RELIABILITY PANEL AEMC

Reliability Panel AEMC

INFORMATION PAPER

THE RELIABILITY STANDARD: CURRENT CONSIDERATIONS

12 MARCH 2020

INQUIRIES

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Reference: ERC0279

CITATION

Reliability Panel, The Reliability Standard: current considerations, 12 March 2020

ABOUT THE RELIABILITY PANEL

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

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SUMMARY

1 Under the National Electricity Law (NEL) and Rules (NER) the Panel is tasked with reviewing, advising and reporting on the reliability and security of the national electricity system.

2 The Panel acknowledges the increasing concern regarding the reliability of the national electricity market (NEM), as well as the increasing use of intervention mechanisms in order to promote reliability in the system.

3 The Panel has prepared this paper to provide background information and promote discussion on reliability in the NEM. It is an early, first step towards the Panel's next statutory review of the reliability standard and settings, which must be completed by 2022 at the latest.

The importance of the reliability standard

4 The reliability standard is a central feature of the NEM because it underpins the effective operation of the market. The reliability standard serves as a signal about reliability to guide decisions of market participants. It underpins the reliability settings, AEMO's forecasts to the market across multiple time-frames, and the Retailer Reliability Obligation.

5 The reliability standard also serves as a trigger for intervention in the market, should that be necessary to shore up reliability, through intervention measures such as AEMO's dispatch of emergency reserves.

6 Crucially, the NEM's reliability framework seeks to deliver customers both reliable and affordable electricity.

7 The reliability standard represents a trade-off between the dual objectives of reliability and affordability. Reliability can be increased by installing more capacity (either generation or demand side) in the system; however, this obviously comes with costs. A balance between the value gained from increasing reliability, versus the costs that this may entail, based on what consumers value in relation to reliability is sought.

8 The standard is currently expressed as 0.002 per cent unserved energy, which represents the maximum expected unmet demand for each financial year, for each region (as a proportion of the total energy delivered).

The Reliability Panel supports discussion about the reliability standard

9 The reliability of the NEM has always been of critical importance. However, for the first twenty years of the NEM's operation there was little concern that there would not be enough generation to meet demand. Reliability has increasingly become a concern only in the last few years.

10 In addition, planning and operating the power system is far more challenging than ever before.

11 Historically power system planning was based on relatively few, well understood risk factors due to uniform generation technologies connecting to the grid. The increase in the diversity of generation technologies that are now being connected to the grid, and their geographic

decentralisation, brings additional, complex and interrelated risk factors to the reliability of supply. Also, many of these risk factors are difficult to forecast. Compounding these risks are increasingly frequent extreme weather conditions that impact on both supply and demand.

12 The reliability standard has been a key regulatory feature since the NEM's inception in 1998. The changes in our physical power system, the climate, and increased planning and operational complexity, mean it is timely to examine this fundamental feature of the NEM framework.

Three questions to focus on when examining the reliability standard

13 Analysing the following three questions will assist when examining the reliability standard. These three questions have been developed based on our experience from past reviews of the reliability standard and settings, and our annual market performance review reports of the NEM.

14 The three questions are:

- What current and emerging problems is the NEM facing that require changes to either the form of the reliability standard, the reliability settings, and/or the mechanisms for delivering reliability? The problems should be identified as specifically as possible, making sure the standard remains effective and delivering the type of reliability that is needed. Being specific about the problem will help with the assessment of the costs and benefits of the various options that might be considered.
- How does the standard (and mechanisms to deliver it), interact with the market's reliability settings, other aspects of the market and each other? Interactions between the reliability standard, the reliability settings and other aspects of the reliability framework need to be considered in order to make sure there is effective operation of the framework and to avoid unintended consequences.
- What should be considered when setting the level of the reliability standard? The two main factors to consider in setting the level of the reliability standard are the value customers place on having reliable supply (known as VCR) and the cost of supply. It also requires consideration of whether current approaches to establishing these reflect the changes that are occurring in the NEM.

Focus of future work

15 In addition, the Panel has considered what areas may be helpful for it to focus on over the coming months toprepare for a comprehensive review of the reliability standard. These include:

- increasing understanding and awareness of the reliability standard and the impacts that it has for consumers
- engaging with the AEMC on its progression of our rule change request, on increasing the *transparency of USE* which aims to provide more clarity on what comprises USE and how it is estimated

- focussing on initial thinking about how the current administered price cap and, potentially the cumulative price threshold, may impact reliability in the future in light of recent events.

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1 INTRODUCTION

A consequence of the significant change underway in Australia's energy system is that there are increasing concerns about reliability in the national electricity market (NEM). Power system conditions have become more volatile due to the changing characteristics of the generation fleet, including a strong take-up of behind the meter resources such as residential solar PV, as well as changing consumer preferences. In addition, the increase in extreme weather events makes the power system less predictable, more volatile and increasingly difficult to operate.

In this context, the Australian Energy Market Operator (AEMO) has suggested that the current reliability standard may no longer be appropriate on the basis that it does not help to insure against high impact co-incident events. These are referred to by AEMO as "tail-risk" events and are described in Box 1 below. This was also a theme of the Australian Energy Market Commission's (AEMC) consideration of appropriateness of the standard, which was assessed as part of the "Enhancement to the Reliability and Emergency Reserve Trader (RERT)" in 2019.

BOX 1: AEMO'S DEFINITION OF TAIL RISK EVENTS

To work out if the reliability standard will be breached in the ESOO, AEMO uses a forecast that comes from a weighted-average across a wide range of possible scenarios, including generator outages, the shape of demand and the profile of wind and solar outputs. The weights are the probabilities (or likelihood) that each individual scenario will occur.

This creates an expected overall outcome for the financial year.

AEMO is concerned that the averaging out of various outcomes masks the risk of "uncontrollable, but increasingly likely, high impact ('tail risk') events, such as coincident unplanned outages".

These 'tail risks', while only expected to occur rarely, would result in large shortfalls in supply that would require the use of emergency reserves or, if there are insufficient emergency reserves, involuntary load shedding. (See Box 2 for an explanation of load shedding).

Source: AEMO, *2019 Electricity Statement of Opportunities*, page 13-14.

Most recently, concerns about the reliability of the power system resulted in the COAG Energy Council tasking the Energy Security Board (ESB) with providing advice on interim measures to preserve reliability and system security in the National Electricity Market, including reviewing the reliability standard, during the transition to the post-2025 market design. This should be achieved by using existing mechanisms where possible. The ESB's advice would be provided for Council consideration and decision by March 2020.

The COAG Energy Council has requested that the ESB's review of the reliability standard should:[1]

- include cost/benefit analysis and impacts on process for consumers by jurisdiction
- identify options that may reduce energy costs to consumer including by incentivising investment in new generation and interconnection
- take into account the increased level of risk to reliability, e.g. from ageing thermal generation units
- reflect community expectations that electricity supply will remain reliable during a "1 in 10" year summer
- undertake any necessary stakeholder consultation.

The COAG Energy Council have also stipulated that any new recommended standard will:[2]

- apply for the 2020-2021 summer and beyond for the purposes of the 2020 Electricity Statement of Opportunities (ESOO).[3]
- enable AEMO to better capture tail risks (such as anticipated deterioration of generation fleet).

The Reliability Panel comprises representatives from consumer groups, generators, retailers, network providers, AEMO, and is chaired by an AEMC Commissioner. Under the National Electricity Rules (NER), the Reliability Panel must review the reliability standard and settings at least every four years. The most recent reliability standard and settings review report was published in April 2018.[4]

This information paper is intended to provide information and promote discussion among stakeholders on reliability in the NEM, and may be helpful informing the debate. We are not seeking submissions on this paper.

The paper can be considered to be the first stage of the Reliability Panel preparing for the next review of the reliability standard.

This paper includes the following sections:

- Chapter two - provides the historical context for the reliability standard, including its objective, its key components, how it is determined and delivered; and the outcomes of the most recent reviews.
- Chapter three - summarises current perspectives on the performance of the reliability standard, including drivers that could be supportive of a change to the standard.

1 http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/Reliability%20and%20Security%20Measures%20-%20Scope%20of%20work.pdf

2 http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/Reliability%20and%20Security%20Measures%20-%20Scope%20of%20work.pdf

3 The ESOO, forecasts reliability in the NEM for the next 10 years against the Reliability Standard and an important role in relation to whether the Retailer Reliability Obligation (RRO) will be triggered.

4 www.aemc.gov.au/markets-reviews-advice/relaibility-standard-and-settings-review-2018

- Chapter four - discusses the alternative *forms* of reliability standard and explains the level at which the current standard is set and why that level has been selected.
- Chapter five - sets out key considerations for deciding how to implement changes to the reliability standard.

2 HISTORICAL CONTEXT

2.1 Power system reliability

A reliable power system has an adequate amount of capacity (generation, demand response and network capacity) to meet consumer needs. A reliable system therefore requires adequate investment in all of these types of capacity, retirement of these when necessary, as well as appropriate operational decisions, so that supply and demand are in balance at any particular point in time.

To achieve a reliable power system it is necessary to include a buffer in the supply/demand balance, known as reserves. The level of reserves in the market reflects the extent to which the expected supply exceeds the expected demand. This allows the actual demand and supply to be kept in balance, even in the face of shocks to the system and loss of some supply, known as "credible contingencies". Reserves can be 'in market' i.e. generators that are available to run, which is represented in their dispatch offers but because supply is greater than demand are not called on to run. Reserves can also be 'out of market' i.e. the emergency reserves that AEMO procures through the reliability and emergency reserve trader (RERT) mechanism to be on standby.

The NEM has historically provided a high level of reliability. However, reliability issues sometimes occur when the balance and supply in a region is tight.

Historically, reliability has typically become an issue on hot days, as hot weather can affect both consumer usage patterns and the power system's ability to provide supply. This is exacerbated when extreme weather occurs on consecutive days as:

- People tend to use more electricity when it is hot, especially on week days. Air conditioners are turned on in offices and homes, substantially increasing electricity use. Consumer appetites to withstand hot weather diminishes as consecutive hot days occur and the heating impacts on buildings increases cooling loads.
- Hot weather also impacts electricity generators and the infrastructure used to transport electricity to our homes and offices. Many generators have constraints on output in hot weather, especially after a number of consecutive hot days, caused by longer-than usual periods of operation. It also becomes harder to cool thermal coal and gas plants, while solar and wind plants may produce lower output at higher operating temperatures.

However, more recently, reliability concerns have also been emerging during 'shoulder' periods. 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 patterns, demand during shoulder periods are less predictable in the past.

