- The Market Floor Price.

This examination will require the Panel to consider reliability outcomes in the NEM to decide if the current reliability standard and settings remain fit for purpose in a changing market and evolving power system. Because of this, the 2019-20 AMPR will focus on power system security, as this will not be covered to the same extent in the RSSR. The Panel will however use its assessment of reliability to inform its future work plan.

97 https://www.aemc.gov.au/energy-system/electricity/electricity-system/reliability
98 Section 38 of the NEL

3.1 What is power system reliability and how is it delivered?

Reliability issues occur when the balance of supply and demand in a region is tight and there may not be enough generation or network capacity to meet all end user demand for electricity.[99] Historically, the NEM has generally provided a high level of reliability, meaning that generation and network capacity have been sufficient to meet customer demands, even at the highest points throughout the year.

The NEM is designed specifically with reliability in mind. It is a gross pool market which does not specifically reward capacity, and instead utilises a high market price cap to incentivise operating and investment decisions during times of supply scarcity. As noted, the design of the NEM also incorporates a series of standards and settings to guide and inform participant decisions, as well as tools AEMO can use to intervene when needed to maintain reliability.

The core objective of the existing reliability framework in the NEM is to deliver efficient reliability outcomes through market mechanisms to the largest extent possible.[100] These mechanisms provide strong financial incentives for participants (generators, retailers, aggregators and customers) to make investment, retirement and operational decisions that support reliability.

In 2020, the Panel developed an Information Paper[101] that explains the concept of power system reliability and the delivery of power system reliability in detail. More in depth information about power system reliability can be found in this paper, which is available on the AEMC website.

99 AEMC, Reliability Standard Information Paper, https://www.aemc.gov.au/sites/default/files/2020-03/Reliability%20Standard%20-%20Information%20Paper.pdf

100 https://www.aemc.gov.au/sites/default/files/2020-03/Reliability%20Standard%20-%20Information%20Paper.pdf

101 Reliability Panel, Information Paper: The Reliability Standard, https://www.aemc.gov.au/sites/default/files/2020-03/Reliability%20Standard%20-%20Information%20Paper.pdf

3.2 Summary of reliability outcomes in 2019-20

BOX 2: SUMMARY OF RELIABILITY OUTCOMES IN 2019-20

Reliability outcomes

- The reliability standard and the interim reliability measure were not breached in 2019-20.
- There was no unserved energy in the NEM in 2019-20.
- AEMO forecast that the reliability standard of 0.002 per cent unserved energy (USE) will be breached in 2029-30 in New South Wales. AEMO also forecast that the interim reliability measure of 0.0006 per cent USE will be breached in 2023-24.
- There were no reliability events (actual LOR3 conditions) where supply was interrupted due to a shortfall of available capacity and reserves.
- AEMO issued 17 actual lack of reserves (LOR) notices, and the number of LOR2 conditions increased significantly compared to historical trends. There was a relatively high concentration of forecast LOR events in the shoulder periods.
- The Reliability and Emergency Reserve Trader (RERT) was activated on four occasions in 2019-20, and RERT costs were $40.6 million.
- AEMO issued six directions to market participants for reliability purposes.
- The Cumulative Price Threshold (CPT) was not breached for energy, and the Administered Price Cap (APC) was not put in place. The CPT was breached for FCAS on 1 February in South Australia, resulting in the application of the APC.
- Forecasting of demand and intermittent generation, which are a key component of the reliability framework, were as accurate as last year in comparable measurements.
- Interconnector flows generally followed trends that have been present in previous years. Transmission unsupplied minutes increased in all regions in 2019-20, particularly in Victoria. Environmental impacts may have led to this being the case. Distribution networks are also assessed in terms of SAIDI and SAIFI metrics.

Panel insights

- 2019-20 presented a greater number of forecasting and operational reliability challenges than previous years due to the increased prevalence of frequent and extreme weather events. This required significantly more directions and use of other interventions by AEMO.
- The Panel notes that due to the increasing penetration of variable generation capacity and continued low wholesale prices, periods where the supply demand balance is tight may continue to occur at a higher rate in traditionally stable periods throughout the year rather than just in the summer. e.g. during shoulder periods.
- The Panel notes challenges are being presented for forecasting, particularly due to the growth in unexpected and extreme events and rapid uptake of rooftop PV which has

changed the traditional demand profiles of consumers, and the impact this has on the operation of the power system. Considering how forecasting can be improved is likely to play an increasingly important role in the management of reliability, particularly in terms of responding to more variable generation as well as growth in extreme and unexpected events.

- The Panel will consider reliability issues in more depth as part of its 2021-22 RSS review, including considering if the Reliability Standard and reliability settings continue to be fit for purpose as the power system continues to evolve.
- The Panel notes that this process is likely to acknowledge the uncertainty surrounding the future management of reliability through the transition period.
- The Panel is working closely with the ESB to consider the interdependencies between ESB market design initiatives and the reliability standard and settings, and operation of the power system more generally. The Panel notes that the resource adequacy mechanisms and ageing thermal retirement workstream, as well as the integration of distributed energy resources and flexible demand workstream are likely to have important implications for ongoing management of reliability in the NEM. There will also be impacts from the essential system services workstream.

3.3 Reliability outcomes in 2019-20

The Panel has considered the following metrics as a way of assessing how the power system performed in terms of reliability in the 2019-20 financial year:

- **The reliability standard and unserved energy.** Whether the standard was met and the amount of customer demand in 2019-20 that was not supplied within a region due to a shortage of generation or interconnector capacity, and the forecasts for unserved energy in the future.
- **Reliability events.** The number of occasions, if any, in 2019-20 where customers experienced supply interruptions specifically because demand was higher than available supply.
- **Energy market reserve levels.** The amount of spare capacity that was available in 2019-20, giving consideration to amounts of generation, forecast demand, demand response and scheduled network service provider capability.
- **Use of AEMO interventions and powers.** Whether AEMO intervened in the market in order to maintain reliable supply using the three key intervention mechanisms related to reliability: the RERT, directions and instructions, and controlling load shedding.
- **Accuracy of forecasts and information.** How accurate forecasts and other information have been. Forecasts help inform operational and investment decisions to deliver reliability.
- **Network performance.** Outage minutes, upgrades and other performance outcomes from interconnectors, transmission networks and distribution networks.

As in previous reports of the AMPR, these indicators have been examined to assess the overall reliability of the NEM.

3.3.1 The reliability standard and unserved energy

People can experience supply outages for a variety of reasons, however this section focuses on incidents where supply interruptions occur because there is not enough supply to meet demand. Reliability outages, measured in terms of unserved energy (USE) have historically made up a small proportion of overall supply outages.

There are two key definitions of USE in the current framework.[102] The reliability standard is designed to reflect generation and interconnection adequacy to supply electricity, and signals to the market when and where more generation is needed, based on a trade-off made on behalf of customers as to the appropriate level of reliability. The reliability standard currently targets a maximum USE in a region of 0.002 per cent of the total energy demanded in that region for a given year.

The Interim Reliability Measure was introduced more recently into the regulatory framework. The interim reliability measure for generation and inter-regional transmission elements in the national electricity market is a maximum expected USE in a region of 0.0006 per cent of total energy demanded in that region for a given financial year. This was developed as part of the ESB work to improve the reliability of the electricity system through interim measures.

AEMO is required by the NER to publish various materials which provide information to market participants - and any other interested parties - on forecast unserved energy across different time periods. Through its forecasting processes, AEMO operationalises the reliability standard by modelling and projecting when the market is not going to meet the reliability standard in the lead-up to real-time.

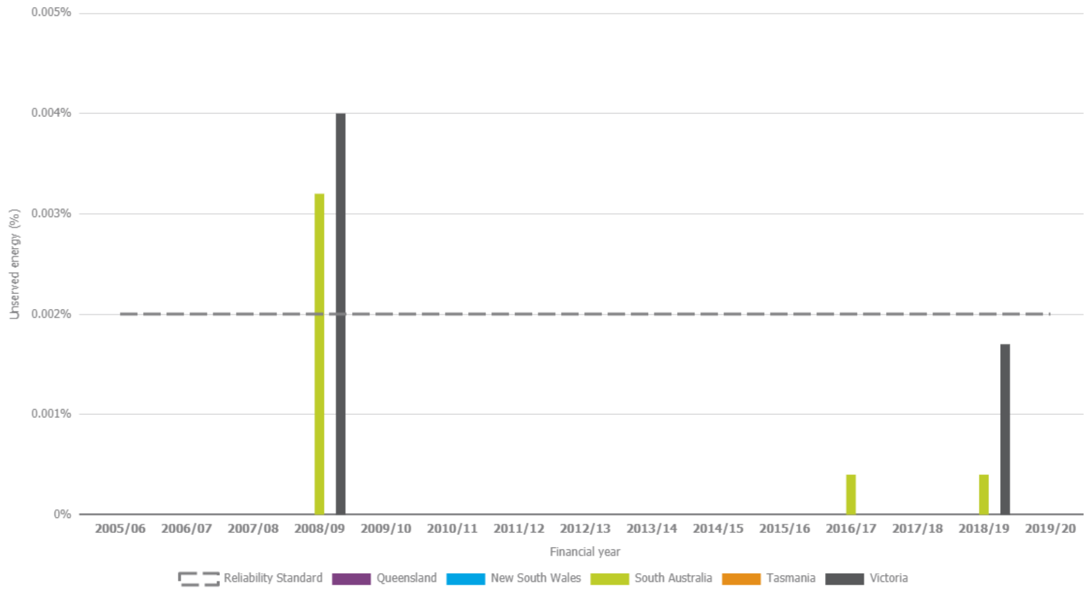
AEMO also calculates how much actual USE (i.e. how much demand went unmet due to a lack of generation, demand response or interconnection capacity) was observed in each region on an ex-post basis. To do this, AEMO uses the definition of USE to assess which types of events should be included or excluded, which then informs AEMO's calculation of USE for the purposes of the reliability standard. If activation of RERT avoids USE, it is not recorded because the purpose of RERT is to avoid a breach of the reliability standard.

The NEM has historically provided a high level of reliability, however reliability issues sometimes occur when the balance of supply and demand in a region is tight. Reliability issues have mostly arisen only on very hot days, as hot weather can affect both consumer usage patterns and the power system's ability to provide supply. More recently, there have been times when reliability issues have been emerging during 'shoulder' period. This is driven by the fact that maintenance on generators and transmission infrastructure is increasingly occurring in these periods, which reduces supply. In addition, given changing weather

102 AEMC, Transparency of unserved energy calculation, https://www.aemc.gov.au/rule-changes/transparency-unserved-energy-calculation

patterns and increases in variable renewables, supply and demand during shoulder periods are less predictable than in the past[103]. Figure 3.1 illustrates the reliability of the performance of the NEM by comparing USE in each region in the NEM over the past decade to the reliability standard.

Figure 3.1: Unserved energy in the NEM



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

There was no USE in the NEM in 2019-20, and therefore the reliability standard, as well as the interim reliability measure were not breached. This occurred despite multiple events when the supply/demand balance in the NEM was tight.[104] In addition to this, the South Australian separation event was managed with no USE.

Forecast unserved energy

As mentioned above, one of the requirements of a reliable power system is the provision of forecasts and notices from the system operator to notify the market of the need for future investment. One way in which AEMO provides this information is through the annual Electricity Statement of Opportunities (ESOO) report.[105] The ESOO includes projections of future USE (both in terms of the reliability standard and interim reliability measure), and these projections are provided to the market with the intention of eliciting a response from market participants to address any projected shortfall.

103 Reliability Panel, Information paper: The reliability standard, current considerations, https://www.aemc.gov.au/sites/default/files/2020-03/Reliability%20Standard%20-%20Information%20Paper.pdf

104 There were 8 lack of reserves 2 conditions in 2019/20. RERT was activated on 4 occasions.

105 https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-reliability/nem-electricity-statement-of-opportunities-esoo#:~:text=The%20Electricity%20Statement%20of%20Opportunities,a%2010%2Dyear%20outlook%20period.

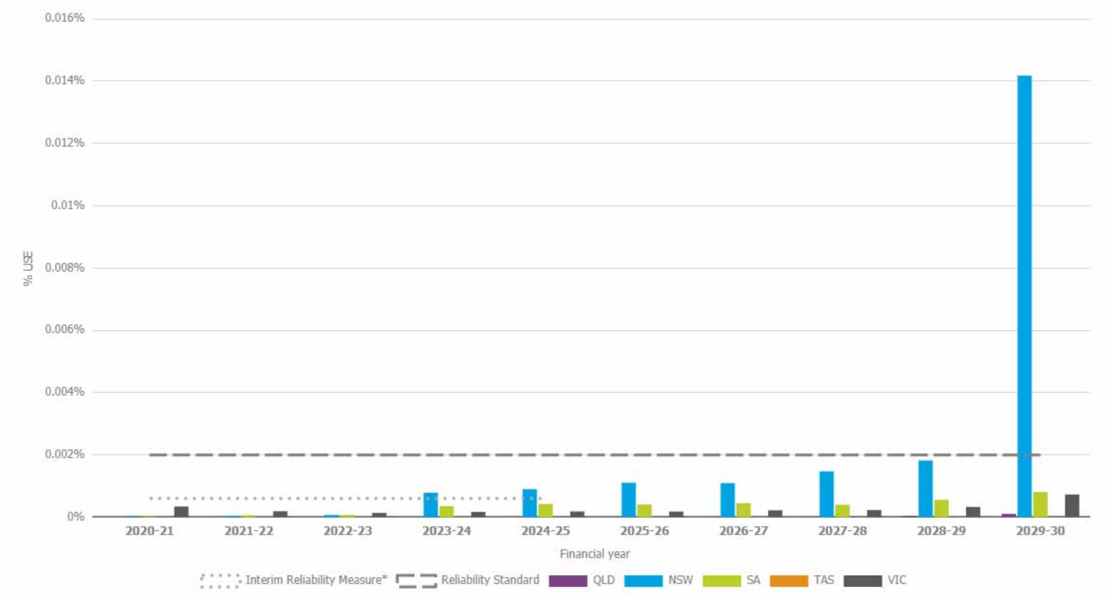
AEMO published the 2020 ESOO in August 2020. As required under clause 3.13.3A of the NER, the ESOO includes projections of aggregate demand and energy requirements for each region, generating capabilities of existing and committed units, planned plant retirements and committed network development.

The 2020 ESOO identified key insights for the future reliability performance of the NEM, including:

- Forecast USE in New South Wales is expected to breach the interim reliability measure of 0.0006 per cent USE in 2023-24, due to the closure of the Liddell power station.
- Forecast USE in New South Wales is expected to breach the reliability standard of 0.002 per cent USE in 2029-30, primarily due to the expected retirement of Vales Point power station.
- In 2029-30, AEMO has forecast that there is an indicative reliability gap of 1480 MW in New South Wales.

These outcomes are illustrated in figure 3.2.

Figure 3.2: Forecast unserved energy



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

AEMO notes in its ESOO that investment to address forecast USE is possible with sufficient lead time, provided a conducive investment landscape exists.[106] Given that approximately five times as much capacity is forecast to be withdrawn in the period of 2030-2040 compared to

106 AEMO, Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

2029-30, the Panel believes that it is important to provide a conducive environment to encourage efficient investment to replace this capacity[107]. This could lead to improved reliability outcomes and reduce the level of intervention that is necessary to maintain power system reliability.

AEMO also notes in the ESOO that expected USE risks remain in all years in Victoria, New South Wales and South Australia if there were multiple long-duration generation or transmission outages coinciding with high demand.[108] As has been stated, extreme weather events such as damaging bushfires and storms can have an impact on operational capabilities of both generation and transmission infrastructure. The Panel therefore notes that the increasing frequency of these events[109] may need to be carefully considered immediately, and as the power system develops, to ensure an adequate level of resilience is maintained.

In the ESOO AEMO also explores the potential benefits arising from the completion of actionable ISP projects in the 2020 ISP are delivered in a timely manner. The ISP highlights four major actionable ISP projects that are due to be completed by 2026:

- VNI Minor, a minor upgrade to the existing Victoria - New South Wales interconnector.
- Project EnergyConnect, a new 330 kV double-circuit interconnector between South Australia and New South Wales.
- HumeLink, a 500 kV transmission upgrade to reinforce the New South Wales southern shared network and increase transfer capacity between the Snowy Mountains hydroelectric scheme and the region's demand centres.
- Central-West Orana REZ transmission link, involving network augmentations to support the development of the Central-West Orana REZ as defined in the New South Wales Electricity Strategy.

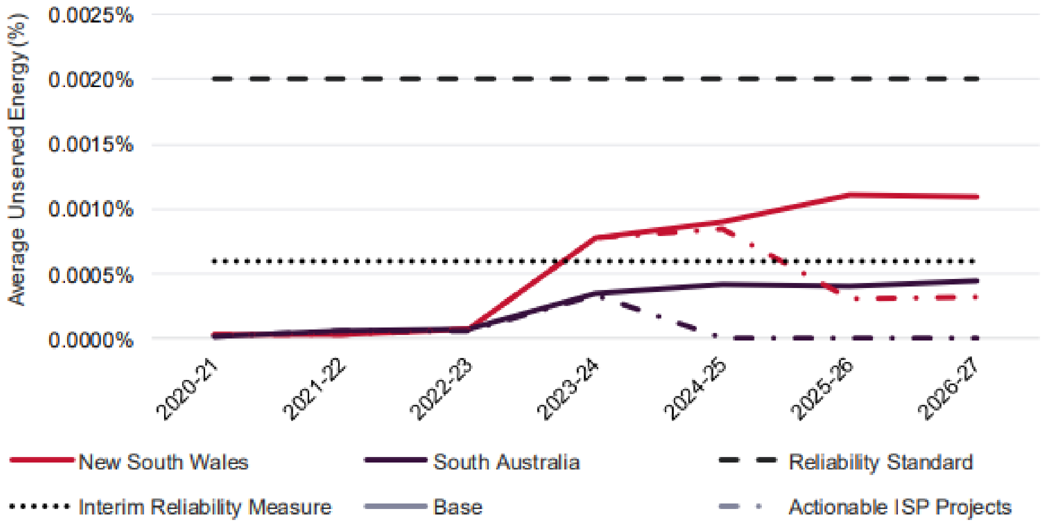
The impact of these augmentations have been included in a sensitivity that considers the impact on reliability of the transmission augmentations over the reliability forecast period, and up to 2026-27.

107 See figure 2.4

108 AEMO, Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

109 Bureau of Meteorology, State of the Climate 2020, http://www.bom.gov.au/state-of-the-climate/documents/State-of-the-Climate-2020.pdf

Figure 3.3: Reliability impact of actionable ISP projects



Source: AEMO, 2020 ESOO, page 65

3.3.2 Reliability events

A reliability event for the purposes of this report, is one where there was insufficient generation, demand response or interconnector capacity to meet consumer demand[110]. These conditions in the system are also referred to as a lack of reserves 3 (LOR3) situation, meaning that the available electricity supply is equal to or less than the operational demand.[111]

In the 2019-20 financial year, there were no reliability events, or LOR3 conditions in the NEM. There have been only 4 events in the past decade in which a reliability event or LOR3 condition has been declared: in South Australia in 2016-17 and in Victoria in 2018-19.[112]

3.3.3 Market reserve levels

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. In simple terms, market reserves can be thought of as the "buffer" that is made available by the market as part of the usual operation of the power system and expectations of future price outcomes in the energy market.

A market reserve level indicates the amount available resources in the market to meet demand. Reserves help cater for unplanned power system events, such as unplanned

110 Reliability Panel, Annual Market Performance Review 2019, https://www.aemc.gov.au/sites/default/files/2020-04/2019%20AMPR%20final%20report%20-%20republished%20with%20minor%20amendments%20in%20April%202020.PDF

111 AEMO, LOR Fact Sheet, https://aemo.com.au/-/media/files/learn/fact-sheets/lor-fact-sheet.pdf?la=en

112 AEMO, Market Notices, https://aemo.com.au/en/market-notices?marketNoticeQuery=&marketNoticeFacets=

transmission outages, sudden loss of a generator or a sudden increase in net demand (which can be caused, for example, by a reduction in VRE output).

AEMO uses its medium-term projected assessment of system adequacy (MT-PASA) reports to provide regular assessments of any projected shortage of market reserves that may result in a failure to meet the reliability standard. This enables market participants to make decisions about supply, demand and the timing of planned outages of transmission networks generator assets for periods up to three years in advance as a result of the extension of MT-PASA[113].

In the short-term (from real time to seven days ahead of real time), AEMO conducts its short-term PASA (ST-PASA) process which includes forecasts of the level of reserves to inform market participants of a potential supply shortage. This can encourage a response from market participants and transmission network service providers (TNSPs) to respond by providing more capacity into the market or a shift of planned outages respectively. For example, generators may offer in more supply, or consumers may reduce their demand. Both responses have the effect of improving market reserve margins, and helping to maintain power system reliability.

In real time when AEMO has certainty regarding demand and supply conditions, AEMO may declare that there is an actual LOR condition in effect. These actual LOR notices signal to the market that there is either a present or potential future shortage of reserves.

There are three levels of lack of reserve notices that AEMO can issue depending on market conditions.[114] These are:

- Lack of reserves 1 (LOR1). This condition exists when reserve levels are lower than the two largest supply resources in a state, or region. LOR1 signals a reduction in pre-determined electricity reserve levels, encouraging generators to offer more supply, or large industrial or commercial consumers to reduce their demand. At this stage, there is no impact to power system security or reliability, and AEMO continues to monitor reserve levels to maintain adequate supply.
- Lack of reserves 2 (LOR2). This condition signals a tightening of electricity supply reserves. This condition exists when reserve levels are lower than the single largest supply resource in a state, or region. At this level, there is no impact to the power system, but supply could be disrupted if a credible contingency event occurred. Once a forecast LOR2 is declared, AEMO has the power to direct generators and activate the RERT mechanism to improve the supply-demand balance.
- Lack or reserves 3 (LOR3). This condition signals a deficit in the supply-demand balance. This condition exists when the available electricity supply is equal to or less than operational demand. This means there are no reserve supplies available. Controlled load shedding may be required as a last resort to protect system security and prevent long

113 AEMC, Improving transparency and extending duration of MT PASA, https://www.aemc.gov.au/rule-changes/improving-transparency-and-extending-duration-mt-pasa#:~:text=The%20key%20differences%20between%20the,from%20two%20to%20three%20years

114 AEMO, Fact sheet: Explaining electricity reserve levels, https://aemo.com.au/en/learn/energy-explained/energy-101/electricity-reserves-explained

term damage to power system infrastructure. An actual LOR3 condition would represent load shedding.

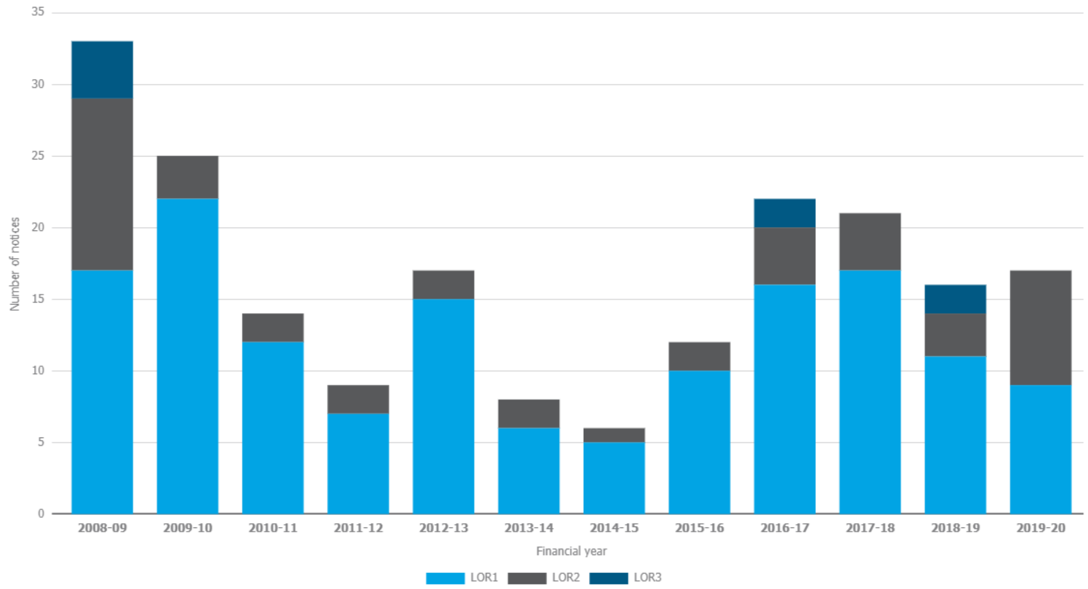
Under the existing LOR framework, AEMO is required to provide analysis on how the LOR framework is operating during the relevant reporting periods.[115] The reports are published within one month following each calendar quarter, and must specify:

- AEMO's observations of any trends in when and why LOR conditions are being declared under the reserve level declaration guidelines.
- A summary of the leading factors or causes of any LOR conditions declared.

Total actual LOR notices

Figure 3.4 shows the number of actual LOR notices that were issued in the NEM each year since 2008-09. As noted, actual LOR notices indicate a situation where AEMO has declared that there is either a present or potential future shortage of market reserves.

Figure 3.4: Actual LOR notices 2008-09 to 2019-20



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

There were 17 actual lack of reserves notices issued in 2019-20. This is an increase of 1 from 2018-19. The Panel notes that there was an increase in the number of actual LOR2 conditions in the NEM during the reporting period compared to historical trends. The Panel notes that this trend will be important to monitor as the retirement of large thermal generation plant approaches. The distribution of actual LOR conditions by state is shown in Table 3.1.

115 Clause 4.8.4B of the NER

Table 3.1: Actual LOR by state

STATE	LOR1	LOR2	LOR3
New South Wales	5	4	0
Queensland	1	0	0
Victoria	1	4	0
South Australia	1	1	0
Tasmania	0	0	0

Source: AEMO

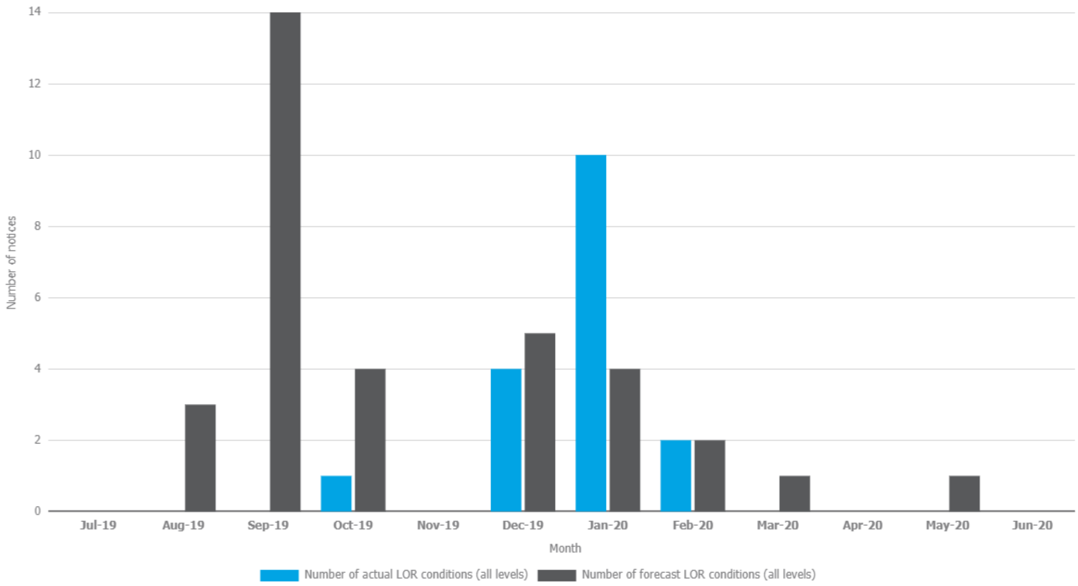
The Panel notes that New South Wales and Victorian are regions that are expected to experience significant retirement of large thermal plant over the next decade, with Liddell, Vales Point, and Yallourn amongst the generators that are believed to be closest to retirement.[116] Given that these regions are already experiencing the highest amount of periods with tight supply-demand balances according to the distribution of LOR conditions, the Panel believes that it will be crucial to ensure that the exit of large-scale thermal generation plant is well managed to avoid further reliability issues.

Reserve levels during shoulder periods

Generally, reliability issues are associated with periods of peak demand in either the summer or winter periods, but the prevalence of generator and transmission outages, including short notice maintenance outages, in other periods leads to LORs being forecast. The Panel notes that as demand in the shoulder periods becomes increasingly variable, there is an increasing risk of reliability issues in these periods. Figure 3.5 shows the actual and forecast LOR conditions per month across the NEM.

116 On 10/03/2021, 2032 announced that the closing date of Yallourn would be moved forward from 2032 to 2028.

Figure 3.5: Actual and forecast LOR notices per month, 2019-20



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

There were a large number of forecast LOR conditions in the period of August to October. Recall that AEMO will declare a forecast LOR condition when reserve levels are less than the size of the two largest (LOR1) or single largest (LOR2) generator in a particular region. Therefore, the number of LOR conditions in the shoulder period indicates a tightening of supply and demand conditions at this time when historically they have not been tight.

The Panel notes that AEMO have reported that there were periods of high demand due to cooler conditions in quarter three 2019. While demand was higher, the increase in the number of LOR conditions compared to the previous quarter was predominantly due to reduced net import into the affected region and reduced generator availability. AEMO notes that the unplanned outage of the Basslink interconnector reduced flows between Victoria and Tasmania between 21 August and 29 September 2019, impacting the reserve conditions in the two regions[117].

The Panel also suggests that this trend is likely to continue if wholesale prices remain low and large scale synchronous generators are exposed to lower prices, as mentioned in Chapter 2.8.1. The increasing occurrence of planned or opportunistic seasonal outages may leave the power system in a vulnerable position to uncharacteristic conditions in shoulder periods, therefore increasing the number of potential reserve shortfall events that occur. The ESB is considering this issue in its current workstream on resource adequacy mechanisms.

117 AEMO, NEM LOR framework report quarter ending September 2019, https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/lor-framework-quarterly-reports/2019/nem-lor-framework-report-qe-30sept19.pdf?la=en

3.3.4 Use of the Reliability and Emergency Reserve Trader mechanism

The RERT mechanism is an intervention mechanism that allows AEMO to contract for additional emergency reserves such as generation or demand response that are not otherwise available in the market when a supply shortfall is forecast. RERT reserves are contracted in addition to the buffer that is already made available by the market as part of the usual operation of the power system. These emergency reserves are used as a safety net to avoid or reduce the need for involuntary load shedding when the market hasn't provided for sufficient reserves.[118]

RERT is activated when there is insufficient market reserve to keep the power system in a reliable operating state, or, where practicable, to maintain power system security[119]. In 2019-20, the RERT was activated on four occasions when there were insufficient reserves. These conditions generally arose due to the impact that extreme weather had on the operation of the power system. This is reflective of a major trend that occurred in 2019-20. This is further discussed below. The cost of RERT increased to $40.57 million in 2019/20 from $34.5 million in 2018/19.

