RELIABILITY PANEL AEMC

REVIEW

Reliability Panel AEMC

CONSULTATION PAPER

SYSTEM RESTART STANDARD REVIEW 2020

20 AUGUST 2020

INQUIRIES

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

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

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ABOUT THE RELIABILITY PANEL

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

RELIABILITY PANEL MEMBERS

Charles Popple (Chairman), Chairman and AEMC Commissioner
Trevor Armstrong, Chief Operating Officer, Ausgrid
Stephen Clark, Technical and Economic Lead – Project Marinus, TasNetworks
Kathy Danaher, Chief Financial Officer and Executive Director, Sun Metals
Craig Memery, Project Team Leader - Energy + Water Consumer's Advocacy Program, PIAC
Ken Harper, Group Manager Operational Support, AEMO
Chris Murphy, Strategic Advisor, Meridian Energy
Keith Robertson, General Manager Regulatory Policy, Origin Energy
Ken Woolley, Executive Director Merchant Energy, Alinta Energy
John Titchen, Managing Director, Goldwind Australia

SUMMARY

1 The Australian Energy Market Commission (Commission) has issued terms of reference to the Reliability Panel (Panel) to review the System Restart Standard (Standard). This review is an outcome of the changes to SRAS frameworks in the National Electricity Rules (NER) made by the Commission's final rule for the *System restart services, standards and testing* rule change (SRAS rule), which was published on 2 April 2020. The Panel is responsible for determining, modifying and publishing the Standard, which guides the Australian Energy Market Operator's (AEMO) procurement of System Restart Ancillary Services (SRAS) from contracted SRAS providers. The Panel has published this consultation paper to facilitate stakeholder feedback on the Panel's review.

2 SRAS are services that AEMO procures to help re-energise parts of the power system affected by a major supply disruption or black system event. SRAS can be likened to an "insurance policy" which AEMO procures to minimise the economic disruption arising from a such events.

3 The Standard provides qualitative guidance and prescribes quantitative settings to guide AEMO's procurement of SRAS. Quantitative settings set out in the Standard include the level of restoration, restoration time and required aggregate reliability for each sub-network in the NEM. Qualitative guidelines in the Standard provide guidance to AEMO on the determination of electrical sub-network boundaries and the assessment of the diversity and strategic location of SRAS. The NER require AEMO to meet the requirements set by the Panel in the Standard when procuring SRAS.

4 The scope of the Panel's review on this occasion is limited by the need to conclude the review prior to AEMO commencing its next round of SRAS procurement in late 2020/early 2021. As such, the terms of reference for the review recommend the Panel limit the scope of the review to:

- amending the qualitative guidance in the Standard to account for changes made to the SRAS frameworks in the SRAS rule
- considering amending relevant quantitative settings in the Standard to account for any decision by AEMO to combine the two existing Queensland electrical sub-networks.

Table 1: **Review approach and time frames**

MILESTONE	
Publish a consultation paper giving notice to all registered participants of commencement of this review and invite submissions on the key issues and questions set out therein for a period of at least four weeks	20 August 2020
Publish an interim Standard updating relevant qualitative elements of the Standard to reflect the inclusion of system restoration support services in the definition of SRAS.	October 2020

MILESTONE	
Publish a draft report setting out proposed restoration time frames, levels of restoration and aggregate reliability requirements for a combined Queensland sub-network. This draft report will be published at the same time as the interim Standard.	October 2020
Publish a final report and final Standard setting out proposed restoration time frames, levels of restoration and aggregate reliability requirements for a combined Queensland sub-network.	January 2021

Source: Reliability Panel

5 Qualitative changes to the Standard to incorporate changes made in the SRAS rule

6 The SRAS rule made a number of changes to the frameworks for power system restoration in the NER. These included expanding the definition of SRAS to include black start services provided by facilities other than generating units and introducing system restoration support services as a new type of SRAS that are needed to support the stable re-energisation of the grid following a major blackout.

7 As the existing Standard is written to accord with the definition of SRAS prior to the SRAS rule, some aspects of the qualitative guidance in the Standard may require amendment to reflect the expanded scope of SRAS under the new definition.