2.2 Blackouts and unserved energy

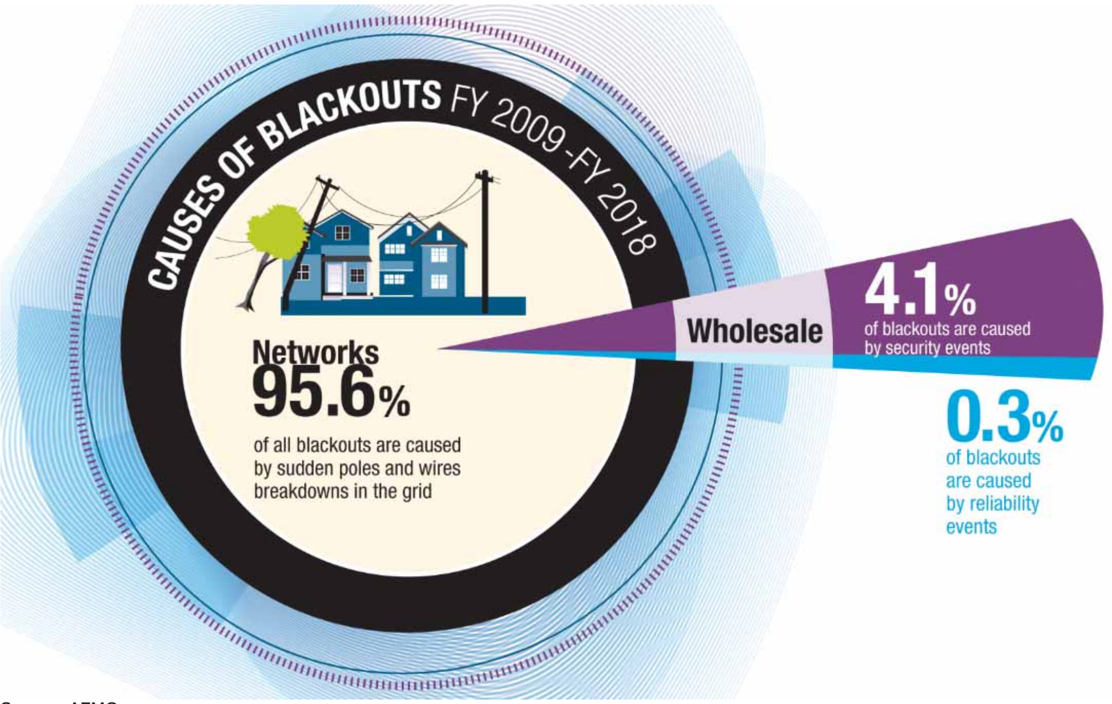
Supply interruptions can originate anywhere in the power system. While customers' experience of power supply interruptions is the same irrespective of the cause, they are classified based on what part of the power system caused the interruption. This is because different parts of the power system have differing regulatory frameworks involving different bodies, and so require different solutions.

Customers can experience interruptions to their electricity supply for three reasons:

- Reliability issues - where there is insufficient generation to meet consumer demand at a place and point in time.
- System security events - due to problems with the security of the network (for example maintaining frequency)
- Transmission/distribution network failures - where there are breakdowns in the grid's poles and wires. For example, when a power pole is knocked down in a storm or power lines are damaged in a bushfire. (Typically most network outages result from distribution network failures and these interruptions only effect small numbers of customers, although sometimes for an extended period.)

The chart below shows the causes of blackouts in the NEM from 2009 - 2018. Historically, just over 95 per cent of all interruptions to the power supply are caused by failures in the transmission and distribution network. Four percent of supply interruptions are caused by events that disrupt the frequency and voltage balance in the system. Less than one per cent of blackouts are caused by insufficient supply.

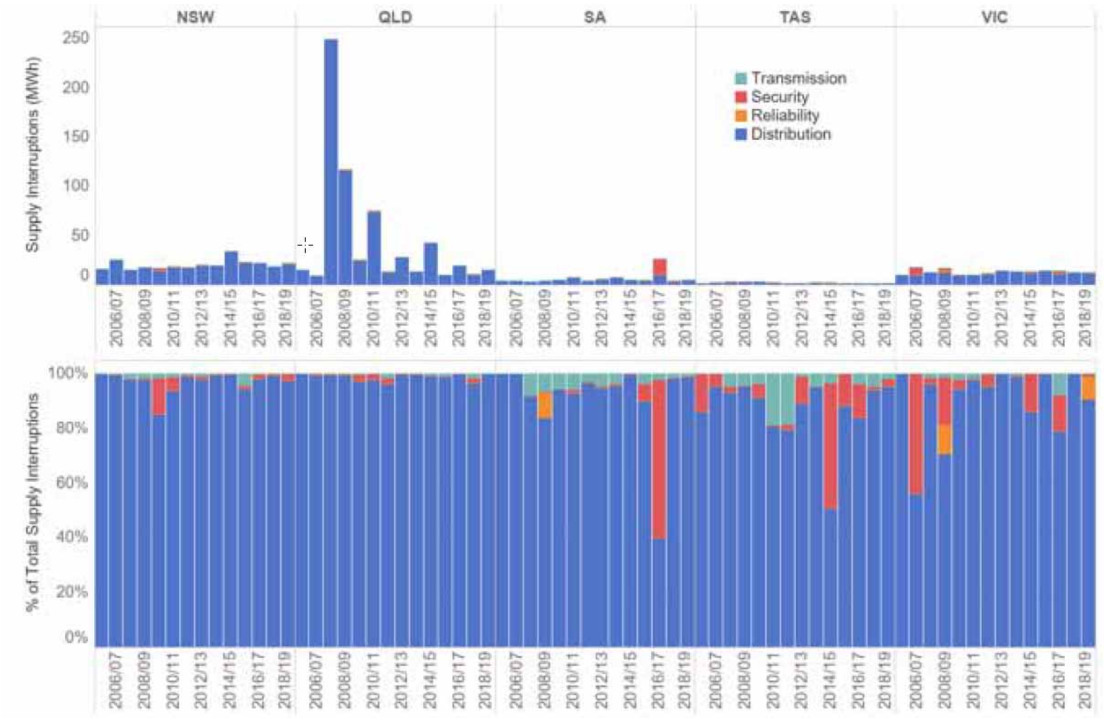
Figure 2.1: Causes of blackouts: FY 2009 - FY 2018



Source: AEMC

The next two charts show how the causes of blackouts differ between NEM states, and how this has changed over time. The top chart presents supply interruptions in aggregate (MWh) and the bottom chart shows the causes as a proportion of all interruptions. Outages caused by reliability events (a shortage of supply) are shown in orange. The charts confirm that for each individual NEM region, reliability events very rarely cause blackouts.

Figure 2.2: Sources of supply interruption in each state from 2008/09 to 2018/19



Source: AEMC analysis and estimates based on publicly available information from AEMO's incident reports and the AER's RIN economic benchmarking spreadsheets.
Note: This chart shows megawatt hours of interrupted supply for each year of the last decade, by state.

When customers experience supply interruptions specifically because demand is higher than supply, we call the demand that went unmet 'unserved energy' or USE. The reliability standard discussed in this paper relates to this less common type of supply interruption i.e. where there is unserved energy.

2.3 How is a reliable supply of electricity delivered in the NEM?

Reliability is currently delivered in the NEM through investment, retirement and operational decisions that are underpinned by various market structures. The framework is supplemented by a series of mechanisms that allow the system operator to intervene in the market in specific circumstances.

The market is primarily the means through which an affordable supply of electricity is delivered to customers. This is appropriate as a competitive market is intended to promote efficient investment and allocation of risk, providing a reliable supply at the lowest cost for consumers.

The core objective of the existing reliability framework in the NEM is to deliver desired reliability outcomes through market mechanisms to the largest extent possible. In a reliable power system, the expected level of supply in the market will include a buffer, known as in market reserves. Expected supply will be greater than expected demand. In the event that the supply / demand balance tightens, spot and contract prices would rise, which will inform operational decisions and provide an incentive for entry and expansion, addressing any potential reliability problems as or before they arise. This allows the actual demand and supply to be kept in balance, even in the face of shocks to the system.

A key aspect to delivering reliability is therefore having a well-functioning market where electricity spot and contract markets provide clear price signals. A well-functioning NEM is supported by high quality information and appropriate incentives for investment. This gives market participants incentives and information to invest in supply generation and demand response equipment when and where it is needed. The market also requires reliable transmission and distribution networks and for the system to operate in a secure operating state, that is, able to withstand shocks to its technical equilibrium.

2.4 What is the reliability standard?

The reliability standard for the NEM is set in the National Electricity Rules (NER). It is maximum forecast unmet energy (i.e. unserved energy or 'USE') for each financial year, as a proportion of the total energy supplied in that region. The reliability standard has been an important regulatory feature since the NEM’s inception in December 1998.

A region in the NEM is an area that is served by transmission wires and has major demand and generation centres. Current arrangements for regions are simple, they are largely divided by state boundaries. The current reliability standard is:

A maximum expected unserved energy (USE) in a region of 0.002 per cent of the total energy demanded in that region for a given financial year.[5]

In other words, the reliability standard implies that we *expect* to have enough supply to meet demand 99.998 per cent of the time, in every region every financial year.

It is *expected* USE since the assessment of the reliability standard requires a forecast. This forecast comes from a weighted-average across a wide range of possible scenarios, including generator outages, the 'shape' of demand over time, and the profile of wind and solar outputs. The weights are the probabilities (or likelihood) that each individual scenario will occur.

For example, extreme weather events tend to occur rarely, and are therefore inputs to the forecast that vary with weather events (such as demand) are weighted based on their likelihood of their occurrence. Common events are weighted more highly given, by definition, they are more likely to occur.

As system operator, the Australian Energy Market Operator (AEMO) incorporates the reliability standard within its day-to-day operation of the market. For example, through its forecasting

5 *3.9.3C(a) of the National Electricity Rules.*

processes that advise the market as to whether or not the reliability standard is being met, and to determine whether interventions are required to ensure reliability.

BOX 2: AT A GLANCE: ROTATIONAL LOAD SHEDDING AND THE RELIABILITY STANDARD

Rotational load shedding occurs when there is a not enough supply to meet demand, and emergency reserves are not available to fill the gap. The objective of rotational load shedding is to avoid an even wider loss of supply, or even an extreme grid shutdown. The process is a controlled where AEMO directs networks to reduce load by turning power off to some areas to maintain balance in the system. It is called rotational load shedding because the outages for consumers are typically kept to about 30-60 minutes, with load shedding rotated between suburbs and regions, based on a priority list set by each jurisdiction.

Rotational load shedding has been uncommon historically. There has only been five instances since 2005 of any load-shedding in the NEM related to reliability – twice in Victoria and three times in South Australia.

When does it occur, what does rotational load shedding look like?

In Victoria on 25 January 2019 – the last time there was unserved energy in Victoria – approximately 270MW of demand went unmet for around two and half hours. Assuming hypothetically this load shedding event would have been completely borne by households, then around 80,000 homes would have been affected by power outages. Typically, homes experience shorter duration outages because load is shed on a rolling basis to different groups of houses. That is, individual houses wouldn't have been without power for the whole two-and-a–half hour period, individual outages would generally be limited to an hour in duration.

How much demand does 0.002 per cent represent?

In NSW, 0.002 per cent of unserved energy could be avoided entirely if – on a very hot day – one in six of the NSW homes with air conditioning turned off their air-conditioners for three hours at peak demand. (Their air conditioners would have been running and cooled the house before being turned off).[1] As a rule of thumb, on a hot day, 1MW of demand response can be achieved by turning off approximately 550 average residential air conditioners.

