RELIABILITY PANEL AEMC

REVIEW

Reliability Panel AEMC

ISSUES PAPER

REVIEW OF THE FORM OF THE RELIABILITY STANDARD AND ADMINISTERED PRICE CAP

30 MARCH 2023

INQUIRIES

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Reference: REL0086

CITATION

Reliability Panel, Review of the Form of the Reliability Standard and Administered Price Cap, 30 March 2023

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

The changing NEM impacts the way we think about reliability

1 The national electricity market (NEM) is undergoing a significant transformation. It is shifting from a centralised and predominately thermal energy system to a more decentralised and complex one, characterised by high levels of variable renewable energy (VRE) and storage. The change requires careful consideration of how reliability is characterised and managed to ensure the system can meet demand at a level of reliability that consumers value.

2 The reliability standard is vital to investment decisions in the NEM as it is used to indicate to the market the required level of supply to meet demand on a regional basis based on the reliability settings. The reliability settings include the market price cap (MPC), cumulative price threshold (CPT), administered price cap (APC) and market floor price (MFP). Together the standard and settings aim to encourage sufficient investment in generation, transmission or demand response to meet consumer demand for energy while protecting market participants from potential financial risks that threaten overall market stability and integrity.

3 This Issues Paper represents the start of an extensive review to allow the Panel to take a broad view of options for reforming the form of the reliability standard and APC.

The current reliability standard may no longer be appropriate

4 The current reliability standard of 0.002 per cent expected unserved energy (USE) for the NEM is set at the maximum forecast unmet energy due to reliability issues for each financial year, as a proportion of the total energy supplied in a region. USE is the amount of energy that is required (or demanded) by consumers but which is not supplied due to the shortage of generation or interconnection, which results in supply interruptions for consumers.

5 Using USE as the reliability standard has historically provided sufficient information to signal reliability risk to the market. Historically reliability risk was relatively well understood, with the range of generation technologies connecting to the grid being dominated by conventional thermal and hydroelectric generators. The introduction of battery storage and VRE generation with availability dependent on factors including weather and geographic dispersal, have brought additional interrelated risks to supply reliability. This coincides with increasing consumer energy resources changing demand patterns.

6 The Panel's 2022 reliability standards and settings review (2022 RSS Review), found that a simple USE standard may no longer be appropriate as the market transitions to a more energy-limited power system with high levels of VRE and storage. It may not effectively reflect changes in the NEM's reliability risk profile, or how consumers value reliability.

7 The Panel recommended that extensive analysis and consultation be carried out before the 2026 RSS Review to consider whether the transformation of the power system means that a new form of the reliability standard may be required to properly reflect the changing risks. For example, a reliability standard that incorporates a 'tail risk' metric in combination with the existing expected value of unserved energy metric may be necessary. Tail risk refers to the risk of large, low probability outcomes reflected in the 'tail' of a USE probability distribution.

8 The Panel is initiating this review to address the changing nature of reliability risk to identify options that may be more appropriate in a future NEM. The review will include options identified in the 2022 RSS review, and evaluate a wide range of other candidate forms that will ultimately inform the Panel's final recommendations.

9 Alongside the reliability standard review, the Panel is also considering the form of the APC.

The Panel is seeking stakeholder feedback

10 The Panel is yet to form a view on what the most appropriate form of a new standard should be. This Issues Paper is an initial step in exploring the issues for the Panel to consider and potential candidate metrics.

11 At a high level, the Issues Paper seeks initial stakeholder feedback on issues raised in this paper, including (but not limited to):

- the types of reliability gaps which may present in a high VRE, weather-dependent NEM
- the proposed approach to assessing candidate metrics
- the proposed approach to modelling USE
- potential mathematical approaches and candidate metrics
- models for a dynamic APC.

12 In particular, the Panel seeks stakeholder views on possible candidate metrics to inform the next stage of the Panel's assessment, including (but not limited to) the following options:

- expected value of USE
- conditional value at risk (CVaR) of USE
- most probable size of risk events
- expected maximum value of USE
- probability that the maximum level of USE is more than a specified/predetermined value
- quantile of USE that specifies a level of USE below which a defined percentage of events will lie
- expected USE divided by the supply
- outage duration
- frequency of outages.

13 The Panel is also seeking feedback on combined metrics or multiple metrics.

14 This review will be carried out in 2023 in consultation with stakeholders and involves publication of an issues paper, draft report and final report. The Panel may also publish a directions paper, if considered necessary. The Panel will consider the level of any new standard in the 2026 RSS Review.

15 The Panel recognises that this review is one of several reliability workstreams completed or currently underway in the NEM. The Panel may consider the outcomes of other workstreams and any subsequent rule changes in making its final recommendations.

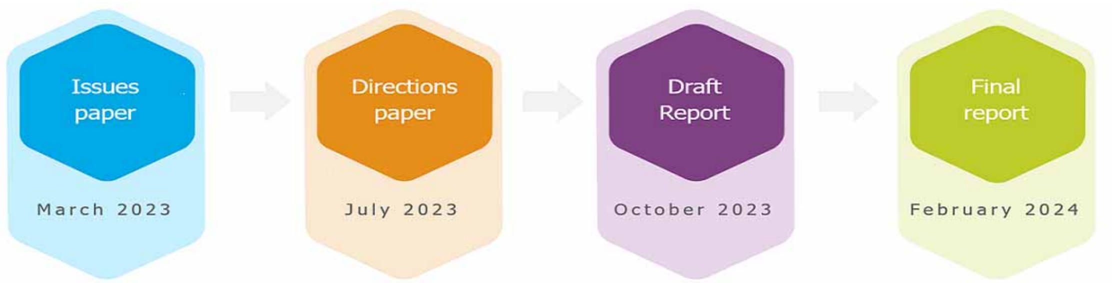
The paper provides context for the review

16 The paper is structured as follows:

- The **first part** introduces the background, scope and terms of reference and the process for the review.
- The **second, third and fourth parts** provide background to the reliability issues presented in the 2022 RSS Review and other issues important to assist with the readers' understanding of the system reliability risks in the transition to a power system where supply is dominated by VRE and storage and demand can be materially affected by residential storage and rooftop PV.
- The **fifth part** outlines the Panel's proposed assessment approach for reviewing new forms of the reliability standard. Any recommendations made by the Panel will be considered against the National Electricity Objective (NEO), the Panel's *Final Guidelines Review of the Reliability Standard and Settings Guidelines 1 July 2021*, and specific objectives and criteria.
- The **sixth part** sets out the Panel's proposed approaches to modelling USE in a high VRE and decentralised power system with greater weather variability and potential mathematical approaches, tools and techniques that could be used to inform the selection of an enhanced reliability standard.
    - As a first stage of the modelling exercise, the Panel proposes to use PLEXOS to develop new fleets of generation and the time sequential simulations to identify corresponding USE events against both standard Australian Energy Market Operator (AEMO) Integrated System Plan (ISP) inputs and a set of appropriately modified VRE data to match expected events such as long term VRE droughts.
    - This will assist with problem definition and provide a baseline for a modelling exercise to assess and test candidate metrics. A third stage of modelling may involve the modelling of multi-metric standards.
- The **seventh part** considers approaches to reform the APC.

The Panel is seeking stakeholder feedback by 4 May 2023

17 The Panel encourages stakeholders to provide feedback on issues raised in the Issues Paper. Submissions are due by 4 May 2023. The key project milestones are shown below.



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1 INTRODUCTION

1.1 The AEMC has tasked the Reliability Panel with reviewing the form of the reliability standard and the administered price cap

The Reliability Panel (the Panel) has prepared this Issues Paper to seek stakeholder feedback on whether the existing form of the reliability standard in the national electricity market (NEM) remains appropriate for power system conditions from 1 July 2028.

In its 2022 reliability standards and settings review (2022 RSS review), the Panel formed the view that reliability risk should be characterised differently in a more energy-limited, high variable renewable energy (VRE) power system, with potentially greater unserved energy (USE) 'tail risk'. Given such a change would require extensive analysis and consultation, the Panel recommended a follow-up review to assess specific changes to the form of the standard.

The Australian Energy Market Commission (AEMC) has issued the Panel with terms of reference to seek advice on the form of the reliability standard that should apply from 1 July 2028.[1]

In requesting the Panel's advice, the AEMC outlined the purpose of the review as follows:

- Reliability risk will need to be characterised differently as the NEM transitions from a primarily capacity-limited thermal power system to a more energy-limited, high VRE power system, with a commensurate shift in USE distribution towards greater 'tail risk'.
- A single average 'expected value of USE' metric may not provide sufficient information on an acceptable USE distribution in a high VRE power system nor effectively reflect the NEM's changing reliability risk profile by 2028.
- The existing standard is 'risk neutral'. It does not provide scope for recognising any possible insurance value of investments to address a higher degree of consumer risk aversion to severe, but low probability, tail risk reliability events.

This review is the first stage in determining whether the form of the reliability standard is appropriate to incentivise efficient reliable investment in a high VRE power system. The Panel's 2026 reliability standards and settings review for the period 1 July 2028 to 30 June 2032 will consider the level of the standard and implementation approach.

The AEMC has also asked the Panel to consider potential changes to the form of the administered price cap (APC). In addition to maintaining the current form of the APC, this review will also consider a change from a fixed to a dynamic value that recognises the link between gas and electricity prices. The Panel will also consider other candidate forms that could better balance systemic risk management and incentives for generation and storage operation in a future high VRE energy-limited NEM.

1 As per section 38(2)(b) of the National Electricity Law (NEL), the AEMC may request the Panel to provide advice on the safety, security and reliability of the national electricity system.

The terms of reference for this review request that the Panel consider the following specific matters about the form of the reliability standard and specification of any appropriate tail risk metric:

- the expected distribution of USE in the NEM given emerging reliability risk drivers associated with high variable renewable generation in a more energy-limited power system
- how to value tail risk outcomes, including whether and how to assess consumer risk aversion to tail risk reliability events
- how AEMO may operationalise an amended reliability standard via market processes, market price settings, and any relevant jurisdictional schemes (if considered appropriate)
- modelling frameworks and approaches to efficiently model and value tail risk given high levels of future uncertainty.

The terms of reference for this review request that the Panel consider the following in relation to the form of the APC:

- the efficiency of a dynamic index linked price versus a fixed APC
- how the signals for efficient operation of storage and other energy-limited plant can be enhanced during an administered price period (APP)
- the impact on different market participants, including customers
- contract market efficiency
- the APC’s relationship with the cumulative price threshold (CPT) and any other potential forms for the APC the Panel considers appropriate.

1.2 The Panel will determine the level and scope of the reliability standard following this review

Reliability standards have three main aspects: form, level and scope.

- **The form** is the method by which reliability is measured.
- **The level** specifies the acceptable quantum of whatever metrics comprise the form of the standard.
- **The scope** defines what does and does not count towards the NEM’s reliability performance.

This review is on the form of the standard rather than its level and scope. The level of the standard is a function of its form and will be evaluated for a number of candidate standard forms as part of the review. The scope of the reliability standard is out of scope for this review, however, the Panel may consider practical issues at the intersection between reliability and security events.

1.3 The Panel will publish several papers before makings its final recommendations

The AEMC has requested that the Panel conduct its review consistent with the consultation process set out in clauses 8.8.3(d)-(l) of the National Electricity Rules (NER).

The AEMC also requests that the Panel publish:

- an Issues Paper for stakeholder consultation at the commencement of the review
- a Draft Report and undertake a second round of stakeholder consultation
- a Final Report with the Panel's recommendations.

The Panel may also publish and publicly consult on a directions paper or any other additional paper it considers appropriate.

The AEMC has requested that the Panel deliver its final report by February 2024, with any relevant rule changes to be submitted as soon as possible following this date.

1.4 We are seeking submissions on the issues raised in this paper

The Panel invites comments from interested parties in response to this Issues Paper by 4 May 2023.