Procurement of RERT reserves

On 25 July 2019, the Panel published the updated RERT guidelines for the reporting period.[120] In issuing these guidelines, the Panel noted that at the request of AEMO, the AEMC made a number of changes to the method for procuring RERT reserves in the NEM in the Enhancement to the RERT rule change, including linking the RERT procurement trigger and volume to the reliability standard and increasing the procurement lead time from nine to 12 months.[121] The Panel notes that the Interim Reliability Measure was introduced in November 2020, leading to further changes to the procurement of RERT, however these changes took place outside the reporting period for this report, and therefore may be included in the next AMPR.[122]

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

- Long-notice RERT: At least ten weeks' (up to 12 months) 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.

118 AEMO, Reliability and Emergency Reserve Trader, https://aemo.com.au/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert

119 Clause 3.20.3 (b) of the NER

120 Reliability Panel, Reliability and Emergency Reserve Trader Guidelines, https://www.aemc.gov.au/sites/default/files/2019-07/Final%20report%20-%20for%20publication.pdf

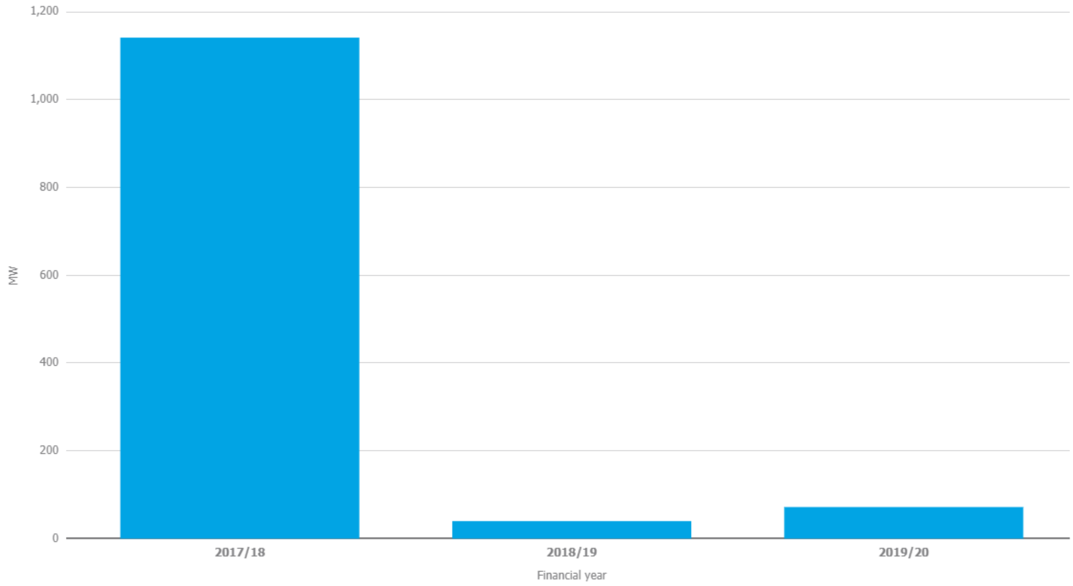
121 AEMC, Enhancement to the Reliability and Emergency Reserve Trader https://www.aemc.gov.au/rule-changes/enhancement-reliability-and-emergency-reserve-trader

122 ESB, Decision Paper Interim Reliability Measure - RRO trigger, https://energyministers.gov.au/sites/prod.energycouncil/files/publications/documents/ESB%20Decision%20Paper%20%20Interim%20Reliability%20Measure%20-%20RRO%20Trigger%20Final_0.pdf

Under the NER, AEMO may enter into reserve contracts to ensure the reliability of supply.[123] Typically, AEMO sets up a RERT panel of providers for both the medium-notice and short notice RERT and only triggers the procurement contract when it has identified a potential shortfall and after seeking offers from RERT panel members[124]. There is no panel for the long-notice RERT; rather, contracts are signed following the close of a public tender process.

Figure 3.6 illustrates the amount of long-notice RERT contracted by AEMO in 2019-20.

Figure 3.6: Long notice RERT contracted



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

AEMO procured 72 MW of long-notice RERT in 2019-20, an increase from 40 MW in 2018-19. The Panel notes that AEMO also established a panel of short- and medium-notice RERT providers for up to 1,698 MW of potential reserve capacity across the NEM, which could be contracted when a supply shortfall occurred. AEMO contracted short-notice RERT on six occasions in 2019-20.[125]

Use of RERT in 2019-20

As mentioned in Chapter 2.3, AEMO activated the RERT mechanism on four occasions in 2019-20. RERT was activated on these occasions due to reserve shortfalls brought about by extreme temperatures, high demand and environmental factors, such as bushfires and storms impacting the capacity of the transmission network.[126]

123 Clause 3.20.2(a) of the NER.

124 From 2020-21, AEMO will only set up a Panel of providers for short-notice RERT.

125 Reliability Panel, Annual Market Performance Review, Market Performance Update, https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2020

126 https://aemo.com.au/-/media/files/electricity/nem/emergency_management/rert/2020/rert-end-of-financial-year-report-201920.pdf?la=en

RERT was activated on 30 December 2019 in Victoria in response to a forecast LOR2 condition with a shortfall of 346 MW.[127] This shortfall occurred due to an unplanned network outage of the Lower Tumut to Wagga 330 kV line in New South Wales which was caused by bushfires in the area. This outage coincided with high demand in Victoria, which contributed to AEMO's decision to activate RERT. There were also two large generators offline in Victoria at the time of the outage; AGL's Loy Yang A2 and Alinta Energy's Loy Yang B1. This plant was offline due to plant failure and a tube leak respectively. RERT was activated from 1630 hrs until 2300 hrs. AEMO activated four contracts with a total capacity of 92 MW and a volume of 283 MWh. An additional 120 MW of RERT was pre-activated but not activated. The total cost of exercising RERT on 30 December 2019 was $3.72 million.

RERT was activated on 4 January 2020 in New South Wales in response to an actual LOR2 condition with an estimated shortfall of 257 MW.[128] This shortfall occurred due to a major bushfire event in the Snowy Mountains area that led to the separation of Victoria and New South Wales. As a result of severe bushfire activity in the area, AEMO constrained flow from Victoria to New South Wales to 650 MW at 1500 hrs, and further constrained the flow from Victoria to New South Wales to 450 MW at 1510 hrs. At 1510 hrs, the Murray - Lower Tumut 330 kV line tripped, resulting in the Yass -Wagga 132 kV line tripping at both ends, the Yass - Burrinjuck 132 kV line tripping at Yass and the Wagga North - Murrumburrah 132 kV line tripping at the Wagga North end. This resulted in the NEM spitting into two islands, with Victoria, South Australia, Tasmania and South West New South Wales separated from Queensland and the remainder of New South Wales.[129] RERT was activated from 1820 hrs until 2145 hrs. AEMO activated two contracts with a total capacity of 68 MW and a volume of 232 MWh. An additional 300 MW of RERT was pre-activated but not activated. The total cost of exercising RERT on 4 January 2020 was $8.36 million.

RERT was activated on 23 January 2020 in New South Wales in response to a forecast LOR2 condition, which developed into an actual LOR2 condition with an estimated shortfall of 258 MW.[130] This shortfall occurred due constrained transmission capacity in the Snowy Mountains area resulting from previous bushfire activity. There was also reduced availability of coal capacity in New South Wales, Bayswater Unit 3 (660 MW) out of service, and Mount Piper Unit 2 (700 MW) only available at 50% capacity. A further 700 MW of additional scheduled generation was expected to be unavailable at the forecast period of high demand due to temperature related limitations. RERT was activated from 1530 hrs until 1830 hrs. AEMO activated seven reserve contracts with a total capacity of 152 MW and volume of 456 MWh. An additional 302 MW was pre-activated but not activated. The total cost of exercising RERT on 23 January 2020 was $7.54 million.

127 https://www.aer.gov.au/system/files/Prices%20above%20%245000%20MWh%20-%2030%20December%202019%20%28Vic%29.pdf

128 https://aemo.com.au/-/media/files/electricity/nem/emergency_management/rert/2020/rert-end-of-financial-year-report-201920.pdf?la=en

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

130 https://aemo.com.au/-/media/files/electricity/nem/emergency_management/rert/2020/rert-quarterly-report-q1-2020.pdf?la=en

RERT was activated on 31 January in Victoria in response to a forecast LOR2 condition, which developed into an actual LOR2 condition with an estimated shortfall of 360 MW.[131] This shortfall arose due to the effect of a severe convective downdraft in Victoria, resulting in the collapse of a number of steel transmission towers carrying the Moorabool - Mortlake and Moorabool - Haunted Gully 500 kV lines, making these lines unavailable for service. This left generation at Mortlake Power Station and the Macarthur and Portland wind farms connected to the South Australian network, and South Australia disconnected from the rest of the NEM. This led to reserve levels in Victoria falling sharply due to the loss of generation and imports from South Australia. Prior to the LOR2 condition being declared in Victoria, there was also approximately 400 MW of scheduled generation unavailable in Victoria, mostly due to high temperatures. RERT was activated from 1530 hrs until 2130 hrs. AEMO activated nine reserve contracts with a total capacity of 185 MW and a volume of 697 MWh. An additional 40 MW was pre-activated but not activated. The cost of exercising RERT in Victoria on 31 January 2020 was $7.71 million. This event also had implications for system security that will be addressed in Chapter 4.

RERT was also activated on 31 January in New South Wales in response to an actual LOR2 condition with an estimated shortfall of 275 MW.[132] This shortfall arose due to approximately 2,800 MW of scheduled generation being unavailable in New South Wales due to unplanned outages or temperature related limitations. AEMO activated six contracts with a total capacity of 134 MW and a volume of 418.5 MWh. An additional 304 MW was pre-activated but not activated. The cost of exercising RERT in New South Wales on 31 January 2020 was $11.15 million. The total cost of activating RERT on 31 January 2020 was $18.86 million.

The Panel notes that over the reporting period, the use of RERT was driven largely by external environmental events, namely bushfires, storms and extreme heat. Environmental events affected the operating state of the power system by limiting generation availability, as well as limiting the capacity of transmission lines at key points on the network. Extreme heat also led to conditions of high demand during these events. The Panel notes that it is important to consider the need for the power system to become more resilient to extreme environmental events as conditions conducive to these events may have been increasing in frequency[133].

Figure 3.7 shows the amount of RERT activated per financial year. The Panel notes that the volume of reserves activated in 2019-20 is less than 2018-19. This was the case because compared to 2018-19, each activation event required a lesser response and not all available RERT was activated because the events in 2019-20 were LOR2 conditions that did not progress to LOR3.

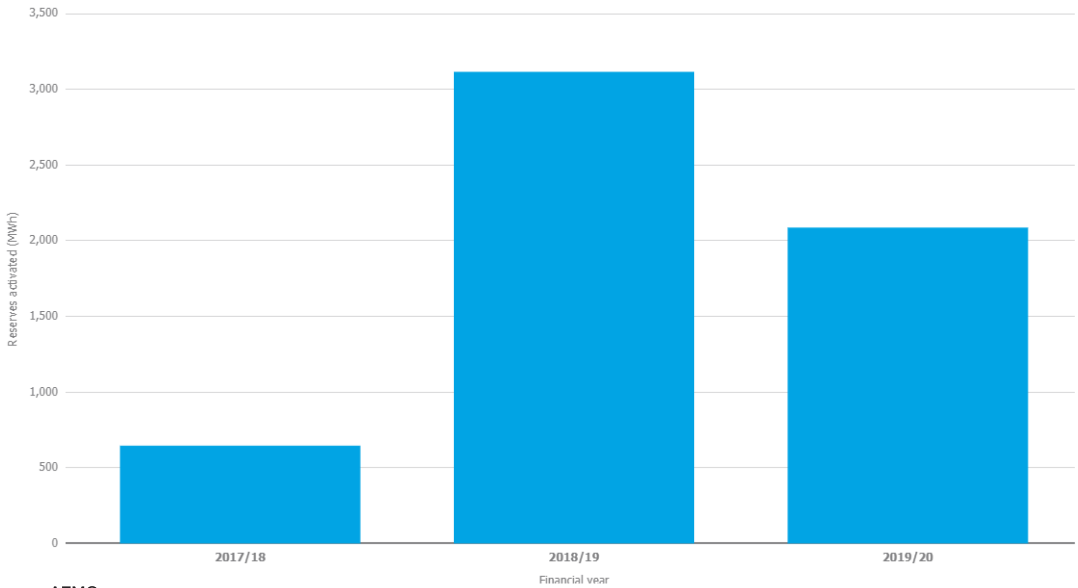
---

131 https://aemo.com.au/-/media/files/electricity/nem/emergency_management/rert/2020/rert-quarterly-report-q1-2020.pdf?la=en

132 https://aemo.com.au/-/media/files/electricity/nem/emergency_management/rert/2020/rert-end-of-financial-year-report-201920.pdf?la=en

133 Bureau of Meteorology, State of the Climate 2020, http://www.bom.gov.au/state-of-the-climate/documents/State-of-the-Climate-2020.pdf

Figure 3.7: RERT reserves activated

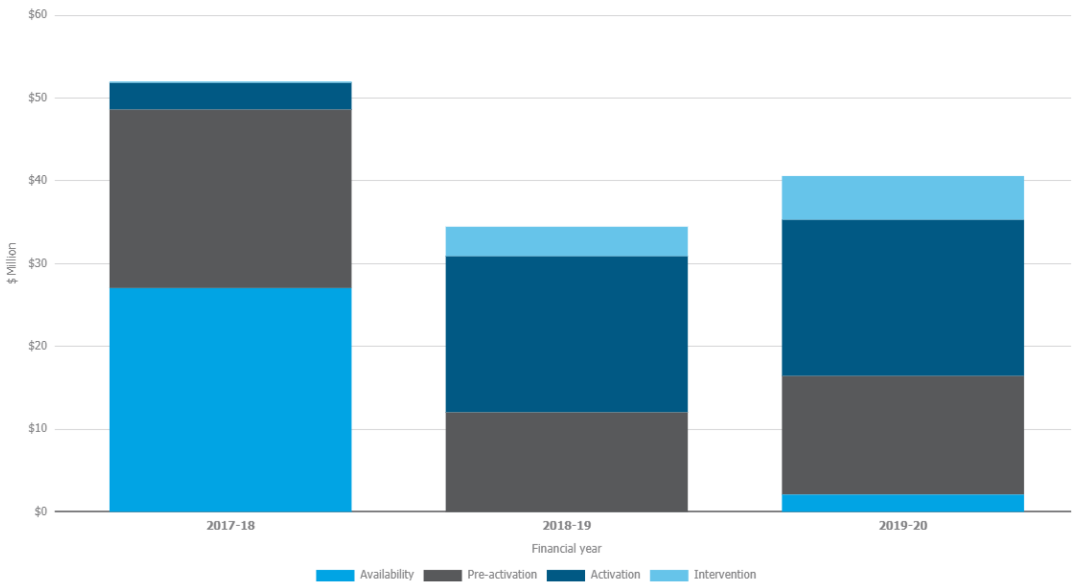


Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

Costs of RERT use

A necessary consequence of using emergency reserves is that there are associated costs paid for by consumers. The total cost of RERT for 2019-20 was $40.57 million, shown in Figure 3.8 below. This is an increase of approximately $6 million from 2018-19, despite the volume of reserves activated decreasing over the same period. The main cause of this was in 2019-20, some RERT was pre-activated, at a cost, but not activated because these contracts were type one and type two contracts and these categories of RERT can be activated post-contingent after LOR3 is declared. The unused, but pre-activated RERT accounts for the higher costs and lower activated volume in 2019-20.

Figure 3.8: Costs of RERT use



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

Costs of using the RERT can also be broken down by the cost per megawatt hour of activated RERT reserves. These figures are calculated as part of AEMO's RERT reporting process, and are outlined in Table 3.2 below.

Table 3.2: Costs of RERT use per megawatt hour

EVENT	REGION	COST OF RERT USE ($/MWH)
30 December	Victoria	$14,148.12
4 January	New South Wales	$28,703.86
23 January	New South Wales	$14,821.80
31 January	Victoria	$13,112.24
31 January	New South Wales	$22,832.52

Source: AEMO RERT reporting

3.3.5 Use of AEMO interventions

AEMO, as the system operator, can intervene in the market to help maintain and/or re-establish the reliability and security of the power system.

Intervention mechanisms enable AEMO to deal with actual or potential supply shortages or system security issues in certain limited circumstances. Intervention mechanisms are an acknowledged and important feature of the market design, however the use of such mechanisms requires careful consideration as to the flow on effects for investment signals, as well as costs to consumers.

This section outlines when and how interventions were used in 2019-20, and considers whether the intervention mechanisms available adequately supported the delivery of reliable supply. The Panel has discussed the use of RERT in Section 3.3.4, which is one method through which AEMO can intervene in the market. This section will consider the use of other methods of intervention in 2019-20, including:

- Reliability directions to generators
- Instructions and load shedding
- Administered pricing.

Reliability-related directions

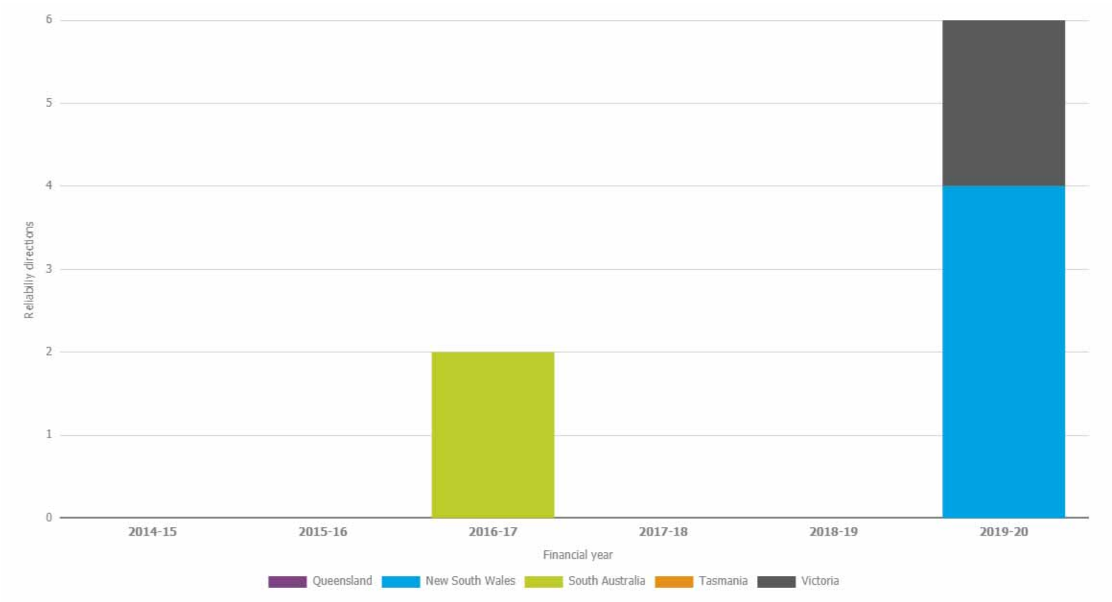
AEMO may issue a direction to registered participants where it is necessary to do so to maintain or return the power system to a secure, satisfactory or reliable operating state.[134] AEMO can issue directions to generators to increase (or decrease) their output or a scheduled load to decrease (or increase) its consumption.

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.

In 2019-20, AEMO issued six reliability directions, which is more than in recent years. This is shown in Figure 3.9.

134 Clause 4.8.9(a)(1) of the NER

Figure 3.9: Reliability directions issued by AEMO



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

All of these directions were issued on 1 February 2020. In New South Wales, Colongra units one, two, three and four were directed on due to New South Wales experiencing an actual LOR2 at the time. Mortlake units 11 and 12 were directed on in Victoria. These are treated as reliability directions as the generation was required to supply the Alcoa Portland aluminium smelter load for an extended period following the South Australian separation event.

Instructions: controlled load shedding

An instruction differs from a direction in the types of market participants that AEMO can require to take action and the nature of the action taken. Instructions often involve AEMO requiring a network service provider or large energy user to shed load.

Controlled load shedding, or involuntary disconnection of customer supply for reliability purposes may be implemented when there is a shortage of electricity supply to meet customer demand, or when demand cannot be satisfied while also keeping the power system in a secure state. Load shedding for reliability purposes is manually initiated as a last resort response to bring power flows into balance. Under manual load shedding a relatively small amount of load shedding for a short period (generally on a rotational basis) reduces the potential for more widespread and prolonged customer supply interruptions.

AEMO was not required to issue instructions for participants to shed load in 2019-20.

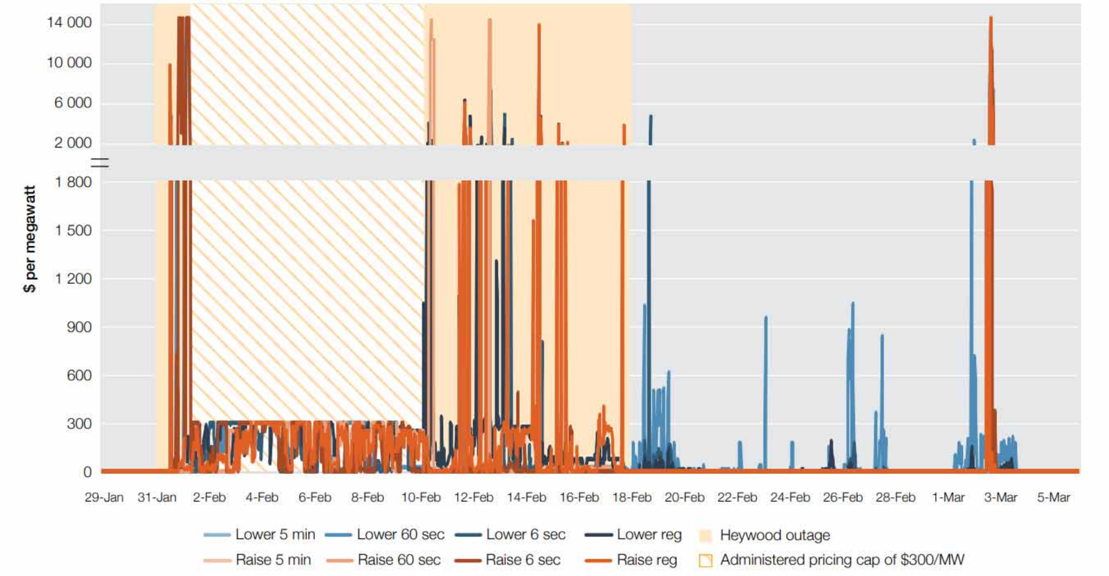
Administered pricing

The CPT is one of the reliability settings that seeks to maintain the overall integrity of the NEM by limiting market participants' exposure to sustained high prices which could threaten the financial viability of market participants. If the CPT is breached, the administered price cap (APC) caps the aggregate market price that can occur over seven consecutive days (336 trading intervals). While this is intended to protect market participants, and ultimately customers from paying excessively high prices, the cap is also set at a level so that prices over the long term can still incentivise enough new investment in generation so the reliability standard is expected to be met.

The CPT was not breached for energy during the 2019-20 financial year. Note that market price cap and market floor price events are discussed in Chapter 2.

During the South Australian separation event, FCAS prices were high for an extended period, leading to the CPT being breached on 1 February. The APC for FCAS caps local FCAS prices for all services at $300/MWh, and was in place for around 10 days.[135] This event is discussed in more detail in Chapter 4.3.1.

Figure 3.10: South Australia local FCAS prices



Source: AER, Wholesale Markets Quarterly Q1 2020

The Panel notes that the CPT, as well as the other reliability settings, will be considered during the Reliability Standard and Settings Review. The review will consider the material changes occurring in the NEM and how these may affect the setting of each of the settings, including the CPT.

3.3.6 Forecast accuracy

In this section, the Panel has considered the accuracy of forecasts, and has considered AEMO's 2019 forecast accuracy report as well as three different forecasts related to planning

135 https://www.aer.gov.au/system/files/Wholesale%20Markets%20Quarterly%20Q1%202020_0.pdf

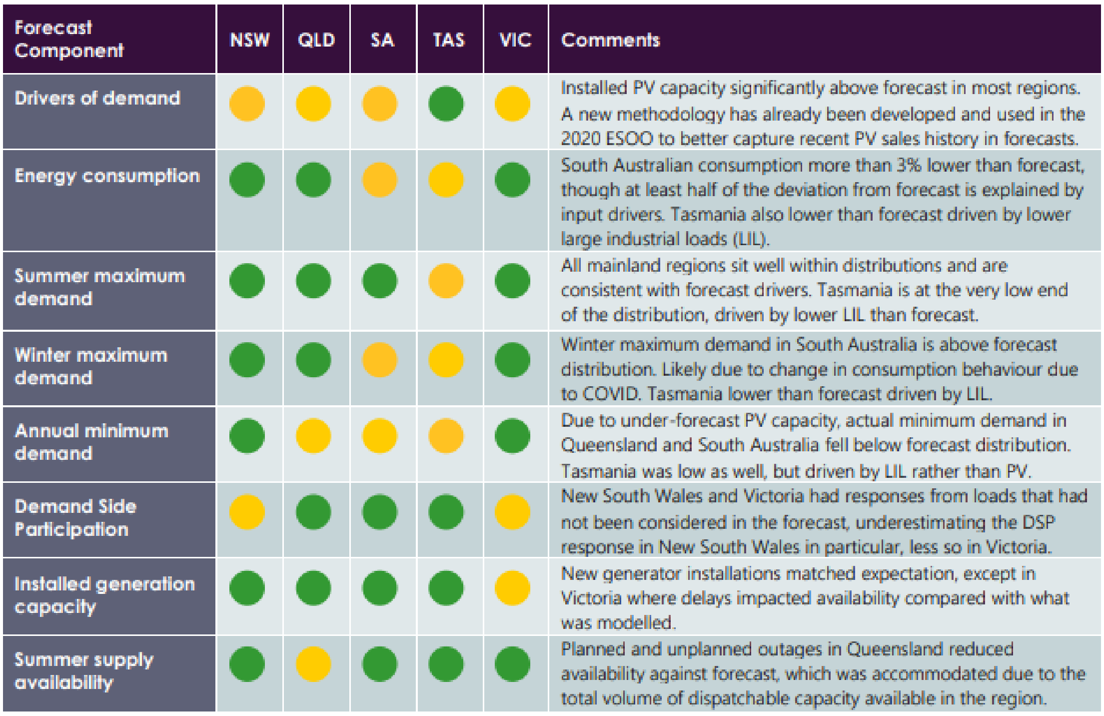
for and delivering enough supply to meet demand, i.e. the delivery of reliable supply. This includes:

- Accuracy of ST-PASA
- Accuracy of wind energy forecasting system and solar energy forecasting system across different time periods and different states.

AEMO's 2020 forecast accuracy report

Annually, AEMO publishes an assessment of forecast accuracy.[136] AEMO's report primarily assesses the accuracy of its annual ESOO which provides forecasts over a 10-year period. A summary of AEMO's assessment of its forecast accuracy for 2019-20 is shown in Figure 3.11.

Figure 3.11: AEMO forecasting accuracy summary by region 2019-20



Forecast Component	NSW	QLD	SA	TAS	VIC	Comments
Drivers of demand	● amber	● yellow	● amber	● green	● yellow	Installed PV capacity significantly above forecast in most regions. A new methodology has already been developed and used in the 2020 ESOO to better capture recent PV sales history in forecasts.
Energy consumption	● green	● green	● amber	● yellow	● green	South Australian consumption more than 3% lower than forecast, though at least half of the deviation from forecast is explained by input drivers. Tasmania also lower than forecast driven by lower large industrial loads (LIL).
Summer maximum demand	● green	● green	● green	● amber	● green	All mainland regions sit well within distributions and are consistent with forecast drivers. Tasmania is at the very low end of the distribution, driven by lower LIL than forecast.
Winter maximum demand	● green	● green	● amber	● yellow	● green	Winter maximum demand in South Australia is above forecast distribution. Likely due to change in consumption behaviour due to COVID. Tasmania lower than forecast driven by LIL.
Annual minimum demand	● green	● yellow	● yellow	● amber	● green	Due to under-forecast PV capacity, actual minimum demand in Queensland and South Australia fell below forecast distribution. Tasmania was low as well, but driven by LIL rather than PV.
Demand Side Participation	● yellow	● green	● green	● green	● yellow	New South Wales and Victoria had responses from loads that had not been considered in the forecast, underestimating the DSP response in New South Wales in particular, less so in Victoria.
Installed generation capacity	● green	● green	● green	● green	● yellow	New generator installations matched expectation, except in Victoria where delays impacted availability compared with what was modelled.
Summer supply availability	● green	● yellow	● green	● green	● green	Planned and unplanned outages in Queensland reduced availability against forecast, which was accommodated due to the total volume of dispatchable capacity available in the region.

Source: AEMO Forecasting Accuracy Reporting

AEMO has identified a comprehensive register of proposed improvement to forecasting. The improvements that AEMO has identified include:

- Improved PV forecasts: AEMO intends to work on improving the visibility of recent rooftop PV uptake.
- Improved visibility and understanding of consumption patterns and trends: AEMO plans to focus on using smart meter data to estimate between business and residential consumption.

136 AEMO, Forecasting Accuracy Reporting, https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-reliability/forecasting-accuracy-reporting

- Better visibility of forecast maximum demand within a year: AEMO will improve how it calculates and publishes more granular forecast data.
- Wind generation trace development: AEMO intends to develop and implement a new wind generation model that will produce more realistic traces in the presence of high wind temperatures or wind speeds.
- Improved modelling of inter-regional transmission elements forced outages: AEMO will use historical weather traces to develop network forced outage simulations that better reflect the compound risk associated with the potential coincidence with high demand events.

The Panel notes that AEMO's continuing assessments and future work program will improve stakeholder and market participant understanding of the changing supply and demand dynamics, a fundamental part of supporting investment, operational and policy decisions that underpin reliability.

Projected assessment of system adequacy

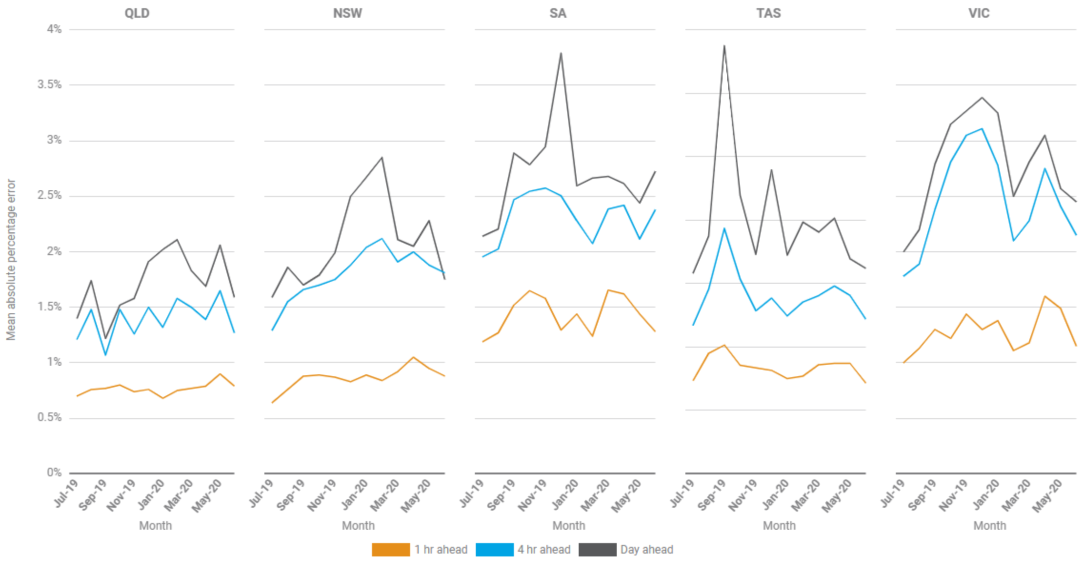
The projected assessment of system adequacy (PASA)[137] is the principal method of indicating to AEMO and market participants a forecast of the overall balance of supply and demand for electricity. PASA is conducted over short and medium-term horizons. This section considers the forecast accuracy of both.