1. The figures above use an average residential air conditioner consumption of 1.86kW per unit when running and assumes NSW experiences the entirety of the USE required to breach the Reliability Standard for the state in 2019 in a single evening peak (1,434 MWh).

2.5 Why was 0.002 per cent chosen as the level for the standard?

The current level of the reliability standard of 0.002 per cent USE was set in 1998 (market start), and has remained unchanged since then. The 0.002 per cent was set to roughly reflect the existing planning standard in each jurisdiction. This roughly translated to 0.002 per cent of demand at that time.

Prior to the NEM, each of the jurisdictions established planning standards for reliability and applied these in decisions relating to the installation of new capacity. Long standing operational practice covering the use of installed capacity was generally directed to managing the number of times interruptions to supply were anticipated to occur. This was generally achieved by arranging for reserve to accommodate the failure of the largest one, two or three generating units relatively quickly (the number varied between the jurisdictions and with time). There was no direct correlation between the reliability standard used in the planning process and the operational reserve policy, except that operational reserves were obviously only available from plant installed through the planning process and some centrally managed demand side capability such as aluminium smelter interruptibility.[6]

Importantly the reliability standard is not set at 100 per cent; this is because it is not physically possible to make sure there is sufficient reliability at any point in time. Even if it were possible, it would be prohibitively expensive to aim for such a level of reliability since it would involve a significant amount of investment, with the costs being passed onto customer bills. It has historically been considered that approaching 100 per cent reliability is not in the long-term interests of consumers as the price would be well above what customers are willing to pay.

2.6 The reliability and cost trade-off

All power systems incorporate a trade-off between what consumers pay for electricity and the cost of not having energy when it is needed. A balance is struck between having enough generation and demand response to meet consumer demand in the majority of circumstances, and keeping costs as low as possible for consumers.

A higher level of reliability requires more investment in capacity (both generation and demand side) in the system. Recovering the costs of new generation plants, expanded inter-state transmission lines, and contracts with energy-intensive customers to reduce usage, are all passed onto consumers through prices, and ultimately reflected in customer bills.

The reliability standard therefore aims to achieve the highest level of reliability practical under reasonable operating conditions, at least cost. This means avoiding a level of investment in supply that would see unreasonable increases in prices.

Of course, as a market benchmark, the reliability standard is inevitably imperfect. Any standard centrally determined has insufficient information to make the trade-off that would perfectly reflect consumers' preferences. Even if all individual consumer preferences were known, the reliability standard needs to be relatively simply articulated in order to be operationalised in real-time. This means it cannot represent the myriad of complexities relating to the cost-reliability trade-off. For example, the complexity associated with different consumers valuing reliability at different levels to one another, and at different times.

6 National Electricity Code Administrator, June 1998, *Reliability Panel Determination on Reserve Trader and Direction Guidelines,* pages 3-4.

2.7 Components of the reliability standard

The reliability standard has three main aspects: form, level and scope:

- The *form* of the standard is the metric by which reliability is measured. The NEM standard is an output-based measure, expressed in terms of 'expected unserved energy per region per year'.
- The *level* of the standard specifies how much unserved energy is deemed acceptable as a percentage of annual demand per region. The level is currently set at 0.002 per cent unserved energy (or 'USE'). This is also an expression of risk, that is, the expected level of electricity at risk of not being supplied to consumers in a region.
- The *scope* of the standard defines what does and does not count towards the NEM's reliability performance. In terms of the electricity supply chain, the standard currently includes generation and inter-regional transmission capacity, and excludes distribution networks. In terms of events, the standard currently excludes power system security incidents, with certain limited exceptions. This is because these other types of interruptions to power supply are subject to different regulatory frameworks and require different solutions that cannot always be addressed by interventions that address reliability.

2.8 How the reliability standard is determined

Under the NER, the reliability standard must be reviewed periodically by the Reliability Panel. The Reliability Panel's most recent review of the reliability standard was concluded in April 2018.[7] Under the NER, the review must be conducted at least every four years.

The Reliability Standard and Settings Guideline set out the approach to reviews of the standard and settings. Under the current guideline the level of the reliability standard is not automatically reassessed every review cycle. Rather, the Panel must apply a materiality test to determine if the reliability standard should be reassessed.[8]If the materiality threshold is not met, then the standard should remain as previously determined.

The current guideline requires the Panel to consider at a minimum the following criteria to determine whether there would be a material benefit in reassessing the level of the reliability standard:

- any change in AEMO's value of customer reliability (VCR) measure
- any marked changes to the way consumers use electricity, particularly through the use of new technology, that suggests a large number of customers may place a lower or higher value on the reliable supply of electricity in the NEM (for instance, due to the technology change such as the take up of rooftop solar and residential batteries).

7 www.aemc.gov.au/markets-reviews-advice/reliability-standard-and-settings-review-2018

8 In relation to the other settings, the guideline states that the "form" of all of the settings are closed to review and that the "level" of the settings are either "open" for review (in which case the Panel will need to give consideration to the principles set out in the Reliability Standard and Settings Guideline) or subject to a materiality assessment, with criteria for this assessment also set out in the guideline.

The current guideline requires a combination of qualitative and quantitative analysis in undertaking the materiality assessments and/or the review of the level of the reliability standard. Regarding quantitative market modelling, the guidelines require that the Panel examine how a long-term equilibrium between price and reliability can be achieved in the market; and in considering this, the modelling should consider both new investment and the potential for retirement of capacity.

In 2010 the definition of the reliability standard was changed – from being "expected USE exceeding 0.002 per cent *over 10 years*" – to "expected USE exceeding 0.002 per cent *in a given financial year*". While the level did not explicitly change, the reliability standard was implicitly tightened (that is less load shedding is tolerated), as the 0.002 USE maximum level now pertains to every 12-months rather than an average over a ten-year period.

Recent review

On 30 April 2018, the Panel completed its most recent review of the reliability standard and reliability settings to apply in the NEM from 1 July 2020.[9] The Panel did not consider that the materiality threshold for a review of the standard had been met and so the level of the standard was not reviewed. The Panel's review recommended keeping the current reliability standard and reliability settings unchanged as they remained appropriate to support reliability in the NEM.

For this review, the Panel commissioned consultants Ernst & Young (EY) to undertake wholesale market modelling to inform its decisions about the appropriate levels of reliability settings. The modelling incorporated the impact of the market transformation that was underway, with a focus on accurately modelling factors such as generation from wind and solar plants. The Panel modelled a range of different futures including different cost paths for renewable technologies and different impacts of uncertainty on investment costs, to test the suitability of the reliability settings.

Also, as part of the 2018 review, the Reliability Panel conducted a desk-top study of the potential cost of moving close to zero unserved energy (the Panel noted that it is impossible to reduce expected unserved energy to zero in all possible modelled futures). In Victoria, as an example, it found an additional 1,000MW of capacity would be needed in 2020-21 to move close to zero expected unserved energy. For the additional plant to recover its fixed costs (excluding variable operating and maintenance costs), additional income would need to be generated in the market. This would equate to additional costs to customers of at least $200 million per year.

2.9 How the reliability standard is delivered

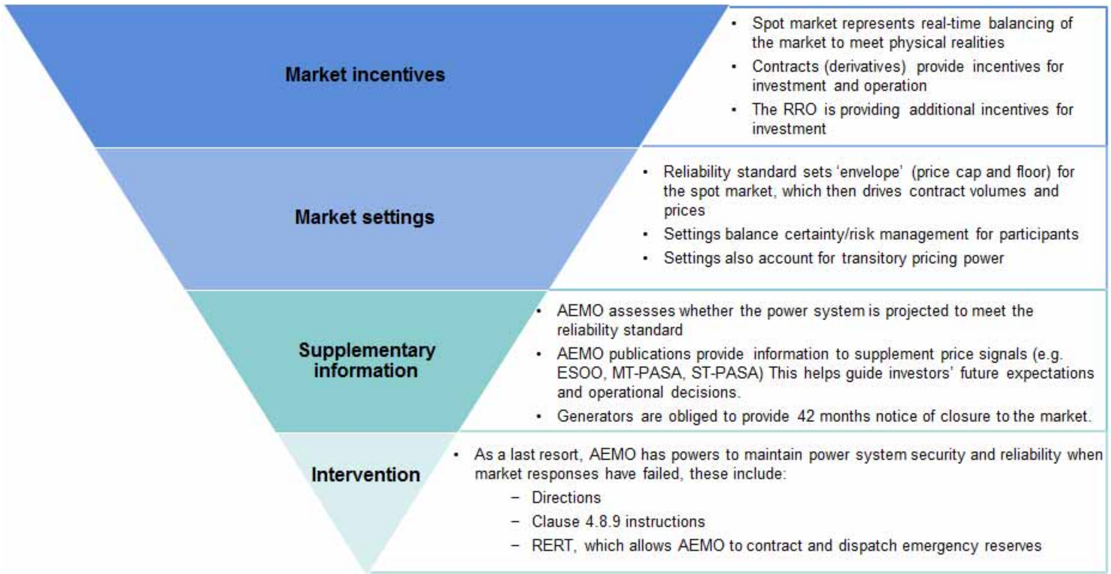
The role of the reliability standard in the NEM reflects the design of the NEM's reliability framework. As illustrated in Figure 2.2, the reliability framework aims to deliver enough power to satisfy the reliability standard through market mechanisms to the greatest extent possible. The market drives investment in new generation and demand response, as well as

9 Under NER clause 3.9.3A(d), the NER requires the Panel to assess the reliability standard and settings every four years.

plant retirement and operational decisions. A range of information is provided to the market that identifies both on short and long term-time horizons, commercial opportunities for meeting demand.

If the market still does not respond adequately, then the reliability framework includes tools that allow the system operator to intervene in specific circumstances to deliver reliability outcomes.

Figure 2.3: Overview of the existing reliability framework



Source: AEMC

AEMO has an important role in the reliability framework. It operationalises the reliability standard through its forecasting processes, including the Projected Assessment of System Adequacy (PASA) processes. These allow AEMO the flexibility to change its assessments about expected levels of unserved energy, based on new information including generation availability (e.g whether a generator is out on maintenance or not) and changes in weather conditions.

AEMO considers different maximum demand outcomes, weather conditions and supply availability combinations in its forecasting, and updates its assessments at regular intervals as real-time approaches. This makes sure market participants, and AEMO, always make decisions based on the latest and most accurate information. AEMO uses this information to assess whether it needs to intervene in the market.

Specifically, the role of the reliability standard in the NEM's reliability framework is two-fold. It serves as:

- **a market signal** - the reliability standard signals to the market where commercial opportunities may lie for more investment in generation, demand response and contracting.

- **an operational driver** - AEMO operates the system to meet the reliability standard.