Electronic submissions must be lodged online through the AEMC's website using the link entitled 'lodge a submission' and reference code 'REL0086'. Submissions will generally be published in full on the AEMC's website, subject to any claims of confidentiality. Our treatment of the content of your submission is further explained on that page.

The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated. If choosing to make a submission by mail, the submission must be on letterhead (if submitted on behalf of an organisation), signed and dated, and posted to:

Reliability Panel
c/- Australian Energy Market Commission
PO Box A2449
SYDNEY SOUTH NSW 1235

2 CONTEXT FOR THE REVIEW

This chapter provides an overview of the reliability framework in the NEM, the role of the reliability standard and how it is operationalised to deliver investment.

2.1 The reliability framework in the NEM is designed to ensure reliability is delivered at a level consumers value

A reliable power system has enough capacity (generation, demand response, interconnector and energy storage capacity) to meet consumer needs. To maintain reliability, a power system needs investment in enough new capacity to meet changing increasing demand and to replace generators when they exit the market or break down. A reliable supply also needs reserves that allow demand and supply to balance when unexpected changes occur to demand and supply.

No power system can be 100 per cent reliable. Rare, or unforeseen and unplanned reliability events can occur. Building a system with sufficient capacity to avoid any outages is prohibitively expensive, as it would involve significant over-capitalisation in power system assets leading to much higher power prices than consumers would be willing to pay.

Reliability can be increased by encouraging investment in more capacity (either generation or demand response) in the system or by using the power system more effectively. However, these come with additional costs. The reliability standard seeks to balance the consumer value gained from increasing reliability with the costs that this may entail. These trade-offs are implemented through the market price settings, based on what consumers value in relation to the reliability sought.

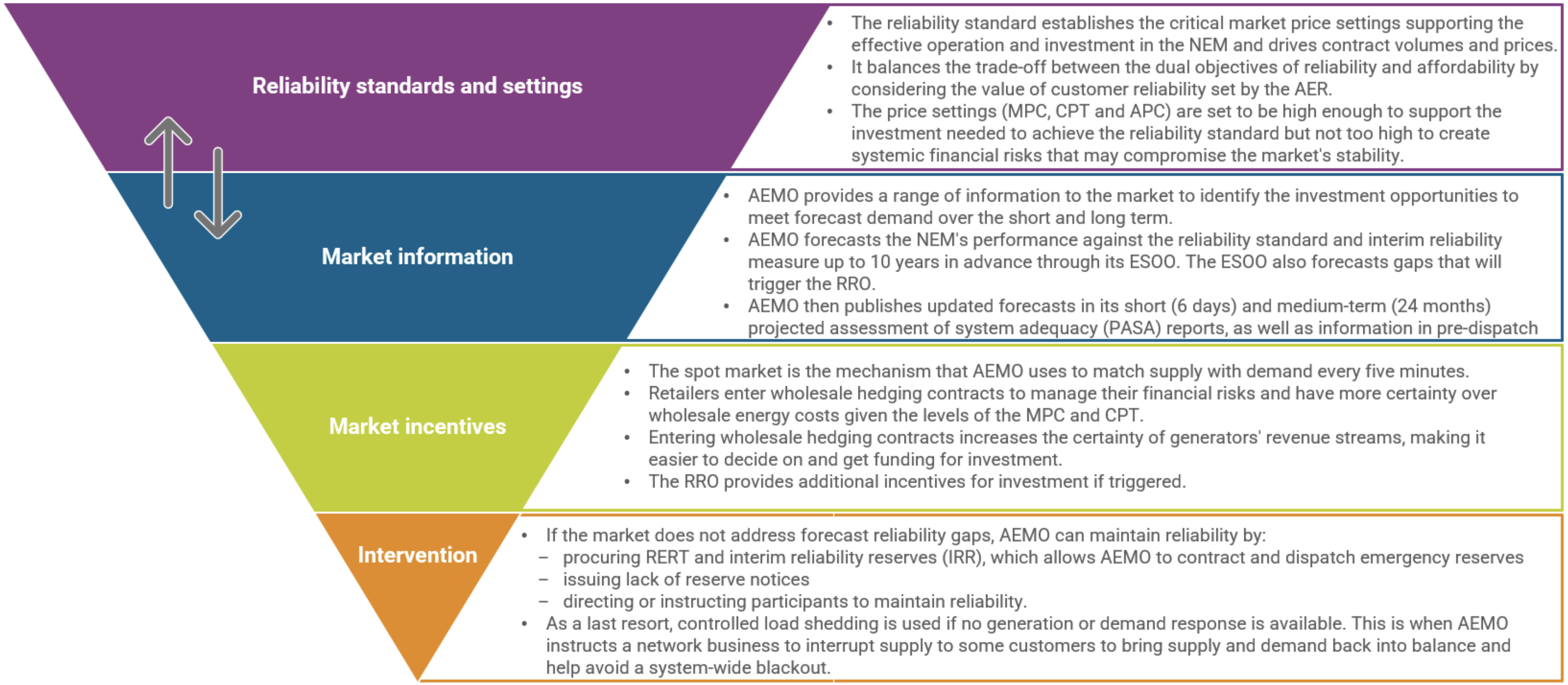
Historically, there has been a strong relationship between generation capacity and energy in the centrally-dispatched, thermal power system based largely on coal and gas generation. However, this relationship starts to break down in the transition to a high VRE and decentralised system, where at certain times, there may be ample capacity but insufficient energy output to meet demand. This results in new reliability risks that emerge from energy storage limits and the potential for extended low VRE ('dark doldrum' or dunkelflaute) events.[2] These events include extended periods of low wind and/or low solar output (such as extended days of high cloud cover).

The NEM operationalises reliability through a broad reliability framework to deliver investment in reliable and affordable electricity to customers. The framework comprises a mix of reliability settings, market prices and incentives, and operational decisions to keep supply and demand in balance.

Figure 2.1 summarises the framework which includes the provision of reliability through spot market incentives supplemented by information and intervention by AEMO as a last resort.

2 Dark doldrums, dunkelflaute or VRE droughts are extended periods in which there is an unusually widespread and prolonged reduction of both sunlight and wind, which results in an extended period of lower-than-expected VRE production.

Figure 2.1: Reliability Framework in the national electricity market



Source: AEMC

2.2 The reliability standard underpins the market settings to drive efficient investment

The reliability standard is a central feature of the NEM because it establishes the market price settings that support the effective operation of and investment in the NEM. It guides the decisions of market participants through the reliability settings, the Australian Energy Market Operator's (AEMO's) forecasts and the Retailer Reliability Obligation (RRO).

The reliability standard is an ex-ante standard that indicates the efficient level of supply required to meet demand on a regional basis. It is not a regulatory or performance standard that is 'enforced'. The standard is intended to provide a clear expression of the economically efficient level of generation and inter-regional transmission capacity sought for the NEM.

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. Crucially, the NEM's reliability framework seeks to deliver customers both reliable and affordable electricity. The reliability standard represents a trade-off between the dual objectives of reliability and affordability.

The current 0.002 per cent USE reliability standard for the NEM, represents the average forecast unmet energy, or USE, for each financial year, as a proportion of the total energy supplied in a region.[3]

Using USE as the reliability standard has historically provided enough information to signal reliability risk to the market through the market price cap and other market settings. In the 2022 RSS Review, the Panel found that using USE may no longer be appropriate because the market is transitioning to net zero with high levels of VRE and a changing USE risk profile. Chapter 3 of the Issues Paper provides more details on the new risk profile.

Market incentives are the foundation of the current NEM reliability framework. Prices in the spot and contract markets provide signals for generation and demand-side resources to be built and dispatched and indicate supply and demand balance in each region over time.

The reliability standard influences new entrant investment revenue potential through the level of the market price settings, being the market price cap (MPC), cumulative price threshold (CPT), administered price cap (APC) and market floor price (MFP).

The market price settings act to limit the prices that generators receive for supplying electricity and therefore the revenue to support investment decisions. The level of the market price settings determined through the RSS Reviews is set at the revenue required by the marginal new generation entrant to maintain the expected level of USE in the NEM to 0.002 per cent.[4]

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3 See clause 3.9.3C(a) of the NER.

4 Further details can be found in the 2022 RSS Review Final Report at https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review.

2.3 The standard also guides AEMO in its role as the system operator

Another key role of the standard is to guide AEMO's decisions in its role as the system operator. AEMO is responsible for operationalising the reliability standard through its forecasting and operational processes. AEMO uses the reliability standard to:

- inform participants, network service providers and potential investors, over ten-year, two-year and six-day outlooks by forecasting the adequacy of supply to meet the standard
- initiate intervention action to maintain power system reliability and security where practicable by monitoring demand and generation capacity.

In operational timescales, AEMO issues lack of reserve (LOR) notices to inform the market when supply scarcity conditions exist. AEMO declares LOR conditions when it determines there is a potential shortfall of supply to meet forecast demand. LOR notices are either LOR1, LOR2, and LOR3 in order of increasing supply scarcity.[5]

As effective as information processes and market incentives can be in delivering the desired reliability outcomes from commercial investment decisions, they do not always elicit the outcomes needed. If the market fails to respond to the market price settings and the information AEMO publishes, AEMO may need to intervene in the market to ensure a reliable and secure electricity supply when needed.[6]

2.4 There is a range of work across the NEM to address the changing nature of reliability

There is a range of work underway across the NEM to manage the increasing pressures on reliability. The projects each manage reliability risk over the short, medium or long term and include:

- **Projects managing reliability risk over the short term**:
  - Energy Ministers agreeing to extend the interim reliability reserve (IRR) to 31 March 2028[7]
  - the AEMC's draft recommendation to extend the application of the interim reliability measure (IRM) to the RRO
  - the AEMC's consideration of the operating reserves rule change requests.
- **Projects managing reliability risk over the medium term**
  - rule change from the Panel to adjust the MPC, CPT and APC for 1 July 2025 to 30 June 2028[8]
  - the AEMC's review of the RRO[9]
  - the extension of the T-3 Ministerial lever for the RRO to all NEM regions.[10]

5 Further information can be obtained from AEMO's reliability standard implementation guidelines.
6 See clauses 3.20 and 4.8.9 of the NER.
7 National Electricity Amendment (Interim Reliability Reserve) Rule 2022.
8 Reliability Panel, *2022 Review of the Reliability Standard and Settings*, Final report, p. iii.
9 Found at https://www.aemc.gov.au/market-reviews-advice/review-retailer-reliability-obligation.
10 ESB, *T3 Trigger for the RRO — Draft Bill*, 20 July 2022.

- **Projects managing reliability risk over the long-term**
  - work underway through the Energy Ministers Meeting on managing risks of the disorderly exit of coal generation
  - the Commonwealth Government's Capacity Investment Scheme
  - the Panel's review of the form of the reliability standard (this review).

The Panel recognises it is vital to have an effective reliability framework as the market transitions to net-zero. The outcome of the range of work above, particularly this review, will be a framework that incentivises efficient investment in appropriate levels of firmed capacity, storage and demand side reductions with sufficient duration to limit USE events to a level that customers value.

2.4.1 Energy ministers introduced an interim standard to address reliability risk in the short term

In November 2019, the then COAG Energy Council requested the Energy Security Board (ESB) provide advice on the reliability standard. Energy Ministers were concerned that the existing standard was insufficient to address emerging tail risk due to uncertainty associated with a more weather-dependent power system.

ESB modelling suggested that a jurisdiction that meets the current 0.002 per cent reliability standard could expect some load shedding one in every three years on average due to insufficient resources to meet demand.[11]

Energy Ministers considered this shedding frequency to be excessive and approved an interim reliability standard of 0.0006 per cent USE for the purposes of AEMO's procurement of long-duration 3-year Reliability and Emergency Reserve Trader (RERT) (known as the interim reliability reserve) and triggering the RRO.[12] The ESB noted that the 0.0006 per cent USE threshold was designed to meet the community expectation that electricity supply remains reliable during a 1 in 10-year summer.[13]

It is worth highlighting that the IRM is not applied when calculating the market price settings which are still calculated based on 0.002 per cent expected USE.