Short-term projected assessment of system adequacy

ST-PASA provides information to market participants on the expected level of short term capacity reserve and hence the likelihood of interruptions due to a shortage of power. It can also provide a benchmark for AEMO to intervene in the market. It covers 6 trading days from end of trading day covered by most recent pre-dispatch schedule with a half hourly resolution. Figure 3.12 illustrates the performance of ST-PASA load forecasts over the reporting period.

137 AEMO, Projected Assessment of System Adequacy, https://aemo.com.au/en/energy-systems/electricity/wholesale-electricity-market-wem/data-wem/projected-assessment-of-system-adequacy-pasa

Figure 3.12: Load forecasting error one hour, four hours and 24 hours ahead



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

The Panel notes that:

- The accuracy of load forecasts appears to have been stable throughout the year.
- As was the case in 2018-19, South Australian load was typically forecast with the least accuracy at all time horizons, with Queensland and New South Wales the most accurately forecast. This is partly due to the percentage measures used, with South Australia having low average loads and high load variability.
- As expected, forecasting error decreased as the forecasting horizon approached real time.

The Panel also notes that different time horizons were used for the assessment of forecasting performance in 2019-20, therefore limiting the comparison between 2018-19 and 2019-20. In the time horizon of one hour ahead, results from 2019-20 are similar to 2018-19 with the following exceptions:

- Queensland performance was better in the period of July to October 2019 compared to the same period in 2018, but largely similar for the remainder of the year.
- South Australian performance was less accurate in the period of January to June 2020 compared to the same period in 2019.

Medium-term projected assessment of system adequacy

In addition to ST-PASA reports, AEMO also publishes MT-PASA reports. MT-PASA assesses the adequacy of expected electricity supply to meet demand across a three-year horizon through regular assessment of any projected failure to meet the reliability standard.

MT-PASA collects and analyses information to assess medium-term power system security and reliability of supply prospects enabling participants to make decisions about supply, demand and outages of transmission networks for periods up to three years in advance.

Each week, scheduled market participants (e.g. generators) must submit forecasts of their availability (total MW capacity available for dispatch) to AEMO for the period covering the next 24 months, commencing eight days after the publication of the MT-PASA report. This report is published every week as a minimum. AEMO publishes the MT-PASA every Tuesday at 16:00 AEST with outcomes of the PASA process as well as input variables. Scheduled generators or market participants are required to submit PASA availability of each scheduled generating unit, load or network service and energy constraints for each scheduled generating unit and load. Network service providers must provide planned network outage information.

Australian wind energy forecasting systems

The Australian wind energy forecasting system (AWEFS) produces wind generation forecasts for all semi-scheduled and non-scheduled wind generators in the NEM.[138]These forecasts are used for the dispatch, pre-dispatch and ST-PASA processes.

AWEFS produces forecasts from the following inputs:

- Real time SCADA measurements from the wind farms
- Numerical weather predictions from weather forecasters from around the world
- Standing data from the wind farms
- Availability information provided by the wind farms, that includes turbines under maintenance and upper MW limit of the wind farm.

Due to the variable nature of wind and solar, there is potential for material variations in energy availability from these generators which may have implications for power system reliability outcomes. At times of peak demand, even small variations within a tight timeframe can create reliability issues, especially if dispatchable generation is not available to replace this capacity.

The accuracy of forecasting is therefore a key factor in the effective integration of VRE generation into the NEM. On this basis, forecasting systems are an increasingly important tool for promoting efficiencies in NEM dispatch, pricing, system reliability and security, as renewable generation continues to make up larger share of the generation mix.

The Panel has looked at the degree of difference between wind forecasts and actual output over different timeframes. The results for 2019-20 are illustrated in Figure 3.13.

138 AEMO is required to prepare forecasts of the available capacity of semi-scheduled generators such as large scale wind and solar farms in order to schedule sufficient generation in the dispatch process (NER clause 3.7B) and to be used in the PASA processes for reserve assessment purposes (NER clause 3.7.1(c)(2)).

Figure 3.13: Accuracy of wind energy forecasts, five minutes, one hour, four hours and 24 hours ahead

Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

The accuracy of wind forecasting varies across regions, as well as across time horizons. The Panel notes that:

- Queensland has displaced Victoria as the region in which wind energy forecasting was most accurate. This is the first time that the Panel has considered wind forecasting results in Queensland.
- There was a significant improvement in forecasting accuracy in Tasmania across all time horizons in December 2019. The number of wind farms in Tasmania increased from one to three over the December to January period. With a larger generation base the percentage accuracy will be less susceptible to impacts from small perturbations in wind speed. Tasmanian wind forecasting accuracy will be less prone to site specific effects which may have been affecting forecast accuracy.
- South Australia and New South Wales were consistently the regions with the least accurate wind forecasts in 2019-20. This is a change from 2018-19, where Tasmania was the least accurate region.

Australian solar energy forecasting system

The Australian solar energy forecasting system (ASEFS) is designed to produce solar generation forecasts for large solar power stations and small-scale distributed PV systems, covering forecasting timeframes from five minutes to seven days.

ASEFS produces forecasts from any solar farms greater than or equal to 30 MW registered capacity and any solar farms that AEMO is required to model in network constraints for power system security reasons, as well as small-scale distributed PV systems.

AEMO started forecasting from large scale solar farms on 30 May 2014. It uses the following inputs to produce solar generation forecasts for large scale solar power stations:

- Real time SCADA measurements from the solar power station
- Numerical weather prediction data from multiple weather data providers
- Standing data from the solar power station as defined in the ASEFS energy conversion model
- Additional information provided by the solar power station, including inverters under maintenance and the upper limit MW on the solar farm
- Imagery from the Himawari-9 satellite

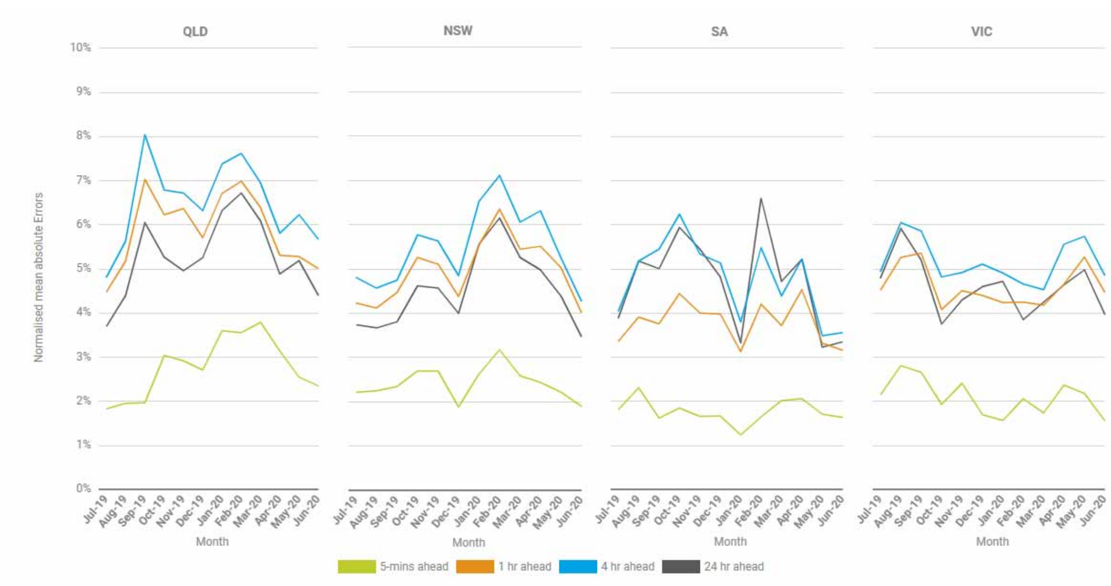
Forecasts of large-scale output are used in dispatch, pre-dispatch and ST-PASA processes.

Forecasts of small-scale distributed PV systems (less than 100 kW system capacity) commenced more recently on 30 March 2016. It uses the following inputs to produce aggregated regional solar generation forecasts for small-scale PV systems:

- Numerical weather prediction data from multiple weather data providers
- Output measurements and static data from selected household rooftop PV systems from PvOutput.org and Solar Analytics
- Aggregate kilowatt capacity by installed postcode for small-scale solar systems as recorded by the Clean Energy Regulator (CER)
- Imagery from the Himawari-8 satellite

Small scale solar forecasts are used in the pre-dispatch and ST-PASA demand forecasts. The performance of solar energy forecasting in 2019-20 is illustrated in Figure 3.14 below.

Figure 3.14: Accuracy of solar energy forecasts, five minutes, one hour, four hours and 24 hours ahead



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

Tasmania was not included in the results due to the low penetration of solar resources in the region. The Panel notes that:

- Unlike with other forecasting, there does not appear to be a significant increase in accuracy until the five-minute time horizon, with results from the 24 hours, four hours and one hour ahead horizon relatively similar. The consistency of accuracy across time horizons is a function of the difficulty in forecasting solar irradiance in any but the shortest time horizons. The movement, formation and dissipation of clouds (and dust) is largely chaotic in nature and therefore difficult for meteorologists to predict with precision. This borne out by the significantly increased accuracy on heavily overcast days and blue-sky days, where cloud variation has no impact. This inherent uncertainty in the behaviour of clouds is transferred as uncertainty into AEMOs solar energy forecasts.
- Queensland is consistently the region where forecasting accuracy is the lowest. This was not the case in 2018-19, where South Australia was the region that was the least accurate in terms of solar forecasting. These forecast performances can vary year on year due to seasonal effects, varying operating conditions and plant commissioning.
- South Australia and Victoria were generally the regions where forecasting accuracy was highest in 2019-20.

Self-forecasting performance

In 2018, a Market Participant Self-Forecasting trial was initiated as a collaboration between AEMO, the Australian Renewable Energy Agency (ARENA) and industry (forecasting service providers, existing and new wind and solar generators) to explore the benefits of self-forecasting unconstrained wind and solar generation[139]. The initial focus of the trial is to determine the relative benefits of using the participant's 5-minute ahead dispatch self-forecast in dispatch, in preference to the equivalent forecast from AWEFS or ASEFS.

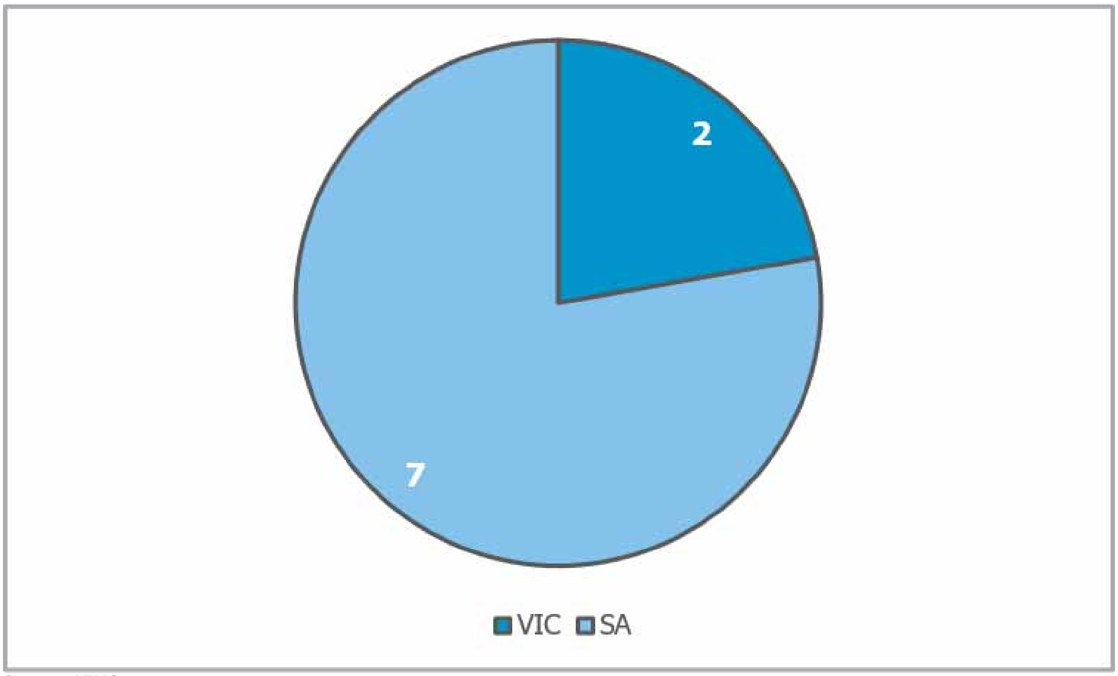
In January 2020, ARENA published a report in collaboration with AEO to summarise insights and progress from initial reports submitted by the 11 participants of the Short-Term Forecasting trial that is taking place between March 2019 and mid-2021. Insights gained from the trial so far include:

- Learning by doing had been beneficial for participants to gain a better understanding of capital costs and timelines to deliver self-forecasting projects.
- It is important for forecasting service providers to have a good working relationship and open communication with the wind farm and solar farm owner/operator and AEMO's operational forecasting team.
- AEMO's troubleshooting of the self-forecasting process and the publication of procedures has assisted participants to submit and maintain their data.
- Ensuring forecasting technology at sites is compatible with remote operation can aid in reducing the need to conduct on site system operations and maintenance.
- Wind forecasting is complex and forecasting algorithms have been revised to accommodate the complexities found in the trial.
- It is important to design and maintain an effective project risk management plan to manage project risks including delays caused by contract negotiations, project partner changes, detailed design, equipment delivery, installation, commissioning, the AEMO accreditation process and the weather.

As of 30 June 2020, there are 9 wind farms taking part in self-forecasting, as well as 19 solar farms. The distribution of these participants is shown in Figure 3.15 and Figure 3.16 below.

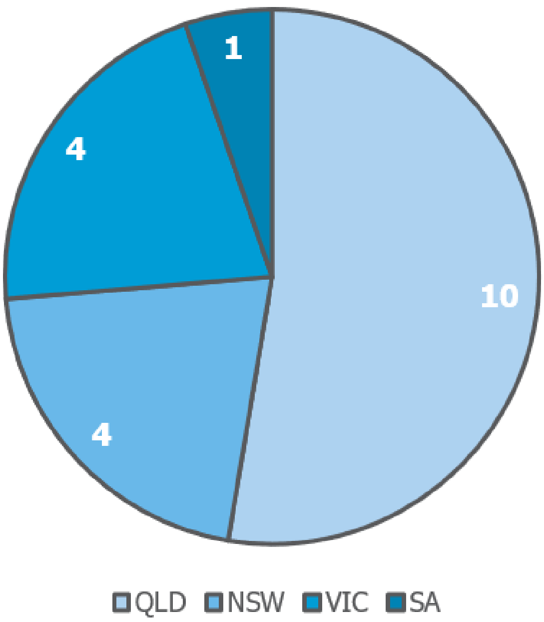
139 ARENA, Short-term forecasting trial on the NEM progress report (April to October 2019), https://arena.gov.au/knowledge-bank/short-term-forecasting-trial-on-the-nem-progress-report-april-to-october-2019/

Figure 3.15: **Distribution of wind self-forecasting participants**



Source: AEMO

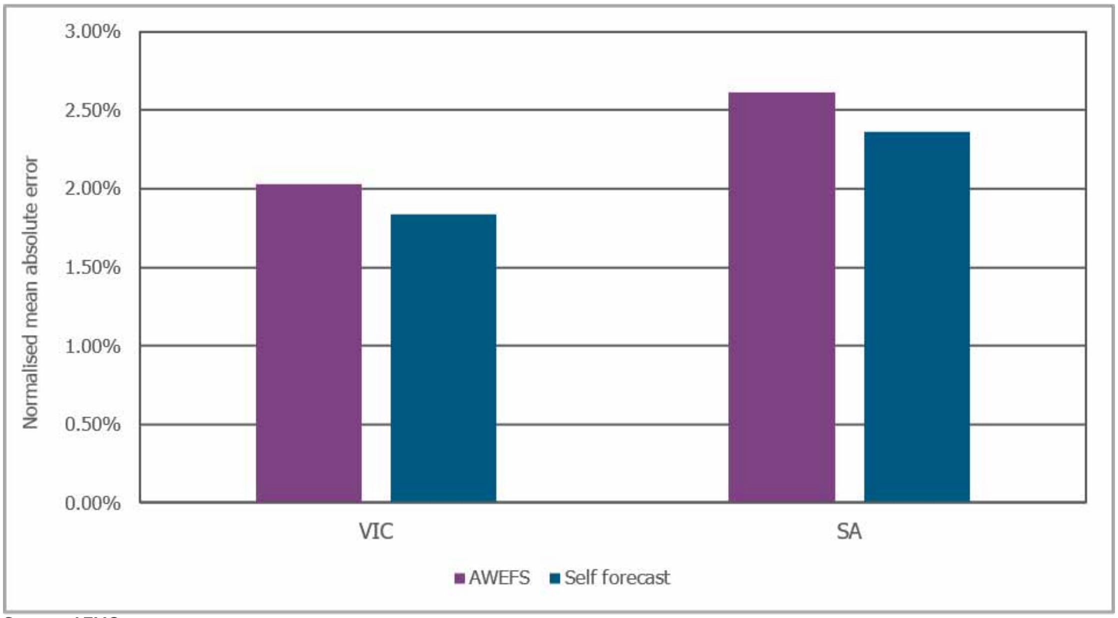
Figure 3.16: **Distribution of solar self-forecasting participants**



Source: AEMO

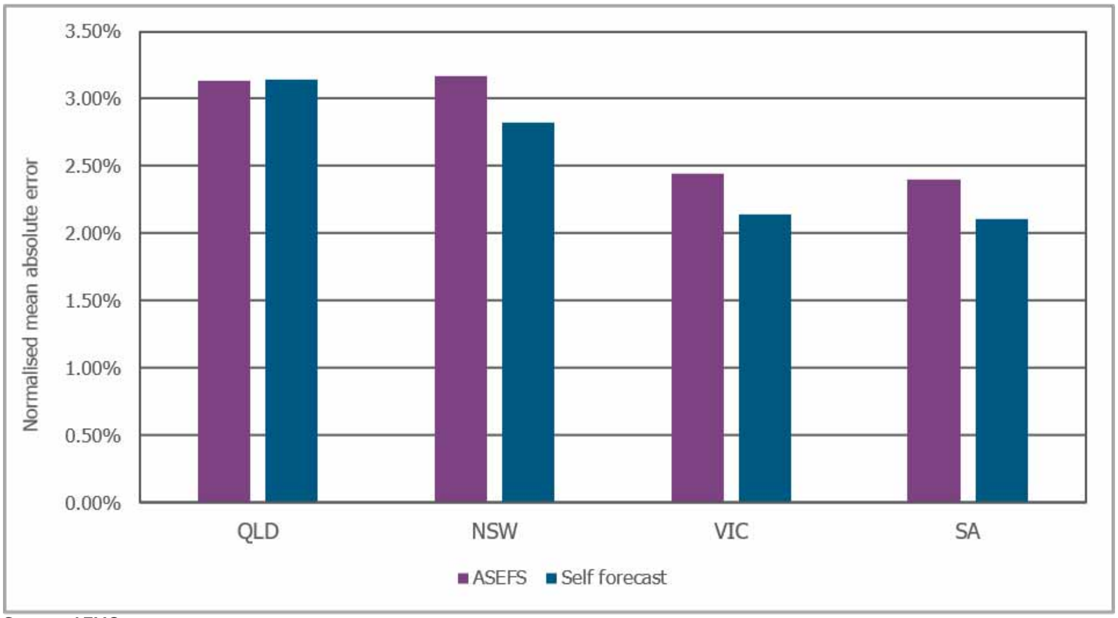
Assessment of normalised mean absolute errors reflect that on average to date, self-forecasting has provided more accurate results than AEMO's AWEFS and ASEFS forecasting. This is illustrated in figures 3.17 and 3.18 below.

Figure 3.17: 2019-29 financial year normalised mean absolute error - wind



Source: AEMO

Figure 3.18: 2019-29 financial year normalised mean absolute error - solar



Source: AEMO

ARENA and AEMO note that it is clear that self-forecasting is beginning to demonstrate that proposed technologies have the potential to provide self-forecasts to AEMO that are more accurate than AWEFS and ASEFS systems within a five-minute period. The range of forecasting technologies includes onsite cloud cameras, wind speed radars, weather satellites, meteorological masts, infrared and machine leaning algorithms that utilise onsite and BoM weather data.

3.3.7 Network performance

In assessing network performance in the NEM in 2019-20, the Panel has considered:

- Performance of interconnectors
- Performance of transmission networks
- Performance of distribution networks.

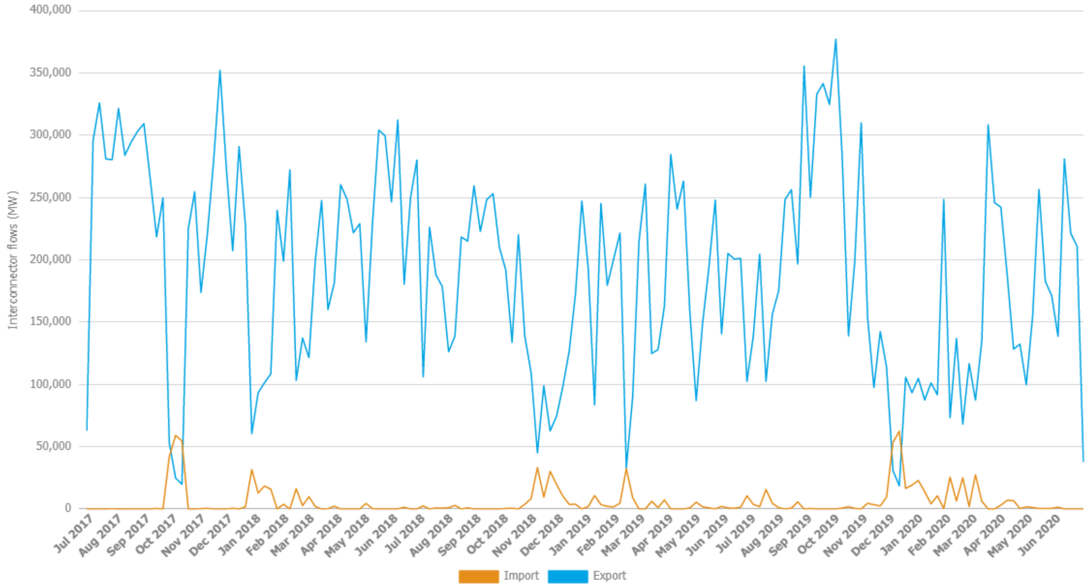
Interconnector performance

In this section, the Panel considers the current performance as well as future development of interconnection in the NEM.

Interconnection between regions allows sharing of generation and reserves.

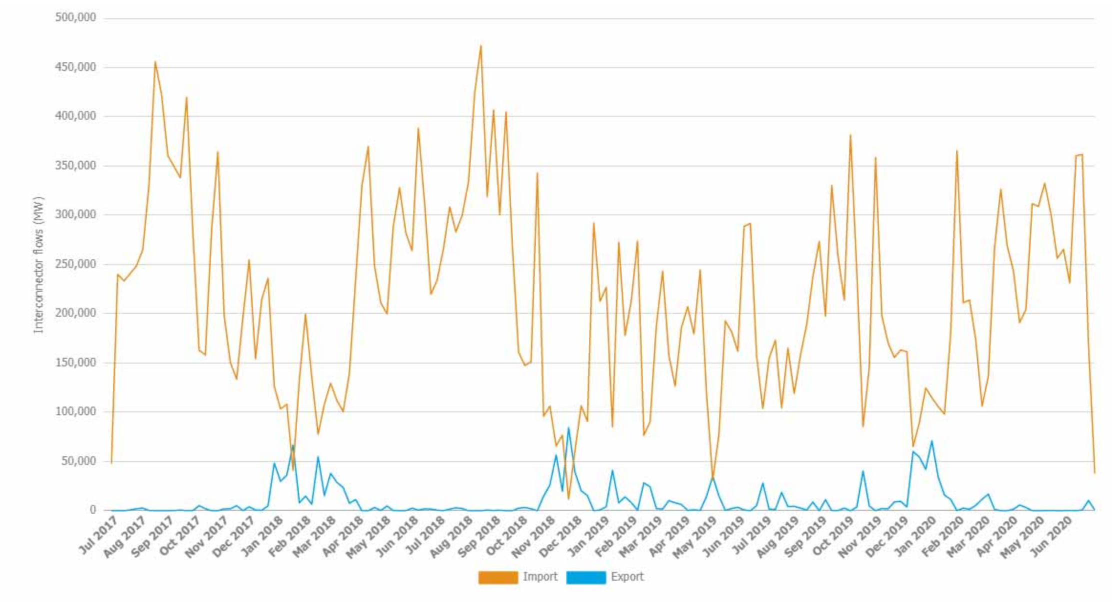
The figures below show the interregional flows across interconnectors between July 2017 and June 2020. The orange line indicates when and how much a region is importing, and the blue line indicates when and how much a region is exporting.

Figure 3.19: Interconnector flow July 2017 - June 2020 - Queensland



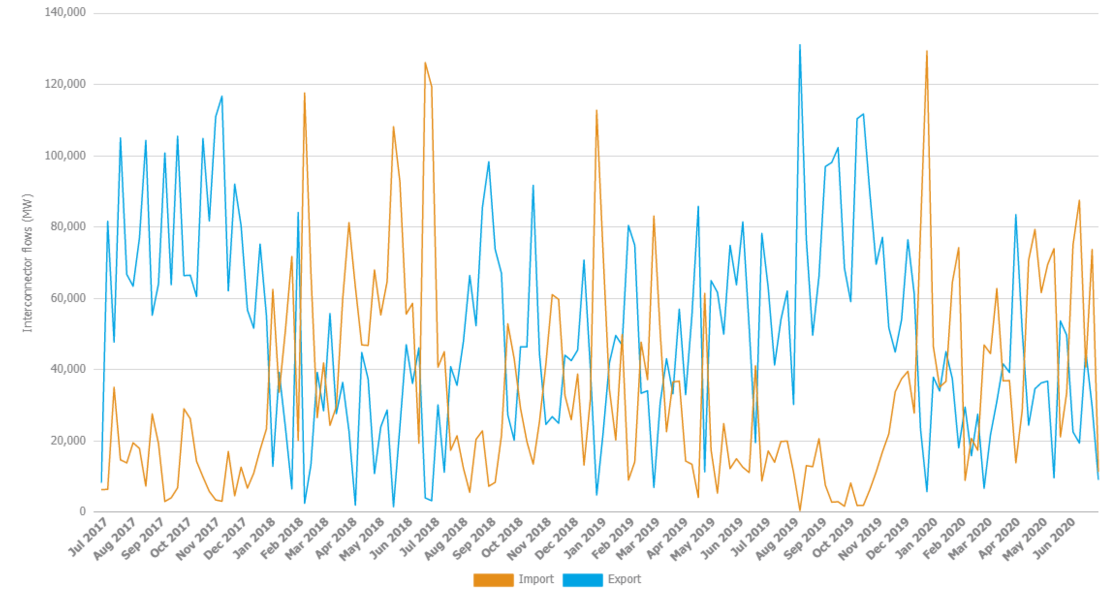
Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

Figure 3.20: Interconnector flow July 2017 - June 2020 - New South Wales



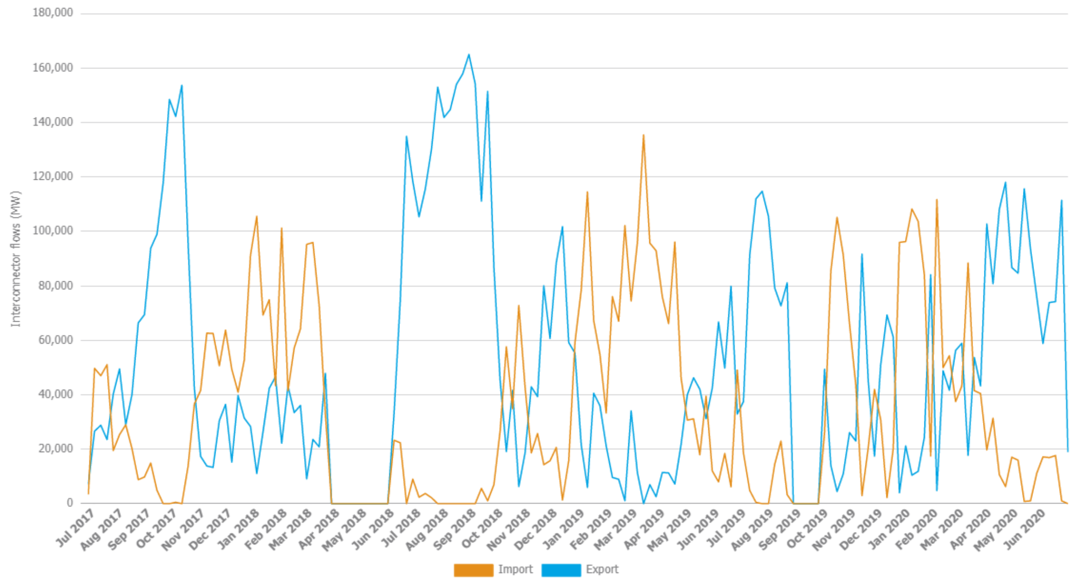
Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

Figure 3.21: Interconnector flow July 2017 - June 2020 - South Australia



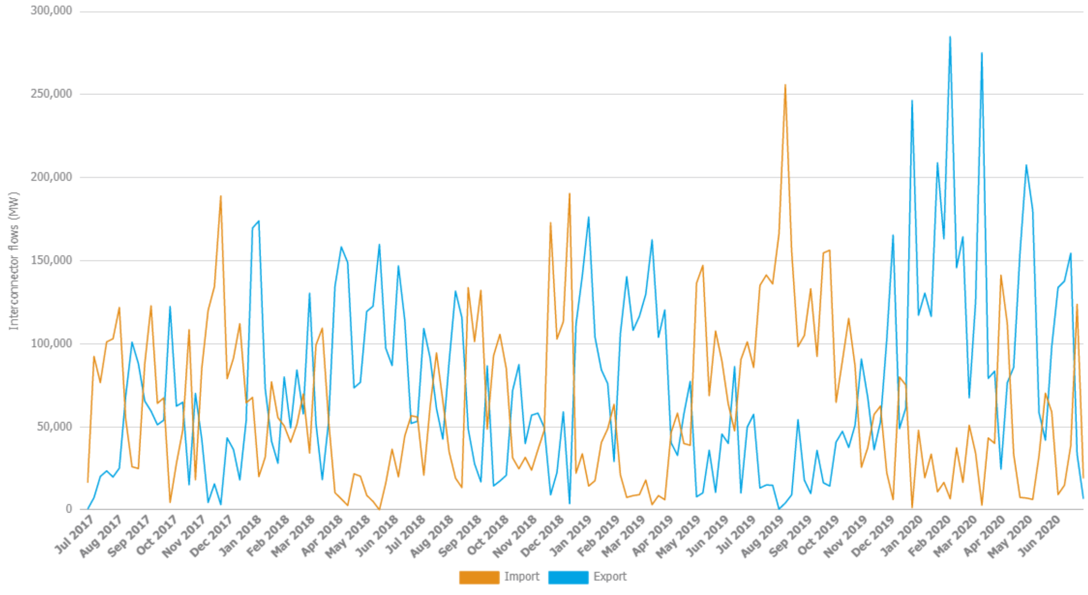
Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

Figure 3.22: Interconnector flow July 2017 - June 2020 - Tasmania



Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

Figure 3.23: Interconnector flow July 2017 - June 2020 - Victoria



Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

Some key points to note in relation to interregional flows include:

- Queensland remained as a net exporter over the 2019-20 financial year.
- New South Wales remained as a net importer over the 2019-20 financial year.
- Seasonal fluctuations that continued in South Australia, Tasmania and Victoria. The Panel notes that Victorian exports increased in volume between January and April 2020.