2.10 The two roles of the reliability standard

2.10.1 The reliability standard serves as a market signal

Market participants make investment decisions based on market signals. Prices in the spot and contract markets provide signals for adequate generation and demand-side resources to be built and dispatched, as well as information about the balance of supply and demand across different places and times. As the expected supply/demand balance tightens, spot and contract prices will rise - within the price envelope set in accordance with the reliability standard - which informs operational decisions and provides an incentive for entry and increased production, addressing any potential reliability problems as or before they arise.

The Retailer Reliability Obligation (RRO), which commenced on 1 July 2019, builds on existing spot market and seeks to facilitate investment in dispatchable capacity and demand response. It is only triggered when a breach of the reliability standard is identified in order to further promote reliability through market incentives.

The reliability framework also includes reliability settings which are closely linked to and derived directly from the reliability standard. They represent a trade-off that balances two priorities – protecting market participants financially and incentivising investment in generation. The settings comprisethe:

- market price cap (MPC), which imposes an upper limit on temporary high prices in the wholesale market
- cumulative price threshold (CPT), which imposes a limit on sustained high prices in the wholesale market
- administered price cap (APC), which is the "default" price cap that applies when the cumulative price threshold is exceeded
- market floor price, which imposes a negative limit on prices in the wholesale market.

These settings are used to contain the extent to which wholesale prices can rise and fall, to protect and limit the financial exposure of prudent market participants. They are also set at a level such that prices over the long-term incentivise enough new investment in generation so that the reliability standard is expected to be met.

The reliability standard and settings are interrelated. For example, an increase in the level of the reliability standard (such as tightening the standard to a higher level of reliability of, say, 0.001 per cent of unserved energy) may require a corresponding increase in the level of the market price cap, or some other form of generation remuneration, to signal the appropriate level of generation capacity and demand-side response to deliver the higher standard.

AEMO is required by the NER to publish various materials which provide information to the market on matters pertaining to the reliability standard; that is, over and above the information contained in contract and spot market prices. The purpose of these forms of supplementary information is to inform market participants of prevailing and forecast conditions, and when reserves may be running low, in order to elicit a market response.

AEMO provides information to the market through the Medium Term-Projected Assessment of System Adequacy (MT PASA), Short Term-Projected Assessment of System Adequacy (ST PASA) and pre-dispatch processes, highlighting how much supply is in the market. If there is forecast to be shortages of supply, then this information encourages market participants to make different operational decisions (for example, shift maintenance periods) to increase supply into the market, creating more "in market reserves".

Over the medium and long-term, AEMO identifies breaches in the reliability standard and declares a low reserve condition (LRC) when it projects that the expected USE in a given year exceeds 0.002 per cent for a region.

2.10.2 The reliability standard serves as an operational driver

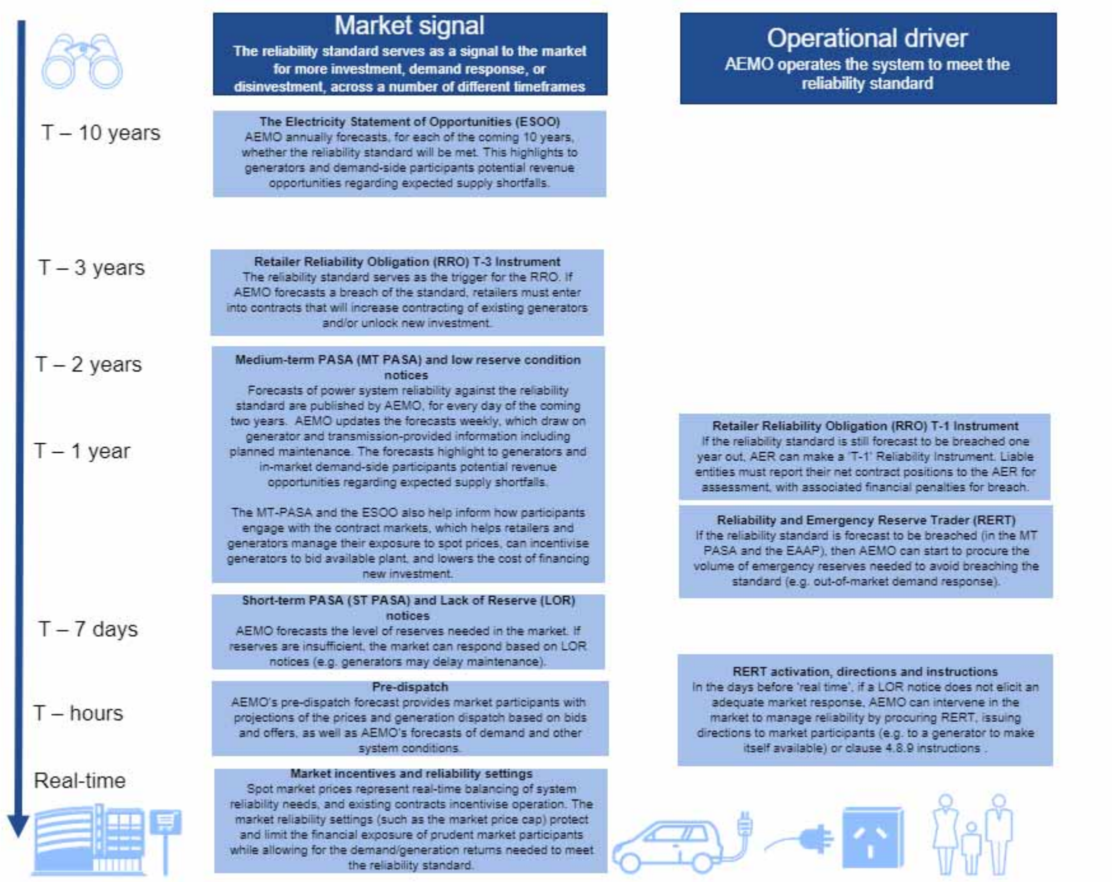
It is AEMO's responsibility to incorporate the reliability standard within the day-to-day operation of the market, and to inform the market of any projection that the reliability standard will not be met. Further information on how AEMO interprets the reliability standard is provided in AEMO's *Reliability Standard Implementation Guideline*.

If a market response is insufficient or not forthcoming from the information that AEMO provides to the market about a low reserve condition, then AEMO can intervene by purchasing emergency reserves under the long-notice RERT. For procurement of short and medium notice RERT, AEMO may set up RERT panels – a breach of the reliability standard is not required to set up these panels.

Seven days ahead of real-time AEMO's reliability assessment changes, and AEMO targets zero unserved energy. AEMO forecasts the buffer or level of reserves needed in the market ("in-market reserves") and provides this information to the market. If these reserves remain insufficient, AEMO publishes a lack of reserve condition notice to encourage market participants to adjust their operational decisions to bring more supply to the market. AEMO will also review any relevant network outages. If market participants do not respond by making more reserves available in the market, then AEMO may intervene through either using the RERT, or issue clause 4.8.9 instructions or directions to participants to maintain reliability.

The role of the reliability standard as both a market signal and operational driver is set out in the figure below.

Figure 2.4: The role of the reliability standard in the reliability framework



Source: Reliability Panel

3 CURRENT DRIVERS

The current NEM is different to what it was in 1998, when the reliability standard was first set. The physical power system has evolved, and the wholesale component of the NEM now operates amidst a changing generation mix, changing market dynamics and a changing climate.

The NEM historically has largely delivered a high level of reliability. However, as the supply/demand balance grows tighter, higher levels of unserved energy are forecast in coming years, and use of the RERT is becoming more common, there is merit in considering whether the reliability standard still reflects the way consumers value reliability and the cost of supplying it.

This section discusses the recent operational experience of the NEM regarding reliability and several of the key factors that are challenging the delivery of reliability in the NEM.

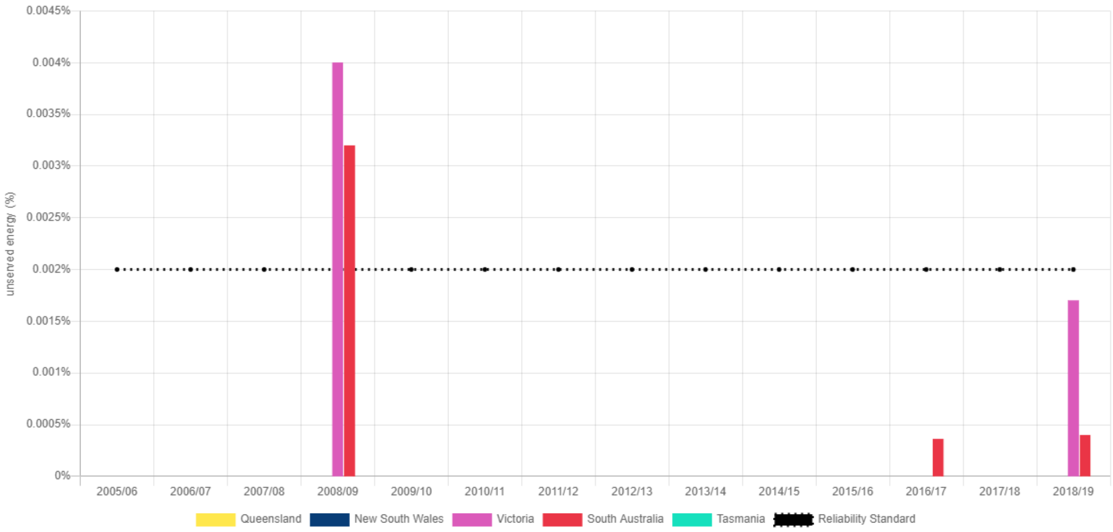
It is the view of the Reliability Panel that recent heightened concern about the reliability of the NEM is due to:

1. the changing generation mix with greater penetration of variable renewable generation, and ageing coal plants, which make the market more susceptible to input variability
2. changing consumer preferences given the increased ability for consumers to participate directly in the market
3. changing wholesale market dynamics for investors and generators, with greater price volatility
4. increasing congestion on the transmission network affecting the transportation of electricity between states now and in the future
5. variable and extreme weather conditions, that impact both supply and demand (such as by reducing output of renewable and thermal generators, causing outages in the transmission and distribution networks, and increasing customer demand)
6. relatedly, increased likelihood that high impact co-incident events will occur (referred to by the AEMO as increased likelihood of tail risk events occurring)
7. an actual increase in the use of interventions such as the dispatch of emergency reserves
8. the reliability of the power system being a regular topic of public discourse in the context of discussions about carbon emissions and the affordability of electricity for Australian consumers.

3.1 Reliability experience in the NEM

Historically, there has been very little unserved energy in the NEM overall. The following chart shows the unserved energy in the NEM from 2005-06 to 2018-19 arising from reliability relative to the reliability standard.

Figure 3.1: Unserved energy in the NEM



Source: From the Reliability Panel and AEMO

The chart shows that in the past 14 years, interruptions to power supply due to reliability have been very rare; there has been very low levels of unserved energy across all NEM regions.[10] In three of the 14 years, power supply was interrupted due a shortfall in supply, relative to demand (a total of five periods of 70).