The Panel's analysis indicated the IRM, at 0.0006 per cent expected USE, is significantly tighter than a level of reliability consistent with consumer willingness to pay for reliability. The Panel also considered 0.0006 per cent was not a level of reliability that could be implemented or reasonably achieved through the market price settings as it would require an impractically high MPC leading to systemic financial risk issues.

The Panel considered that a tighter USE standard alone would not address the specific risks in a high VRE, more energy-limited and decentralised power system. Further, a tighter USE standard would have little value in identifying the efficient mix of new investment, and thereby the trade-off between customer value and investment cost, given the new set of underlying reliability drivers in a future NEM.

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11 ESB, *Reliability Standard Review*, March 2020, page 4.

12 The RRO commenced on 1 July 2019, providing stronger incentives for market participants to invest in the right technologies in regions where it is needed, to support reliability in the NEM.

13 ESB, *Reliability Standard Review,* March 2020, pages 5-6.

3 KEY CONCEPTS FOR THE RELIABILITY STANDARD

This chapter provides background on essential concepts for the reliability standard.

3.1 The reliability standard is defined in the National Energy Rules

The reliability standard for the NEM is defined as the maximum expected USE in a region of 0.002 per cent of the total energy demanded in that region for a given financial year.[14] 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.

3.2 Reliability events occur when supply does not meet demand

Understanding unserved energy and reliability and security events is essential to understanding how the reliability standard acts as an investment trigger supporting reliability.

The NER states that for the purposes of the reliability standard, USE in megawatt hours (MWh) includes energy demanded but not supplied due to power system reliability incidents resulting from:

- a single credible contingency event on a generating unit or an inter-regional transmission element that may occur concurrently with generating unit or inter-regional transmission element outages; or
- delays to the construction or commissioning of new generating units or inter-regional transmission elements, including delays due to industrial action or acts of God (such as extreme weather events).[15]

The NER specifies that a 'power system reliability incident' is an incident that AEMO considers would have been avoided only if additional active energy had been available to the relevant region or regions from generation, demand response or inter-regional transmission elements.

USE excludes energy demanded but not supplied due to power system security incidents resulting from:

- multiple credible contingency events[16], protected events or non-credible contingency events on a generating unit or an inter-regional transmission element, that may occur concurrently with generating unit or inter-regional transmission element outages;
- outages of transmission network or distribution network elements that do not significantly impact the ability to transfer power into the region where the USE occurred; or
- industrial action or acts of God at existing generating facilities or inter-regional transmission facilities.[17]

14 Clause 3.9.3C(a) of the NER.
15 Clause 3.9.3C(b)(1) of the NER.
16 Clause 4.2.3 of the NER.
17 Clause 3.9.3C(b)(2) of the NER.

3.3 The existing reliability standard is the expected amount of USE

The existing reliability standard is expressed as the 'expected' amount of USE.

It is *expected* USE since assessing the reliability standard requires modelling a forecast of future system operations. The expected USE is derived from a weighted-average of unserved energy across a wide range of possible simulated 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, rare extreme weather events that affect supply and demand are inputs into the forecast and have low weighting based on their low likelihood of occurring. Common events are weighted more highly given, by definition, they are more likely to occur. Therefore, the reliability standard of 0.002 per cent expected USE in a region in a financial year represents the average of the probability distribution of all possible USE outcomes forecast in a NEM region over a financial year, where outcomes are weighted by probability of occurrence.

A reliability standard of 0.002 per cent USE does not imply that there is no possibility of an actual outcome that is worse than 0.002 per cent USE. Outcomes with levels of USE far higher than 0.002 per cent are possible, although will have a low probability and thus a correspondingly low impact on the averaged reliability standard. Similarly, it is likely that the majority of outcomes will have no USE.

The new risk profile from an increasing dependence on high VRE sources of power changes the shape of the distribution of reliability events and may cause a shift towards an extended 'tail risk'. Where previously reliability events tended to be of short duration and normally closely related to periods of peak demand, the increasing dependence on VRE may result in less frequent but potentially longer duration reliability events driven by sustained periods of reduced wind and solar output. This means that there could be significant reliability events that occur with low enough probability (in the 'tail' of the probability distribution) that they have little impact on the average unserved energy and therefore do not impact the market price settings sufficiently to signal that more investment would be needed.

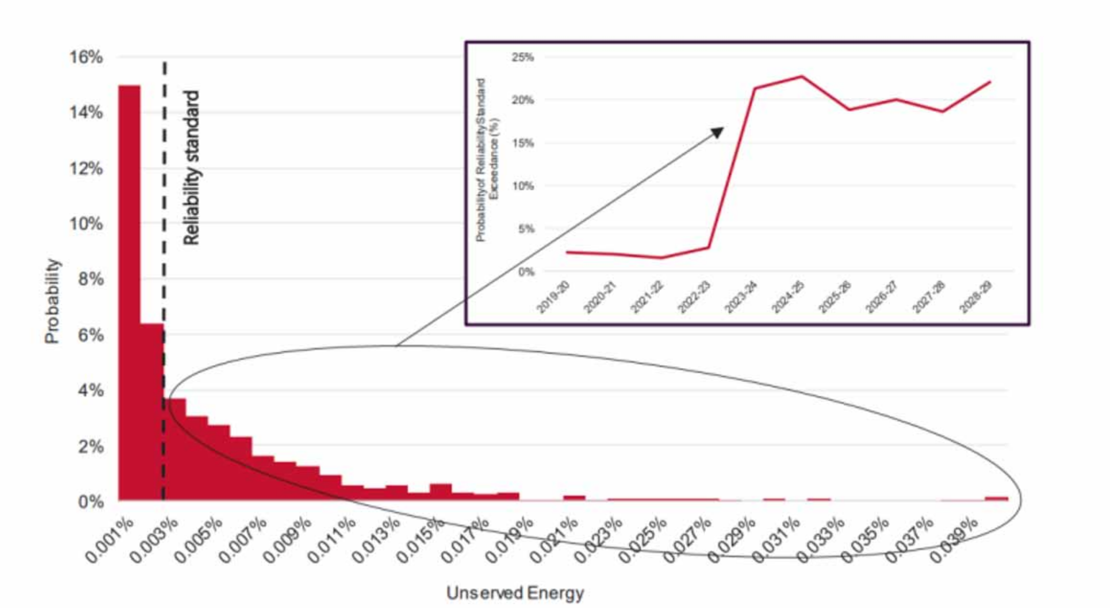
Irrespective of changes in reliability risk, customer values of reliability *may* not be sufficiently well captured by the current reliability standard. The current standard is implemented such that each hour of unserved energy is valued equally. Thus, a customer is indifferent between:

- events on weekdays vs. weekends, winter vs. summer, nights vs. daytime
- seven day-long events and one week-long event
- two back-to-back events vs. two comparable events several months apart.
- a day-long event with certainty vs. a ten-day event with ten per cent probability.

Under the previous thermal generation system, with short-duration reliability events occurring at times of system stress, the simplification of consumer preferences may have been an appropriate approximation. However, as we transition to a different risk profile and the system moves closer towards the actual level of reliability implied by the standard, this approximation may be less appropriate, and more granularity in customer preferences over event timing, duration, frequency and risk may help to make better decisions on the appropriate value that customers have for reliability.

Figure 3.1 illustrates the distribution of possible USE that can arise even when the expected value remains below the level of the reliability standard.[18] In its 2019 Electricity Statement of Opportunities (ESOO), AEMO identified that while 'expected' USE is 0.00174 per cent, which is within the current standard, there was a risk that actual USE may be significantly higher than 0.002 per cent. AEMO specifically identified a 21 per cent probability of USE outcomes above 0.002 per cent.

Figure 3.1: Range of USE Outcomes, Central Scenario — Victoria 2019-20 (AEMO 2019 ESOO)



Source: AEMO, 2019 Electricity Statement of Opportunities, August 2019, p. 13
Note: Samples with zero USE have been omitted from the chart.

Section 4.1 of the 2022 ESOO also highlighted that large USE events are possible even when expected USE is forecast within the IRM. These large events may be driven by weather uncertainty or other circumstances such as simultaneous generator and/or transmission outages that may erode available supply when it is required.

Another example presented in the 2022 ESOO (Figure 3.2) on the probability density of USE forecast in South Australia for the 2022-23 summer shows that:

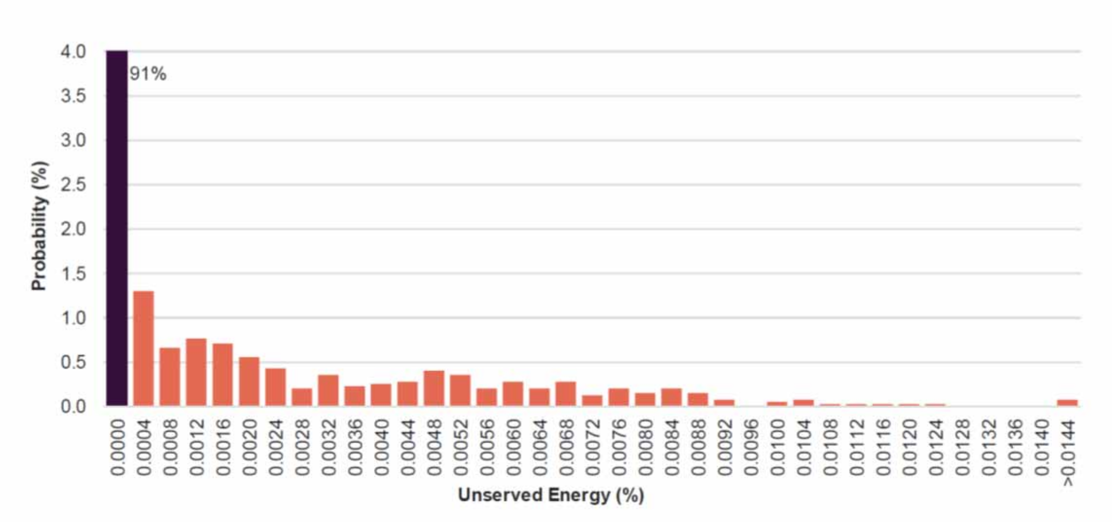
- most likely outcome (91 per cent probability) is no USE (purple bar in the figure)
- there is still a nine per cent probability of a reliability incident, approximately equivalent to an expectation of one incident every 11 years. This is the sum of all the non-zero USE probabilities (all the red bars)
- there is a one per cent probability of an outage of greater than 1,000 MWh (greater than 0.008 per cent USE), which is approximately equivalent to a four-hour outage for 100,000 households.

18 The distribution represents modelled outcomes from NSW in 2023-24.

This shows that while the ESOO may forecast that USE is statistically unlikely in a year, or that 'statistically expected' USE is within the relevant standard, it can also identify a risk that events could compound to affect the reliability of the power system and lead to unlikely, but possible, extreme outcomes.

This information demonstrates, the long tail of potential high impact outcomes that may occur under some circumstances. The reliability standard of 0.002 per cent USE is determined from the weighted average of all USE outcomes. The average therefore may be a truer reflection of the USE outcomes if the distribution of outcomes is normally distributed and tighter. As VRE and storage begin to dominate the supply of electricity this is unlikely to be the case and the longer tail demonstrates the risk and range of higher USE outcomes.

Figure 3.2: Probability Density of Forecast USE in South Australia 2022-23, Central Scenario



Source: AEMO 2022 ESOO

3.3.1 The approach for characterising expected USE outcomes was appropriate in a thermal power system

In a more centrally controlled power system, thermal generation and key transmission element forced outages occur largely independently of each other and can be modelled by an understanding of the probability each generator or transmission element will fail, also known as its forced outage rate (FOR).[19]

Supply availability and power demand requirements at peak times could at first approximation be statistically represented as 'normally' distributed.[20]

19 AEMO characterises the forced outage rates of all major generators and transmission lines in the NEM which are key inputs into the Monte-Carlo assessments of reliability.