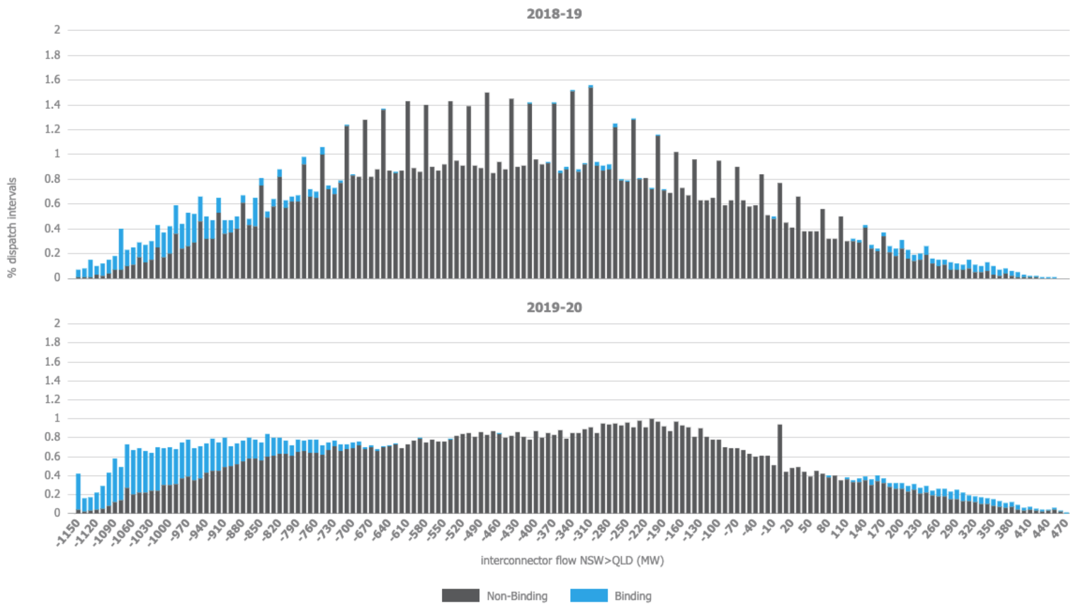
The Panel has included some analysis below on the performance of QNI, VNI and Heywood in 2019-20 compared to 2018-19.

Interregional flow across QNI

QNI runs between Bulli Creek in Queensland and Dumaresq in New South Wales. QNI currently has a nominal capacity of about 300-600 MW from New South Wales to Queensland and about 1,080 MW from Queensland to New South Wales.

Figure 3.24 shows the trend of flows across QNI.

Figure 3.24: Interregional flows across QNI



Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

In 2019-20:

- New South Wales imports and exports across QNI bound at similar levels compared to 2018-19.
- Flows across QNI shifted more towards higher levels if imports for New South Wales, with QNI binding more at high NSW import levels.

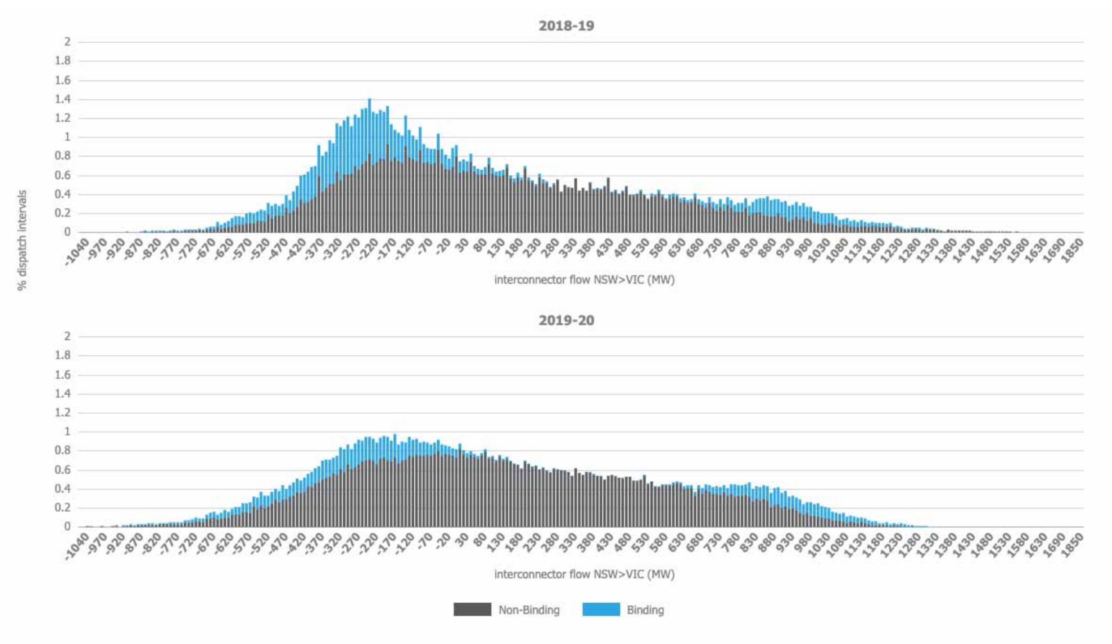
AEMO has identified the QNI [140]as a committed ISP project. On 28 April 2020, the AER published its final decision in relation to TransGrid's QNI minor upgrade contingent project application, noting that the project is consistent with the preferred investment option identified through the Expanding NSW-QLD Transmission Transfer Capacity Regulatory Investment Test for Transmission process[141]. The upgrade will allow a further 460 MW of to be transferred into Queensland and 190 MW more into NSW.[142]

Interregional flow across VNI

VNI connects northern Victoria with southern New South Wales. VNI currently has a nominal capacity of 700-1,600 MW from Victoria to New South Wales, and 400-1,350 MW from New South Wales to Victoria.

Figure 3.25 shows the trend of flows across VNI.

Figure 3.25: Interregional flow across VNI



Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

In 2019-20:

- Flows bound less often at low levels in 2019-20 compared to 2018-19.

140 AEMO, Integrated System Plan 2020, https://aemo.com.au/-/media/files/major-publications/isp/2020/final-2020-integrated-system-plan.pdf?la=en&hash=6BCC72F9535B8E5715216F8ECDB4451C

141 AER, TransGrid - QNI minor upgrade contingent project, https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/transgrid-qni-minor-upgrade-contingent-project

142 TransGrid, Queensland to New South Wales Interconnector Upgrade, https://www.transgrid.com.au/what-we-do/projects/current-projects/ExpandingNSWQLDTransmissionTransferCapacity/Documents/QNI%20project%20overview%20fact%20sheet%20-%20March%202021.pdf

- There was an increase in intervals where New South Wales was exporting to Victoria in 2019-20.

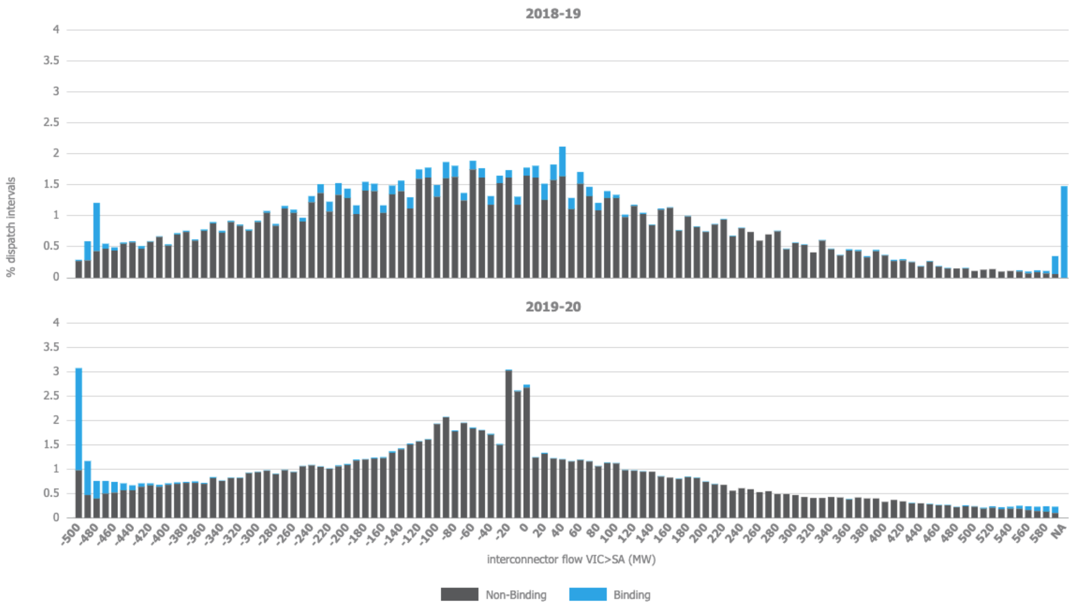
On 13 April 2021, the AER published its final decision in relation to TransGrid's VNI minor contingent project application[143]. The AER determination will allow TransGrid to expand the transmission capacity between Victoria and New South Wales.

Interregional flow across Heywood

The Heywood interconnector connects Heywood in Victoria to the south-east of South Australia. The Heywood interconnector has a nominal capacity of approximately 650 MW in both directions of flow.

Figure 3.26 shows the trend of flows across VNI.

Figure 3.26: Interregional flows across Heywood



Source: Reliability Panel analysis of AEMO MMS data
Note: The data for this chart is available in the AMPR data portal.

Flows are similar from 2018-19 with a greater proportion of dispatch intervals clustered around zero due to the South Australia islanding event.

Transmission network performance

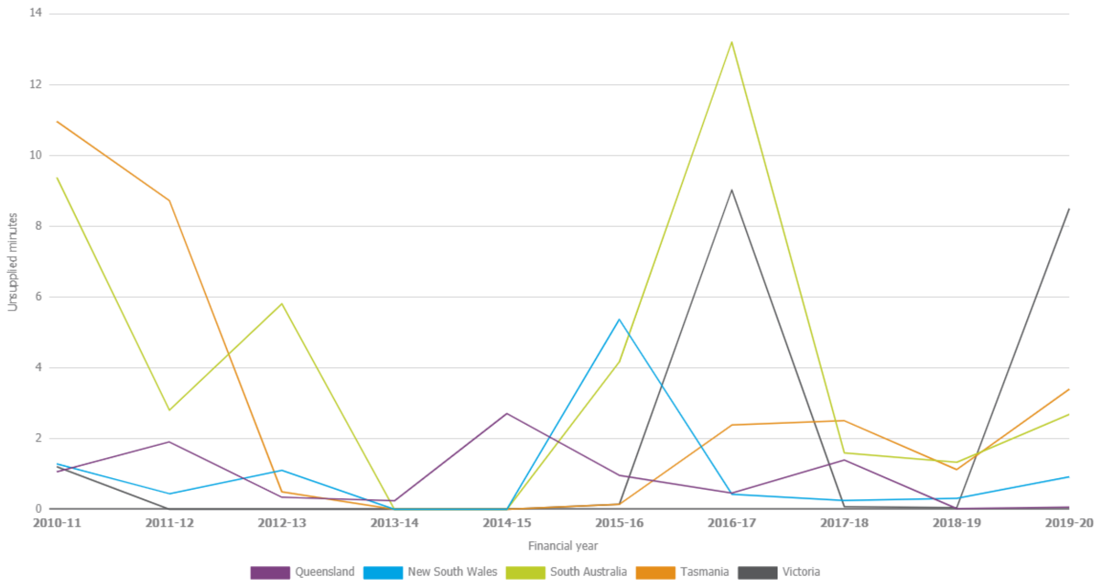
This section provides a summary of transmission network performance in 2019-20. The Panel has considered both unplanned network outages and the resulting market impacts.

143 AER, TransGrid - Expanding Victoria-New South Wales Transmission Transfer Capacity (VNI) Contingent Project Application, https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/transgrid-%E2%80%93-expanding-victoria-new-south-wales-transmission-transfer-capacity-vni-contingent-project-application

Unplanned network outages result in lost load which is not counted towards unserved energy for the purposes of the reliability standard. This is because unserved energy 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.

Unsupplied minutes increased for all regions in 2019-20. The most significant increase was in Victoria . The increase in unsupplied minutes may have been influenced by weather events such as storms and bushfires.

Figure 3.27: Transmission unsupplied minutes



Source: Powerlink, TransGrid, ElectraNet, AusNet Services, Tasnetworks
Note: The data for this chart is avaiable in the AMPR data portal.

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 reliability of distribution network service providers (DNSPs).

Two important indicators of distribution network reliability are[144]:

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

DNSP performance in 2019-20 in relation to each of these is discussed below.

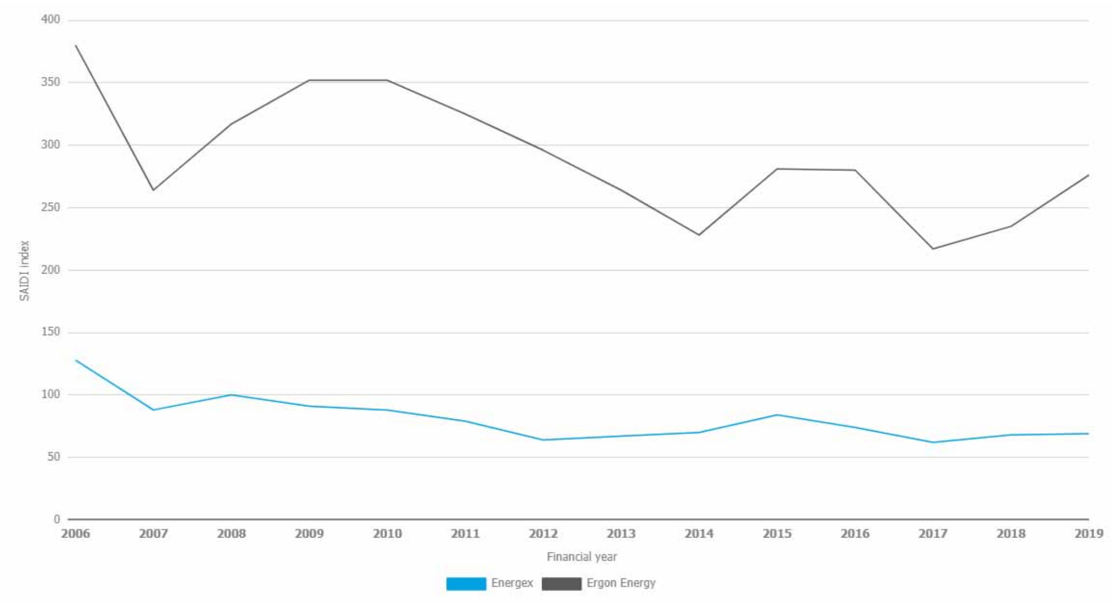
144 AER, Distribution Reliability Measures Guideline, https://www.aer.gov.au/system/files/AER%20-%20Distribution%20Reliability%20Measures%20Guideline%20-%20Version%201%20-%2014%20November%202018%20%28updated%2020%20November%202018%29.pdf

SAIDI indicates the average number of minutes of outages that each customer served by the DNSP 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. SAIDI is an indicator of how long it took to respond to and restore power after an outage.

Network reliability standards are often measured in terms of the SAIDI. It is calculated for different parts of each DNSP's network, for example the reliability on long rural lines is calculated differently to the reliability on CBD networks. The reliability targets for these different parts of the network are also different.

The average SAIDI figure for each DNSP is shown in Figures 3.28 to 3.31. As shown in the figure, DNSPs that largely serve urban customers such as Ausgrid, Energex and Citipower have lower SAIDI outcomes compared to DNSPs such as Essential Energy, Power & Water and Ergon Energy which have larger proportions of rural customers.

Figure 3.28: SAIDI Queensland

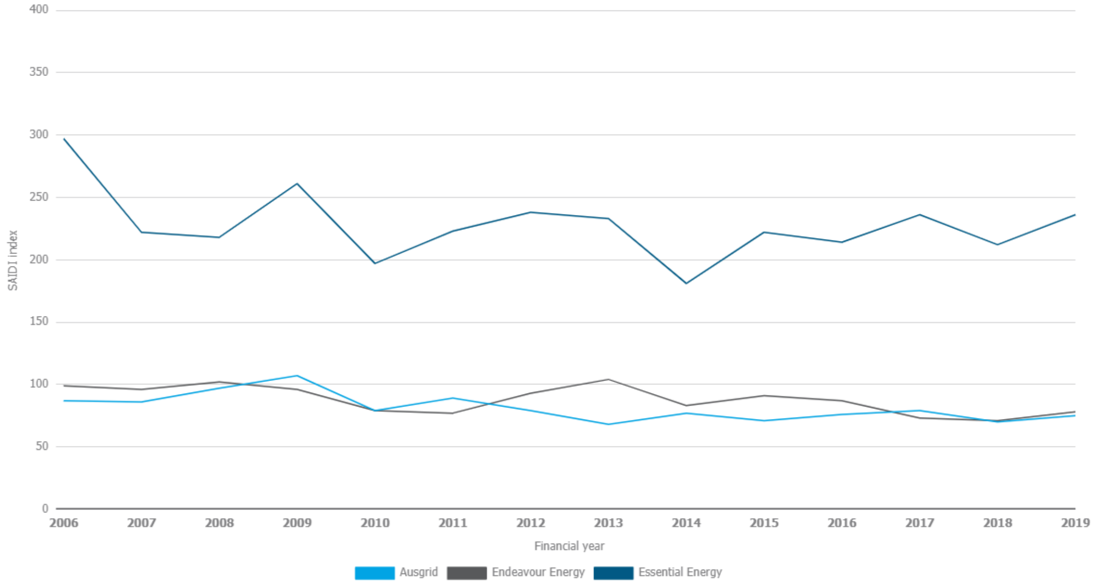


Source: AER RIN responses

Note: The data for this chart is available in the AMPR data portal.

Ergon Energy experienced an increase in SAIDI outcomes for the second year in a row. Energex stayed largely unchanged from 2018, and has continued a historically low level of SAIDI outcomes.

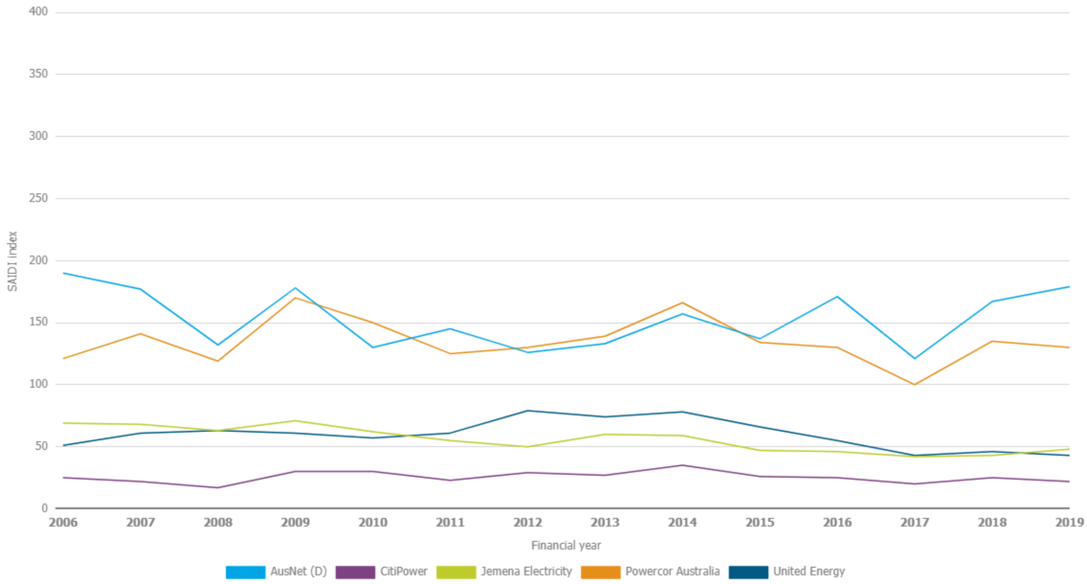
Figure 3.29: **SAIDI New South Wales**



Source: AER RIN responses
Note: The data for this chart is available in the AMPR data portal.

Essential Energy saw an increase in SAIDI outcomes, however this remains within the general historical trend. Ausgrid and Endeavour Energy both saw little change from 2018 outcomes, with a continued low SAIDI score relative to Essential Energy.

Figure 3.30: SAIDI Victoria

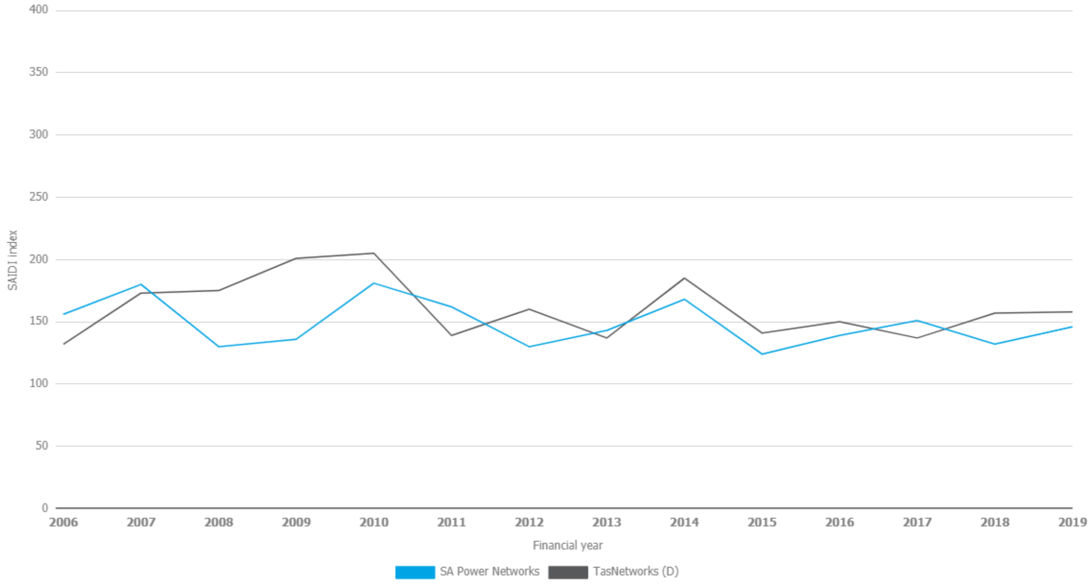


Source: AER RIN responses
Note: The data for this chart is available in the AMPR data portal.

AusNet saw a continued increase in SAIDI outcomes, with the level in 2019 approaching historic highs. AusNet noted in their final report that this decrease in reliability outcomes was due to weather related reasons.[145] Powercor saw a decrease in SAIDI outcomes. CitiPower, Jemena and United Energy a saw little change relative to 2018, with United Energy consolidating on improved SAIDI performance.

145 Ausnet, 2019 Annual Report, https://www.ausnetservices.com.au/-/media/Files/AusNet/Investor-Centre/Reports/ANE1267_Annual-Report_FA2_web.ashx?la=en

Figure 3.31: SAIDI South Australia and Tasmania

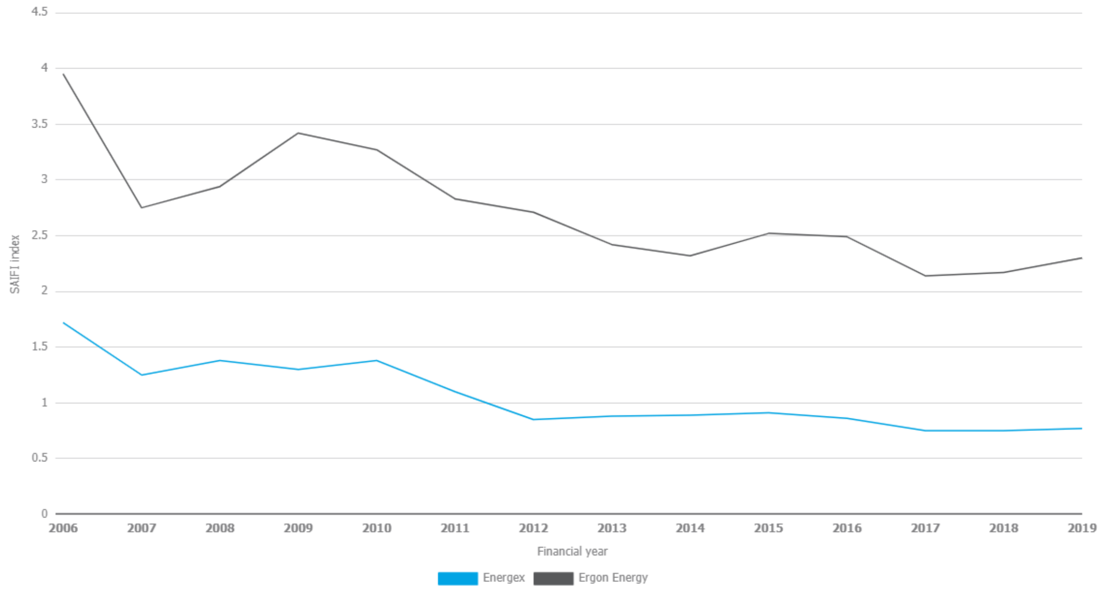


Source: AER RIN responses
Note: The data for this chart is available in the AMPR data portal.

SA Power Networks and TasNetworks both saw little change in terms of SAIDI outcomes in 2019.

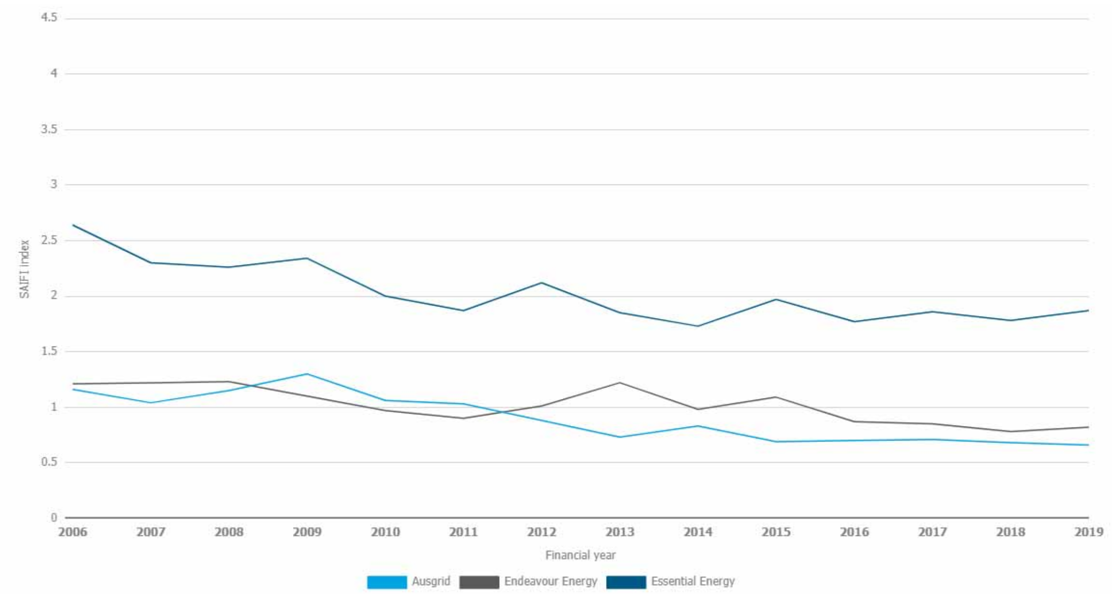
SAIFI indicates the average number of outages for each customer served by the DNSP. Figures 3.32 to 3.35 show the SAIFI outcomes for each DNSP.

Figure 3.32: SAIFI Queensland



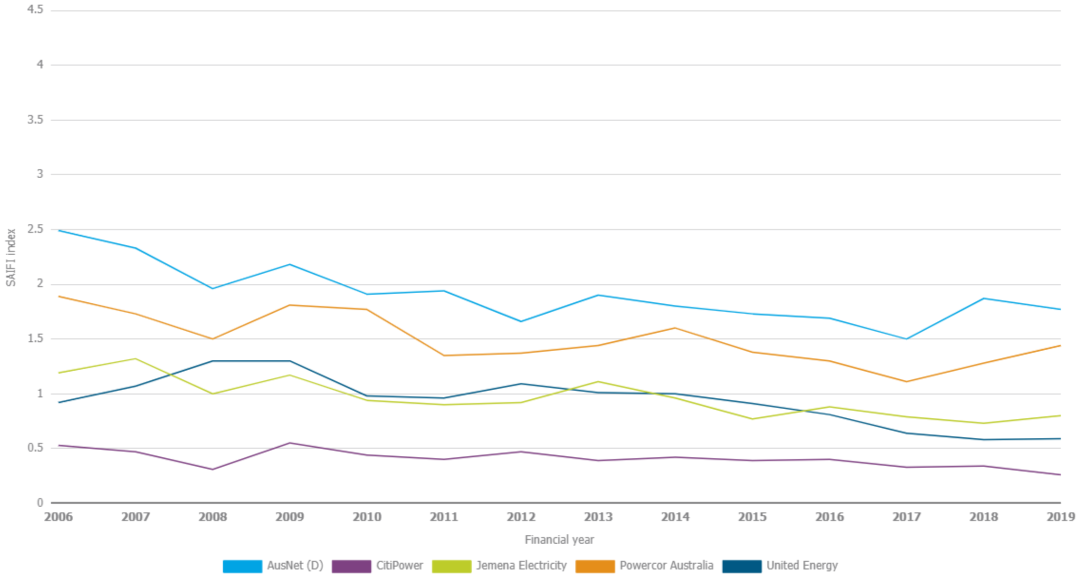
Source: AER RIN responses
Note: The data for this chart is available in the AMPR data portal.