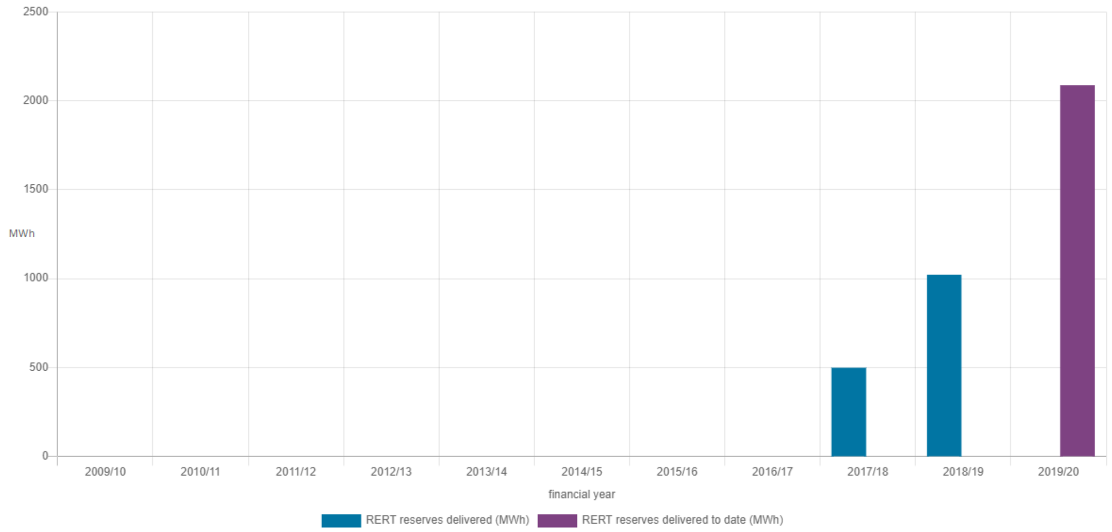
Most recently, the reliability standard was met in 2018-19 in all regions. However, unserved energy was experienced in Victoria (0.0017 per cent) and in South Australia (0.0004 per cent). Prior to 2018-19, South Australia experienced a smaller sum of unserved energy in 2016-17 (0.00036 per cent).

The only time unserved energy exceeded the reliability standard was in 2008-09 in Victoria and South Australia, when extreme temperatures in both states and reduced availability of the Basslink inter-connector and Victorian generators contributed to 0.004 per cent and 0.0032 per cent unserved energy respectively.

While historically unserved energy has been very rare in the NEM, out-of-market emergency reserves have increasingly been used to help deliver reliability. As AEMO seeks to use emergency reserves before it sheds any load, the use of emergency reserves can also serve to indicate the performance of the NEM in terms of reliability. The following chart presents the emergency reserves used in the NEM from 2009-10 to 2019-20 (RERT reserves, MWh).

10 In the NEM the concept of unserved energy is applied to measure any supply interruptions consumers experience from generation and interconnection inadequacy only, and excludes unserved energy associated with power system security incidents. See clause 3.9.3C of the NER for more details.

Figure 3.2: RERT reserves delivered in 2017/18 to 2019/20



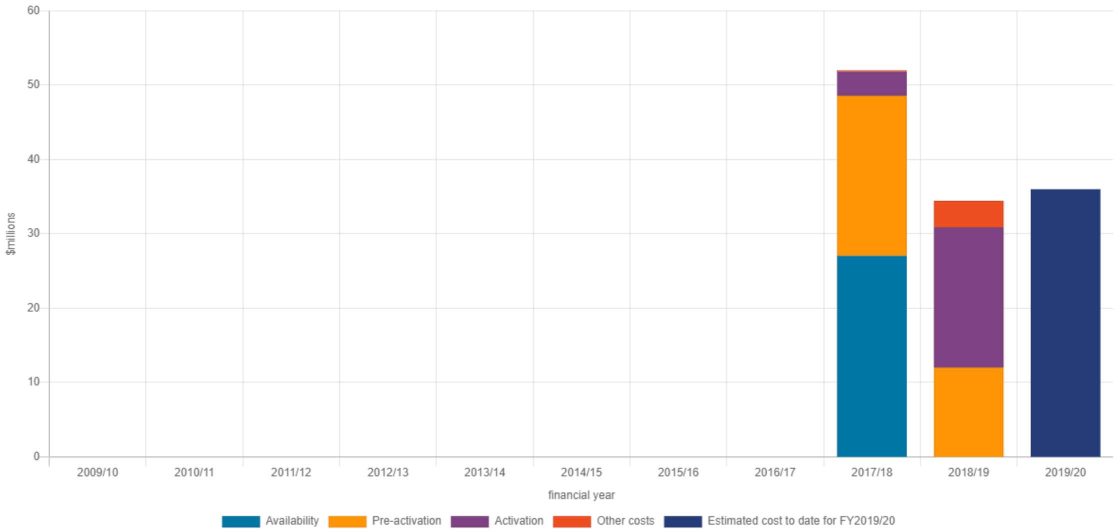
Source: AEMC analysis of AEMO data

It shows that the RERT was not activated for many years in the NEM (although it had been contracted, but not used, several times prior to 2017). The recent past has seen a trend of increasing use of emergency reserves. These have been dispatched during peak summer periods. The RERT was first activated in Victoria in November 2017. Since then, the RERT has mainly been procured and activated in South Australia and Victoria.

However, the 2019/2020 summer has seen RERT activated in New South Wales on three occasions (4 January, 23 January, 31 January) and in addition to activations in Victoria. The conditions that triggered the use of RERT during the 2019/2020 summer include coincident peak demand events on very hot days, as well as generation and transmission assets being removed from service due to widespread bushfires.

Given that the costs of procurement, activation and dispatch of RERT are passed onto consumers, it is important to understand what these costs are. The figure below illustrates the RERT costs as published in AEMO's reports or market notices. It is likely there are costs that are not published, and therefore not illustrated on the chart, such as availability and long-notice contracts for years prior to FY2017-18. The chart represents a best estimate with the information that is available, but it is important to note this information is likely to become more detailed over time as reporting methods improve.

Figure 3.3: Known cost of RERT 2009-10 to 2019-20



Source: AEMC analysis of AEMO data

Looking forward, AEMO forecasts the following key points regarding reliability conditions over the medium term:

- Only slight improvements in reliability for peak summer periods are expected until new transmission and dispatchable supply and demand resources become available.
- Unserved energy in New South Wales will increase, but remain below the current reliability standard. However, New South Wales is expected to be exposed to significant supply gaps and involuntary load shedding during a combination of high summer demand and unplanned generator outages following the closure of the Liddell power station if no new investment is undertaken.[11]

3.2 Recent operating experience

Recent experience has shown that it is more challenging to operate the power system. As discussed in the previous section, the past three years indicate an increasing trend to 2019-20 of the use of the RERT by AEMO. Extreme conditions were experienced during the 2019-20 summer that placed the power system under pressure. As per AEMO reports, RERT was activated twice in Victoria and three times in NSW.

30 December 2019 - Victoria

RERT was activated on 30 December 2019 with the following conditions being faced:

- Extreme weather conditions including high temperatures (above 40 C) and extreme bushfire conditions.

11 AEMO, 2019 Electricity Statement of Opportunities, p. 4

- Volatile power system conditions with high forecast maximum demand with the following units out of service:
  - Loy Yang A2 (500 MW)
  - Loy Yang B2 (580 MW).
- De-rating of semi-scheduled and non-scheduled generation throughout the day due to the effects of high temperature on their equipment.
- Bushfire in the vicinity of several transmission lines.
- A transmission line trip in New South Wales that lead to constrained flows across the Victoria – New South Wales interconnector (VNI) that resulted in reduced level of support to Victoria from New South Wales by over 1000 MW.

AEMO activated 283 MWh of RERT to maintain reliability.

4 January 2020 - NSW

RERT was activated in NSW on 4January following severe bushfires conditions leading to unplanned outages on several transmission lines. As a result of these outages, the availability of generation was reduced, the NSW and Victoria regions became separated (with the NEM operating as two islands) leading to tight supply demand balance in NSW.

The reduction in reserves meant an actual LOR-2 was declared by AEMO. In response, AEMO activated an estimated 232 MWh of RERT.[12]

23 January 2020 - NSW

On 23 January, the RERT was again activated in NSW. AEMO declared an actual LOR-2 condition on this day due to very high temperatures, the ongoing impact of severe NSW bushfires on transmission assets, and unscheduled coal generation outages. AEMO activated an estimated 456 MWh of RERT.

31 January 2020 - Victoria and NSW

RERT was again deployed on 31 January with conditions including:

- high demand levels caused by high temperatures across the south-east Australian states, with AEMO forecasting the highest demand in Victoria since January 2014
- multiple generation outages
- tripping out-of-service of two 500kV transmission circuits in western Victoria caused by a collapse of double circuit transmission towers in a wind storm leading to an extended separation between Victoria and South Australia.

During this event, AEMO activated an estimated 697 MWh of RERT in Victoria and 418.5 MWh in NSW. An actual LOR-2 was declared in Victoria and NSW.

These events demonstrate the recent challenging experience of operating the power system.

12 https://www.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

3.3 Key factors driving reliability in the NEM

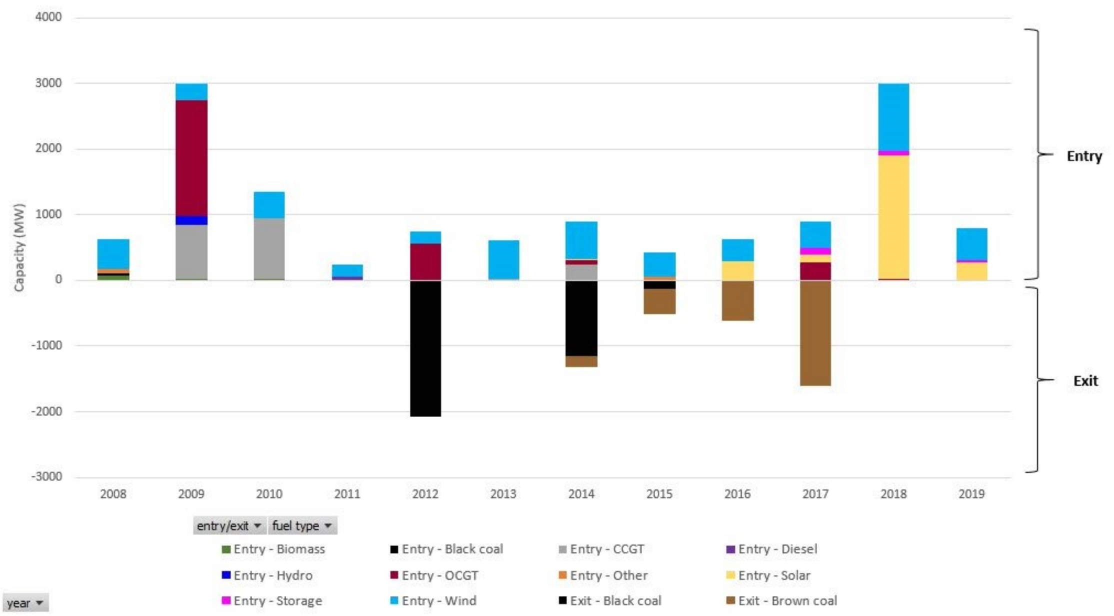
A range of factors are driving the operational experience of, and heightened concern about, reliability. Key amongst these are the:

- changing generation mix
- changing wholesale market dynamics
- network congestion
- a changing climate
- heightened public awareness and concern.