20 Strictly speaking, the distribution describing available capacity from conventional generation based on their Forced Outage Rates is binomial, which in traditional power systems can be approximated as normally distributed.

There is usually one typical provider of 'marginal' capacity, for the purpose of reliability modelling, which does not change with time or as a function of the state of the system, given generation levels or demand conditions.

Annual peak power demand drives reliability requirements, which may be translated into the availability of generation/network capacity at peak times. Off-season and off-peak times can be generally ignored.

The relationship between installed capacity and expected peak demand could be easily translated into a reserve margin of generation capacity which would remain available during peak times and therefore available to cover the loss of generation from a 'credible' forced outage occurring at peak demand.

The duration and depth characteristics of an 'average' USE event are a reasonable representation of 'all' events under typical conditions (e.g., driven by generator or transmission forced outage, not too high, representing a limited source of uncertainty in peak demand forecast).

Energy-limited resources, such as hydro, would generally be modelled in terms of their expected available power at peak times and are not major contributors to overall reliability outcomes.

Supply power availability at peak times is not significantly influenced by the past operational history and by any specific control strategy and forecast uncertainty of system and market conditions would only play a minor role.

The shape of the distribution in Figure 3.1 and Figure 3.2 reflects reliability risk arising under the existing largely thermal capacity-limited power system. The shape of this distribution is expected to change as the power system transitions to a high VRE, more energy-limited and decentralised system. Chapter 4 discusses this change and its implications for the form of the standard.

3.4 What do we mean by tail risk?

'Tail risk' is a term used to describe the events at the extreme end of a non-normal probability distribution that occur infrequently but can have large individual consequences.

In the context of planning for reliability in a future high VRE, energy-limited power system, tail risk refers to USE outcomes that have low probability of occurrence, but if they do occur could have large implications for the reliability of the power system.

Graphically, this is seen in the long, thin 'tail' of a USE probability distribution curve. Figure 3.1 and Figure 3.2 graphically shows the long tail of USE outcomes under a scenario in Victoria modelled in the 2019 ESOO.

The current form of the reliability standard uses a mean (probability-weighted) USE value, or 'expected USE', which accounts for all USE outcomes. Large USE outcomes are included in the calculation but as they are infrequent and represent a small part of the sample set, their impact is diluted.

Historically the tail of the distributions of USE events in the power system was relatively well known, with large tail events characterised by very rare instances of multiple supply elements failing during peak demand periods (for example multiple coal unit failures during summer heatwave events).

Major failure events, being driven by multiple failures would be very rare and may occur only once in one hundred or more years. Other more moderate events such as the failure of a specific supply element may be shorter in duration, perhaps several hours during a peak event (for example a hot summer afternoon), but may be repeated for several days in a row.

While such tail events are rare, they could still occur several times over the course of a hundred year period. In a high VRE, energy-limited system, which is both weather dependent and subject to significant consumer energy resources, planning for tail risk must consider not just high demand periods, but very different types of USE events.

The changes in the NEM outlined in this paper may results in a changing shape of reliability risk distribution from more frequent, lower impact events, to less frequent, more extensive events. Expected USE, which is a mean value, cannot identify this change in shape of a USE distribution in the new NEM. Two different USE distributions could very plausibly have the same expected value but with very different risk profiles.

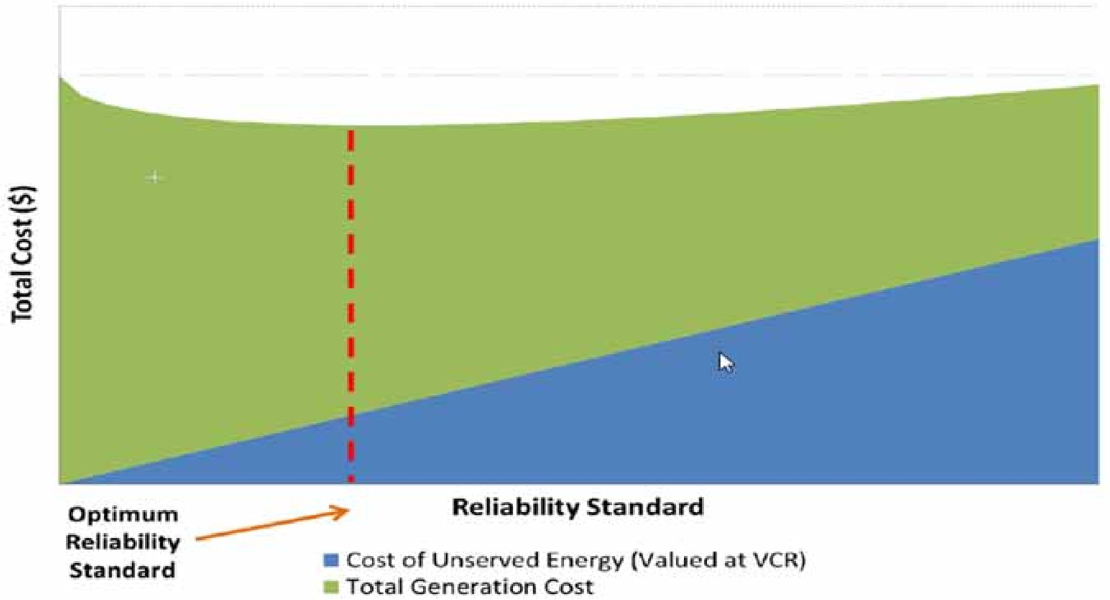
Concern with tail risk recognises that the high impact of large amounts of USE warrants greater consideration of these tail outcomes than would be implied by the low probability used in calculating the mean.

3.5 Determining the reliability standard requires a trade-off between reliability and affordability

The level of the standard expresses an efficient level of reliability which is determined from an economic trade-off between reliability and affordability, based on what customers value. Therefore, the level of the standard trades off the cost to consumers from USE arising from a range of different reliability events and procuring additional power system resources to address this USE.

The efficient level of the standard is the level of USE that minimises the total cost of operating and investment costs and the value customer are willing to pay to avoid an additional MWh of USE. Figure 3.3 conceptually illustrates this efficient level.

Figure 3.3: Conceptual illustration of the efficient level of the reliability standard



Source: ROAM, Reliability Standard and Settings Review, Final report 21 May 2014

3.6 It is important to understand the value customers place on avoiding unserved energy

It is important to understand the value consumers place on avoiding unserved energy to understand the trade-offs to be made when setting an efficient level of reliability. The value of customer reliability (VCR) is an essential parameter in defining the efficient level of the reliability standard:[21]

> How different customers value electricity supply depends on what they use their energy for, from running air conditioners in residential homes to helping to manage a small business to powering large scale manufacturing processes. The value customers place on electricity reliability therefore depends on the value they place on these services and because these services differ, so too does the value of reliability across these different customer segments.

The VCR represents the amount consumers would pay to avoid an incremental unit of USE in each region of the NEM. It is expressed in $/kWh and is reflective of willingness to pay to avoid USE for residential and business consumers under 10 megavolt ampere (MVA), or costs associated with USE for businesses over 10MVA. The AER uses a combination of survey techniques to derive these figures. VCR values are used to estimate the cost of an expected level of USE, which is optimised with operational and investment costs to calculate the efficient level of the reliability standard.

21 AER, Value of Customer Reliability — Final report on VCR values, December 2019, page 4.

The last VCR survey in 2019 collected responses from 1,821 business customers and 7,426 residential customers. In their surveys, the AER collect data on how customers value events of different duration and geographic cover, that occur at different times of day, different seasons weekdays and weekends.[22] These values are then used to calculate a single VCR value for each region based on the likelihood of different types of events occurring in that region. This likelihood is backward-looking and uses historic data for each region and includes all loss of load type events, not just unserved energy from rotational load shedding during reliability events.

In understanding the VCR, it is worth noting that the duration of a USE event is different from the customer experience of a reliability event. For the most part, any reliability event that does occur would be managed through rotating load shedding.

The Panel must have regard to any VCR determined by the AER, which it considers to be relevant, when conducting the reliability standard and settings review.[23] The AER publishes VCR values for each region of the NEM at least every five years with the last set being published in 2019. The AER must complete its next iteration of VCRs by 31 December 2024.[24] The outcomes of the review of the form of the reliability standard may help inform a better understanding of the changing values customers place on reliability in the new power system. Changing the way that the VCR is determined may help inform consideration of the efficient level of the standard to be determined in the 2026 RSS Review.

3.7 The current standard assumes consumers have no preference over timing, duration or frequency of outages

In setting the level of the reliability standard, the Panel considered the base case VCR as well as high and low sensitivity cases. These high and low cases are derived from changing the assumptions in calculating the base VCRs. For example, in the 2022 RSS Review, the low-case VCR was calculated by only aggregating VCR values from survey respondents who experienced rotational load-shedding. These cases show the sensitivity of the efficient level of the reliability standard to the inputs and assumptions built into the VCR.

However, the Panel have otherwise only used the single value VCR per region as calculated by the AER. This means that:

- if the distribution of event types changes in the future due to a changing generation mix and weather conditions, the average VCR that the AER has calculated based on historic data may be quite different from any forward-looking VCR
- the VCR may poorly reflect the value of some event types that have not occurred in the past, but are subject to greater concern moving forward, such as renewable droughts and weather extremes due to climate change
- events of different duration are valued equally on a per-hour basis, so one eight-hour event would be valued the same as four two-hour events

22 Ibid.

23 Clause 3.9.3A(e) of the NER.

24 Clause 8.12(g) of the NER.

- events occurring at different times of day, days of week and season are valued equally.

The current reliability standard assumes that consumers are risk neutral and value each event independently.

- Risk neutrality means that a customer is indifferent between one event occurring with certainty and two comparable events occurring with 50 per cent probability each. If customers were risk averse, they would say the cost of the two potential events more highly than the one certain event.
- Independent valuation of events means that customers consider each event independently of what happened before. Thus, a customer is indifferent between two events that occur within the same week compared to two comparable events that occur several years apart.

The assumptions made in respect of the form of the standard and VCR are a simplification of consumer energy preferences that allow policy-makers to balance out the costs of USE with that of additional reliability. However, these simplifications will increasingly translate into actual consumer experiences, as the NEM transitions to a system that is operating closer to the limits of the current standard than the previous thermal system. In addition, changing generator, weather and demand characteristics will alter the type and probability of USE events moving forward.

4 ISSUES WITH THE CURRENT FRAMEWORK

As discussed in Chapters 2 and 3, the NEM is transitioning from being a capacity-limited thermal power system to becoming a high VRE, more energy-limited and decentralised power system with reliability outcomes which are more dependent on storage and other flexible resources.

A different and wider set of reliability risks will be present in such a system that is fundamentally weather driven on both the supply and demand sides. This chapter discusses this changing reliability risk profile and identifies issues with the current form of the standard in terms of reflecting efficient levels of reliability in such a system.