Figure 3.33: SAIFI New South Wales



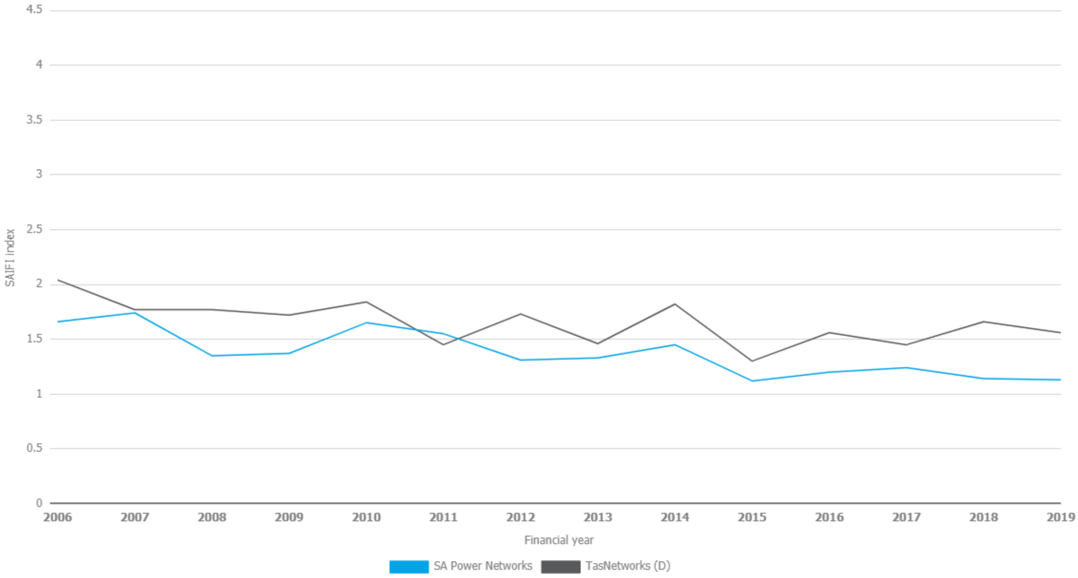
Source: AER RIN responses
Note: The data for this chart is available in the AMPR data portal.

Figure 3.34: SAIFI Victoria



Source: AER RIN responses
Note: The data for this chart is available in the AMPR data portal.

Figure 3.35: SAIFI South Australia and Tasmania



Source: AER RIN responses
Note: The data for this chart is available in the AMPR data portal.

SAIFI outcomes remained generally steady from 2018, with the exception of AusNet and PowerCor in Victoria. Ausnet saw a decrease from 2018 levels, and PowerCor saw an increase from 2018 levels.

In addition to these performance metrics, Section 2.6.4 outlined the impact that COVID has had on DNSPs during the 2019-20 financial year. The Panel notes that increased instances of people working from home have led to significant changes in network load profiles, and may prompt changes to network operation in future if current trends continue.

3.4 Key changes to reliability frameworks in 2019-20

As the power system itself changes, so too must the regulatory framework that supports reliability outcomes. During the 2019-20 financial year, a range of changes were made to improve reliability outcomes in the NEM. The Panel has explored the key changes below and provided commentary on the impact that these rules had during the year, or, where it is too early to tell, the expected impact of new arrangements.

Key changes to the reliability frameworks in 2019-20 include:

- Extension of MT-PASA to three years
- Introduction of five minute settlement
- Wholesale demand response mechanism
- Transparency of new projects

The Panel notes that in the second half of 2020, the ESB published a number of changes to the NER to introduce the Interim Reliability Measure and amend the triggering of the RRO.[146]The Panel expects that these changes will impact on reliability outcomes in the NEM, and may address these changes in more detail in the next AMPR.

3.4.1 Extension of MT-PASA to three years

The MT-PASA is a key part of the reliability framework in the NEM. It is one of the components of the information that AEMO must publish to inform the market of prevailing and forecast conditions, and when reserves may be running low, to elicit a market response. Providing information to the market helps participants make operational and investment decisions with respect to reliability and also helps AEMO manage the power system.

On 20 February 2020, the AEMC made a rule to amend the MT-PASA[147]. The final rule:

- Improves transparency of the MT-PASA process
- Makes market information available when it is most needed
- Extends the period generation availability is published from two to three years.

These changes will give the market more granular detail on projected assessments of power system reliability and generation availability. They will likely result in participants making

146 ESB, Interim Reliability Measured, https://energyministers.gov.au/reliability-and-security-measures/interim-reliability-measures

147 AEMC, Enhancement to the Reliability and Emergency Reserve Trader, https://www.aemc.gov.au/rule-changes/enhancement-reliability-and-emergency-reserve-trader

more effective and efficient decisions on how they interact with the market. The key features of the final rule are that it will provide the market with:

- Information on the generation availability of individual scheduled generating units
- An extended outlook of generation availability from two to three years
- A maximum and minimum aggregated scheduled generating availability adjusted for forced outage assumptions
- Greater transparency of the maximum and minimum of daily forecast peak demand, for both the adjusted 50% and 10% probability of exceedance (POE) load traces used in the reliability assessment
- Actual demand and forecast demand published in the same format (operational 'as generated')
- A requirement on participants to provide MT-PASA inputs that represent their current intentions and best estimates

The Panel notes that given the expected rate of thermal generation retirement, as well as the potential for increased planned outages of existing thermal generators,[148]this change to the MT-PASA may provide important information that may lead to improved reliability outcomes. The Panel notes that the potential for increase planned outages may occur due to changing market conditions that could encourage plants to move away from the traditional base load operation to load cycling.

3.4.2 Five minute settlement

The AEMC made a final rule in November 2017 to change the settlement period for the electricity spot price from 30 minutes to five minutes, starting in July 2021. Five-minute settlement provides a better price signal for investment in fast response technologies, such as batteries, new generation gas peaker plants and demand response.

Price signals that align with physical operations lead to more efficient bidding, operational decisions and investment. Over time, this is expected to flow through to lower wholesale costs, which should lead to lower electricity prices than in a market with 30-minute settlement.

Specifically, the rule change is expected to create the following benefits compared to the current arrangements:

- Improved price signals for more efficient generation and use of electricity
- Improved price signals for more efficient investment in capacity and demand response technologies to balance supply and demand
- Improved bidding incentives.

The AEMC noted in its final determination that there is no direct impact to system security or reliability from making this rule because:

148 AEP elical on behalf of AEMO, Assessment of ageing coal-fired generator reliability, https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2020/aep-elical-assessment-of-ageing-coal-fired-generation-reliability.pdf?la=en

- Work is underway to promote the effective and efficient integration of fast frequency response technologies into the NEM
- Peaking generators are likely to continue selling cap contracts
- Recent announcements and investment decisions relating to gas generation and energy storage highlight the rapid speed with which they can be implemented if there are any emerging supply shortfalls.

On 9 April 2020, AEMO submitted a rule change request to delay the start of five-minute settlement by 12 months due to the impact of COVID-19 on power system safety, security and reliability. The AEMC noted the short-term impact of COVID-19 on industry capabilities, and in July 2020 decided to delay the implementation by three months, in order to:

- Recognise the short-term impact of COVID-19 on participant capabilities
- Not significantly increase or decrease implementation costs and
- Not materially reduce the broader market and consumer benefits from implementation.

The final determination means that five-minute settlement will now commence on 1 October 2021, as opposed to 1 July 2021.

3.4.3 Wholesale demand response mechanism

Demand response is a subset of demand side participation. Providing wholesale demand response in the NEM has been difficult to date because consumers need to be technically equipped to respond (for example, with advanced metering and control over consumption), as well as needing a 'signal' to respond to. Most consumers elect to not respond to wholesale prices themselves, and instead a retailer typically manages the risk on their behalf.

On 11 June 2020, the AEMC published a final rule to implement a wholesale demand response mechanism[149]. The final determination sets out a series of changes to the NER to facilitate wholesale demand response in the NEM. This represents a significant reform for the NEM. Under this rule, consumers would be able to sell demand response in the wholesale market either directly or through specialist aggregators for the first time.

Under the final rule, a new category of registered participant, a demand response service provider (DRSP), will be able to bid demand response directly into the wholesale market as a substitute generation. A DRSP can also engage directly with a customer without the involvement of that customer's retailer.

The mechanism introduced under the final rule is designed to provide greater opportunities for consumers to participate in the wholesale market by bidding in demand reductions as a substitute for generation, therefore unlocking under-utilised demand response in the NEM. This mechanism will promote greater demand side transparency, as well as price and reliability-related benefits.

The Panel notes that unlocking demand response capacity in the NEM could have positive impacts on future reliability outcomes, particularly as the intra-day demand profile becomes

149 AEMC, Wholesale demand response mechanism, https://www.aemc.gov.au/rule-changes/wholesale-demand-response-mechanism

increasingly volatile and the ramping capability of existing scheduled generators may not be to meet future requirements.

3.4.4 Transparency of new projects

On 24 October 2019, the Australian Energy Market Commission made a final rule to improve publicly available information about new grid-scale generation projects. This rule also allows a broader set of project developers direct access to important system information required to build grid-scale assets.

The final determination improves information provision for new generation projects in the NEM[150]. The final rule:

- Facilitates greater access to relevant system information for developers that sell grid-scale assets prior to connection, while recognising that certain types of developers can already access this information by registering as intending participants
- Codifies AEMO's generation information page in the NER. The page is an information resource that provides source of regularly updated data on existing and proposed generation connections to the national grid.
- Requires TNSPs to share basic connection information about new generation projects with AEMO. AEMO must then publish this data on the generator information page.

The final rule supports the energy market transition by making it easier and quicker for developers to assess the viability of proposed projects. The final rule also means market participants are better informed of proposed connections which may assist them with their operational and investment decision-making.

The Panel notes that increased transparency in the connections process may help to make the development of new plant more efficient, and may reduce uncertainty for investors in the NEM. This could lead to improved reliability outcomes as new investment will more easily be able to connect to the NEM to replace retiring thermal generation capacity.

3.5 Panel insights: Reliability

The Panel notes that the management of power system operational reliability was challenging from the perspective of AEMO. As the power system continues to transition towards higher penetrations of intermittent, inverter-based generation resources with changing demand side trends, the challenges experienced in 2019-20 may continue to grow in magnitude.

The challenges in maintaining power system operational reliability are reflected in the metrics that the Panel have considered. Although there was no unserved energy in the NEM over the reporting period, the Panel notes that there was an increase in the number of times when the supply/demand balance in the NEM was tight. This is evidenced by the relative increase in the number of actual LOR2 conditions, as well as the increase in forecast LOR conditions in off-peak periods. Given the change in the generation mix towards more variable capacity and market dynamics including low wholesale prices, the Panel considers that periods where the

150 AEMC, Transparency of new projects, https://www.aemc.gov.au/rule-changes/transparency-new-projects

supply demand balance is tight may continue to occur at a higher rate in traditionally stable periods throughout the year rather than just in the summer, e.g. during shoulder periods. There were also increases in a number of market interventions used by AEMO in order to maintain reliability of supply. The RERT was activated on more occasions in 2019-20 compared to 2018-19, and AEMO issued six reliability directions over the same period, which is a large amount compared to historical trends.

Over the reporting period, many of these interventions were made in response to the impact of extreme weather events on the physical power system. Bushfires throughout the summer period had material impacts on the physical power system, leading to transmission line deratings and separation of regions. Furthermore, the South Australian separation event on 31 January 2020 led to two reliability directions being issued to maintain reliability of supply.

The Panel considers that improving the ability to accurately forecast supply and demand should be a key area of focus and will play an increasingly important role in the management of reliability in the power system. As the generation mix continues to incorporate higher penetrations of variable generation capacity, the ability to manage the increasing variability across the day will be important, so that any shortfalls in supply can be addressed in a timely manner. In addition to this short-term forecasting, the Panel considers that the ability to plan and account for unexpected and extreme events in the future should be an area of continued focus, given the impact that these events had on the operation of the power system over the reporting period.

The Panel notes that the current reliability framework has been adequate for ensuring reliability of supply to date. As noted above however, the existing frameworks and interventions were used to a greater extent in the face of changes to the power system operating environment. As trends in operating conditions continue to change as well as the make-up of the physical power system, the Panel notes that it is important for these trends to be considered in future planning exercises. In addition to this, the ongoing assessment of reliability should be considered to ensure that it is aligned with and applicable to the broader transition of the NEM.

3.5.1 Consideration of future reliability standard and settings

Review of the reliability standard and settings guidelines

The Panel published a consultation paper for the review of the reliability standard and settings guidelines (guidelines) on 4 March 2021. These guidelines set out the principles and assumptions that the Panel must use when undertaking the broader reliability standard and settings reviews (RSS reviews). The next RSS review must be completed by 30 April 2022.

In the consultation paper for the review of the guidelines, the Panel notes that since the guidelines were first established in December 2016, the NEM has undergone a period of rapid transition. This is expected to continue in large part due to changes in the generation mix and associated reforms. The Panel considers that it is important that the guidelines are sufficiently broad and continue to be relevant as the market evolves, so that they remain applicable for future reliability standard and settings reviews.

Given the changes to both demand and supply side trends noted in this report, the Panel considers that it is important that future reviews of the settings take into account these material changes to ensure that efficient price signals are sent to market participants to achieve the reliable operation of the NEM.

In the 2016 guidelines, the Panel considered that there was a need to:

- Balance and deliver both a stable and flexible regulatory framework for system reliability, and
- Focus on the most important components that should be subject to regular assessment that would result in material market benefit and reduce complexity.

The Panel notes that there is still a need to support stability and predictability in the market to the greatest extent possible, but there is also a need to align and have regard to the market changes and post-2025 reforms going forward.

The Panel considers that the benefits from stability may no longer outweigh the benefits of a flexible framework in a changing environment. Therefore, the Panel is considering:

- Removing from the existing guidelines the determination that only certain components could be re-examined in each of the broader reliability standard and settings reviews. That is, the approach the stated whether each of the components was "open, subject to a materiality assessment or closed for review."
- Relying on the assessment principles and the criteria related to the reliability standard and settings in the NER as the basis for the Panel's recommendations. This effectively forming a materiality assessment for the guidelines.

The Panel intends to consider future management of reliability in a holistic manner in the broader RSS review, and will be taking account of recent challenges to the maintenance of reliability.

4 SECURITY

One of the Panel's key responsibilities, as set out in the National Electricity Law, is to monitor, review and report on the security of the national power system, at the request of the AEMC. This chapter considers the security performance of the NEM over the 2019-20 financial year in line with the Panel's NEL obligations[151] and the review's terms of reference.[152]

This chapter outlines:

- What is power system security and how is it delivered?
- The security performance of the NEM in 2019-20.
- Panel insights, challenges to security and work underway to address these.

In assessing the system security performance of the NEM, the Panel has considered a number of indicators. Power system security involves keeping the power system within a technical envelope across a range of characteristics[153]. Often, an event will impact a number of these characteristics. For example, if a generating unit was to trip, it can have impacts on the local voltage levels, while also impacting on power system frequency across the entire NEM.

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 will use its assessment of system security to inform its future work plan.

4.1 What is power system security and how is it delivered?

The national electricity system is a large scale complex machine made up of thousands of different elements each with specific technical characteristics and operating requirements. Power system security involves maintaining these components within their allowable equipment ratings, maintaining the system as a whole in a stable condition within defined technical limits and returning the power system to operate within normal conditions following a disturbance.[154]

In a secure power system, technical parameters such as power flows, voltage and frequency remain stable during normal operations and are returned even after a significant change in power system conditions, such as the loss of a major transmission line or large generator. A secure power system is one that, among other things:

- Is able to maintain a satisfactory operating state following the occurrence of a credible contingency event

151 Section 38 of the NEL

152 See Appendix A

153 AEMC, Security, https://www.aemc.gov.au/energy-system/electricity/electricity-system/security

154 Reliability Panel, Annual Market Performance Review 2019, https://www.aemc.gov.au/sites/default/files/2020-04/2019%20AMPR%20final%20report%20-%20republished%20with%20minor%20amendments%20in%20April%202020.PDF

- Maintains power system frequency, voltage, current and plant operation within appropriate limits as specified by the power system security standards.[155]

In practice, a power system is in a secure state if it would remain within the technical operating parameters in the event of a credible contingency. [156]More information on power system security can be found at the AEMC website.[157]

4.2 Summary of security outcomes in 2019-20

The Panel's objectives in assessing the NEM's performance are set out in the terms of reference provided by the AEMC[158]. This chapter assesses the system security performance of the NEM in 2019-20 by considering:

- Key security-related events. The power system and markets' response to a number of security events that occurred during 2019-20.
- The amount of power system directions issued by AEMO.
- The number of constraint changes required in the NEM dispatch engine (NEMDE).
- Frequency and frequency control performance.
- The amount of system services required by AEMO and the cost of these services.

Box 3 presents a summary of the Panel's assessment of the NEM's security performance in 2019-20.

BOX 3: SYSTEM SECURITY PERFORMANCE IN 2019/20

Security outcomes

- There was an increase in reviewable operating incidents in 2019-20 compared to 2018-19, driven by a major increase in combined generation/transmission incidents.
    - One notable event was the separation of South Australia from the rest of the NEM in late January and February 2020.
- There was an increase in the number of power system directions issued by AEMO. The majority of these directions were issued in South Australia.
- There were approximately 15,000 constraint changes in NEMDE. This is a decrease from 2018-19, however still above historical levels.
- There was an improvement in frequency performance on both the mainland and in Tasmania compared to 2018-19. AEMO remains concerned about elements of frequency that are not covered by the Frequency Operating Standard.

155 Clause 4.2.2 of the NER

156 A 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.

157 https://www.aemc.gov.au/energy-system/electricity/electricity-system/security

158 See Appendix A.

- The cost of frequency control ancillary services increased in 2019-20 compared to 2018-19. The South Australian separation event contributed to this increase.

Panel insights

- 2019-20 saw AEMO face significant challenges operating and maintaining the power system in a secure state. These challenges arose due to the rapid transition towards high penetrations of intermittent, inverter-based generation as well as extreme environmental events.
- The Panel notes that the continued uptake of distributed energy resources such as rooftop solar are continuing at a rate that is significantly higher than was forecast. System security issues associated with this trend, including system strength, voltage control, inertia and ramping will therefore also occur faster than was initially forecast. The Panel notes that the rate of onset of these issues is a significant challenge for AEMO.
- The Panel considers that the ability for AEMO to accurately forecast and account for the impact of rooftop PV across the day is an important area of development, given the increasing penetrations of rooftop PV and the impact it has on issues related to minimum system load.
- The South Australian separation event saw AEMO manage the power system in an extended island configuration, which had not happened before. Management of power system security during this event required significant intervention and use of Frequency Control Ancillary Services.
- The ongoing challenge and complexity to maintain power system security is a key focus of the Panel, particularly in the context of extreme events and declining minimum system load that is occurring significantly faster than forecasts indicated. The Panel acknowledges that there is work underway to address these issues, including the ESB Post-2025 Market Design work, as well as the AEMC work program on system strength and AEMO's Engineering Framework. The Panel will continue to assess and monitor system security as part of its future work.

Note: The Reliability Panel propose conducting a review of the guidelines for identifying reviewable operating incidents (guidelines) following a request from the Australian Energy Market Operator (AEMO) to amend the guidelines. The guidelines are applied by AEMO in determining when a power system incident is considered a 'reviewable operating incident'. Reviewable operating incidents are generally incidents that occur in the power system that could have a significant effect on the operation of the power system in terms of system security. Under the NER, AEMO is required to review these incidents and report its findings.

4.3 Security outcomes

4.3.1 Reviewable operating incidents

One indicator of power system security performance in the NEM is the number of system security-related operating incidents occurred during the year.

AEMO has responsibility to investigate and review all major power system operational incidents and publish detailed incident reports to assess the adequacy of the provision and response of facilities or services, and the appropriateness of actions taken to restore or maintain power system security.[159]. A reviewable operating incident is an incident identified, in accordance with guidelines determined by the Reliability Panel under the NER, to be of significance in the operation of the power system or a significant deviation from normal operating conditions.[160]

AEMO is required to report on the following categories of incidents as reviewable operating incidents:

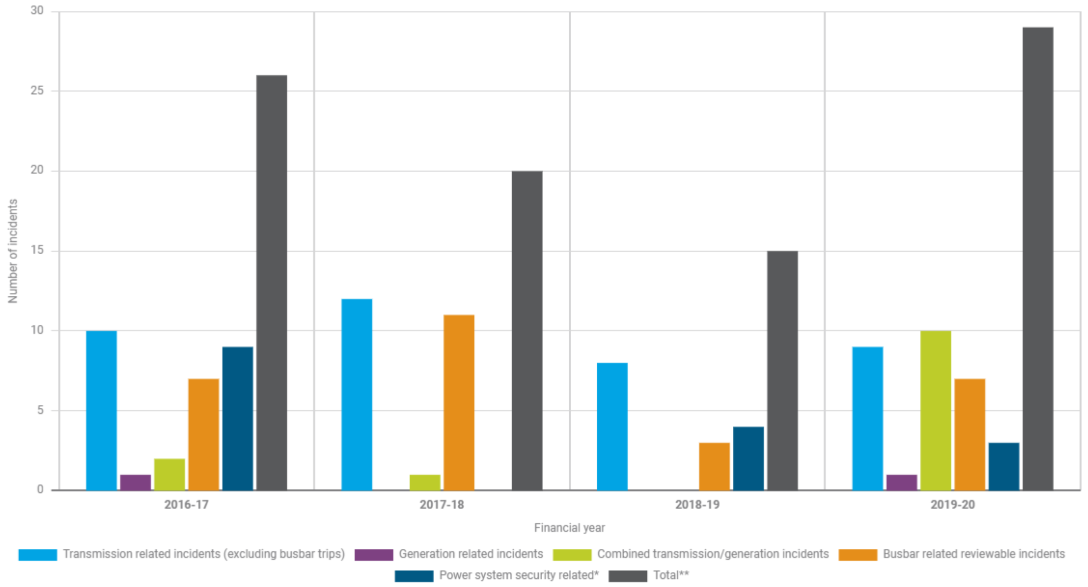
- A non-credible contingency event or multiple contingency events on the transmission system
- A black system condition
- An event where the frequency of the power system is outside limits specified in the power system security standards
- An event where the power system is not in a secure operating state for more than 30 minutes
- An event where AEMO issues a clause 4.8.9 instruction for load shedding.
- An event where AEMO's oscillatory and transient stability monitoring systems detect potential generator instability for more than 30 minutes.
- Incidents that result in the operation of under frequency or over-frequency protection and control schemes
- Incidents where the power system is not in a satisfactory state for more than five minutes.

AEMO may also report on other significant events or systemic issues at its discretion, or be requested to review particular events by the Panel.

Figure 4.1 shows the number and type of incidents that have occurred over time.

159 Clause 4.8.15(b) of the NER
160 Clause 4.8.15(a) of the NER

Figure 4.1: Number of reviewable operating incidents



Source: AEMO
Note: * Power system security refers to the power system not being in a secure state for more than 30 minutes.
Note: ** 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.
Note: The data for this chart can be found in the AMPR data portal.

There were 29 reviewable operating incidents in 2019-20, an increase from 15 in 2018-19. This increase was driven by an increase in the number of combined transmission/generation incidents. This increase in combined transmission/generation incidents was partially driven by increases in external power system shocks, including bushfires and storms. While the number of incidents is a large increase from 2018-19, it is not historically out of place, with a similar number (26) of incidents occurring in 2016-17.

There were three incidents in 2019-20 that led to the power system not being in a secure operating state for more than 30 minutes[161].

Tasmania region not in a secure operating state 23 October 2019

During this event, Tasmania was not in a secure operating state for 37 minutes due to low inertia levels[162]. Inertia levels within power systems must be maintained above certain levels to ensure correct frequency response following generation or load contingencies. Power systems with high inertia can resist the large changes in frequency arising from contingency events that lead to an imbalance in supply and demand. At 1050 hrs on 23 October, Hydro

161 In Chapter four of the NER, the power system is defined to be in a secure operating state if the power system is in a satisfactory operating state and the power system will return to a satisfactory operating state following the occurrence of any credible contingency event in accordance with the power system security standards.

162 AEMO, Tasmania inertia issue report, https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2019/tas-inertia-issue-report.pdf?la=en&hash=7950F7B08AD661638F7D7B9332D7E095

Tasmania took one of the generating units at the Liapootah Power Station out of service as part of normal operation, resulting in a reduction of total inertia levels in Tasmania to below the minimum level. Although AEMO has indication of inertia levels, at the time of the incident, AEMO did not have alarming in place to alert operators to any shortfall. TasNetworks provided AEMO with initial advice of the inertia shortfall at 1100 hrs on 23 October 2019.

Hydro Tasmania, when contacted by AEMO, voluntarily committed the generating unit at the Cethana Power Station in synchronous condenser mode, resulting in the inertia in Tasmania increasing to above minimum levels.

AEMO's investigation of this event concluded that:

- The reduction in inertia was the result of a generating commitment variation modifying the available generation mix as part of normal operation.
- AEMO was not initially aware of the reduced inertia. AEMO has subsequently installed alarming on inertia levels and updated its internal procedures.
- Capabilities for managing system inertia are expected to be improved by new processes for managing inertia in Tasmania, due to be implemented from 1 April 2020.

New South Wales and Victoria separation event 4 January 2020

This event resulted in the separation of the New South Wales and Victorian regions due to a major bushfire event in the Snowy Mountains area[163]. The power system was not in a secure operating state over two distinct periods on this day.

Prior to the separation event, several lines interconnecting New South Wales and Victoria were lost due to bushfires, leaving New South Wales and Victoria connected via a single line. The power system was not in a secure operating state for 13 minutes prior to separation while New South Wales and Victoria were connected via this line, as its loss was a credible contingency and would have resulted in significant thermal overloading of lines in this area. The power system was not in a secure operating state for up to 45 minutes after the islanding event due to a shortage of FCAS in the New South Wales/Queensland island.

The Panel notes that this event could have been more severe, with the transmission network operating with t only one line providing supply to the Canberra substation for short periods of time. The loss of this line under these conditions would leave Canberra islanded and dependent on local generation. This would have resulted in a large supply demand imbalance in this island, and would result in the trip of local generators on low frequency with a complete loss of supply to Canberra.

As described in Chapter 3.3.4, this event also led to an actual LOR2 condition and the activation of RERT in New South Wales.

<u>Frequency in the New South Wales/Queensland island</u>

The Frequency Operating Standard (FOS) for a multiple contingency event allows the frequency to fall to a minimum of 47 Hz, with the frequency returning to above 49.5 Hz

163 AEMO, Final report NSW and Victoria separation event 4 Jan 2020, https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/final-report-nsw-and-victoria-separation-event-4-jan-2020.pdf?la=en

within two minutes and to above 49.85 Hz within 10 minutes. During this event, the minimum frequency reached in New South Wales/Queensland was 49.52 Hz. The FOS was met in the New South Wales/Queensland island in relation to the containment and stabilisation frequencies, however despite considerable over-delivery of delayed raise FCAS in the New South Wales/Queensland island, the frequency only returned to above the recovery frequency after approximately 18 minutes. Despite this delay, AEMO considers that the FOS was met as all reasonable endeavours were taken to restore the frequency to within the recovery band as soon as possible.

Frequency in the Victoria/South Australia island and Tasmania

The FOS for a multiple contingency event allows the frequency to rise to a maximum of 52 Hz, with the frequency returning to lower than 50.5 Hz within two minutes and to below 50.15 Hz within 10 minutes. During this event, the maximum frequency reached in the Victoria/South Australia island was 50.43 Hz. In the Victoria/South Australia island, the FOS was met but the frequency remained at approximately 50.15 Hz for a further 10 minutes.

The FOS in Tasmania for a multiple contingency event allows for the frequency to rise to a maximum of 55 Hz (containment), with the frequency returning to lower than 52 Hz (stabilisation) within two minutes and to blow 50.15 Hz (recovery) within ten minutes. The containment and stabilisation frequency were met, however a post event oscillatory behaviour resulted in small short duration deviations above recovery frequency. AEMO has noted that these are not a material issue as it had no adverse impact on the power system.

Availability of FCAS

AEMO notes that there was a significant shortage of FCAS for up to 45 minutes in the New South Wales/Queensland island. This resulted in the power system not being in a secure operating state for this period, as the FOS would not have been met on the trip of the largest generating unit in the island at the time.

There was insufficient FCAS available because the capacity was instead dispatched into the energy market, particularly in New South Wales. This applied to multiple generating units predominantly in New South Wales. Dispatch of FCAS from Queensland was limited by raise services in Queensland being co-optimised with QNI.

AEMO made a number of conclusions and recommendations following this event. These include:

- Implementing corrective action for the majority of generating units that did not fully deliver enabled FCAS requirements.
- Recommending TransGrid review its policies for splitting the Wagga-Yass 132 kV network under certain operational configurations.
- Modifying constraint formulation to reduce the probability of reoccurrence of FCAS shortages.
- Reviewing PASA tools to correctly determine reserve levels in New South Wales after the islanding event due to the effective change in region boundaries, with changes expected to be implemented in mid-2021.

- Working with stakeholders to identify and address the source of non-compliance with the Generator Performance Standards.

Trip of Eildon - Mount Beauty No. 1 and No. 2 220 kV lines, 10 January 2020

This incident involved the trip of both Eildon Power Station (EPS) to Mount Beauty Terminal Station (MBTS) No. 1 and No. 2 220 kV lines[164]. The power system was not in a secure operating state for one hour and 42 minutes.

Prior to the event, AEMO had reclassified loss of Dederang Terminal Substation (DDTS) to South Morang Terminal Substation (SMTS) 330 kV lines as a credible contingency event due to bushfires, resulting in an unusual scenario where Victoria and New South Wales would have been interconnected via Bendigo and Red Cliffs 220 kV circuits only should a contingency on the SMTS-DDTS lines actually have occurred.

At 1526 hrs on 10 January 2020, the EPS-MBTS No. 1 and No. 2 lines tripped simultaneously. Following a helicopter line patrol of the relevant section of lines, no defects were found, and AusNet Services notes that it was likely that the cause of the faults was strong winds and smoke caused by nearby bushfires.

Constraint automation was used to manage the reported violations, ultimately resulting in correctly weighted changes to the applicable interconnectors across the south-east of Australia to relieve the violation. Additional actions taken by AEMO to resolve the underlying security issues included placing capacitor banks in service at BATS, BETS, Horsham Terminal Substation (HOTS), Shepparton Terminal Substation (SHTS) and Glenrowan Terminal Substation (GNTS).

AEMO made the following conclusions from the event:

- The EPS-MBTS 220kV lines tripped, auto reclosed and tripped again to lockout.
- No physical damage was identified. Adverse weather conditions associated with bushfires are the most likely cause of the repeated trip events.
- AEMO correctly reclassified the trip of both lines as a credible contingency event.
- AEMO determined the power system was not in a secure operating state for one hour and 42 minutes.
- Power system issues could have been resolved earlier by deliberately separating the Victorian and New South Wales regions.

In addition to these, there were other security-related incidents in the NEM that the Panel notes are important to discuss. These include:

- The separation of the South Australian and Victorian regions on 16 November 2019.
- The separation of South Australia from the rest of the NEM in January and February 2020.