3.3.1 The changing generation mix

As is the case with many power systems around the world, the technologies producing electricity in the NEM (the generation mix) is changing and this has consequences for reliability. There is an increased penetration of variable renewable generation, and retiring and ageing coal plants, which make the supply side more variable, as well as the demand side due to the strong uptake of roof top solar. The chart below shows the entry and exit of generation capacity in the NEM by technology type. The current capacity of the NEM is expected to be replaced by 2040.

Figure 3.4: Entry and exit of capacity in the NEM by technology type



Source: AEMC analysis of AEMO data

This chart shows the significant black and brown coal capacity that has exited the market since 2012 and that the new generation is predominantly wind and solar plant with some storage.

The NEM's generation mix is changing from few large, centrally located thermal generation units to many small, dispersed, variable semi-scheduled units. Also, the thermal fleet is ageing, and the trend of thermal, scheduled generation withdrawing from the market has continued since 2012. In recent years, there has been significant investment in new generation capacity leading to higher penetrations of renewable, intermittent generation.

This changing generation mix has had a number of impacts on reliability, including:

- Currently most of this variable renewable generation is non-dispatchable (in the absence of adequate storage capacity). AEMO cannot usually rely upon those types of generation to ramp up when a shortage emerges because the availability of this generation is dependent on the weather.
- Thermal assets generally will become increasingly unreliable with age, a trend exacerbated when plants generate in hot weather and over long periods, and frequently 'ramp' up and down. The failure of some thermal units to generate at peak times has recently been a key factor in reliability events for some NEM regions (see previous section).
- The displacement of dispatchable generation with variable renewable generation may have had the potential to affect the liquidity of secondary markets for the provision of hedging contracts, as much renewable generation is financed through power purchase agreements and not secondary market contracts. However, this is not necessarily bearing out given many generators are starting to offer 'firming' products, or other innovative products.
- Variable renewable energy generators often do not generate at full capacity during peak demand times and/or may be positioned in a congested part of the network. While contributing significant energy resources during typical operating periods, they may sometimes make a limited contribution to meeting demand during peak hours, unless thermal and security constraints are overcome.
- While storage (batteries and pumped hydro) are an increasing feature of the generation mix in the NEM, their relative capacity is not yet at a point that NEM-wide storage is playing a significant role in mitigating the broader changes in the generation mix.

3.3.2 Security issues impacting reliability

In power system management, system security and reliability are addressed through separate regulatory mechanisms. While addressed separately, both are essential in maintaining a power system that meets consumers' needs.

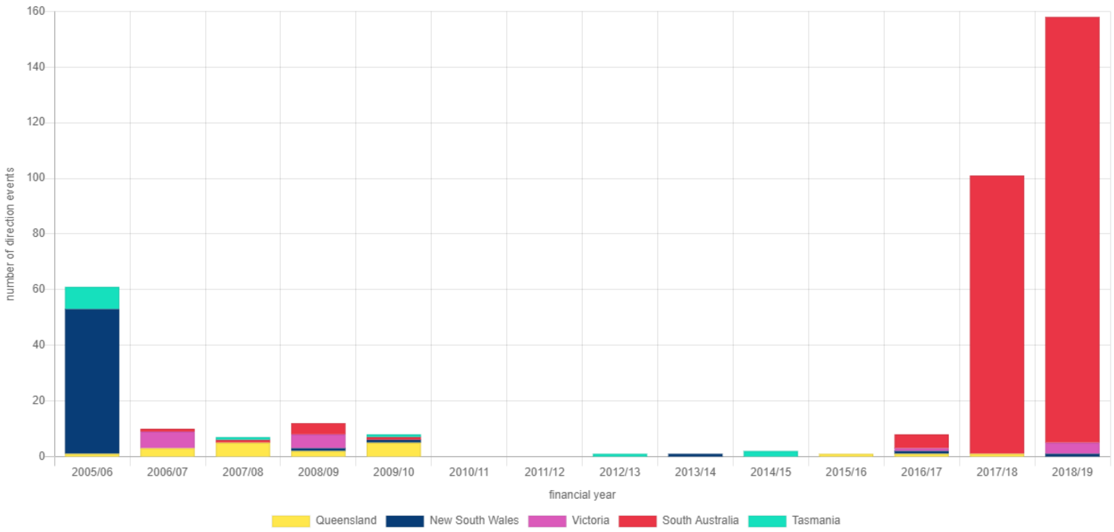
System security management and mechanisms have typically addressed the technical parameters of the system. For example, frequency and voltage, the rate at which these parameters can change, and the ability of the system to withstand faults. Reliability, as discussed, refers to the whether the power system has enough generation, demand response and network capacity to meet consumer demand.

As the NEM transitions, however, power system operators are increasingly identifying instances where system security issues—such as maintaining a secure technical operating envelope by keeping frequency and voltage at appropriate levels—have begun to limit the ability of generators to deliver their electricity to the wholesale market. In the NEM this trend is most apparent in regions of the grid where high penetrations of non-synchronous generation, accompanied by declining concentrations of technologies that provide fault current (thermal and hydro fleet), contribute to declining levels of system strength. Low levels of system strength can jeopardise the ability of generators to maintain connection to the power grid, thereby causing flow-on effects to the stability of grid frequency and voltage.

To address these issues, AEMO may undertake a number of solutions, including:

- Proactively coordinate network maintenance and planned outages to reduce their impact on security and reliability (noting the window periods for undertaking maintenance are narrowing).
- Direct synchronous generation, such as thermal generators, to generate (as has occurred in South Australia and is illustrated in the chart below).
- Curtails generation from non-synchronous generation (such as wind and solar) located in weak parts of the grid (as has occurred in north-west Victoria).

Figure 3.5: Number of power system security directions issued by AEMO over the past 10 years



Source: AEMC analysis of AEMO data

This trend will increasingly challenge the ability of the system to deliver reliability outcomes, particularly as the influx of new generation into the NEM in forthcoming years is likely to be non-synchronous, and typically located in weak parts of the grid. The AEMC is progressing system strength work streams to address these challenges.

3.3.3 Changing market dynamics

Trends in the physical system – both on the supply side and the demand side – are changing wholesale market dynamics with consequent impacts on system reliability.

On the supply side, the changing generation mix has driven changes in the dynamics of the market, altering the bidding behaviour of market participants. The following chart shows changes to the prices for electricity in the wholesale market.

Figure 3.6: Price band contribution to spot prices from 2000/01-2018/19

Source: AEMC analysis of AEMO data.

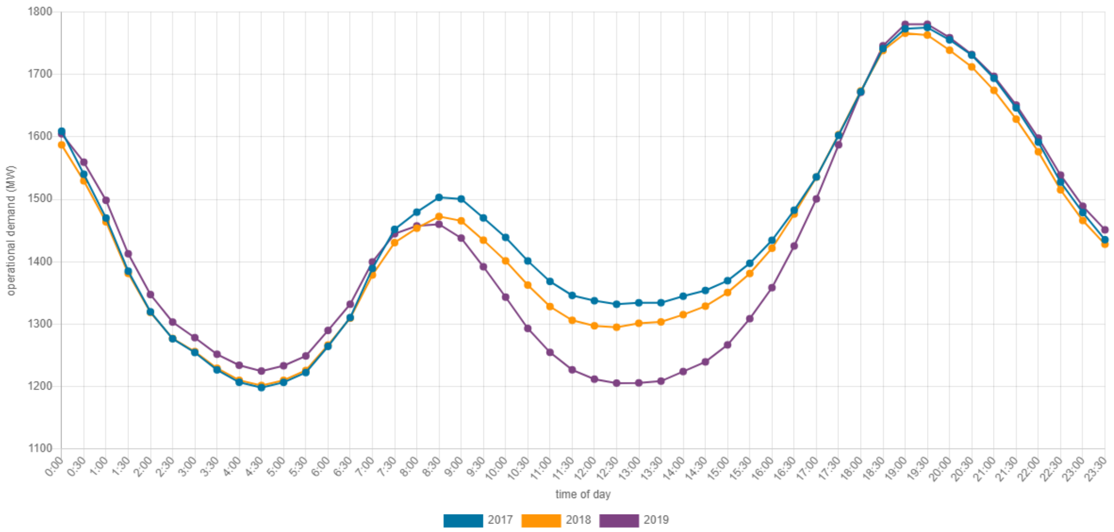
The chart shows a trend of an increase in the wholesale prices in the $100 - $200 per MWh band in all NEM regions since 2015-16. Increasing penetration of renewable generation with low short run marginal costs, which is variable and poorly correlated with demand, tends to bid capacity into the wholesale market at low or negative prices. As penetration increases, variable plant is likely to increasingly become the price setters and price volatility will increase. For non-variable plant to recover their long-run costs, spot prices have to be higher when variable generators are not setting the prices, typically at times of higher demand. As such, non-variable plant is increasingly recovering long run costs in the $100-$200 bracket of spot prices.

Developments in the physical power system are also impacting the wholesale market. The rapid uptake of distributed energy resources (such as roof-top solar panels and household batteries) influence the net demand profile to be met by the wholesale market.

Overall total consumption and demand is projected to rise in coming years, as consumers take up electric vehicles, adopt battery storage and switch from gas to electric appliances. However, actual consumption of grid-supplied energy is projected to remain relatively flat over the next 10 years. A major factor influencing this outcome is the increased penetration of residential rooftop solar PV panels.

The rapid uptake of rooftop solar in Australia is changing the profile of the evening peak demand, as shown in the following chart of historical demand in South Australia from the wholesale market. In the coming three to five years, AEMO forecasts that minimum demand will decline in New South Wales, Victoria, South Australia, and Queensland. Within two years, it is projected that minimum demand will coincide with the middle of the day in all states (except Tasmania), rather than in the middle of the night as is currently the case.[13]

Figure 3.7: Changes in operational demand in South Australia over time.



Source: AEMC analysis of AEMO data

Additionally, the rapid uptake of distributed energy resources is making evening peak demand occur later and shorter in length. From both a commercial and system reliability perspective, this favours resources that respond quickly and for relatively short durations (such as OCGT, hydro or battery storage).