4.1 Reliability needs to be thought about differently as the NEM transitions

In contrast with the characteristics of reliability assessments in a traditional capacity-limited power system, reliability in a high VRE, energy-limited and more decentralised NEM will involve a range of different considerations including:

- **Seasonal weather-driven impacts on supply and demand** shift reliability issues from peak demand times into other periods of the year which may overlap with generator and transmission maintenance periods.
- **Available reserve margin may not be normally distributed** and may be heavily skewed. For example, wind output is often described as a Gamma or Weibull distribution, both characterised by heavy tails.[25]
- **A simple capacity margin over peak demand does not recognise the variability of the supply resource** in a high VRE, energy-limited power system.
- **VRE supply sources are linked to each other by wider wind and solar characteristics**, even though geographic dispersal of VRE facilities may result in diversity of supply**.**
- **Energy limits on grid-scale and domestic storage assets and demand side response** become increasingly important.
- **Variations in solar resources will affect both the grid scale generation and rooftop PV**. That is, a weather event can affect supply and demand in opposite ways because a change in solar conditions will affect grid scale solar production and at the same time change the demand which comes from customer rooftop PV potentially compounding the impact on supply.[26]

The factors listed above will lead to a shift in the USE distribution and resulting reliability risk profile in the NEM. Part of this change will involve a wider range of drivers of USE relative to the situation in a capacity-limited thermal power system. These drivers include:

25 A 'reserve margin' (available capacity minus demand)/demand, where 'capacity' is the expected maximum available supply and 'demand' is expected peak demand. As an example, a reserve margin of 15% means that the power system has excess capacity in the amount of 15% of expected peak demand.

26 This includes changes to supply and demand due to extremely hot/cold weather causing loss of efficiency, capacity, outages, etc.

- **An increase in the potential for relatively short USE events from insufficient flexible resources**. Rapid changes in solar conditions that result in a change to grid-scale production and the corresponding and offsetting change in customer demand may create very high ramping requirements requiring high levels of flexible capacity and energy to manage. This may be particularly evident at the beginning and end of each solar day.
- **Thermal generation forced outage events** will remain a reliability risk while the power system has significant levels of ageing thermal generators reaching the end of their useful lives (although this is expected to be a declining driver of USE as the power system transitions over time).
- **Short and long duration energy shortfall events, from low solar and wind generation levels (dark doldrums) in the order of hours to weeks.** The exposure to periods of low VRE generation will be a function of the reliance on storage and other sources of energy to support reliability over the duration of these events.
- **Separation events** and local security requirements to manage network failures in a NEM with significantly higher levels of transmission assets.

4.2 A range of more unusual weather outcomes may impact reliability

The existing reliability standard, being an annual regional average USE measure, needs to provide more insight into an acceptable, or efficient, shape of the USE distribution in a weather driven power system which is subject to more supply volatility and diversity.

Currently, shorter duration forced outage related events dominate the existing USE distribution.

However, reliability in a weather driven power system will be potentially impacted by a range of more unusual weather outcomes. Most notably, low probability dark doldrum events (low VRE generation due to co-incident lower than average solar and wind generation) are likely most relevant to reliability outcomes in a high VRE more energy-limited future NEM, in which there is increasing penetration on uncontrolled rooftop solar PV. In addition to extended periods of low rainfall which may impact water availability for hydro-electricity and pumped hydro storage. This means that USE events in the power system are likely to shift towards more widespread longer duration reliability events.

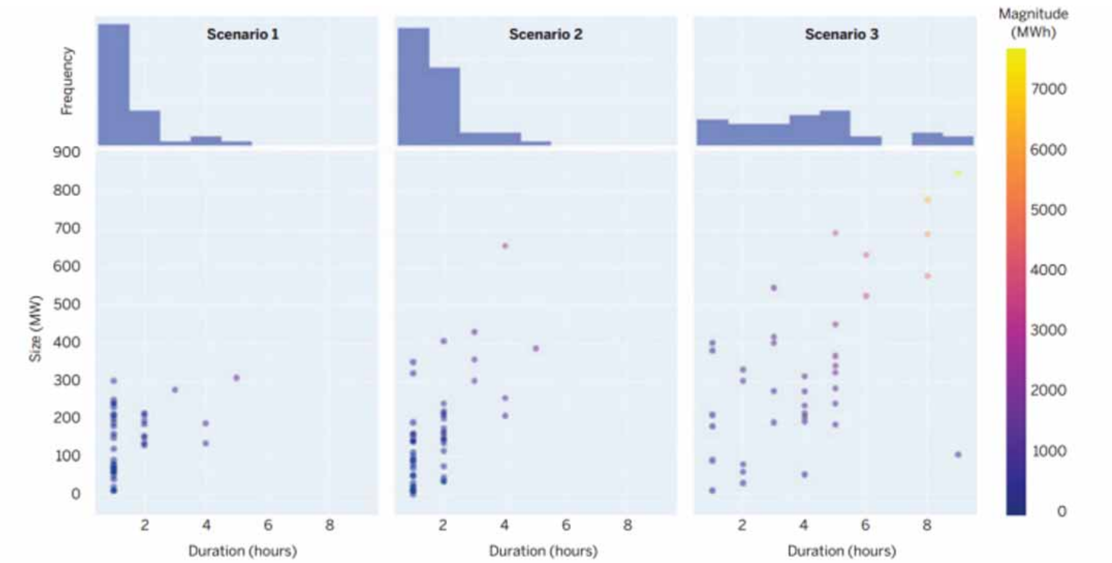
The change in the distribution of USE and reliability risk is illustrated in the Figure 4.1 published by the Energy Systems Integration Group (ESIG) in their report on redefining resource adequacy for modern power system.[27]

Figure 4.1 shows a scatter plot of size, frequency, and duration of USE events for three power system scenarios each of which progressively includes higher VRE penetration and

27 The ESIG is a non-profit educational organisation whose mission is to chart the future of grid transformation and energy systems integration. Further information on ESIG can be found at www.esig.energy/about/.

reliance on storage. An important point is that each of these three scenarios has the same Loss of Load Probability (LOLP).[28] The difference in size, duration, and frequency of USE events in scenario 3 — the high VRE and storage power system — is clear relative to the capacity-limited thermal power system in scenario 1. In particular, the increase in longer duration outages in scenario 3, despite no change in the system LOLP, illustrates both the shift in the distribution of USE in a high VRE power system and the shortcomings of a LOLP-based reliability standard in a high VRE power system where the risk of an individual event may be lower, but their relative size is larger.

Figure 4.1: USE at Varying Levels of VRE Penetration



Source: Redefining Resource Adequacy Task Force. 2021. Redefining Resource Adequacy for Modern Power Systems. Reston, VA: Energy Systems Integration Group, Fig. 8.
Note: For further information see: https://www.esig.energy/resource-adequacy-for-modern-power-systems/

The ESIG goes on to identify the risk that an improperly planned high-renewables grid may experience much larger shortfall events than those for which we usually plan due to sustained periods of lower VRE production. They observe this could cause longer and larger disruptions—even if the probability of these events occurring is lower than historical norms.

Importantly, to avoid this challenge the ESIG identified that the reliability standard could be improved by using additional metrics.[29]

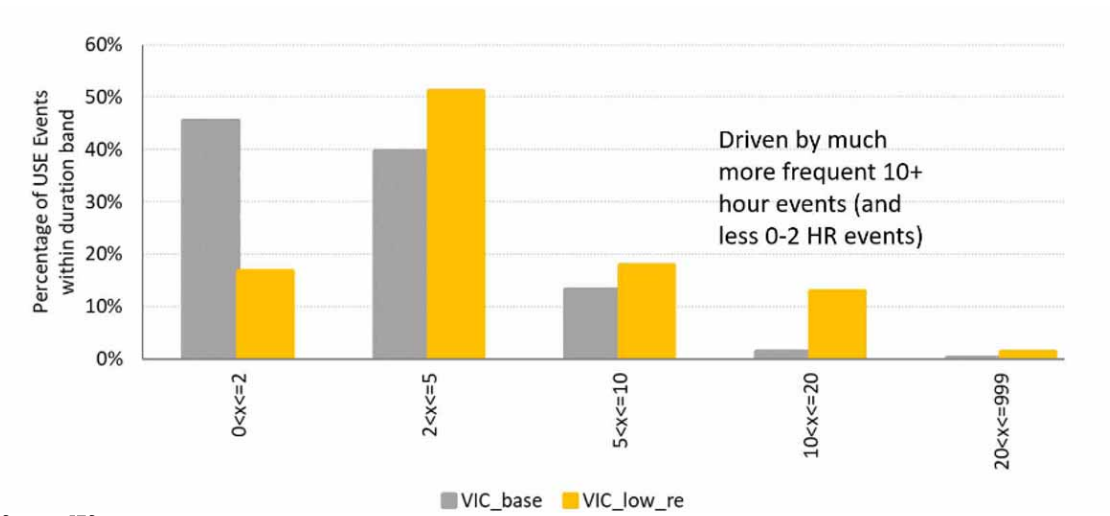
As a further example, the Panel's 2022 RSS Review considered the outcomes associated with the anticipated Victorian generating fleet in 2028 using a set of plausible low VRE generation renewable energy traces. The studies revealed a material shift in the distribution of USE. Figure 4.2 illustrates the change in the duration of the frequency and events between the base and low VRE cases for 2028. This analysis supports the type of shift in reliability risk

28 LOLP refers to the number of unserved energy events and does not consider the magnitude of any event and is determined from the number of periods where there is USE compared to the total number of periods in the year.

29 ESIG, redefining resource adequacy for modern power systems, 2021, p. 13.

profile in high VRE conditions in a future NEM, particularly as further thermal generation capacity retires post-2028. Further details of this case study can be found in the IES RSS review modelling report.[30]

Figure 4.2: A shifting unserved energy distribution in VIC for 2028



Source: IES
Note: Base case and low VRE scenario Victorian event duration for 2028.

QUESTION 1: ISSUES WITH THE CURRENT RELIABILITY FRAMEWORK

1. Do stakeholders agree with the way reliability risks in the current framework are set out? If so/not, why?
2. Are there other reliability risk factors the panel should take into account?
3. Does the current form of the standard best reflect the value that consumers place on reliability?
4. Are there other issues stakeholders see with the current framework that the Panel should consider?

30 Found at https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review.

5 HOW THE PANEL WILL ASSESS OPTIONS

This chapter provides an overview of the Panel's assessment principles and approach to the review and terms of reference. Consistent with the 2022 RSS Review, the Panel will apply a specific framework for the review. The framework includes:

- the general assessment principles in the Panel's *2021 Final Guidelines Review of the Reliability Standard and Settings Guidelines* (2021 Guidelines) to contribute to the NEO[31]
- the overarching assessment criteria and considerations set out in the terms of reference
- specific objectives and criteria for assessing different candidate metrics.

5.1 General assessment principles in the guidelines

The Panel will be guided by the NEO in making recommendations in this review. The NEO is:[32]

> to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to: (a) price, quality, safety, reliability and security of supply of electricity; and (b) the reliability, safety and security of the national electricity system.

The General Assessment Principles set out in the *2021 Guidelines* are:

1. **Allowing efficient price signals while managing price risk:** The Panel will exercise its judgement when balancing the need for efficient price signals against managing wholesale price risk for participants. The settings should:
   a. allow sufficient scope for competition between buyers and sellers in the market to set efficient prices to achieve the standard, over the long run
   b. be designed to provide a sufficient range to promote this behaviour in the market
   c. provide protection from uncapped prices in any given trading interval, and sustained high prices over a defined period, such that wholesale market outcomes do not result in inefficient over-investment, overly high financing costs or excessive price risk for all participants.
2. **Delivering a level of reliability consistent with the value placed on that reliability by customers:** The Panel will have regard to estimates of the value placed on reliability by customers when exercising its judgement as to the level of the standard. The settings should be sufficient to support the level of investment necessary to deliver the reliability standard, over the long run.
3. **Providing a predictable and flexible regulatory framework:** The Panel will exercise its judgement to achieve predictable outcomes recognising the importance stability creates for market participants in terms of investment, while accounting for changing market conditions, to support efficient investment and operational decisions by

31 Found at https://www.aemc.gov.au/market-reviews-advice/review-reliability-standard-and-settings-guidelines-0.

32 Section 8 of the NEL.

participants. The assessment principle, approach and supporting criteria informs the materiality assessment that the Panel will apply in its consideration of the form and level of reliability standard and settings.