164 AEMO, Trip of Eildon Mount Beauty no1 and no2 220 kV lines, https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/trip-of-eildon-mount-beauty-no1-and-no2-220-kv-lines.pdf?la=en

4.3.2 South Australia and Victoria separation 16 November 2019

On 16 November 2019 at 1806 hrs, two 500 kV transmission lines in Victoria were disconnected simultaneously due to malfunction of telecommunications equipment that caused operation of protection equipment on both circuits[165]. The following lines tripped as a result of this incident:

- Heywood - Alcoa Portland - Mortlake 500 kV line (HYTS-APD-MOPS 500 kV line)
- Heywood - Alcoa Portland - Tarrone 500 kV line (HYTS-APD-TRTS 500 kV line)

This non-credible contingency event resulted in the disconnection of the South Australia region from the rest of the NEM power system for nearly five hours, and disconnection of electrical supply to the Alcoa Portland (APD) aluminium smelter for nearly three hours.

Following the disconnection of the 500 kV lines, AusNet Services advised AEMO that the incident was due to malfunction of a communication multiplexer which caused the X unit protections on both of the affected transmission lines to operate and open the circuit breakers at each terminal on both lines. Ausnet Services has reviewed associated protection failures and modifications have been implemented at APD to interlock Digital Current Differential (DCD) pickup with other trip events including distance trip elements and disturbance detector elements on the X and Y protection schemes respectively.

Following the incident, Ausnet Services advised AEMO that the malfunctioning communication multiplexer that initiated the non-credible contingency event had been isolated and other protection functions remained in place. Based on this information, AEMO determined that it was not necessary to reclassify the possible recurrence of this non-credible event as credible. AusNet Services also advices that a repeat of the same fault was not likely.

The preliminary report published by AEMO highlighted ongoing frequency alignment issues experienced when attempting to resynchronise Victoria and South Australia at Heywood Terminal Station[166]. AEMO had identified the frequency and phase angle settings in teh synchronisation check relay at HYTS were very narrow and contributed to the delays in resynchronising the South Australia and Victoria regions. AusNet Services has since modified the synchronisation check relay settings at HYTS at AEMO's request to increase these tolerances. This is expected to reduce the time required to resynchronise South Australia and Victoria under similar circumstances.

Frequency performance

For this event, the maximum frequency reached in the South Australia island was 50.7 Hz and did not exceed the FOS containment or stabilisation boundaries. Despite under-delivery of delayed lower FCAS from some FCAS-enabled facilities, the frequency in South Australia recovered to below 50.5 Hz within approximately five minutes.

165 AEMO, Final report, South Australia and Victoria separation event 16 November 2019, https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2019/final-report-sa-and-victoria-separation-event-16-november-2019.pdf?la=en&hash=231CA53842A89C65036F1F288D0DCF73

166 AEMO, Preliminary incident report, 16 November 2019 SA VIC separation, https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2019/preliminary-incident-report---16-november-2019---sa---vic-separation.pdf

For the remainder of the mainland NEM, the frequency briefly exceeded the FOS upper recovery limit of 50.15 Hz in the minutes after the separation of South Australia, with the loss of the APD load exceeding the reduced generation capacity from South Australia. A maximum frequency of 50.17 Hz was recorded in the mainland regions excluding South Australia. This is only marginally outside the FOS recovery limit and returned within the FOS limits within the 10-minute window.

AEMO made the following conclusions from the event:

- The loss of two 500 kV lines that led to the separation of the South Australia region was caused by the malfunction of a communication multiplexer.
- The faulted communications equipment cards were replaced by AusNet Services on 17 November 2019 and no similar events have been recorded since.
- AusNet Services has indicated that additional assets may be susceptible to the same type of malfunction, however the assessed probability of failure remains very low.
- AEMO actions to manage and restore the system during the incident were appropriate.
- Modifications to synchronisation check relay settings are expected to reduce issues with re-synchronising island regions.
- Factors contributing to the under-delivery of FCAS services have been identified and rectified by the appropriate parties.
- No generators were identified as non-compliant with applicable performance standards.
- Further work is required between stakeholders to develop measures to improve compliance with new and existing technical performance standards and connection requirements for distributed PV systems.

4.3.3 South Australia separation event 31 January 2020

On 31 January at approximately 1324 hrs, the collapse of several steel transmission towers on the Moorabool - Mortlake (MLTS-MOPS) and Moorabool - Haunted Gully (MLTS-HGTS) 500 kV lines resulted in these lines tripping and remaining unavailable for service[167]. At the same time, the Haunted Gully - Tarrone (HGTS-TRTS) 500 kV line also tripped. The loss of the MLTS-MOPS and MLTS-HGTS lines resulted in the separation of the South Australia region and part of western Victoria from the rest of the power system. The incident also left the Alcoa Portland (APD) aluminium smelter and generation at Mortlake Power Station and the Portland and Macarthur wind farms connected to South Australia but disconnected from the rest of Victoria. The power system had never before operated in this 'extended island' configuration.

The Bureau of Meteorology (BoM) issued several forecasts predicting severe thunderstorm activity with damaging winds in the range of 90-125 km/h in Victoria for 31 January. Analysis provided by the BoM indicates that a severe convective downdraft event occurred, resulting from thunderstorm activity in the area of the failed transmission towers. Further analysis

167 AEMO, Final report - Victoria and South Australia separation event on 31 January 2020, https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/final-report-vic-sa-separation-31-jan--2020.pdf?la=en

commissioned by AusNet Services concluded that in the area of the damaged transmission towers there were likely gusts in the range of 138-150 km/h near ground level and potentially up to 185-201 km/h at an altitude of 70 meters above the ground.

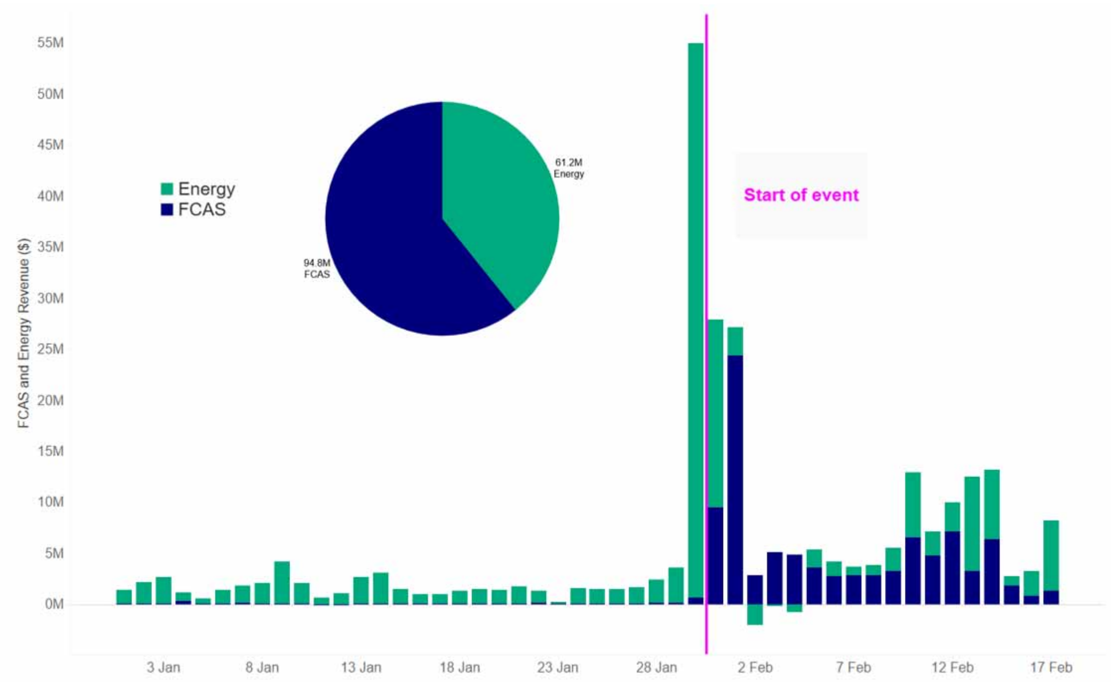
The incident had several impacts on the power system, including:

- High frequency in South Australia and the response of generating units to this high frequency
- Low reserve levels in Victoria
- The trip of APD load

Due to the nature of the damage to the transmission equipment in Victoria, the extended South Australia island was not reconnected to the rest of the NEM until 17 February 2020. Ongoing secure operation of this island for the period of separation required new constraints and AEMO intervention to manage power system conditions not previously experienced.

Management of the South Australia separation event required AEMO to issue more than 50 power system directions in 17 days. In addition to this, the total cost of frequency control ancillary services (FCAS) was $94.8 million. As can be seen in Figure 4.2, this is a large increase compared to FCAS required in the days leading up to the event.

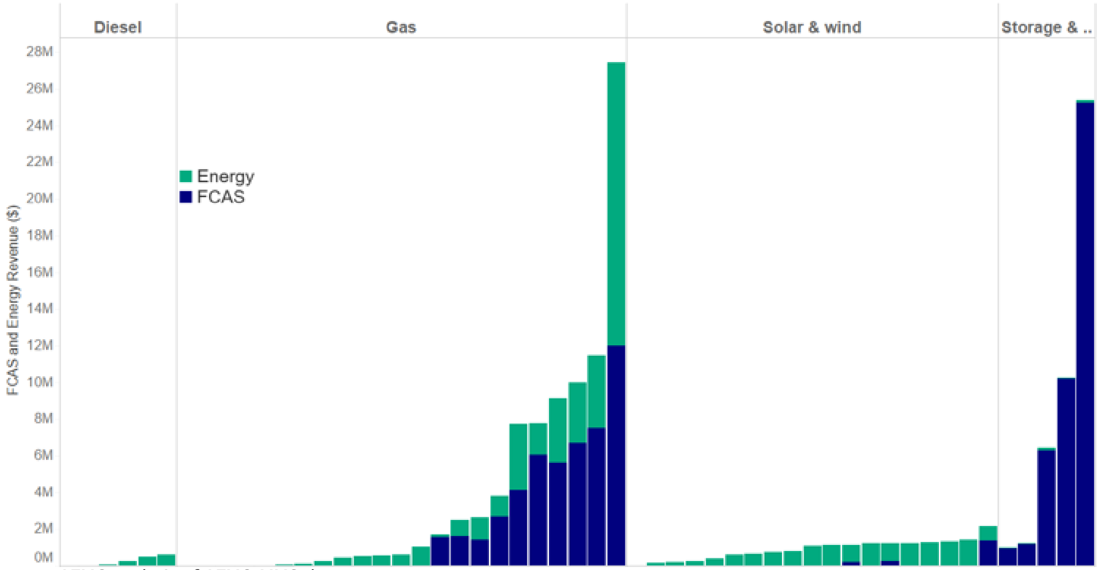
Figure 4.2: Energy and FCAS costs South Australia separation event



Source: AEMC analysis of AEMO MMS data

The situation was able to be managed by AEMO, however a high level of intervention was required. Gas and battery generation played an important role during the event, providing almost 100 per cent of required FCAS as shown in Figure 4.3.

Figure 4.3: FCAS revenue by technology type, South Australia separation event



Source: AEMC analysis of AEMO MMS data

The need for services from battery storage was identified following the 2016 black system event[168]. The 2018 South Australian separation event led AEMO to recommend improved primary frequency response[169].

The Panel notes that the lessons taken from these two events both proved useful for AEMO in managing the power system after this significant external event. The Panel therefore encourages the relevant market bodies and participants to give thought to what changes could allow the power system to better endure further events of this nature. It is also important that the changes in environmental conditions conducive to extreme weather events is considered to ensure that the power system is well-equipped to deal with such events in the future[170].

The Panel notes that the AEMC completed the Mandatory primary frequency response rule change in March 2020, requiring scheduled and semi-scheduled generators to support secure operation of the power system[171]. The Panel also notes that the AEMC is currently considering the primary frequency response incentives rule change.[172]This rule change raises issues

168 AEMO, Black system South Australia 28 September 2016, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf

169 AEMO, Final report - Queensland and South Australia system separation 25 August 2018, https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2018/qld---sa-separation-25-august-2018-incident-report.pdf?la=en&hash=49B5296CF683E6748DD8D05E012E901C

170 Bureau of Meteorology, State of the Climate 2020, http://www.bom.gov.au/state-of-the-climate/documents/State-of-the-Climate-2020.pdf

171 AEMC, Mandatory primary frequency response,https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response

172 AEMC, Primary frequency response incentive arrangements, https://www.aemc.gov.au/rule-changes/primary-frequency-response-incentive-arrangements#:~:text=On%2026%20March%202020%2C%20the,in%20a%20frequency%20responsive%20mode

related to the incentive arrangements in the NEM for the provision of primary frequency response during normal operation. There are a range of other projects underway that are expected to help improve power system security outcomes in the future, and these are outlined in Section 4.4.

4.3.4 Power system directions

AEMO may issue directions to participants to maintain or re-establish the power system to a secure operating state. It can direct participants to manage voltage and system strength.

System strength reflects the sensitivity of power system variables to disturbances. It indicates inherent local system robustness with respect to properties other than inertia. System strength affects the stability and dynamics of generating systems' control systems, and the ability of the power system to both:

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

Large synchronous machines, such as hydro, gas and coal generation, as well as synchronous condensers, inherently contribute to system strength. Non-synchronous generators, such as batteries, wind and solar generation, do not presently provide inherent contribution to system strength.[173]

Currently, most directions given by AEMO are to synchronous gas fired generators to ensure that there is adequate system strength in South Australia. To ensure adequate system strength for secure operation of the South Australian power system, certain combinations of synchronous generating units must be in service at all times.[174]This trend started in early December 2016, when AEMO announced that at least two large synchronous generating units should be online at all times to maintain system strength in South Australia[175]. Directions in South Australia are needed to maintain system strength given low spot prices lead to gas powered generators having an incentive to de-commit from the market due to economic reasons[176].. This usually occurs during periods of high wind and solar output with low to moderate demand.

During 2019-20, AEMO issued 278 power system directions. Of these, 273 were issued in South Australia, with the remaining five issued in Victoria. This is a continuation of an upwards trend in recent years that can be observed in Figure 4.4.

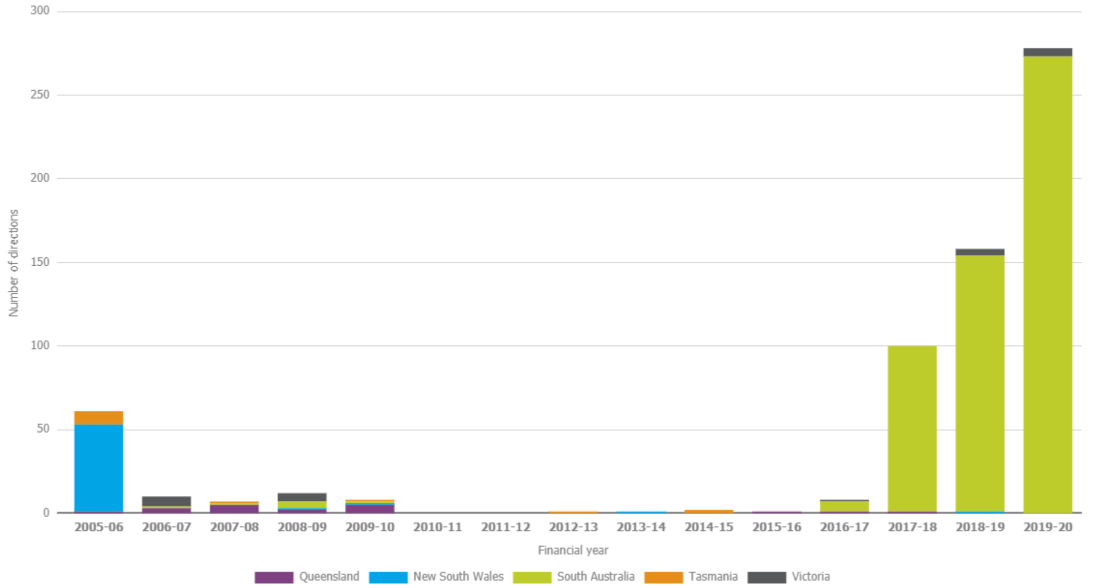
173 https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/transfer-limit-advice-system-strength.pdf?la=en

174 https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/market_event_reports/2019/nem-event--direction-to-south-australian-generators-02-to-09-november-2019.pdf?la=en&hash=B547DB6565CA21C540FD2B51692DB683

175 AEMO, Second update to the 2016 National Transmission Network Development Plan, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NTNDP/2017/Second_Update_to_the_2016_NTNDP.pdf

176 AEMO, Quarterly Energy Dynamics Q1 2020, https://www.aemo.com.au/-/media/files/major-publications/qed/2020/qed-q1-2020.pdf?la=en

Figure 4.4: Power system directions issued by AEMO



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

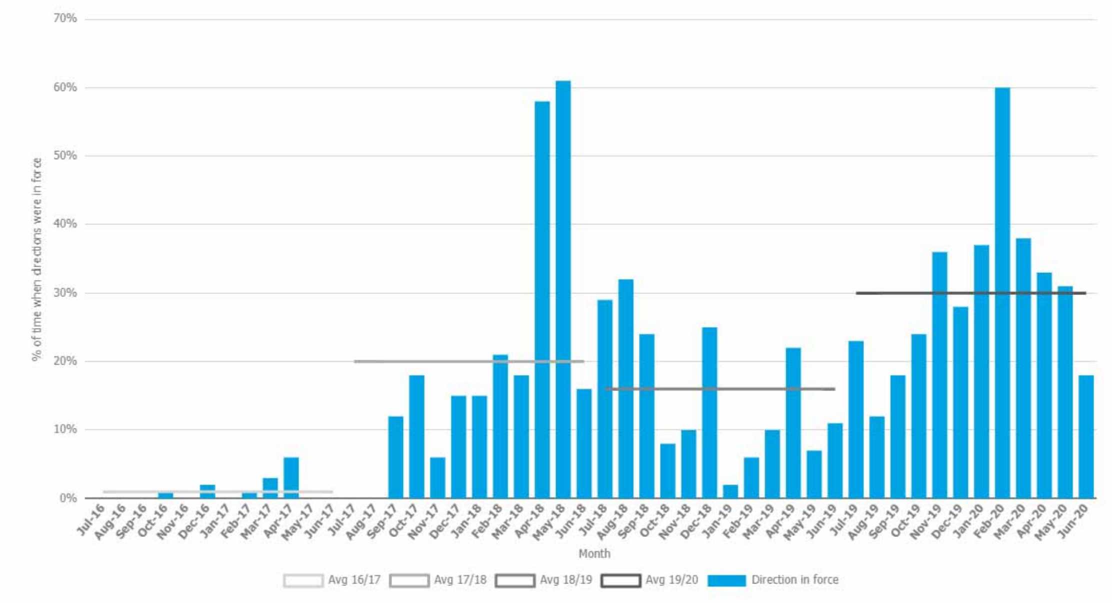
As discussed in Section 4.3.2, the South Australia separation event contributed to this increase in directions. The Panel notes that this trend is reflective of the challenges facing the NEM in the immediate future as rates of VRE penetration are expected to continue to rise[177]. It is important that power system security outcomes are considered in the development of reforms to manage the power system transition. The Panel notes that the installation of synchronous condensers at the Davenport and Robertson substations in South Australia are likely to provide part of a solution to these issues, as synchronous condensers can provide a similar effect in terms of providing inertia and system strength[178].

The proportion of time under security directions has increased in 2019-20. Security directions were in place across the NEM for approximately 30 per cent of the 2019-20 financial year, increasing from 17 per cent in 2018-19 and 20 per cent in 2017-18.

177 AEMO, Integrated System Plan, Appendix 6, https://aemo.com.au/-/media/files/major-publications/isp/2020/appendix--6.pdf?la=en

178 https://www.electranet.com.au/what-we-do/projects/power-system-strength/#:~:text=Synchronous%20condensers%20are%20estimated%20to,existing%20gas%20fired%20generators%20to

Figure 4.5: Percentage of time when directions in force in the NEM



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

The Panel notes that while directions were in place for approximately 60 per cent of the time in February 2020 and this would have impacted the annual average, such high levels are not unprecedented, as can be seen in April and May 2018. The Panel notes that there were more months when directions were in place for more than 20 per cent of the time than in recent history, indicating an increase in the difficulty of managing power system security across the whole year.

As noted in Chapter 3.3.3, management of power system security and operational reliability are becoming challenging in shoulder periods during periods of low demand. The Panel notes that there is has been an observable trend in recent years of the percentage of time when security directions were in force during shoulder periods, which have been defined as the months of September, October, November, March, April and May. Intervention pricing was in place 2 per cent of the time in these months in 2016-17, 29 per cent of the time in 2017-18, 14 per cent of the time in 2018-19 and 30 per cent of the time in 2019-20. The Panel notes that the combination of increased LOR notices as well as increased proportions of time when directions were in place reflects the increasing challenges of maintaining security in these periods.

4.3.5 Constraint changes

AEMO operates the power system to balance supply and demand for power using the most economic resources available, while also maintaining a secure and reliable system. To do so, the NEM is operated within a technical envelope of constraints that aim to prevent the power system from operating in a state that is vulnerable to supply disruptions in response to a credible contingency event.

Network constraints are developed from TNSP advice to AEMO about the technical limits of plant, and are used by AEMO in the NEM dispatch process to ensure that plant remains within rating, and power transfers remain within stability limits, so that the power system is in a secure operating state[179].

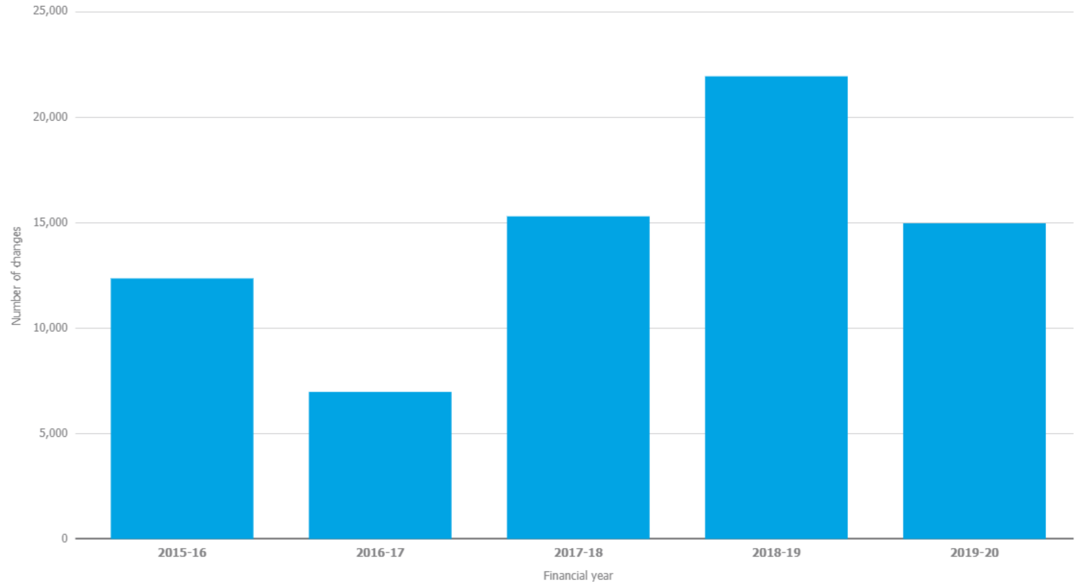
As the power system transitions from one dominated by a limited number of large synchronous generating systems, located in areas with strong transmission connections, to a system dominated by inverter connected renewable generation connecting in weaker parts of the network, the number of constraint changes is likely to increase to reflect this complexity. 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.

In 2019-20, there were 14965 constraint changes. This is a decrease from 2018-19, however this level is above historical averages.

179 AEMO, Constraint frequently asked questions, https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/constraint-faq

Figure 4.6: Constraint changes in NEMDE



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

As can be seen in previous years of AMPR reports, constraint changes have historically been less than 10,000 per year, and in some cases less than 5,000. This increase to around 15,000 per year reflects the increasingly complex optimisation process being run by AEMO to operate the power system.

4.3.6 Frequency performance

Controlling or maintaining frequency is a key element of power system security[180]. All generation, transmission, distribution and load components connected to the power system are standardised to operate at a normal system frequency of 50 hertz. The power system must therefore stay at or close to this level for equipment to stay connected to the system and continue to operate within technical bounds.

To maintain a stable system frequency at or close to 50 Hz, AEMO must balance the supply of electricity into the power system against consumption of electricity at all times. When there is more generation than load, the frequency will tend to increase. When there is more load than generation, the frequency will tend to fall.[181] The dispatch process is the main way of achieving this balance, but AEMO also relies on frequency control services, which are mostly designed to inject or remove power from the grid to restore the balance of supply and demand.

180 AEMC, Security, https://www.aemc.gov.au/energy-system/electricity/electricity-system/security

181 A more detailed explanation of power system frequency variation is provided in Appendix C of the AEMC's *Frequency control frameworks review* draft report, p. 187.

Frequency performance in the NEM is assessed against the frequency operating standard which defines the range of allowable frequencies for the electricity power system under different conditions, including normal operation and following contingencies.

Uncontrolled changes in frequency can cause cascading failures leading to major supply disruptions or black system events. To protect against this, it is important there are sufficient measures in place to provide for frequency control.

Under the NER, AEMO must keep the power system stable and securely operating at a frequency in line with the NER's power system security requirements set out in the Panel's Frequency Operating Standards (FOS)[182]. Where frequency deviates from 50 Hz, there are acceptable limits defined for different scenarios.

Figure 4.7: Frequency bands for the NEM and Tasmania

COLUMN 1	COLUMN 2		COLUMN 3		COLUMN 4
	NORMAL (HZ)		ISLAND (HZ)		SUPPLY SCARCITY (HZ)
	MAINLAND	TASMANIA	MAINLAND	TASMANIA	MAINLAND[1]
normal operating frequency band	49.85 – 50.15		49.5 – 50.5	49.0 – 51.0	49.5 – 50.5
normal operating frequency excursion band	49.75 – 50.25		49.5 – 50.5	49.0 – 51.0	49.5 – 50.5
operational frequency tolerance band	49.0 – 51.0	48.0 – 52.0	49.0 – 51.0	48.0 – 52.0	48.0 – 52.0
extreme frequency excursion tolerance limit	47.0 – 52.0	47.0 – 55.0	47.0 – 52.0	47.0 – 55.0	47.0 – 52.0

Source: Reliability Panel, Frequency Operating Standard

Note: The Reliability Panel has not determined separate frequency bands for periods of supply scarcity in Tasmania. Where a state of supply scarcity exists for the Tasmanian power system, the frequency bands set out in the "normal" column apply for an intact power system, and the frequency bands set out in the "island" column apply for an island with the Tasmanian power system.

The FOS also provides that in the absence of a contingency event, AEMO should maintain system frequency within the applicable normal operating excursion band and should not exceed the applicable normal operating band for more than five minutes on any occasion, and not for more than 1% of time over any 30-day period. AEMO calculates the percentage of time spent inside the normal operating band on a daily rolling average.

The Panel notes that changes to the frequency operating standard that were recommended in the Review of the Frequency Operating Standard in 2019 came into effect on 1 January 2020[183]. These changes include:

- The limit on the size of the largest generation event in the Tasmanian power system: The FOS includes revisions that clarify the scope of the existing 144 MW limit in relation to the operation of the Tasmanian power system. This limit was included in the FOS by the Panel following the 2008 review of the FOS for Tasmania. In the context of the operational limitations of the Tasmanian power system, it limits the quantity and cost of

182 Clause 4.4.1

183 Reliability Panel, Review of the Frequency Operating Standard, https://www.aemc.gov.au/markets-reviews-advice/review-of-the-frequency-operating-standard

contingency FCAS required to manage larger contingency events in the Tasmanian system. The particular changes in the FOS in relation to this issue include:

  - The definition of a generation event includes the disconnection of generation as the result of a credible contingency in relation to a dedicated connection asset providing connection of one or more generating systems to the shared transmission network.
  - Clarification that the limit for the largest generation event in the Tasmanian system applies for disconnection of generation based on an initially intact network, in the absence of network outages. This means that the limit does not apply in the event of planned network outages.

- Improvements to the structure and consistence of the FOS: The FOS has been restructured and consolidated to avoid duplication and improve the clarity of the obligations that it places on AEMO to manage the power system frequency.

Performance against the Frequency Operating Standard in 2019-20

Frequency performance of the NEM generally improved on both the mainland and in Tasmania in the 2019-20 financial year compared to 2018-19. The FOS specifies outcomes that should be achieved during normal operation, as well as a number of system frequency outcomes following specified conditions.

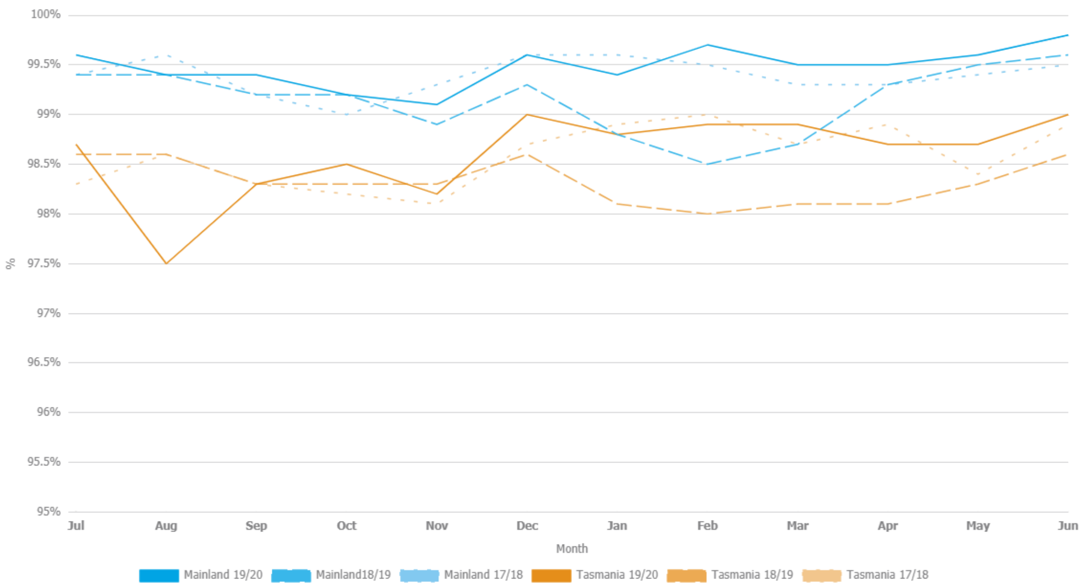
AEMO provides quarterly reports[184] on the NEM and Tasmanian power systems' performance against the FOS. According to AEMO's reports, frequency performance showed a general improvement in 2019-20. In quarter three 2019, an unplanned outage on the Basslink interconnector from 24 August until 29 September caused a decline in frequency performance. Additionally, the numerous separation events in quarter one 2020 presented significant challenges for AEMO when managing frequency. AEMO have noted that despite these unique events, frequency remained largely within the limits set by the FOS. The frequency control responses within the NEM contained and recovered these disturbances within the set requirements of the FOS most of the time. The instances where the FOS was not maintained do not necessarily suggest underlying issues in the aggregate system capability to respond to frequency disturbances.