13 AEMO, 2019, Electricity Statement of Opportunities, p. 56

Moreover, it is possible for the NEM to have enough resources to meet the reliability standard while simultaneously having a high risk of insufficient supply to meet demand under more extreme, but still plausible, future conditions.[14]

3.3.4 Network congestion

Network congestion is a key factor in the NEM's ability to deliver reliability into the future. Along with the change in generation mix and profile, transmission networks are becoming more interconnected (both within and across regions), and transfers between NEM regions are increasing. As signalled previously, the power system of the future is likely to be characterised by numerous, relatively small and geographically dispersed generators. AEMO's ISP in the 'neutral with storage' modelling scenario shows that by 2030 over 6,000 MW of existing generation is expected to close and be replaced by approximately 22,000 MW of renewable generation and 6,000MW of storage.[15]

The importance of the inter-regional transmission network to the reliability of the NEM overall, and individual regions, is increasing. Key drivers and considerations include:

- New generation may not locate where there is substantial existing transmission to serve them, instead being connected in sunny or windy areas at the edges of the grid where the network is less strong.
- New types of generation can in general be built more quickly than transmission infrastructure required to serve it.
- Transmission businesses are already experiencing congestion across their networks and this is forecast to increase. Network congestion is measured by the frequency and extent to which network constraints bind, and the same trends that effect binding constraints often also affect the flow and direction of flow across interconnectors.
- Congestion on the transmission network may be influenced by events occurring away from the physical line that is constrained. Consequently, flows across the interconnectors and the capacity for inter-regional trade in the NEM is not only influenced by the limits of the physical assets that cross region boundaries, but also by constraints occurring in parts of the network further removed from the actual interconnector infrastructure.

The work being progressed by the ESB to action the ISP seeks to address the transmission capacity of the network, with a focus on inter-connectors while the AEMC's work on COGATI seeks to reform transmission access arrangements to integrate new technologies across the grid in ways that are reliable, secure and work best to benefit consumers.

3.3.5 The changing climate

Power systems have always been subject to the influence of the weather conditions. However, the climate is changing, and the power system will be expected to deliver reliability under climatic conditions that place more extreme demands on power system assets and simultaneously put upward pressure on demand.

14 AEMO, AEMO observations: operational and market challenges to reliability and security in the NEM, p. 7

15 AEMC, Renewable Energy Zones Discussion Paper, October 2019, p.6

Particularly relevant to reliability is the outlook for temperature over summer periods. The incidence, duration and levels of high temperatures are increasing in Australia. For instance, in 2017 Australia's area-averaged mean temperature was 0.95° Celsius (C) above the 1961-1990 average.[16] The likelihood of drought and extreme bushfires are also forecast to increase.

From a power system standpoint, climate trends are material for many reasons including:

- Many generators' output becomes constrained under high temperatures due to limitations in cooling systems and solar and wind plants may produce lower output at higher operating temperatures.
- Solar and wind resources are now a major fuel source.
- More intense and more frequent extreme weather events risk removing from service crucial generating assets or transmission lines and network assets for extended periods of time.
- Gross demand will rise as consumers adapt to prolonged periods of higher temperatures (purchase of air conditioners).[17]

Climate change will also drive an increased risk of "compound events". This where extremes occur across multiple regions of the NEM and/or variables like windspeed and rainfall occur at the same time.[18]

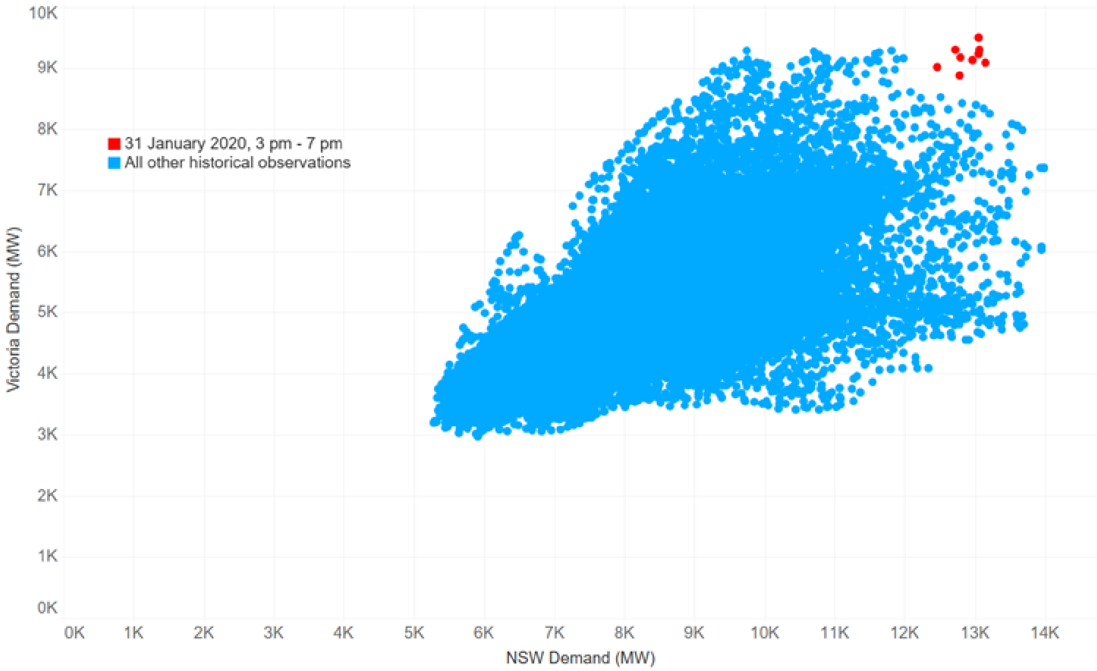
To illustrate, on 31 January 2020 there was coincident high demand in Victoria, NSW and South Australia on a scale not seen previously. The following chart shows NSW demand versus demand in Victoria for every half-hour from 1 January 2015 to 30 January 2020 (in blue) along with demand on 31 January 2020, from 3 pm to 7 pm (in red). The levels for 31 January 2020 were well outside the historical limits (the envelope of recent historical outcomes in blue).

16 BOM, State of the Climate 2018, p. 4

17 AEMO, AEMO observations: operational and market challenges to reliability and security in the NEM, p. 5

18 BOM, State of the Climate 2018

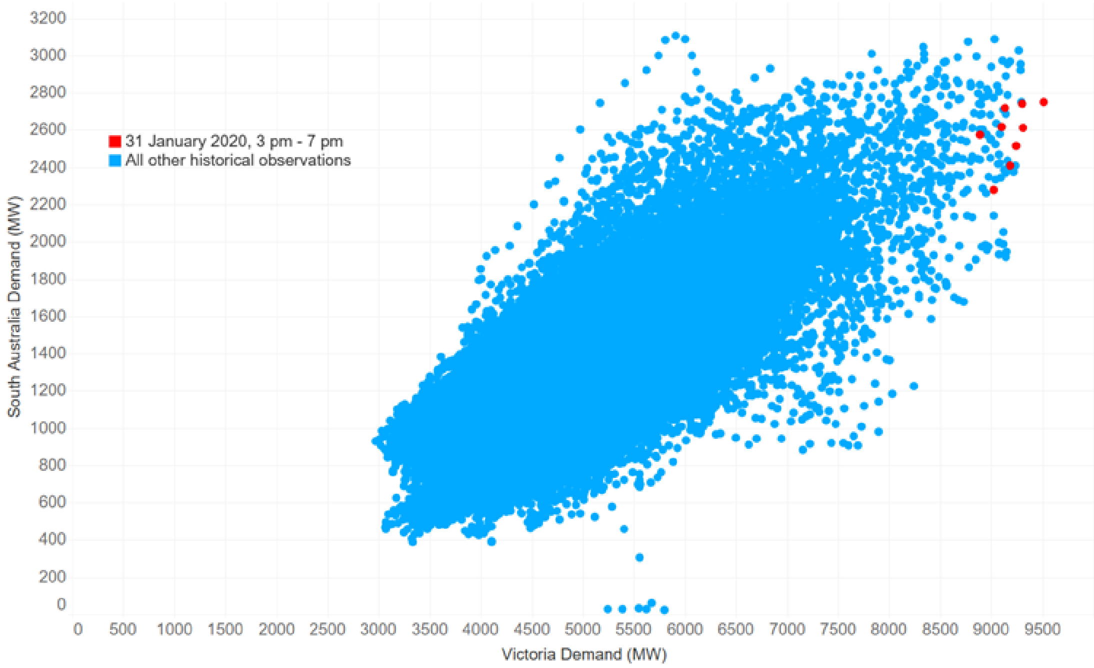
Figure 3.8: NSW Demand versus Victoria Demand, 1 January 2015 to 30 January 2020 and 31 January 2020



Source: AEMC analysis

A similar analysis of Victorian and South Australian demand is shown in the following chart.

Figure 3.9: Victoria Demand versus South Australia Demand, 1 January 2015 to 30 January 2020 and 31 January 2020



Source: AEMC analysis

As well as impacting on the power system, climate change is also driving changes in the physical system. The uptake of both large scale and rooftop penetration of intermittent, variable renewable generation, as well as uptake of electric appliances and electric vehicles at the consumer level, is likely to increase. As discussed previously, this contributes to greater price volatility and exacerbates the ramp to the evening peak, which at times will occur simultaneously across multiple jurisdictions.

These trends pose challenges for reliability going forward in the NEM—in terms of the likelihood of certain events occurring, their impact, and the level of certainty we can have when making policy decisions around both likelihood and impact.

3.3.6 Heightened public awareness and concern

The reliability of the power system has become a regular topic of public discourse in the context of specific forecasts and events, and also in the broader context of discussions about carbon emissions and the affordability of electricity for Australian consumers. For instance, AEMO proposed in the 2019 ESOO a modification to the reliability standard to ensure there are sufficient reserves resources in the NEM in 9 out of 10 years.[19]

19 AEMO, 2019 Electricity Statement of Opportunities, p. 86

As noted earlier, the COAG Energy Council has tasked the Energy Security Board (ESB) with providing advice on the implementation of interim measures to preserve reliability and system security in the NEM, including reviewing the reliability standard, during the transition to the post-2025 market design.

In December 2019 the AER released their final report on the VCR that examined how customers have come to value the reliability of their electricity supply. The report set out the VCR values for unplanned outages of up to 12 hours in duration for the NEM and Northern Territory.[20] The report was based on a survey of over 9,000 residential small business and industrial energy customers. The AER found:[21]

- In general, VCR values are similar between the two survey years, 2014 (the last time that VCRs were estimated by AEMO) and 2019.
- Business customer VCRs continue to be higher than residential customer VCRs. Residential customers continue to value reliability and have a preference to avoid longer outages and outages which occur at peak times.
- The direct cost survey results show that VCR values amongst the approximately 300 business sites that consume the most energy in the NEM can vary greatly depending on the sector.

20 See https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/values-of-customer-reliability-vcr/final-decision

21 AER, Values of customer reliability factsheet, December 2019, p.2

4 THE FORM OF THE STANDARD

The reliability standard employs a metric by which the desired level of reliability is expressed. Having a good metric for reliability (like anything) is important; in this case the metric drives the reliability outcomes that are delivered to customers. The wrong metric can drive outcomes, but not necessarily those that customers want.

The current reliability standard is expressed in terms of outputs. It expresses the maximum amount of energy demand that can be unmet in each NEM region in a year. (It is expressed as a proportion – 0.002 per cent – but could equally be expressed as a volume that gets updated each year if forecast demand changes.) The form of the standard has remained more or less constant since the market started, aside from some changes in terms of how it is measured over time.[22]

A number of different forms of the reliability standard could be used to express and assess power system reliability. Several alternate forms are summarised below.