For any recommended changes, the Panel would need to be satisfied that they will, or are likely to, contribute to the achievement of the NEO and meet the 2021 Guidelines. Any change would need to be progressed through an AEMC rule change process.[33]

> **QUESTION 2:** ASSESSMENT PRINCIPLES AND GUIDELINES
>
> 1. Do stakeholders have any feedback on the principles and high-level approach proposed?
> 2. Are there additional high-level principles that the Panel should consider when makings its recommendations for this review?

5.2 Any change should reflect an improved understanding of the trade-off between reliability and affordability

A change in the form of the reliability standard must be shown to advance the long-term interests of consumers by better balancing the price, and costs borne by consumers, with the reliability of the power system than would be possible under existing arrangements. To achieve this, a change to the form of the reliability standard should deliver a standard that:

- better reflects customer expectations and the value they place on system reliability
- is clear, simple and implementable
- captures increasing diversity and complexity in the characterisation of reliability risk
- achieves reliability at low cost
- is agnostic to future market design and technology changes
- delivers a common reliability experience across all NEM regions.

Further, the current standard is complex to understand and translate into a tangible measure to which consumers can relate. Careful design and assessment are required to ensure the chosen form provides sufficient information to signal efficient investment, can be operationalized through market/reliability frameworks and can provide a more accessible representation of the extent or likelihood of consumers experiencing unserved energy.

> **QUESTION 3:** OBJECTIVES AND CRITERIA
>
> 1. Do stakeholders have any feedback on the specific objectives and criteria?
> 2. Are there other relevant considerations that could be included as objectives or criteria?

33 Clause 3.9.3A(i) of the NER.

6 POTENTIAL MODELLING AND MATHEMATICAL APPROACHES

Modelling provides a quantitative basis for the Panel to identify the USE risk profile in a future high VRE, weather-dependent power system and the efficient form of the standard.

This chapter introduces and outlines issues relevant to the Panel's approach to modelling to inform any changes to the form of the reliability standard. Specifically, this part introduces:

- the modelling to inform the future USE risk profiles
- potential mathematical approaches and metrics to achieve efficient levels of investment given the changing risk profile.

The Panel will publish the details that underpin the modelling throughout the course of the Review.

The Panel will transparently set out the methods, assumptions and scenarios that inform the modelling results. In addition, detailed draft and final reports will also be published setting out results from the modelling conducted.

6.1 Detailed modelling of the electricity market is needed

The development and examination of additional metrics to augment or replace the existing reliability standard will require extensive modelling. The Panel proposes to build on existing modelling performed by AEMO for its Integrated System Plan (ISP) to generate extensive detailed information over unserved energy events that will form the basis for evaluating additional metrics and costs.

6.1.1 Developing a shape of the distribution of USE

The ISP results developed by AEMO provide an opportunity to examine the evolution of the shape of unserved energy events over time and with alternative demand and supply drivers that vary across scenarios and sensitivities. The ISP analysis will provide a considerable number of individual USE events with:

- multiple simulations based on different historical demand and weather years
- different least cost generation portfolios, inter-connector developments and consumer energy resources growth
- total costs based on, consistent, and well-socialised input assumptions.

This approach utilises AEMO's least cost optimisation of generation and transmission developments across the NEM based on transparent and consistent assumptions, government policy, constraints and future scenarios. It capitalises on optimising different:

- **locations** — the modelling examines the location of a wide range of potential regional and sub-regional locations to consider their individual contribution to local and regional constraints, access to fuel and transmission and potential change to marginal loss factors.

- **costs** — the modelling considers fuel, capital and operating costs for all new and existing technologies and, for new projects, it also considers the cost of connection and transmission access.
- **relative performance and output correlation** — by considering the relative performance of individual projects against the overall requirement for capacity and energy, the modelling selects the most appropriate developments across different regions and sub-regions of the NEM.
- **network development** — the optimisation process in the modelling will also consider the development of generation projects and any potential network constraints or upgrades within the scope of the transmission development options with which it is provided.

This forms the foundation for initial indicators of the depth, duration and frequency of USE events and shows how these characteristics of the USE change with the development and utilisation of increasing penetrations of renewables, storage and other complimentary flexible technologies.

An examination of the trends in both the generation portfolio and unserved energy events over the ISP horizon, will inform the selection of a future year, when higher penetrations of VRE have occurred, on which a more detailed examination of USE events would occur, and in particular on which long-term VRE droughts (dark doldrums) can be tested. The Panel proposes to use virtually the same method used by AEMO in the ISP to develop new generation fleets and identify corresponding USE events against both the standard AEMO inputs and new VRE data adjusted to match expected events such as long-term VRE droughts. This approach will ensure that the result is optimised for each situation and allow comparison against the ISP's investment/generation development pathway as a counterfactual. At each stage, it will be necessary to ensure that the development pathways are consistent with the assumptions, including delivering acceptable levels of expected USE.

QUESTION 4: DEVELOPING USE DISTRIBUTION

1. Is using AEMO's ISP and overlaying realistic weather-driven dark doldrums as a source of USE events the best approach?

6.1.2 Existing ISP construction path

Basing the USE analysis on the latest ISP outcomes and creating alternate generator development pathways using the same method as AEMO ensures that the results will be based on assumptions and inputs familiar and transparent to most stakeholders. The Panel also proposes to establish alternate generator development paths and examine results from individual ISP input reference years, and adjust some reference input files to replicate dark doldrums. Time-sequential modelling using these inputs will provide individual USE events from which duration, depth and frequency can be correlated against weather-based VRE and demand inputs.

Comparing the USE event characteristics from the ISP generator development pathway with the characteristics of USE events using dark doldrum supply and demand inputs should show how the utilisation of each generator and transmission element of the generation development pathway changes with the different input conditions. Furthermore, a more detailed analysis of USE results from AEMO's individual VRE source inputs (AEMO bases their demand and VRE input files on outcomes from 10 historical years) could be used to calculate:

- incremental inconvenience to customers
- incremental changes to the cost of operation of the market
- utilisation of different asset types in the model, including battery and hydro storage, gas turbines and consumer energy resources
- information on the USE distributions — in particular their depth, duration and frequency and correlation across NEM regions.

Creating and utilising dark doldrum weather patterns is a key input into this simulation stage of work. Since weather patterns are changing and likely to be more extreme than past weather patterns, using historic data is not sufficient to understand the distribution of USE moving forward. Further, the nature of renewable droughts, which require long periods of weather that is similar over time (no wind, no sun), means that the Panel will need chronologically consistent weather and cannot simply over-sample from the more extreme parts of the historic weather distribution. As such, the Panel is considering the need to develop a number of chronologically consistent, weather biased solar, wind and demand adjustments to be applied to existing model inputs. That effectively means that the modelling will adjust the period-by-period shape of the demand profiles and solar and wind inputs to reflect a lower solar and wind contribution and rerun the simulations.

These additional inputs will augment the suite of existing simulation input data and the results of the simulations with the existing and adjusted inputs will increase the number of USE results that ultimately inform the USE probability distributions. The Panel is aware that the duration and frequency of dark doldrum events in the simulations will influence the distribution of USE, and consequently the resulting choice of the form of the standard. To this end, the Panel will work to ensure that the projections align with external climate/weather data where available. Where/if credible and relevant external data is not available, the Panel will need to make estimate results for several assumed levels of renewable droughts (frequency and duration) to illustrate the impact on USE.

Repeating the analysis, including this use of the normal and dark doldrum inputs, against new generator development pathways, for example, a generator development pathway based on dark doldrum inputs, would, all other things being equal, provide information on the change in capital cost and operating cost from the lower VRE output.

Rerunning time sequential models on the dark doldrum generator development pathway against the original ISP inputs would reveal changes in total operating costs, USE distributions and characteristics and generator utilisation that could further inform the form of the reliability standard.

This approach maximises the use of results already available from the ISP and builds on the transparency of the process, and the familiarity participants have with the inputs. It would also ensure that an optimal plant distribution was maintained but could be examined against individual events and used to inform statistical analysis of metrics.

6.1.3 Getting an indicator of the variation of total cost of supply

The PLEXOS time sequential modelling may provide a narrow view of the progressive total cost curve that could be used in the optimisation to minimise the total cost of market operation and consumer costs. This could be done by looking at the individual year USE outputs and total market costs (investment and net present value (NPV) of fuel and variable operating and maintenance (VOM) costs) for different input source years, as each will have different actual costs.

While investment costs are constant for each generation plant mix the NPV of the VOM and fuel costs will vary and could be isolated for individual USE events — this granularity could also provide insight regarding dispatch and cost from events of different depths or duration, revealing how different technologies are used and at what cost.

6.1.4 Should the simulations include forced outages for thermal generators

The existing approach to ISP simulations does not specifically replicate forced outages for thermal plant. Rather, for the capacity outlook modelling AEMO uses a single 10 per cent probability of exceedance (PoE) demand trace and derates the capacity of each thermal generator by their equivalent forced outage rate. According to AEMO, while using a constant derating provides a conservative outcome compared to modelling random forced outages, the use of the higher 10 PoE demand compensates for this conservatism to some degree. It would be possible to apply random forced outage patterns for the thermal generators in the AEMC modelling for each simulation as this is the approach taken by AEMO in their ESOO. The application of random forced outages is designed to test the capacity of the power system to deliver capacity and energy at peak demand times. Wind, solar and interconnectors are not subject to forced outage rates.

As this analysis is primarily focused on the tail end of the USE distribution from low VRE events, rather than using the random Monte Carlo process it could be more appropriate to apply tailored forced outages at peak times to specifically test the changes to USE which result from thermal generator failures. Probabilities for these manually initiated failures during peak periods could potentially be determined mathematically. This approach facilitates the examination of specific effects of VRE and dark doldrums on generation development pathways and energy limitations as it relates to network congestion, short-duration storage, the use of peakers and, potentially, ramping issues. Using a similar approach to the AEMO's ESOO, the AEMC modelling will also consider changes to USE events from the 50 per cent and 90 per cent PoE demand and VRE profiles.

This is intended to provide a substantial set of USE events spanning different time frames, penetrations of VRE and considering average and reduced levels of VRE output. While it may not facilitate the consideration of the impact of individual technologies on the USE results, it informs the total cost of market development and, through some manipulation of additional constraints on the load profile (LP), facilitate the consideration of potential reliability qualifiers either individually or together.

These USE results, investment and operating cost information, will be mapped against flexibility, capacity and energy risk to support the analysis of the different candidate metrics. Analysing the shapes of the tails with respect to the depth, duration and frequency of outages experienced will highlight their sensitivity and cost. This is essential to balance the trade-off of additional generator development and the cost to consumers. Furthermore, the utilisation and development of thermal plant against different outage duration and frequencies will provide more information on the efficacy of the two technologies together and as substitutes.

Once the USE distributions are generated against the ISP and new generator development paths, analysis of both the shape of the distribution of USE against the drivers in the model is anticipated to provide indicators of potential candidate metrics most relevant to potential new forms of the reliability standard.

Additional modelling could then explore the resilience of that form of the reliability standard to alternate events.

QUESTION 5: MODELLING APPROACH

1. Do stakeholders have any feedback on the proposed modelling approach?

QUESTION 6: FORCED OUTAGES

1. Should random forced outages be included or is the proposed method to apply tailored outages on thermal plant appropriate?

6.2 There are a range of potential mathematical approaches, tools and techniques the Panel will use

This section outlines potential mathematical approaches, tools and techniques that could be used to address the limitations of the current form of the reliability standard. It discusses the:

- approaches used internationally to address reliability
- options considered in the RSS review final report
- Panel's 'straw person' RSS review option
- considerations relevant to implementing a multi-part reliability standard.

The Panel is seeking stakeholder feedback on these or other potential options for it to consider in its draft report.