AEMO have reported that 15 FOS exceedances occurred on the mainland, and 77 FOS exceedances occurred in Tasmania in 2019-20. AEMO notes that the true number may have been higher if quarter three and quarter four 2019 had been analysed using the same methodology as implemented from 1 January onward.

The performance of the NEM in terms of frequency control is illustrated in Figure 4.8.

184 These reports are available at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/frequency-and-time-deviation-monitoring

Figure 4.8: Percentage of time in normal operating band on the mainland and in Tasmania



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

As can be seen, 2019-20 generally saw an increase in the amount of time in the normal operating band on the mainland as well as in Tasmania. The exception to this was in August 2019 in Tasmania, when frequency remained in the normal operating band 97.5% of the time. As noted above, this sharp decrease in performance can be attributed to an unplanned outage on the Basslink interconnector.

Despite this, AEMO remains concerned about increasing risks presented by aspects of frequency control that the FOS does not directly address, including:

- Lack of frequency control within the NOFB.
- More excursions from the NOFB.
- Unpredictable frequency behaviour.

In the NEM, there are six contingency frequency control ancillary services (FCAS) markets designed to ensure that there is enough frequency response in the system to deal with a single credible contingency, which is typically the loss of a large generating unit or major industrial load[185]. The amount of contingency FCAS is equal to the largest credible contingency minus assumed load relief. Load relief is an assumed change in load that occurs when power system frequency changes. It relates to how particular types of load (particularly traditional motors, pumps and fans) draw less power when frequency is low and more power when frequency is high. The nature of load relief has been changing, driven by new

185 Contingency FCAS is used arrest a major increase or decrease in frequency following a contingency event https://aemo.com.au/-/media/files/pdf/guide-to-ancillary-services-in-the-national-electricity-market.pdf

technology and changing customer preferences and behaviour. These changes might be expected to impact load relief, and further analysis by AEMO has indicated that observed load response is significantly lower than the 1.5 per cent level that has been in place since the commencement of FCAS markets in 2001. In September 2019, AEMO made a change to reduce the amount of assumed mainland load relief from 1.5 per cent to 0.5 per cent, with a review point at 1 per cent.

In addition to these changes, AEMO increased mainland NEM base regulation FCAS volumes to 220 MW raise and 210 MW lower in over the period of March - May 2019[186]. These changes were made to improve power system security performance in terms of frequency management.

The Panel notes that increases to the base volume of regulation FCAS and reduction in mainland load relief have improved frequency performance over summer compared to 2018-19. The Panel also notes that the introduction of mandatory primary frequency response is expected to improve frequency performance in 2020-21[187]. This rule is discussed in more detail in Section 4.4.

4.3.7 System services

Ancillary services are used by AEMO to manage the power system safely, securely and reliably. These services maintain key technical characteristics of the system, including standards for frequency, voltage, network loading and system restart processes.

AEMO operates eight separate markets for the delivery of frequency control ancillary services (FCAS), and purchases network support control ancillary services (NSCAS) and system restart ancillary services (SRAS) under agreements with service providers. Payments for ancillary services include payments for availability and delivery of these services.

FCAS markets

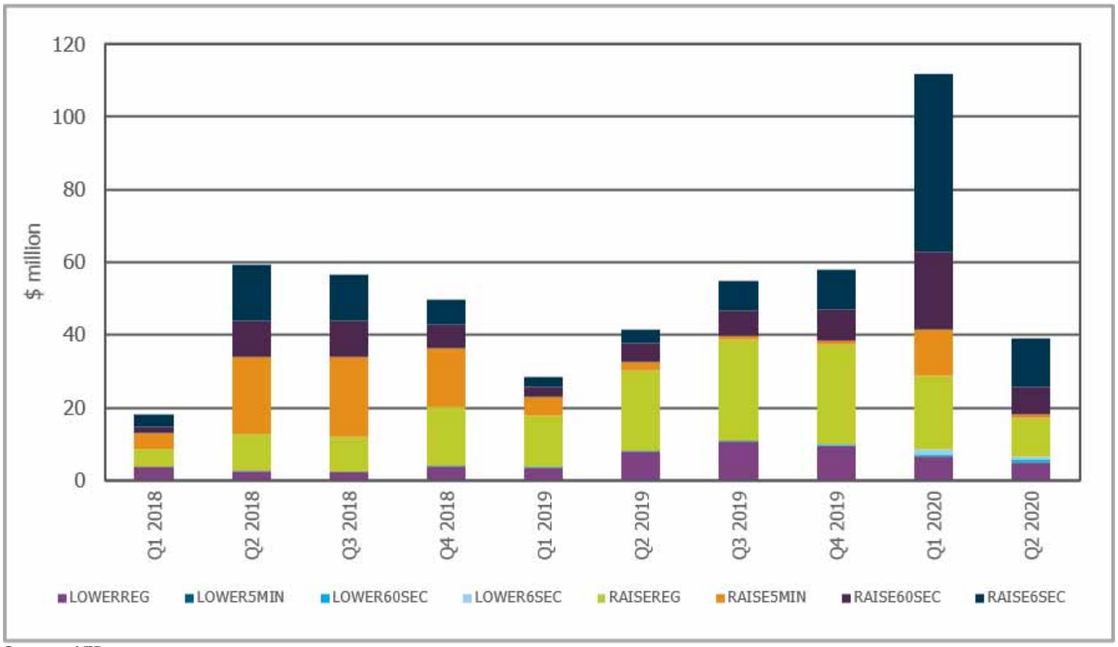
FCAS services are used to raise system frequency if it has fallen (by increasing generation or reducing load) and to lower system frequency if it has risen (by decreasing generation or increasing load). FCAS are intended to work together to maintain a steady frequency during normal operation, and to stabilise and restore the frequency by reacting quickly and smoothly to contingency events that cause frequency deviations.

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. Overall, FCAS costs were $263.8 million in 2019-20, up from $176 million paid in 2018-19. Raise services continued to represent the majority of FCAS costs in 2019-20, which has been the case historically. The Panel notes the South Australian separation event contributed to this increase, with FCAS costs spiking during quarter one 2020 as can be seen in Figure 4.9.

186 Regulation FCAS is used to correct minor increases or decreases in frequency https://aemo.com.au/-/media/files/pdf/guide-to-ancillary-services-in-the-national-electricity-market.pdf

187 AEMC, Mandatory primary frequency response, https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response

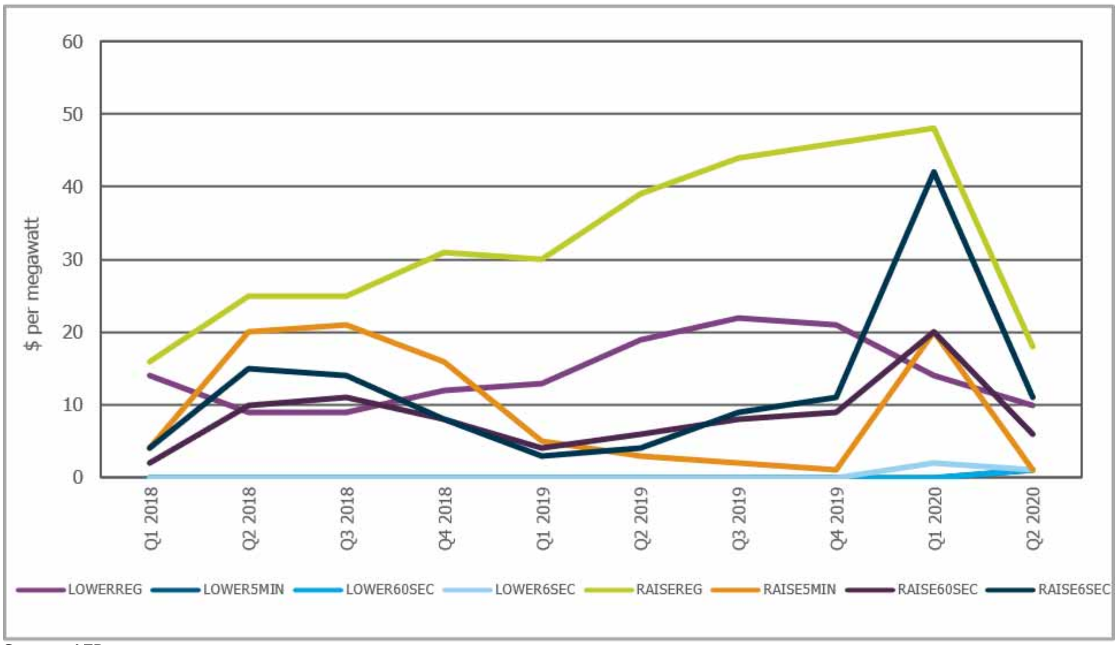
Figure 4.9: Quarterly global FCAS costs by service



Source: AER

The price of FCAS services also changes in response to changing market conditions. As with FCAS costs, prices for raise services including regulation, five minute, 60 second and six second all spiked in quarter one 2020, driven by the South Australian separation event. Prices for lower services on the other hand did not experience the same changes, with regulation lower decreasing in price from quarter four 2019 to quarter one 2020. Following the spike in quarter one 2020, FCAS prices decreased in quarter two 2020, with services such as regulation raise and regulation lower moving to low prices relative to the last two years.

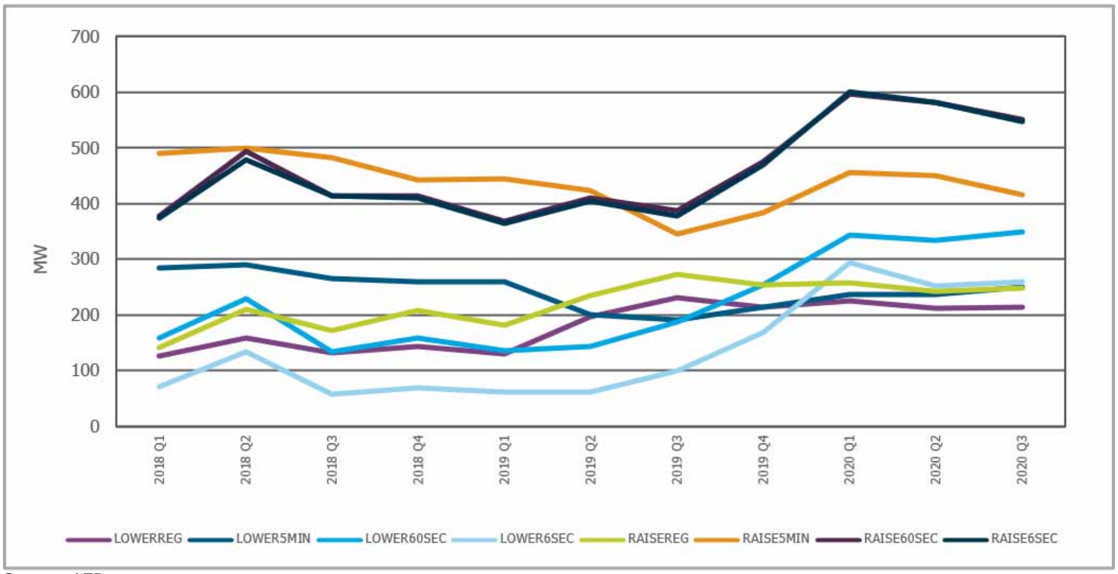
Figure 4.10: Quarterly global FCAS prices by service



Source: AER

Finally, as noted in Section 4.3.4, in quarter two 2019, AEMO implemented increases to the base volume of regulation FCAS procured to help control frequency within the normal operating band at least 99 per cent of the time. AEMO has also reduced the mainland load relief from 1.5% to 0.5%, leading to the average volume of contingency FCAS enabled increasing since quarter three 2019. This trend is illustrated in Figure 4.11.

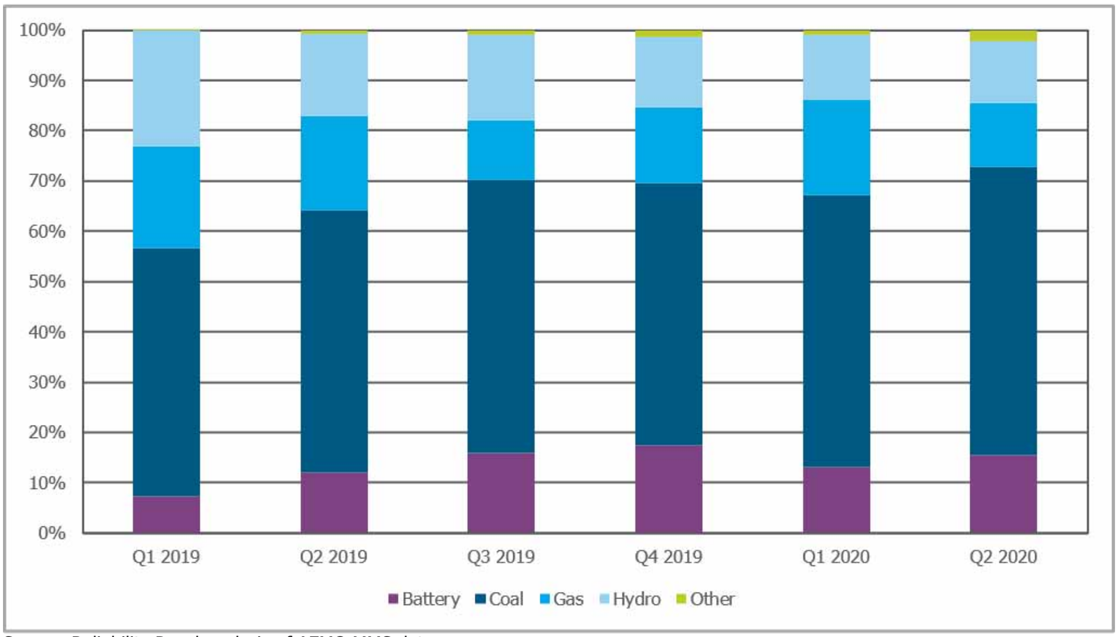
Figure 4.11: Quarterly global FCAS enablement by service



Source: AER

Figure 4.12 illustrates the providers of regulation raise FCAS services by fuel type. FCAS provided by batteries has increased since quarter one 2019, and the amount provided by hydro and gas has decreased. The amount of services provided by coal has remained relatively steady over this period.

Figure 4.12: FCAS regulation raise provision by fuel type



Source: Reliability Panel analysis of AEMO MMS data

Procurement of system restart ancillary services

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[188]. SRAS is currently provided by generators with the capability to start, or remain in service, without electricity being provided from the grid. Once an SRAS provider has restarted its own plant, it provides energy to restart other generators and commence the processes required for system restoration. There is an additional cost involved to equip generating plant with this capability and not all generators have it.

The Panel is responsible for determining the system restart standard, which specifies the level of supply restoration for which AEMO is to procure system restart services.[189] The system restart standard specifies the parameters for restoring generation and transmission system operations after a major supply disruption including a black system event. The parameters included in this standard are:

- The maximum time in which a specified level of generation capability must be restored in each sub-network

188 AEMO, SRAS guidelines 2020, https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/sras/sras-guideline-2020.pdf?la=en

189 Reliability Panel, Review of the system restart standard 2020, https://www.aemc.gov.au/market-reviews-advice/review-system-restart-standard-2020

- The aggregate level of reliability of restart services in each sub-network, that is, the overall reliability of the SRAS procured for the sub-network rather than just for any individual sources of SRAS.

AEMO must use reasonable endeavours to acquire sufficient SRAS for each defined electrical sub-network to meet the requirements of the system restart standard. The NER sets out a framework for how the restoration of the system should be managed. Careful planning and clear communication between these various parties is critical to the effective restoration of supply to customers.

The system restart standard applicable to the reporting period was determined in December 2016 following a year-long consultation process with energy users, industry, jurisdictional system security co-ordinators and state and territory governments, and came into effect on 1 July 2018.[190] The standard has a more stringent process for procurement of restart services that is tailored to the specific requirements of each electrical sub-network and made recommendations to improve testing and load restoration.

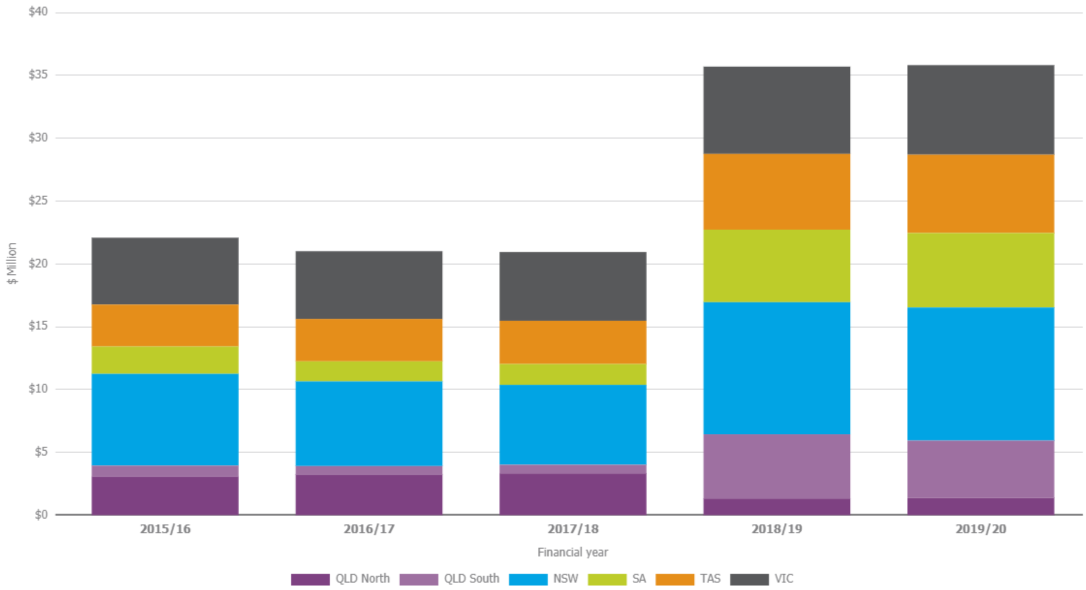
Under the standard:

- The level and time components are now tailored for each electrical sub-network to reflect the speed at which the generation can be restored, the characteristics of the transmission network and the economic circumstances that apply to the sub-network
- Costs of SRAS are minimised by specifying the minimum level of generation and transmission capacity to be restored by SRAS in each sub-network in accordance with a detailed economic assessment of procuring different levels of SRAS
- The aggregate reliability of the SRAS procured for each electrical sub-network is included. This requirement better specifies the performance of the procured SRAS, and includes a requirement for AEMO to consider the reliability and damage to the transmission network following a major supply disruption when it calculates aggregate reliability.

For 2019-20, AEMO procured 12 SRAS contracts, with a total of two being procured for each sub-network area in the NEM, namely North Queensland, South Queensland, New South Wales, Victoria, South Australia and Tasmania. The total cost of these SRAS contracts was $35.8 million, a slight increase from 2018-19 that largely occurred due to inflation. As mentioned in 2019 AMPR, the increase in costs from 2017-18 to 2018-19 can be attributed to new requirements of the new system restart standards that commenced in 2018.

190 Reliability Panel, Review of the system restart standard, https://www.aemc.gov.au/markets-reviews-advice/review-of-the-system-restart-standard

Figure 4.13: SRAS costs



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

The Panel notes that in January 2020,the AEMC made a final rule to enhance the frameworks for system restart and restoration[191]. The final rule makes changes to the frameworks for the procurement, testing and deployment of SRAS that need to take place prior to the procurement of the next round of SRAS contracts. This will be discussed further in Section 4.4.2.

Procurement of network support and control ancillary services

Network support and control ancillary services (NSCAS) are a non-market ancillary service that may be procured by AEMO or TNSPs to maintain power system security and reliability and to maintain or increase the power transfer capability of the transmission network.[192] AEMO is required to assess NSCAS needs in the NEM for the upcoming five-year period. When AEMO identifies an NSCAS gap, the National Electricity Rules give TNSPs the primary responsibility for having arrangements in place to address the gap.

AEMO may be required to acquire NSCAS only to ensure power system security and reliability of supply of the transmission network in cases where AEMO considers that the gap will remain after receiving advice from the TNSPs about its proposed arrangements to address the gap.

191 AEMC, System restart services, standards and testing, https://www.aemc.gov.au/rule-changes/system-restart-services-standards-and-testing

192 https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/network-support-and-control-ancillary-services-procedures-and-guidelines#:~:text=Network%20Support%20and%20Control%20Ancillary%20Services%20(NSCAS)%20are%20non%2D,capability%20of%20the%20transmission%20network.

AEMO did not procure any NSCAS contracts in its role as the market operator in 2019-20.[193] NSCAS costs for AEMO as the market operator were $0 in 2019-20. AEMO has not forecast the need to procure NSCAS contracts in its role as the market operator in 2020-21.

The Panel notes that AEMO has recently updated its NSCAS procedures.[194] In September 2020, AEMO determined to amend the NSCAS description and quantity procedure. A key change to the NSCAS description was to change the types of NSCAS to reflect the NSCAS need.[195]Currently, NSCAS types are classified according to electrical phenomena. The procedures will now classify NSCAS types according to which of the two NSCAS needs the service would primarily address. The new types are:

- Reliability and Security Ancillary Services (RSAS): A non-market ancillary service primarily procured in order to assist AEMO to operate the NEM within the System Security and Reliability Standards. This service will exclude any services excluded by the rules that have existing frameworks.
- Market Benefit Ancillary Services (MBAS): A non-market ancillary service primarily acquired to increase the power transfer capability of the transmission network, to maximise the present value of net economic benefit to all those who produce, consumer or transport electricity in the market. The identification of the top binding current and/or projected top binding future constraints would be assessed to determine if there is an identified need to alleviate these constraints.

Key changes to the NSCAS quantity procedure include:

- The ability to restore the network to a secure operating state within 30 minutes in RSAS assessments
- The assessment of forward-looking constraints in MBAS studies, which can be proposed by participants along with viable, technology agnostic solutions
- Improved collaboration with TNSPs at the start and finish of the quantity determination process, to discuss inputs and assumptions and later study results.

These changes became effective on 1 October 2020. The Panel notes that these changes may have an impact on NSCAS procurement in the future.

4.3.8 Market notices

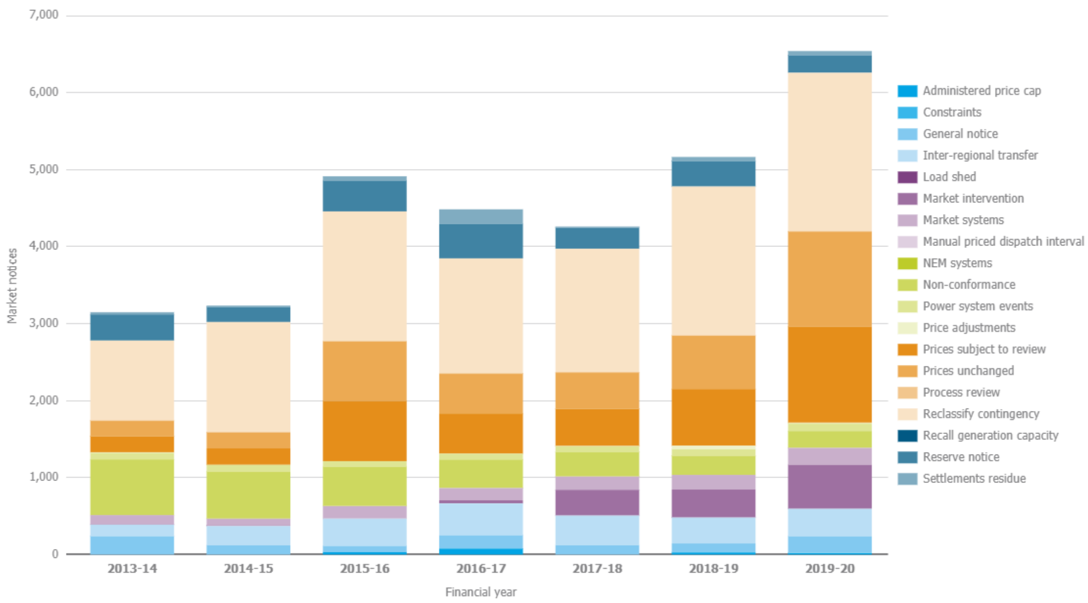
AEMO issues market notices to communicate to participants events that impact on the market, including interventions, reserves notices and power system events. Figure 4.14 displays the number and type of market notice issued each financial year.

193 AEMO is also the TNSP for Victoria, and may have procured NSCAS contracts in this capacity.

194 https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/ncas/nscas-final-report-and-determination.pdf?la=en

195 https://aemo.com.au/en/consultations/current-and-closed-consultations/network-support-and-control-ancillary-services-description-and-quantity-procedure-amendments

Figure 4.14: Market notices issued by AEMO



Source: AEMO
Note: The data for this chart is available in the AMPR data portal.

The total number of market notices issued by AEMO in 2019-20 was 6,539, an increase from 5,540 in 2018-19. The significant drivers of this increase compared to 2018-19 included an increase of 210 for market intervention notices, an increase of 510 for prices subject to review and an increase of 544 for prices unchanged. The Panel notes that the has been an upwards trend in notices issued by AEMO since 2017-18. This may be reflective of the increasing challenges faced by AEMO when operating the power in a secure state.

4.4 Rule changes and other work

During 2019-20, a number of changes were made to the frameworks governing the management of system security in the NEM. The Panel has provided an overview of these changes and the impact that they may have on system security outcomes below. Key changes to the system security framework include:

- Changes to the provision of primary frequency response
- Changes to the provision of system restart services, standards and testing
- Changes in monitoring and reporting of frequency performance, and
- COAG Energy Council interim security measures.

4.4.1 Mandatory primary frequency response

As noted in Section 4.3.6, the maintenance of power system frequency at 50 Hz is important for ensuring the power system remains in a secure operating state. Frequency varies whenever electricity supply does not exactly match consumer demand and uncontrolled changes in frequency can cause blackouts.

On 26 March 2020, the AEMC made a final rule to require 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.[196] Key aspects of the final rule include:

- All scheduled and semi-scheduled generators who have received a dispatch instruction to generate to a volume greater than 0 MW, must operate their plant in accordance with the performance parameters set out in the primary frequency response requirements (PFRR) as applicable to that plant.
- AEMO must consult on and publish the PFRR, which will specify the required performance criteria for generator frequency response, which may vary by plant type.
- Generators may request and AEMO may approve variations of exemptions to the PFRR for individual generating plant.

AEMO has advised that the application of a mandatory obligation on generators to provide primary frequency response will address the immediate system security needs of the power system. As noted in Section 4.3.6, the introduction of mandatory primary frequency response is expected to result in an improvement frequency performance over 2020-21. This rule commenced on 4 June 2020.

This rule is part of the frequency control work plan which sets out a series of actions that the ESB, AEMO, AEMC and AER are undertaking to review and reform the frequency control frameworks in the national electricity market. This workplan was a key outcome of the Frequency control frameworks review, that was completed in 2018.[197] The AEMC, in collaboration with the ESB and other market bodies, has developed a revised Frequency control work plan that provides an update on progress to date, as well as an indication of the next steps in the reform pathway for frequency control frameworks in the NEM.

AEMO is currently in the process of co-ordinating changes to generator control systems in accordance with the Mandatory primary frequency response rule change. This implementation commenced in June 2020 and is being undertaken over 3 tranches, with an expected completion date of December 2021[198].

The AEMC intends to develop enduring arrangements for primary frequency response through its ongoing assessment of AEMO's related rule change request, the Primary frequency response incentives rule change[199]. Through this rule change, the AEMC will investigate the appropriateness of the existing incentives for primary frequency response during normal operation and amend these arrangements as required to meet future needs of the power system. Through this rule change, the AEMC intends to develop enduring arrangements for primary frequency response which will include:

196 https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response

197 AEMC, Frequency control frameworks review, https://www.aemc.gov.au/markets-reviews-advice/frequency-control-frameworks-review

198 AEMO, Primary frequency response, https://aemo.com.au/en/initiatives/major-programs/primary-frequency-response

199 AEMC, Primary frequency response incentive arrangements, https://www.aemc.gov.au/rule-changes/primary-frequency-response-incentive-arrangements#:~:text=On%2026%20March%202020%2C%20the,in%20a%20frequency%20responsive%20mode.

- Confirmation of the regulatory arrangements and the enduring role of mandatory primary frequency response.
- Development of alternative or complementary arrangements to procure and price continuous narrow band primary frequency response.
- Consideration of the cost allocation arrangements for primary and secondary frequency regulation services. This includes consideration of potential changes to the existing causer pays process, and
- Consideration for potential revisions to the frequency operating standard in relation to how the required frequency performance of the power system during normal operation is specified.

Monitoring and analysis of plant and power system impacts during the roll out of the mandatory primary frequency response requirement will help inform the AEMC's determination of the enduring primary frequency response arrangements.

4.4.2 System restart services, standards and testing

As noted in Section 4.3.7, system restart ancillary services 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. On 2 April 2020, the AEMC made a final rule to enhance the frameworks for system restart and restoration.[200]

The final rule:

- Expands the definitions of SRAS and black start capability to allow AEMO to procure the services needed to effectively and promptly restore supply to customers.
- Clarifies that AEMO can take overall costs into account when procuring SRAS (including both short-term and long-term costs).
- Establishes a transparent framework for the physical testing of system restart paths.
- Clarifies the role of different parties involved in system restoration and the communication processes they must follow with respect to SRAS.

The key changes to the definition of SRAS and black start capability are:

- The definition of black start capability is amended to allow for this capability to be provided by plant other than generating units. This may include, for example, battery storage systems and new technologies utilising grid-forming inverters which may be capable of providing this service.
- The definition of SRAS is expanded to include system restoration support services. These are a new type of ancillary service that support the stable re-energisation of the grid, in support of black start services. These services will be specified by AEMO and procured under the SRAS procurement framework.

The AEMC considers that these changes are necessary to make sure that the SRAS frameworks in the rules can adapt as needed as the power system continues to change.

200 https://www.aemc.gov.au/rule-changes/system-restart-services-standards-and-testing

Taken together, these changes are expected to improve the security and resilience of the power system and reduce costs for consumers over the long-term.'

The Reliability Panel published a final report and determination for its 2020 System restart standard review in January 2021. The Standard specifies requirements applying to AEMO's procurement of SRAS which are used to restart the power system in the event of a major supply disturbance or black system event[201].

The scope of the review is to consider changes to the Standard to:

- Account for changes made in the Commission's SRAS rule to the types of services AEMO can procure as SRAS and
- Determine restoration timeframes, levels of restoration and aggregate reliability requirements for a single Queensland electrical sub-network in a final standard, following AEMO's decision on 16 October 2020 to combine the two existing Queensland sub-networks.

The 2020 Review was required to address changes made by AEMO to the boundaries of Queensland sub-networks and the AEMC to the SRAS framework. The review was therefore focused on the elements of the Standard relevant to those specific changes. A holistic review to consider the Standard settings in each NEM region is proposed following completion of AEMO's 2021 SRAS procurement round.