Table 4.1: **Key aspects of different reliability standard forms**

FORM	DESCRIPTION	OBJECTIVE
Frequency of interruptions	An output-based metric, this could set a maximum level of how frequently supply is interrupted. For example, the number of days per year in which an interruption occurs or hours. This is typically called a loss of load expectation (LOLE) metric.	This is important when the number of interruptions is the critical factor for consumers. This may be most relevant in circumstances where the system has the potential for a number of small outages but these are not necessarily large or of long duration.
Maximum probability of USE	Expresses a maximum tolerable probability of breaching an upper limit of unserved energy (a loss of load probability, LOLP). This metric combines a focus on the tolerable likelihood with a certain size of supply interruption (e.g. no more than a 10 per cent probability of exceeding 0.002 per cent USE). It is a probabilistic measure.	This is important when consumers are willing to tolerate some USE so long as is only likely to occur on a certain basis (e.g. no more than 10 per cent likelihood).

22 At market start, the standard was measured in terms of whether it was met "over the long term". In 2007, the Panel redefined "over the long term" as the preceding 10 years. The standard currently refers to a time period of the previous financial year.

FORM	DESCRIPTION	OBJECTIVE
Maximum probability of any lost load	This metric expresses the tolerable probability of having *any unserved energy at all* (e.g. no more than 10 per probability of having any unserved energy). As per the metric above, this is also a loss of load probability, LOLP metric, and is a probabilistic measure.	This would be used where consumers have a low tolerance for any USE at all.
Volumetric buffer	This is an input-based metric, often called a minimum reserve margin, that sets a minimum amount of reserve generation capacity to be available at all times.	This is useful when larger generators feature in the physical power system and is a useful indicator of the risk appetite in regards to reliability.

Recent studies have examined the approach taken by other jurisdictions for setting reliability requirements. The following table presents the reliability metric of other major industrialised countries:

Table 4.2: **Reliability metric of other major industrialised countries**

JURISDICTION	RELIABILITY STANDARD
PJM interconnection (USA)	0.1 loss of load events (LOLE) per year
ISO – NE (USA)	0.1 loss of load events (LOLE) per year
OFGEM (UK)	3 hours of LOLE per year
ERCOT (USA)	Uses scarcity pricing mechanism in the form of an administratively-determined price adder in pricing intervals with elevated wholesale-level reliability risks. The calculation of the Operating Reserve Demand Curve (ORDC) is based on LOLP.

There are strengths and weaknesses associated with each of these approaches to the form of the standard. For example:

- Metrics that focus on the likelihood of frequency of interruptions generally do not address the magnitude of the shortage (i.e. the actual volumes of energy not served). That is, they focus on the likelihood of load being shed but not the severity. For the same value, a supply interruption may be less than 1 MWh (minor) or greater than 1000 MWh (very serious). As such, they can exaggerate risks for stakeholders. These are likely to be more useful in a less volatile system.

- A volumetric measure, such as USE, captures the volume of energy lost effectively, but does not limit the likelihood of interruptions to customer supply.
- A deterministic standard (such as a minimum reserve margin) may be relatively simple to implement, but the actual level of reliability it provides is a function of the number of generators actually in service at any given time. In some cases, it may just be more an expression of redundancy rather than energy not delivered to customers, which is more relevant when considering reliability.

More specifically:

- When considering a Loss of Load Probability (LOLP) form of standard, the standard would set a probability at which the likelihood of the loss of any load would not be exceeded, but not the level of severity that may be associated with that likelihood.
- When considering a Loss of Load Expectation (LOLE) form of standard, the standard level would set the number of hours, or number of days over a reporting period, where supply is expected to not meet demand. Like the LOLP form, this method does not factor in the severity of the loss of load instances.
- When considering a volumetric measure, such as unserved energy, the level would be set with regards to the maximum tolerable volume of energy loss. Such measures can, but in the NEM does not currently, incorporate a probability tolerance.
- A deterministic standard, such as one that determines the minimum level of generation reserves that need to be available at any one time, may not reflect the specific needs of the market when shortfalls do occur (either over or under procured). This may run the risk for very volatile systems that even where average USE is comparatively low, there may be rare instances where the shortfall is unmanageably high.

5 KEY CONSIDERATIONS FOR ASSESSING THE RELIABILITY STANDARD

The reliability standard helps guide decisions of market participants and AEMO, but it does not, in itself, deliver reliable supply to consumers. It is the market operating within the market's reliability settings, or if that fails,AEMO's intervention measures including the RERT and the RRO that deliver reliability in the existing market.

In considering changes to the reliability standard, the Panel considers there are three key questions that need answering. The answers will provide an indication of the costs, risks and other impacts to customers and participants. The questions are:

Question 1 – What problems is the NEM facing that require changes to the reliability standard, settings and/or any new mechanisms?

The NEM has delivered a high level of reliability for the past twenty years. With the supply/demand balance becoming tighter, as well as the other drivers of change discussed above, there are concerns that the reliability standard is no longer fit for purpose.

In order to consider what changes to the reliability standard may be effective, the problem that is being addressed should be identified as specifically as possible.

For example:

- **Low probability, high impact** - Is the key concern not having enough reserves on standby in the case of low likelihood but high impact events? For instance, co-incident events across several NEM regions. In this case consideration should be given to ways to facilitate resources that have low ongoing fixed costs for availability but a high degree of 'on call 'certainty.
- **Reduced tolerance of load shedding** – Is the key problem that the community has an increased desire to avoid load shedding? In this case, consideration should be given to 'insuring' against most load shedding, irrespective of its scale or duration.[23] The cost of supplying generation and/or demand response to meet such a standard should not exceed the value consumers place on most types of reliability events, evidenced in the value of customer reliability.

If the problem is related to factors outside of, but impacting the power system (for example, uncertainty in the investment environment), then other ways to address concerns may be warranted.

Being specific about the problem will help with the assessment of the costs and benefits of the various options for reform.

Question 2 - How should the standard (and mechanisms to deliver it) interact with the market settings, other aspects of the market and each other?

23 Noting that the vast majority of blackouts are caused by failures in the network not inadequate supply.

The reliability framework contains both in-market incentives and settings as well as out-of-market interventions. These are:

- **Market incentives:** the spot market represents real-time balancing of the market to meet physical realities; contracts (derivatives) provide incentives for investment and operation and the RRO is providing additional incentives for investment
- **Market settings: the** reliability standard sets the 'envelope' (price cap and floor) for the spot market, which then drives contract volumes and prices; the reliability settings balance certainty/risk management for participants; settings also account for transitory pricing power.
- **Interventions:** as a last resort, AEMO has powers to maintain power system security and reliability when market responses have failed, these include: directions, clause 4.8.9 instructions and RERT which allows AEMO to contract and dispatch out of market emergency reserves.

All the components of the reliability framework are interrelated and changes to the reliability standard or a particular mechanism within the reliability framework has the potential to impact on the operation of other mechanisms including the bidding behaviour of generators within the wholesale spot market. Such interactions should be considered in order to avoid unintended consequences. For instance, impacts on bidding behaviours and investments in the wholesale market should be thought about when considering out of market mechanisms. For example, out of market mechanisms can potentially distort wholesale market outcomes, which could actually lead to a worsening of reliability.

This is why it is important to consider: the cost (both direct and indirect) implications of the proposed reforms; how many additional resources may or may not be encouraged; as well as how different aspect of the framework interact with each other.

Question 3 - What should be considered when setting the level of the reliability standard?

The level of the reliability standard in the NEM is a trade-off between a reliable supply and an affordable supply of what is an essential service.

Setting the reliability standard is about striking a balance between having enough generation available to meet consumer demand for the vast majority of scenarios, and keeping costs at levels customers are willing to pay.

Moving along a continuum, there will always be a point where the level of reliability exceeds the amount that customers are willing to pay in their electricity bills. At one extreme end of the spectrum, providing 100 per cent reliability is not possible (something will always go wrong), and so will not be affordable and therefore not desirable for the vast majority of customers. Conversely, very low levels of reliability at cheaper prices would also not be acceptable in today's world that is so dependent upon electricity for the functioning of the economy, and the health and comfort of the community.

There are two factors to consider in setting the level of the reliability standard. These are:

- the value customers place on having reliable supply (known as VCR)

- the cost of supply.

VCR is not a perfect indicator of the value that each individual customer places on reliability. Different VCR values are set for residential versus business customers, and for different climate zones. However this still does not capture the differences between individuals, or the value customers may place on reliability on a very hot day compared to a mild day.

The cost of supply is a more straightforward calculation. It depends on the amount and type of reserves and the way they are procured. Risk allocation is also an important consideration given some parties are more able to bear investment risk and uncertainty.

In general, the more conservative the reliability standard (i.e. protecting against more scenarios), the higher the cost for consumers. If the cost of supplying generation outweighs the value customers place on it, the standard is too conservative.

It should be noted that any actions to improve the function of the competitive market will lead to investment in reserves that are available when needed. A clear emissions policy, new frameworks to coordinate transmission and generation investment, and new markets for system security services would all improve the investment environment for new reserves.

It may also be worth thinking through whether there is a need for a short-term measure to cope with the transition. If so, how could this be designed to put in place effective arrangements for the interim, but could transition to a more market based process at some point in the future when more stability has been established.

6 CONCLUSION

The reliability standard is the central component of the NEM's reliability framework. The framework is centred around, and driven by, the reliability standard. Concern about there being enough supply to meet demand as the market transitions has resulted in questions about the appropriateness of the reliability standard.

The Reliability Panel agrees that heightened concern about the reliability is warranted, and that the reliability issues are a consequence of the considerable changes underway in the NEM. These include changes to the generation mix, consumer preferences, and wholesale market dynamics. Reliability issues are also being caused by greater constraints on inter regional and intra-regional transfers of electricity and an evolving climate that increases the likelihood that high impact co-incident events will occur.

This paper has provided an overview of reliability in the NEM to educate and promote discussion among stakeholders. It is also a first step towards the Panel's next statutory review of the reliability standard and settings.

In light of the complexity of the NEM's reliability framework, the paper provided a description of the role of the reliability standard in relation to delivering reliability. It also provided a suggested approach to thinking about the costs and benefits of changing the reliability standard. These are:

1. What problems is the NEM facing that require changes to the reliability standard, settings and/or any new mechanisms?

2. How should the standard (and mechanisms to deliver it) interact with the market settings, other aspects of the market and each other?

3. What should be considered when setting the level of the reliability standard?

In addition, the Panel has considered what areas may be helpful for it to focus on over the coming months. These include:

- increasing understanding and awareness of the reliability standard and the impacts that it has for consumers
- engaging with the AEMC on its progression of our rule change request, on increasing the *transparency of USE* which aims to provide more clarity about how USE is estimated
- focussing on initial thinking about how the current administered price cap and, potentially the cumulative price threshold, may impact reliability in the future in light of recent events.