6.2.1 There are different reliability standard forms used in international markets

Some international electricity markets use reliability standards that are in different forms to that used in Australia. These address the unique reliability challenge for each market, including duration (hours), depth (MW) and frequency of interruptions and encompass:

- how frequently supply is interrupted — for example, the number of days per year in which an interruption is expected to occur. This could include the number of consecutive days unserved energy may occur in a dark doldrum.
- the cumulative duration of interruptions — for example, the total number of hours per year that interruptions are expected for any (not necessarily the same) consumer.
- the amount of energy that is not supplied in a period — for example, the NEM's unserved energy standard.

Known as loss of load expectation (LOLE), loss of load probability (LOLP), or loss of load hours (LOLH) they are defined as follows:

- **LOLE** is defined as the expected proportion of time for which the available generation capacity is insufficient to meet demand at least once per day. In the US, LOLE counts the days having loss of load events, regardless of the number of consecutive or non-consecutive loss of load hours in the day.[34] LOLE is also commonly used in Europe. For example, Ireland targets a LOLE of eight hours per year; France targets three hours per year, and the Netherlands targets four hours per year.
- **LOLP** is defined as the probability of hourly demand exceeding the available generating capacity during a given period. It is expressed as a percentage of days per year, half-hours per year, or events per season, in which available generating capacity is insufficient to meet demand. LOLP is calculated from the number of loss of load events (where capacity is insufficient to meet demand) divided by the number of possible Loss of Load events.[35]
- **LOLH** is generally defined as the expected number of hours per time period (often one year) when a system's hourly demand is projected to exceed the generating capacity. This metric is calculated using each hourly load in the given period (or the load duration curve). LOLH is less commonly used as a reliability standard measure than LOLP or LOLE.

LOLP and LOLE target different unserved energy event characteristics. LOLP indicates the frequency (events/or affected days per year) of supply interruptions and not their duration (hours), depth (MW) or energy (the combination of duration and depth in MWh). LOLE indicates the expected duration of loss of load events and not their frequency and depth.

6.2.2 The Panel will consider a range of options to recommend a fit-for-purpose reliability standard

While international experience provides some alternative formulations for the Reliability Standard it is immediately evident that the impacts on reliability from high dependency on renewable generation is yet to be completely resolved. Even the LOLE, LOLP and LOLH do

34 NERC, Probabilistic Adequacy and Measures Report, July, 2018.
35 Ibid.

not encompass rare extended periods of reduced VRE output that could result in consumers experiencing a number of days of short interruptions as a result of rotational load shedding. The 2022 RSS review recommended that the form of the standard be changed by 1 July 2028 to accommodate a 'tail risk metric' in combination with an 'expected value unserved energy standard' metric. The Panel intends to consider this approach alongside a range of other approaches to ensure it recommends an enduring, fit-for-purpose reliability standard for the NEM. The Panel considered:

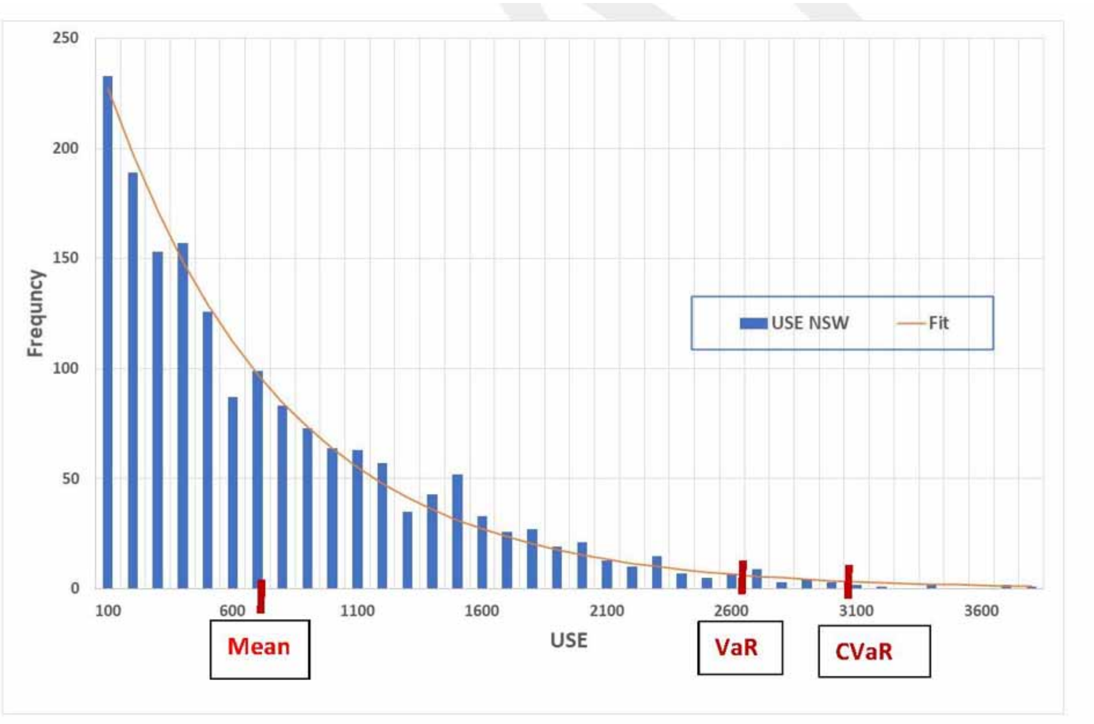
- introducing one of the reliability standard forms commonly used internationally as well as tightening the existing form of the standard as a means of addressing tail risk.
- changing the reliability standard to a LOLE or LOLP based reliability standard. However, it concluded that neither sufficiently captured a changing reliability risk profile in the NEM as insufficient information on the characteristics of USE events would be captured to allow an efficient level of reliability to be described.
- a tighter expected USE standard. Changing the form of the standard, rather than tightening the level of the existing standard was the Panel's preferred approach to reflect the changing nature of reliability as the NEM transforms to a low emission, high VRE more energy-limited power system. They acknowledged the concerns that led to implementation of the IRM but did not consider tightening the level of the reliability standard beyond efficient levels to be a preferable means of addressing these risks.[36]

While the Panel didn't consider either of these options attractive, this review may consider these approaches as elements of a future multi-metric reliability standard.

IES performed analysis for the RSS review that simulated market outcomes and USE events for the 2028 calendar year based on an assumed set of market generators and future demand profiles. This analysis produced a data set in which over 400 unserved energy events occurred. Analysis of a sample these simulated unserved energy events provides a useful example. Figure 6.1 gives the mean of the USE values for NSW, the Value at Risk (VaR) and the Conditional Value at Risk (CVaR). Note that an exponential distribution provides a good fit for the histogram of USE values. For this calculation, using relatively standard mathematical concepts consistent with those from the mean is 706, VaR = 2731, and CVaR = 3,079 MWh.

36 The Panel's analysis indicates the IRM, at 0.0006 per cent expected USE, is significantly tighter than a level of reliability consistent with consumer willingness to pay for reliability. The Panel noted that a tighter USE standard wouldn't address the specific risks in a high VRE, more energy-limited power system and would have little value in identifying the efficient mix of new investment, and thereby the trade-off between customer value and investment cost to address the reliability risk profile as a result of the new set of underlying reliability drivers a future NEM.

Figure 6.1: The USE values for NSW in the simulation with various metrics



Source: AEMC

6.2.3 The Panel's 'straw person' 2022 RSS Review option

The Panel put forward a 'straw person' composite reliability standard in the 2022 RSS Review as one possible approach that could be considered. This was provided to elicit stakeholder feedback on the issues and options for reforming the reliability standard. The Panel's 'straw person' approach was based on advice received from Professor Pierluigi Mancarella from the University of Melbourne[37], and could be described as a weighted combination of:

- **average and therefore risk-neutral** — which is equivalent to the current standard that considers a simple probabilistic measure, such as the expected value from the USE probability distribution function. It is risk neutral because it uses a single value of VCR for all outages
- **tail and therefore risk-averse** — such as the conditional value at risk (CVaR) of the USE probability distribution function which is a probabilistic measure specifically designed to consider the value at risk for a predefined maximum acceptable level of risk.

Together these may provide some recognition of the tail risk, but neither the average nor tail CVaR provide clarity on incentives that would address the frequency or duration of outages.

37 Found at https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review

The use of a CVaR tail risk metric may also be applied to the reliability event probability, duration, and depth distributions, but linking the assumptions for each may be challenging.

6.2.4 Options considered by the Maths in Industry Study Group

To support the Panel's work, the AEMC presented the topic of options to address USE in an energy-limited high VRE power system as a special project at the 2023 Mathematics in Industry Study Group (MISG) workshop, which ran from 30 January 2023 to 3 February 2023.

The MISG is a special interest group of the Australian New Zealand Industrial and Applied Mathematics, which is a division of the Australian Mathematical Society. The workshop offered an opportunity for the AEMC and Panel members to collaborate with leading academics to consider work identified in the 2022 RSS Review and identify new components that could improve the form of the reliability standard. The workshop identified mathematical approaches, tools and techniques that could inform the selection of new metrics for a reliability standard for a future low-emission national electricity market.

The MISG will release a detailed academic paper in mid 2023 outlining the issues considered. The table below lists a number of statistical metrics that could aid in describing the tail of the distribution of USE events.

Overall, an expression of what is happening in the tail is preferable. This is supported by Figure 6.1, which is generated from the projections for NSW given present supply plus committed generation, plus estimations of future demand. The mean is materially different to the events that could occur in the tail that would produce higher costs. For this example, calculation, CVaR and the value emanating from Extreme Value Theory are very similar, but more studies would have to be done to select between them. Alternatively, a combined metric could be used, not specifically some linear combination of mean and one of those but using the mean as is done currently, plus some proviso on CVaR or Extreme Value Theory derived measure.

Table 6.1: **Potential metrics and initial considerations**

METRIC	PROS	CONS	USED IN OPTIMISATION	COMBINED WITH OTHER METRICS
Annual Average USE	Current familiar measure — ideal to retain and combine with other metrics	Provides no information on the tail	Yes	Yes
Mean of USE	Simple to understand	Figure 6.1 shows that a tail metric is probably more suitable. Could be a combination		Yes
Conditional Value at Risk (CVaR) — describes the value in the tail	In wide use for fat tail distributions	No information on the extent of the tail, its shape or extremes	Yes	
Most Probable Maximum Risk (MPMR) — the mode of distribution	An estimate of maximum unserved energy that would be expected to occur in a single event	It is the mode of the distribution of maxima from subsets — this may not define the tail end of the distribution or provide insight into the customer experience with respect to frequency or duration	Yes	
EMR — Expected Maximum Risk (EMR) — the mean of the distribution	More realistic than MPMR	An expected value of the maxima, rather than an estimate of the possible maximum	Yes	
The probability that the maximum of the USE is greater than some value	Deals with a measure of maximum USE	Selecting a value of USE could be arbitrary but it then provides a probability of that USE value occurring		Yes

METRIC	PROS	CONS	USED IN OPTIMISA-TION	COMBINED WITH OTHER METRICS
Extreme Value Theory	Simple — the maximum USE is greater than a specific value is very low	The design of the blocks for which you select the maxima for setting your distribution has to be carefully done. e.g. daily winter rainfall would use a number of winters selecting the maximum daily for each		Yes
A quantile of USE	Simple and descriptive	Selecting the quantile is subjective		Yes
Expected USE divided by supply	Easy to calculate	It does not appear to have a usable interpretation		Yes
Outage duration	Intuitively important	Need to determine sensitivity of consumers to different outage durations through VCR questions		Yes
Frequency of outages	Intuitively important	Connected to duration. The question was about whether a one-hour outage 5 days in a row was worse than a 5-hour outage on one day. Or how would it vary if the 5 outages of one hour were spaced over 10 or more days		Yes

6.2.5 Considerations in developing multi-metric standards

A critical role of the reliability standard is to inform the market price settings that ultimately provide investment signals for generation, transmission and demand-side responses. However, the panel found in the 2022 RSS Review that the current standard as the average annual unserved energy as a percentage of total regional demand, is not simple to understand or translate into a tangible measure to which consumers can relate. Including additional metrics that may define how often an outage would occur or the maximum percentage of customer demand that should be interrupted at any time, greatly improves that clarity for customers and policymakers.