4.4.3 Monitoring and reporting on frequency control framework

On 25 July 2019, the AEMC made a final rule which establishes ongoing reporting requirements on AEMO in relation to the frequency and frequency control performance[202]. The final rule also establishes ongoing reporting requirements on the AER in relation to the performance of FCAS markets.

The final rule requires:

- The AER to report quarterly on each FCAS market, as well as provide an analysis of key trends and outcomes in these markets.
- AEMO to report weekly on key frequency performance metrics as well as on the amount and utilisation of regulation FCAS.
- AEMO to report quarterly on frequency performance against the frequency operating standard.

This final rule improves the transparency and consistency of information provided to the market in relation to frequency performance and FCAS market outcomes. This will help market participants make more efficient investment and operational decisions by providing additional information on frequency and frequency performance.

201 Reliability Panel, Review of the system restart standard 2020, https://www.aemc.gov.au/market-reviews-advice/review-system-restart-standard-2020

202 AEMC, Monitoring and reporting on frequency control framework, https://www.aemc.gov.au/rule-changes/monitoring-and-reporting-frequency-control-framework

4.4.4 Interim security measures

At the meeting on 20 March 2020, the COAG Energy Council considered a range of actions to improve security in the NEM[203]. This included noting the System Security Workplan reflecting the regulatory and technical tasks that are either already underway or scheduled to be underway in order to promote system security. The workplan builds on a number of recent rule changes that address system security challenges. The interim measures under consideration include:

- The provision of information from scheduled generation units of commitment timeframes, cost and operating information to assist potential intervention decisions.
- Semi-scheduled plant being required to continually inform AEMO of any restrictions on their available capacity due to physical factors, ambient weather conditions and their market intentions.
- Consideration to requiring large loads of a certain size and type to submit the intent to respond to spot prices.
- Clear notice periods and potential constraints on scheduled generators changing their commitment and decommitment decisions at short notice.
- That semi-scheduled generators be obligated to follow their dispatch targets, in a similar manner to scheduled generators.
- That compensation mechanisms be reviewed to determine whether compensation should be payable if the generator in question changes its intentions to commit or decommit at short notice and whether other refinements to the compensation regime are warranted.

4.5 Panel insights: Security

The Panel notes that the management of system security was challenging in 2019-20. Challenges in maintaining system security were contributed to by the rapid transition to higher penetrations of inverter-based generation resources as well as extreme environmental events.

The challenge in maintaining system security is reflected in the increase in key metrics over the reporting period. 2019-20 saw an increase in reviewable operating incidents, as well as three events when the power system was not in a secure operating state for more than 30 minutes. In addition to this, the South Australian separation event, caused by damaging storms, required AEMO to operate the system in a new configuration. This event led to significant increases in use of directions as well as FCAS over the reporting period.

The Panel considers that in addition to these already noticeable trends, the speed at which DER uptake is continuing may exacerbate issues associated with minimum system load, including system strength, inertia and ramping in the near future. These issues have been considered, however the speed of onset is faster than was initially forecast. AEMO have noted that these issues are of immediate concern. The Panel notes that the rapid changes in DER uptake has presented challenges to accurately forecast changes occurring in the power

203 Energy Ministers Meeting, Interim Security Measures, https://energyministers.gov.au/interim-security-measures

system. The Panel considers that the ability for AEMO to accurately forecast and account for the impact of rooftop PV across the day is an important area that needs some consideration, particularly, given the impact that this reduction in demand has on the maintenance of system security and the ability to respond and manage rapid changes occurring in the power system that may occur at any one time.

The Panel notes that the existing system security framework has enabled AEMO to avoid major negative impacts. There is a large work program underway to ensure that AEMO is able to effectively manage system security in the future. Given the NEM is at the global forefront of integration of inverter-based generation into the grid, the Panel considers that it will be important to ensure that updated security frameworks provide the flexibility necessary to deal with unexpected issues effectively.

The Panel notes that the AEMC is currently considering a rule change from the COAG Energy Council regarding the implementation of a general power system risk review.[204]

The Panel also notes that AEMO is currently investigating the necessary features to ensure that the power system security framework is fit for purpose for the transition through its Engineering Framework report. As part of this study, AEMO have identified 10 focus areas across three key themes, being:

- Attributes: Fundamental technical elements of power system operation that are needed to ensure reliability and security
- Operability: Ability to manage the power system within security and reliability standards, and included the data, tools, training analytical capability and market mechanisms to support operation.
- Integration: The process of adapting both the existing system and the innovative ways in which parties are interacting with the power system so that the system can continue to meet consumer expectations.

The Panel notes that this work, along with the AEMC work on frequency control and system strength and the ESB Post 2025 Market Design work will be important for ensuring that the system security framework remains fit for purpose.

204 AEMC, Implementing a general power system risk review, https://www.aemc.gov.au/rule-changes/implementing-general-power-system-risk-review

5 SAFETY

This section covers the Panel's assessment of safety of the power system in 2019-20. The Panel notes that its role in regard to safety for the purposes of this report relates primarily to the operation of assets and equipment within their technical limits.

This chapter sets out:

- Outline and definition of power safety for the purposes of this review,
- Safety performance in 2019-20
- Developments around system safety.

5.1 What is power system safety for the purposes of this review?

The safety of the national electricity system can be understood to mean that:

- The transmission and distribution systems and the generation and other facilities connected to them are safe from damage, or
- The transmission and distributions and generation and other facilities connected to them are not a source of injury and danger.

Safety performance of the power system: The National Electricity Law and NER set out the functions and power of the Reliability Panel, which include a function to monitor, review and report on safety in accordance with the rules. However, the NER do not specify additional requirements in relation to safety performance reporting.[205] The Panel also has the function of advising in relation to the safety of the national electricity system at the request of the AEMC. The terms of reference provided by the AEMC request that the Panel provide advice in relation to the safety, security and reliability of the power system. In accordance with the terms of reference issued by the AEMC, for the purposes of the safety assessment the Panel has considered the maintenance of power system security within the relevant standards and technical limits.

5.2 How is a safe power system delivered?

The safety of the power system, and associated equipment, power system personnel and the public is covered in general terms under the NEL.[206] 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. Each jurisdiction has its own approach to setting out obligations relating to safety in the power system, and enforcing these obligations. Network service providers and other market participants also have specific responsibilities to provide for the safety of personnel and the public.

205 Instead, the functions of the Reliability Panel under clause 8.8.1 of the NER provide that the functions of the Panel is to, among other things, monitor, review and report on the performance of the market in terms of reliability of the power system, report to the AEMC and jurisdictions on overall power system reliability matters and undertake a number of functions relating to the security of the power system. The reliability and security focus of the Panel under the NER is reflected in the scope of the annual market performance review that the Panel is required to undertake under clause 8.8.3(b) of the NER.

206 Section 38(2)(b) of the NEL.

The power system is also designed with extensive safety systems to provide the protection of the system itself, workers and the public. Network constraints, developed from TNSP limit advice, are used by AEMO in the NEM dispatch process to make sure that plant remains within rating and power transfers remain within stability limits so that the power system is in a secure operating state.[207] Should AEMO not be able to manage secure and satisfactory limits through the use of network constraints, the following options can be used, potentially in combination. These options are listed in AEMO's suggested priority order and may not all be available under all circumstances:

- Revision to generator thermal ratings.
- Revision to power system limits.
- Implement plan agreed between AEMO and relevant registered participants (e.g. Contingency plan, Network Support Agreement (NSA)).
- Reconfigure network.
- Dispatch or activation of reserve contracts to address a power system security event.
- System security direction or instruction issued under clause 4.8.9 of the rules
- If sufficient raise FCAS are unavailable, use system security constraints to reduce the size of the largest generation at risk. If sufficient lower FCAS are unavailable, issue a direction under section 116 of the NEL for a reduction in the size of the largest load at risk.
- Instruct involuntary load shedding.

5.3 Safety performance of the power system in 2019/20

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 2019-20 reporting period where AEMO's management of power system security has resulted in a safety issue with respect to maintaining the system within relevant standards and technical limits.

The Panel also notes that there were no instances in 2019-20 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.

5.4 Developments in system safety

The Panel notes that there have been a number of changes that will improve the safety of the power system and reduce the risk of a significant safety event occurring. These changes include:

- Alarming added inertia monitoring.

207 AEMO, Power System Security Guidelines, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3715---Power-System-Security-Guidelines.pdf

- Improvements in process safety on the generation side.

5.4.1 Alarming added to inertia monitoring

As noted in section 5.2, the maintenance of the power system inside the relevant standards and technical settings is an important part of ensuring power system safety. As noted in Chapter 4.3.1, on 23 October 2019, the Tasmania region was not in a secure operating state for 37 minutes due to a shortfall in inertia levels.[208]

During this incident, Hydro Tasmania took one of the generating units at the Liapootah Power Station out of service as part of normal operation, resulting in a reduction of total inertia in Tasmania to below the required minimum level. AEMO was not made aware of the unit decommitment at the Liapootah Power Station prior to the event. TasNetworks advised AEMO of the inertia shortfall at 1100 hrs. Generating units at Liapootah are part of an aggregated generating unit for dispatch purposes, and AEMO had previously agreed with HydroTasmania that there was no requirement for Hydro Tasmania to advise AEMO of the commitment/de-commitment of individual generating units given that the aggregated unit met its dispatch targets.

Prior to TasNetworks providing AEMO with notification of the inertia shortfall, AEMO was unaware of the inertia shortfall. At the time of this event, AEMO had indications of inertia levels, but did not have alarming in place to alert operators to a shortfall. AEMO noted that had alarming been in place for inertia and procedures to manage any shortfall prior to this incident, the time that the power system was not in a secure operating state would likely have been reduced.

In response to this event, AEMO made the following changes:

- On 29 October 2019, AEMO updated its internal procedures dealing with managing inertia shortfalls.
- On 31 October 2019, AEMO implemented alarming on the inertia value for the Tasmanian region. Alarms are configured at 4200 megawatt seconds (MWs) to provide time to respond before critical levels (less than 3800 MWs) are reached.

The Panel notes that these measures may help avoid future periods where the power system is operating outside of its technical specifications, and therefore improve overall safety of the power system.

5.4.2 Improvements in process safety

Process safety management is the application of management principles and systems identification, understanding and control of process hazards to prevent process related incidents[209]. It is defined in the OHS Body of Knowledge as managing the integrity of operating systems by applying inherently safer design principles, engineering and disciplined

208 AEMO, Tasmania Inertia Issue Report, https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2019/tas-inertia-issue-report.pdf?la=en&hash=7950F7B08AD661638F7D7B9332D7E095

209 CS Energy, Process Safety Management, https://www.csenergy.com.au/ArticleDocuments/251/CS-RISK-08%20-%20Process%20Safety%20Management%20(12%2018)%20-%20CS%20Energy%20Registered.pdf.aspx

operating practices. Process safety generally has a greater focus on engineering and design of the safety of the system in comparison to occupational health and safety measures, which focus on those who interact with the system.

The Panel notes that since 2018, a number of NEM participants have published statements recognising the importance of process safety in their operations, and committing to improving process safety over time, including CS Energy[210], Origin[211] and Stanwell[212]. The Panel notes that these commitments to improving process safety may be beneficial to the overall safety performance of the NEM in the future.

210 CS Energy, Process Safety Management, https://www.csenergy.com.au/ArticleDocuments/251/CS-RISK-08%20-%20Process%20Safety%20Management%20(12%2018)%20-%20CS%20Energy%20Registered.pdf.aspx

211 Origin Energy, Our approach to Health safety environment, https://www.originenergy.com.au/content/dam/origin/about/Origin_our_approach_Health_safety_environment.pdf

212 Stanwell, Health and Safety Policy, https://www.stanwell.com/wp-content/uploads/Health-and-Safety-Policy-poster-V1.pdf

ABBREVIATIONS

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
Commission	See AEMC
MCE	Ministerial Council on Energy
NEL	National Electricity Law
NEO	National electricity objective
NERL	National Energy Retail Law
NERO	National energy retail objective
NGL	National Gas Law
NGO	National gas objective

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 TERMS OF REFERENCE

Introduction

These terms of reference are intended to guide the Reliability Panel (the Panel) in its annual market performance review (AMPR). The Australian Energy Market Commission (AEMC) requests that the Panel consider these to be the standing terms of reference for its annual review of the performance of aspects of the market specified under clause 8.8.3(b) of the National Electricity Rules (NER). For clarity, the market that this review relates to is the National Electricity Market (NEM). The purpose, scope and timing for this review are set out below.

Background

The functions of the Panel are set out in clause 8.8.1 of the NER.

- Under clause 8.8.1(a)(1), the Panel has a role to monitor, review and report on the performance of the market in terms of reliability of the power system.[213]
- Under clause 8.8.1(a)(5), the Panel has a role to report to the AEMC and participating jurisdictions on overall power system reliability matters, power system security and reliability standards and the Australian Energy Market Operator's (AEMO) power to issue directions in connection with maintaining or re-establishing the power system in a reliable operating state. The Panel may also make recommendations on changes to the market or the NER and any other matters which it considers necessary.

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 other such times as the AEMC may request. The Panel must conclude each annual review under this clause by the end of 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);[214]
- the policies and guidelines referred to in clause 8.8.1(a)(4);[215] and
- the guidelines referred to in clause 8.8.1 (a)(9).[216]

213 In performing this function, clause 8.8.1 (b) prohibits the Panel from monitoring, reviewing or reporting on the performance of the market in terms of reliability of distribution networks. However, the Panel may collate, consider and report information in relation to the reliability of distribution networks as measured against the relevant standards of each participating jurisdiction, in so far as the reliability of those networks impacts on overall power system reliability.

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

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

216 The guidelines referred to in clause 8.8.1 (a)(9) 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.

In addition, at the request of the AEMC, the Panel must provide advice in relation to the safety, security and reliability of the national electricity system.[217]

The Panel may, but is not required to, conduct this review in accordance with the Panel review process outlined in clauses 8.8.3(d)-(l) of the NER.

Purpose of the review

The AMPR provides the Panel with the opportunity to consider specific events that have occurred in the NEM over the previous financial year, and to assess the performance of the power system against various reliability, security and safety measures.

The AEMC requests the Panel to prepare:

1. at least two concise market performance updates to communicate key findings for each half-year period, or other relevant period determined by the Panel.
2. a written report, to communicate the findings of its full review of the previous financial year, including its complete observations and commentary on the reliability, security and safety performance of the power system.

The concise market performance updates provide an opportunity for the Panel to report on initial findings, update information in a more timely manner and to contextualise this update of the power system and market for that chosen period. Among other things, this will allow for more timely information to be communicated to stakeholders and to supplement the Panel's engagement with stakeholders.

The more fulsome written report provides an opportunity for the Panel to consolidate key information related to the performance of the power system and to present its more detailed observations and commentary in a single publication for the purpose of informing stakeholders. Among other things, this may assist governments, policy makers and market institutions to monitor the performance of the power system, and to identify the likely need for improvements to the various measures available for delivering reliability, security and safety.

Scope of the review

The AEMC requests that the Panel:

1. review the performance of the market in terms of reliability and security of the power system; and
2. provide advice in relation to the safety, security and reliability of the power system.

The Panel should have regard to the following matters when conducting its review:

- Overall power system performance

To provide a comprehensive overview of the performance of the power system, and where relevant information is available, the Panel should consider performance in terms of reliability and security, and from the perspective of:

217 National Electricity Law s.38(2)(b).

•
- the transmission and distribution sectors
- the generation sector.

The Panel's review of overall power system performance should include consideration of the impact on end-use customers. For example, customer impact could be measured in terms of the length of time that energy was not supplied to customers due to an incident occurring on the power system.

The Panel should also consider significant power system incidents ("reviewable operating incidents") which have occurred in the previous year. Where possible, consideration should be given to the cause of the incident (a reliability or security event), the impact of the incident (on reliability or security) and the sector of origin (generation, transmission or distribution).

The Panel should also consider general trends in the power system, such as changes in the generation mix or bulk transmission capability. This should include consideration of historic changes, as well as any forecasts or projections of future changes in the power system.

- Reliability performance of the power system, historic and forecast

The Panel should review performance against the reliability standard for generation and bulk transmission. This would require consideration of actual observed levels of unserved energy (USE) over the previous financial year, as well as projections and forecasts of expected levels of USE in future years. As such, consideration should be given to actual and forecast supply and demand conditions, by way of providing context and explanation as to the potential causes and drivers of these historic and forecast USE outcomes. This may assist the Panel to form a view on whether any underlying changes to reliability performance have, or are expected to have, occurred.

The Panel should also consider AEMO's use of the reliability safety net mechanisms over the previous financial year. This includes incidents of, and reasons for, the use of directions and the Reliability and Emergency Reserve Trader (RERT) mechanism. It also includes consideration of the frequency of AEMO’s issuance of lack of reserve notices over the previous year.

- Security performance of the power system, historic and forecast

The Panel should review historic performance of the power system against the relevant technical standards. In particular, the Panel should have regard to: frequency operating standards; voltage limits; interconnector secure line rating limits; system stability; and any other factors that the Panel may consider relevant. The Panel should also consider any projections or forecasts of future power system security performance. The Panel should provide context and explanation on the potential causes and drivers of both historic and forecast power system security performance.

- Safety performance of the power system

Safety of the power system is closely linked to the security of the power system and relates primarily to the operation of assets and equipment within their technical limits. Therefore, for the purposes of the safety assessment the Panel should consider the maintenance of power system security within the relevant standards and technical limits.

The Panel may also wish to consider the following matters when conducting its review:

- A comparison of power system performance against the previous year, and the reasons for any variations.
- A comparison of power system performance between regions, and reasons for any variations.
- The degree of accuracy in forecast and actual data, and reasons for any variations.
- Mechanisms in place for promoting power system performance, and whether they are effective.

The Panel should also have regard to any relevant reviews, reports or other processes being progressed by the other market bodies, or any other agency, that considers or proposes potential market framework changes that will directly impact the NEM power system. The Panel should consider and explain how these reports and processes are relevant to any issues identified by the Panel in its review.

Process and deliverables

The Panel must notify all registered participants of the commencement of this review and of the indicative timetable for this review. This information is to be published by the AEMC on its website.

The Panel may consider where practicable inviting stakeholders' submissions and/or holding a public meeting, in each case with a reasonable period of notice to stakeholders.

The Panel must send a copy of each market performance update to the AEMC for publication on the AEMC website.

By the end of the financial year following the financial year to which the review relates, the Panel must send a copy of the final report to the AEMC for publication on the AEMC website.

The Panel should engage with key stakeholders during the AMPR for the purposes of coordinating and gathering all relevant information for preparation of the market performance updates and the final report. Key stakeholders include the following:

- AEMO.
- The Australian Energy Regulator (AER).
- Transmission network service providers.
- Distribution network service providers.
- Jurisdictional regulatory bodies and governments.

The Panel should also engage more broadly with other external stakeholders including consumer representatives.

The Panel should have regard to any relevant reports/material, which may include consultant reports or advice.

B SECURITY AND RELIABILITY WORK PROGRAM

In this section, the Panel has listed the current and recently completed projects that relate to reliability and security in the NEM. It includes some of the projects led by each of the three market bodies and the ESB. The list is not exhaustive but aims to provide stakeholders with a better understanding of market body and ESB actions to address the security and reliability challenges facing the NEM.

The Panel notes that governments are also taking action to improve security and reliability outcomes in their jurisdictions. Government actions are not captured in the list below.

B.1 Energy Security Board

Post 2025 market design: The COAG Energy Council requested the ESB advise on a long-term, fit-for-purpose market framework to support reliability, modifying the NEM as necessary to meet the needs of future diverse sources of non-dispatchable generation and flexible resources including demand side response, storage and distributed energy resource participation. The ESB published an options paper for consultation in April 2021, and is preparing final advice for ministers due to be published in June 2021.

Interim Reliability Measure: On 18 November 2020 the Energy Security Board (ESB) published a set of changes to the National Electricity Rules to amend the triggering of the Retailer Reliability Obligation (RRO). These Rules will align the declaration of a Forecast Reliability Gap with the new Interim Reliability Measure (0.0006% USE) that commenced in August 2020. These rules were recommended and approved by Energy Ministers in November 2020, following consultation undertaken by the ESB at the request of the former COAG Energy Council. The implementation of this will be covered in the next AMPR.

Health of the NEM: Each year the ESB delivers a Health of the National Electricity Market report to the Council that tracks the performance of the system, the risks it faces, and the opportunities for improvement. The ESB has reported on the health of the NEM annually since December 2017. The 2020 Health of the NEM was released on 5 January 2020, and noted that security remains the most concerning issue in the NEM, and that these issues are complicated by the significant pace of change and lack of markets for all necessary system services.

Renewable Energy Zones: On 5 January 2020, the ESB published a consultation paper on Renewable Energy Zones. The purpose of this document was to outline the options for the implementation of REZs being considered by the ESB and to seek input from stakeholders. It sets out options for how REZs could be implemented in the near term, addressing questions of how to establish a REZ, and how to maintain a REZ once it is established.

B.2 AEMC

Table B.1: Security-related rules - current and recently completed

RULE	STATUS	DESCRIPTION
Technical standards for DER	Initiated 25 June 2020; final determination published 25 February 2021.	The final determination was to make a more preferable rule to create an initial set of technical standards that will apply to DER across the NEM. These Technical Standards have been achieved by using the existing compliance and monitoring systems under the CEC and the CER.
Effective management of system strength	Initiated 2 July 2020; draft determination published in April 2021 and currently out for consultation.	Draft rule to amend the NER to deliver an evolved framework for system strength, comprising of three key elements: • A new obligation on transmission networks to provide the right amount of system strength, when and where it is needed, to keep the power system secure • New access standards for large loads like hydrogen and generators • A new way of charging for system strength
Changes to intervention mechanisms	Initiated 28 May 2020; final determination published 10 September 2020.	Improve the efficiency and clarify of interventions mechanisms. The rule: • Removes the mandatory restrictions framework • Removes the obligation on AEMO to counteract during an intervention • Clarifies the basis for affected participant compensation cost

RULE	STATUS	DESCRIPTION
		recovery following activation of emergency reserves under the RERT.
System restart services standards and testing	Initiated 19 September 2019; final determination published 2 April 2020.	Enhancing the frameworks for system restart and restoration. The final rule: • Expands the definitions of SRAS and black start capability, to allow AEMO to procure the services needed to effectively and promptly restore supply to consumers. • Clarifies that AEMO can take overall costs into account when procuring SRAS (including both short-term and long-term costs). • Establishes a transparent framework for the physical testing of system restart paths. • Clarifies roles of the different parties involved in system restoration and the communication processes they must follow with respect to SRAS.
Mandatory primary frequency response	Initiated 19 September 2019; final determination published 26 March 2020.	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. Key aspects of the final rule include: •

RULE	STATUS	DESCRIPTION
		• All scheduled and semi-scheduled generators, who have received a dispatch instruction to generate a volume greater than 0 MW, must operate their plant in accordance with the performance set out in the primary frequency response requirements as applicable to that plant. • AEMO must consult on and publish the PFRR, which will specify the required performance criteria for generator frequency response, which may vary by plant type. • Generators may request and AEMO may approve variations or exemptions to the PFRR for individual generating plant.
Implementing a general power system risk review	Initiated 14 January 2021; draft determination published 4 February 2021.	Implementation of a general power system risk review, covering future management of non-credible contingencies and other events and conditions may lead to cascading outages or major supply disruptions.
Enhancing operational resilience in relation to indistinct events	Initiated 17 December 2020; draft determination to be published 28 October 2021.	Introduction a framework to manage indistinct events. The proposed rule would: • Introduce the new definition of an 'indistinct event'. • Clarify that standing risks from indistinct events can

RULE	STATUS	DESCRIPTION
		be managed as a type of protected event. • Enhance the protected event approval process to manage standing indistinct events. • Implement a new operational tool, protected operation, allowing AEMO to more effectively manage condition-dependent indistinct events.
Synchronous services markets	Initiated 2 July 2020; draft determination due 30 September 2021.	Amend the NER to create a market for synchronous services, including inertia, voltage control and fault level/system strength. The rule change proposal involved: • Creating a new generator category of synchronous service generator. • Generators being paid based on their bid price for providing synchronous services, rather than the spot price.
Fast frequency response market ancillary service	Initiated 2 July 2020; draft determination published 22 April 2021.	Introduction of two new market ancillary services to help control system frequency and keep the future electricity system secure. The draft rule introduces two new market ancillary service categories into the NER for: • The very fast raise service • The very fast lower service
Capacity commitment	Initiated 2 July 2020; draft	Introduction of capacity

RULE	STATUS	DESCRIPTION
mechanism for system security	determination due 24 June 2021.	commitment mechanism to provide access to operational reserve and other system security or reliability services. The proposed rule would involve: • Day-ahead commitment of dispatchable capacity, at a level set by AEMO to ensure peak demand can be reliably met • Generators would guarantee to commit their coal/gas boiler synchronous units for either an entire day of for specific trading intervals during the day rather than via half-hour ahead market for reserve.
Introduction of ramping services	Initiated 2 July 2020; directions paper released 5 January 2021.	Introduction of new 30-minute raise and lower ramping frequency control ancillary services. The directions paper: • Considers the ability of the current market frameworks address variability and uncertainty in power system conditions. • Outlines high-level designs for four options to procure reserve services.
Maximum reactive current during a fault	Pending.	Maximum reactive current value would be changed to correctly align the frame of voltage control in remote/weak grids.

RULE	STATUS	DESCRIPTION
Review of the system restart standard 2020	Initiated 24 June 2020; final determination published 28 January 2021.	Amend the targets set out in the standard applying to AEMO's procurement of SRAS in Queensland. The Panel also included a requirement for AEMO to procure SRAS north of Bundaberg as an additional locational element of its final determination.

Table B.2: **Reliability-related rules - current and recently completed**

RULE	STATUS	DESCRIPTION
Operating reserve market	Initiated 2 July 2020; directions paper released 5 January 2021.	Introduction of an operating reserve market in the NEM to respond to unexpected changes in supply and demand. The directions paper: • Considers the ability of the current market frameworks address variability and uncertainty in power system conditions. • Outlines high-level designs for four options to procure reserve services.
Reliability standard and settings review 2021	Pending	Review of the reliability standard and settings for the period of 2024-2028. The reliability settings consist of: • Market Price Cap • Market Floor Price • Cumulative Price Threshold • Administered Price Cap
Improving transparency and	Initiated 18 July 2019; final	The final rule:

RULE	STATUS	DESCRIPTION
extending duration of MT PASA	determination published 20 February 2020.	• Improves transparency of the MT PASA process. • Makes market information available when it is most needed. • Extends the period generation availability is published from two to three years.
Delayed implementation of five minute and global settlement	Initiated 14 May 2020; final determination published 9 July 2020	Delays the implementation of five minute settlement by three months, so that they commence on 1 October 2021. The shorter delay: • Recognises the short-term impact of COVID-19 on participant capabilities. • Does not significantly increase or decrease 5MS and GS implementation costs. • Does not materially reduce the broader market and consumer benefits from the rules.
Wholesale demand response mechanism	Initiated 15 November 2018, final determination published 11 June 2020	Introduction of a mechanism for wholesale demand response in the NEM. The final rule: • Creates a new participant category of demand response service provider. • A DRSP can bid into the wholesale market as a substitute for generation.
Transparency of new projects	Published 24 October 2019	Allows a broader set of project developers direct access to important system information required to build grid-scale assets. The final

RULE	STATUS	DESCRIPTION
		rule: • Facilitates greater access to relevant system information for developers that sell grid-scale assets prior to connection. • Codifies AEMO's generation information page in the NER. • Requires TNSPs to share basic connection information about new generation projects with AEMO.
Participant derogation - Financeability of ISP projects (TransGrid)	Initiated 5 November; final determination published 8 April 2021.	Rule not made to bring forward cash flows for its share of current and future actionable ISP projects.
Semi-scheduled generator dispatch obligations	Initiated 15 October 2020; final determination published 11 March 2021	Amend semi-scheduled generator dispatch obligations to comply with a MW dispatch level for all dispatch intervals. • Semi-scheduled generators may vary above or below the dispatch level as a result of energy source availability except in a semi-dispatch interval where the semi-scheduled generator must not exceed the dispatch level regardless of its energy source availability.
Transparency of USE calculation	Published 19 November 2020	Improve the transparency of the unserved energy calculation and the clarity of the framework that underpins the calculation. The final rule:

RULE	STATUS	DESCRIPTION
		• Requires AEMO to set out, through the Reliability Standard Implementation Guideline, the method for calculating unserved energy, including how the amount of energy demanded in the relevant region is determined. • Includes a purpose statement or principle for the definition of unserved energy, to assist stakeholders and AEMO with the definition's interpretation.

B.3 AEMO

The Electricity Statement of Opportunities (ESOO) provides technical and market data that informs the decision-making processes of market participants, new investors, and jurisdictional bodies as they assess opportunities in the National Electricity Market (NEM) over a 10-year outlook period. The NEM ESOO incorporates a reliability assessment against the reliability standard defined in the National Electricity Rules (NER) clause 3.9.3C and AEMO's Reliability Forecast under the Retailer Reliability Obligations (RRO).

Integrated system plan: The Integrated System Plan is a whole of system plan that provides an integrated roadmap for the efficient development of the NEM over the next 20 years and beyond. Its primary objective is to maximise value to end customers by designing the lowest cost, secure and reliable energy system capable of meeting any emissions trajectory determined by policymakers at an acceptable level of risk. AEMO published the most recent ISP in July 2020, and the next iteration is scheduled to be published in 2022.

Engineering framework: The Engineering Framework is the next step in a multi-year plan to deliver an integrated roadmap for the NEM. It builds on the RIS Stage 1 which delivered the first step. The Engineering Framework seeks to go beyond the renewable integration alone, by taking a broader perspective, and acknowledging the various activities that are already happening across industry. AEMO published the initiation report March 2021.

Quarterly Energy Dynamics: AEMO's Quarterly Energy Dynamics reports (QED) detailed market dynamics, trends and outcomes in Australia's electricity and gas markets. It is produced quarterly. Geographically, the report covers the National Electricity Market – which includes Queensland New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania – and the gas markets operating in the same states (except Tasmania). The latest QED, covering quarter four 2020, tracks falling NEM demand, rising east coast gas prices and the market and system impact of record renewables output.

DER register: The DER Register is a database of information about DER devices, and stores information about a DER device installed on-site at a residential or business location. This information will be requested by Network Services Providers (or network operators) from qualified electrical contractors and solar installers at the time of the DER installation. The DER Register launched on 1 March 2020.

B.4 AER

Murraylink determination: On 30 December 2020, the AER issued a decision to amend Murraylink's current Framework and Approach. The 2018-23 F&A paper for Murraylink was published on 28 July 2016. In accordance with the NER, the AER intends to publish an emended F&A paper for Murraylink by 31 July 2021.

Wholesale demand response participation guidelines: On 12 March 2021, the AER published an Issues Paper seeking stakeholder comments on the information demand response service providers must retain regarding compliance with their obligations under the new rules. The Issues Paper also seeks feedback on what guidance may help DRSPs to better understand their bidding obligations under the new rule.

Transgrid Humelink contingent project: TransGrid is currently undertaking a Regulatory Investment Test for Transmission for the Humelink project which is looking at reinforcing the transmission network in southern New South Wales.