More than a single reliability standard metric may be required to reflect an efficient level of reliability in a future high VRE power system given the increasingly diverse set of reliability drivers and USE event characteristics and considerations identified above.

Individual risk metrics may be able to be combined into a multi-metric standard to address a range of different types of risk, including the drivers of unserved energy identified in this Issues Paper. A multi-metric reliability standards, such as the 'straw person' mean-CVaR option, apply two metrics involving an average and 'tail' metric. There is a range of other options such as those identified by the MISG which could be used in combination to more adequately describe average, tail, and possibly deterministic elements.

Multi-metric standards which limit the frequency or depth of USE events (to an acceptable level of confidence) will unavoidably affect the overall average level of unserved energy. In addition, hybrid standards are also as restrictive as their most constraining element. Introducing an additional parameter, whether that is expected USE, annual shortfall, or shortfall from an individual event, may result in the expected USE outcomes being lower than the current standard. All of these however clarify to some degree the expected USE experience for consumers.

A multi-metric reliability standard defines a space of acceptable reliability outcomes in addition to managing overall risk. Multi-metric standards, which combine different measures such as probability, magnitude and duration of outages need to be very carefully designed to ensure that they encompass the appropriate drivers and can reflect customer needs. They must also avoid undesirable interactions and ensure the different elements taken together, appropriately reflect efficient levels of overall reliability risk.

Careful design and assessment are required to ensure the chosen form provides sufficient information to signal efficient investment can be operationalized through market/reliability frameworks and provides a more accessible representation of the extent or likelihood of consumers experiencing unserved energy.

QUESTION 7: FORM OF THE STANDARD

1. Do stakeholders have feedback on the potential statistical metrics?
2. Do stakeholders have feedback on the relationship between the potential statistical metrics and customer value of reliability?
3. Changing the form to include risk aversion, take account of tail risk, or exclude certain event types, may result in higher market price settings. Are there other factors to consider besides the value customers place on reliability and the cost of new generation in making this decision, which will impact the market price cap?
4. Do customers find the current form of the standard easy to understand? Would a standard that more explicitly precludes certain event types provide customers with a greater understanding of the reliability of the system?

7 REVIEWING THE ADMINISTERED PRICE CAP

As part of this review, the Panel is also reviewing the form of the APC. In the 2022 RSS Review, the Panel identified a need to conduct a future review of the form of the APC following the events in June 2022 and the misalignment between the electricity APC and fuel prices.

This chapter sets out the purpose of the APC, findings from the 2022 RSS Review, and the initial range of options the Panel is exploring on the form of the APC. This review is not considering the level of the APC, but whether a fixed level remains appropriate from 1 July 2028, regardless of what that level is.

7.1 The purpose of the APC is to cap participant exposure to high prices while maintaining incentives to supply

The APC is the maximum market price paid to participants, measured as a fixed $/MWh value, that can be reached in any dispatch interval and any trading interval during an administered price period (APP). The purpose of the APC is to cap participant exposure to the potential of what could otherwise be high prices during an APP, while maintaining incentives for participants to supply energy.[38]

The APC is triggered after a series of sustained high dispatch prices exceeding the CPT. The APC, combined with the CPT, is a mechanism to minimise financial instability in the market that arises from an extended period of supply scarcity and correspondingly high prices. It is intended to be at a level sufficiently high to incentivise generation to make itself available during an APP.

Following the events in June 2022, the AEMC recently made a final rule to temporarily increase the APC from $300/MWh to $600/MWh from 1 December 2022 until the end of 30 June 2025.[39] The Panel has submitted a rule change request for the AEMC to consider its recommendation in the 2022 RSS Review to set the APC at $500/MWh from 1 July 2025 to 30 June 2028.

7.2 Following the June 2022 market suspension the Panel recommended an increase in the APC and a review into its form

Following the market suspension in June 2022, many stakeholders raised the need to examine the form of the APC to increase flexibility and ensure it remains fit for purpose in the long-term for a range of scenarios.[40] In June 2022, high prices and issues with generation capacity availability caused the CPT to be breached in all regions except for Tasmania. The $300/MWh APC at the time was then applied to the affected regions. However, given the

38 Reliability Panel, Review of the Reliability Standard and Settings Guidelines, 1 July 2021, p. 8.

39 AEMC, Amending the Administered Price Cap Final Determination, 17 November 2022.

40 Submissions to the Reliability Panel's 2022 Reliability Standard and Settings Review Draft Report, 9 June: Alinta Energy pp. 4-5, Snowy Hydro p. 2, Iberdrola p. 4, Clean Energy Council p. 5, Australian Energy Council pp. 2-3, AEMO pp. 10-11, and South Australian Department for Energy and Mining p. 3.

increased cost of key generator inputs such as gas, coal and liquid fuel prices, many generators withdrew capacity from the market. This led to AEMO issuing market directions and eventually suspending the market from 15 to 24 June 2022.

The events led to a number of costs which are not hedgeable by retailers and are instead recovered directly from consumers. These included compensation costs from the APC, directions and market suspension, and RERT costs. The Panel considered an increase to the level of the APC to $500/MWh (from 1 July 2025 to 30 June 2028) was justified to minimise the risk of many thermal generators withdrawing capacity in a possible future APP with high fuel prices, and to reduce undue reliance on APC compensation which is directly passed through to consumers.

Given the significant impact that high fuel costs had on thermal generators withdrawing capacity from the market during the APP, many stakeholders considered that the current form of the APC should be examined to account for links to fuel prices. While the Panel did not consider amending the form of the APC during the 2022 RSS Review, it committed to further work to assess the feasibility, opportunities and risks of moving away from a fixed APC level.

7.3 There are a range of options the Panel will consider for the form of the APC

The Panel will consider a range of possible options for amending the current fixed form of the APC, and is having particular regard to the operational feasibility of different options and how these may impact market certainty. Stakeholders recommended exploring the possibility of:

- **indexing the APC to gas hub price series** on a weekly or more regular basis[41]
- **calculating a base APC using a formulaic approach** for a benchmark facility and indexing it to a fuel input price series such as the Australian Competition and Consumer Commission (ACCC) LNG netback price series[42]
- **multiplying the gas APC by a benchmark Open Cycle Gas Turbine (OCGT) plant** with a deemed heat rate such as 12 GJ/MWh[43] (or up to 18 GJ/MWh)[44] e.g. $40/GJ multiplied by 12 GJ/MWh results in an electricity APC of $480/MWh
- **keeping the APC at a fixed level and only increasing it temporarily** in the event of unforeseen extreme market disruptions,[45] or if the marginal unit required to meet demand has an SRMC above the fixed APC.[46]

Stakeholder suggestions can be broadly grouped into the three categories outlined in Table 7.1.

41 Submission to the Reliability Panel's 2022 Reliability Standard and Settings Review Draft Report, 9 June: Clean Energy Council, p. 5.

42 Submission to the Reliability Panel's 2022 Reliability Standard and Settings Review Draft Report, 9 June: Alinta Energy, pp. 4-5.

43 Submission to the Reliability Panel's 2022 Reliability Standard and Settings Review Draft Report, 9 June: Snowy Hydro, p. 2.

44 Submission to the Reliability Panel's 2022 Reliability Standard and Settings Review Draft Report, 9 June: AEMO, pp. 10-11.

45 Submission to the Reliability Panel's 2022 Reliability Standard and Settings Review Draft Report, 9 June: South Australian Department for Energy and Mining, p. 3.

46 Submission to the Reliability Panel's 2022 Reliability Standard and Settings Review Draft Report, 9 June: Iberdrola, p. 4.

Table 7.1: Categorising stakeholder suggestions on amending the form of the APC

CATEGORY	DESCRIPTION
Index to dynamic fuel price	This may involve determining a benchmark facility and indexing it to a fuel input price series such as the ACCC LNG netback price series. This would mean the APC would change dynamically in line with movements in the fuel input price series it is indexed to.
Index to fixed gas APC	This would result in a fixed electricity APC based on the fixed gas APC which may change every four years in line with the review of the gas APC every four years. It would not lead to a dynamically changing electricity APC.
Change level temporarily if triggered	This may involve retaining the fixed level of the APC, and only increasing it if a certain threshold is breached. This would require determining the threshold which would trigger any temporary changes to the APC, as well as the criteria for returning the APC back to its original value.

QUESTION 8: FORM OF THE ADMINISTERED PRICE CAP

1. Do stakeholders consider the current form of the APC to be fit for purpose?
2. If the form of the APC were changed, do you consider it should be:
   - indexed to the gas APC
   - dynamically indexed to a price series such as STTM gas hub prices or the ACCC LNG netback price series
   - consist of two fixed levels and only increased to the upper fixed level if triggered by a defined circumstance
   - indexed to the Consumer Price Index
   - some other alternative form?
3. Does the value of the APC impact long-term commercial decision-making (e.g. contracts market), and if so, how?
4. How would changing the form of the APC impact market certainty, and in particular the contracts market?

ABBREVIATIONS

ACT	Australian Capital Territory
ACCC	Australian Competition and Consumer Commission
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
APC	Administered Price Cap
APP	Administered Pricing Period
ASX	Australian Securities Exchange
Commission	See AEMC
CPT	Cumulative Price Threshold
CVaR	Conditional Value at Risk
EENS	Expected Energy Not Served
EMR	Expected Maximum Risk
ENS	Energy Not Served
ESB	Energy Security Board
ESIG	Energy Systems Integration Group
ESOO	Electricity Statement of Opportunities
FCAS	Frequency Control Ancillary Services
FOR	Forced Outage Rate
IASR	Inputs Assumptions and Scenarios
INV	Investment Cost
IRM	Interim Reliability Measure
ISP	Integrated System Plan
KWh	Kilowatt hour
Liable Entity	has the meaning given in the NEL and as determined in accordance with clause 4A.D
LOLE	Loss of Load Expectation
LOLH	Loss of Load Hours
LOLP	Loss of Load Probability
LOR	Lack of Reserve
MFP	Market Floor Price
MISG	Mathematics in Industry Study Group
MPC	Market Price Cap
MPMR	Most Probable Maximum Risk
MW	Megawatt
MWh	Megawatt Hour
NEL	National Electricity Law

NEM	National Electricity Market
NER	National Energy Rules
NEO	National Electricity Objective
NSW	New South Wales
OCGT	Open-Cycle Gas Turbine
OP	Operational Cost
OTC	Over-the-Counter, referring to contracts
Panel	Reliability Panel
PoLR	Procurer of Last Resort
PV	Photovoltaic
RERT	Reliability and Emergency Reserve Trader
RRO	Retailer Reliability Obligation
RSS Review	Reliability Standard and Settings Review
SA	South Australia
USE	expected Unserved Energy
VIC	Victoria
VOM	Variable Operating and Maintenance
VRE	Variable Renewable Energy

A GLOSSARY

Table A.1: **Glossary of terms**

TERM	MEANING
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).
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: • 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.
Dark Doldrums (Dunkelflaute)	Dark doldrums or VRE droughts are extended periods in which there is an unusually widespread and prolonged reduction of both sunlight and wind, which results in an extended period of lower-than-expected VRE production.
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.

TERM	MEANING
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.
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.
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.
Medium term projected assessment of system (MT PASA) (also see ST PASA)	A comprehensive program 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.
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 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.

TERM	MEANING
Operating state	The operating state of the power system is defined as satisfactory, secure or reliable:. 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 NEM.
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.
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

TERM	MEANING
	participation.
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.
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 PASA (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.
Tail Risk	The risk of large, low probability outcomes reflected in the 'tail' of a USE probability distribution.
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.
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.