8 The Panel is seeking stakeholder feedback on its proposed approach to amending the Standard to reflect the revised definition of SRAS. While the Panel may include some additional guidance relevant to restoration support services and non-traditional providers of black start capability, the Panel is not proposing to include detailed guidance on the procurement of these new services in the amended Standard. Given the need to align this review with AEMO's SRAS procurement processes, the Panel intends to focus in this review on amending the Standard's qualitative guidance to remove language that is inappropriate and/or could act as a barrier to AEMO's procurement of restoration support services and SRAS from non-traditional providers.

9 Quantitative changes to Standard settings for a combined Queensland sub-network

10 There are currently two electrical sub-networks for Queensland for the purposes of SRAS: North Queensland and South Queensland. On 3 August 2020, AEMO published a draft determination to combine the two existing SRAS sub-networks in Queensland.[1] The current

1 AEMO is responsible for determining sub-network boundaries. AEMO's draft determination is to combine the sub-networks in Queensland to maximise operational flexibility when restoring the power system.

Standard specifies quantitative settings for the two existing Queensland sub-networks. Amendments to the quantitative settings for Queensland in the Standard are therefore required to ensure that the Standard is able to guide AEMO's procurement of SRAS for a single Queensland sub-network in its next procurement round, which is likely to commence in early 2021. AEMO is currently consulting on its draft determination.

11 If AEMO makes a final determination to combine the two existing Queensland sub-networks into a single sub-network, the terms of reference recommend that the Panel determine and publish quantitative settings, including the level of restoration, restoration time and required aggregate reliability of SRAS, for a single Queensland sub-network in a final Standard. In light of AEMO's draft determination and the timeframes involved in AEMO's SRAS procurement, the Panel will commence consultation on amending the quantitative Standard settings to provide for a single Queensland sub-network.

12 This consultation seeks stakeholder feedback on a number of issues relating to how the proposed combination of the two existing Queensland sub-networks into a single sub-network should be dealt with in the Standard, including:

- the method of determining quantitative Standard settings for a combined Queensland sub-network. The Panel proposes applying the method used in its 2016 review of the Standard, as it considers that this method remains appropriate for this purpose.
- the approach to valuing the benefits of SRAS. The unserved energy avoided by procuring SRAS must be valued in order to identify the efficient level of SRAS. In 2016, the Panel utilised estimates of the Value of Customer Reliability (VCR) published by AEMO for this purpose. On 23 March 2020, the AER published a draft model for estimating the economic costs of Wide Area Long Duration Outages (WALDO) such as major supply disruptions and black system events. The Panel is considering how the WALDO model could be applied in this review to value unserved energy avoided by the procurement of SRAS.
- any additional requirements for SRAS to be procured at specific locations in a combined Queensland sub-network. The Queensland transmission network is characterised by long transmission flow paths, the presence of large industrial loads in central Queensland and transmission corridors that are vulnerable to cyclone damage. AEMO's draft determination to combine the Queensland sub-networks identified the potential for an explicit requirement in the Standard to procure SRAS in central or northern Queensland. The Panel is interested in stakeholder feedback on how the Standard can effectively address any locational power system needs in the context of a single Queensland sub-network.

13 Next steps

14 The Panel invites written submissions on this consultation paper from interested parties by no later than 18 September 2020.

15 An interim Standard and final report on changes to qualitative elements of the standard, along with a draft determination on quantitative Standard settings for a combined Queensland sub-network, is planned for publication in October 2020.

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1 INTRODUCTION

The Australian Energy Market Commission (Commission) has issued terms of reference to the Reliability Panel (Panel) to review the System Restart Standard (Standard). The Panel is responsible for determining, modifying and publishing the Standard which guides the Australian Energy Market Operator's (AEMO) procurement of System Restart Ancillary Services (SRAS) from contracted SRAS providers.[2] The Panel has published this consultation paper to facilitate stakeholder feedback on the review.

The NEM has historically delivered a safe, secure and reliable supply of electricity to consumers. The requirements for system security, generally set out in Chapter 4 of the NER, impose obligations on AEMO to maintain the power system in a secure state without load-shedding for any contingency event which is considered credible.[3] Such events are those that AEMO consider to: be reasonably possible to occur; and have the potential for a significant impact on the power system e.g. the loss of a single element or generator. The NER also requires AEMO to maintain emergency control schemes to prevent a major supply disruption or black system event due to a severe non-credible event affecting the power system.[4] These are generally considered to be events that are rare in occurrence, such as the combination of a number of credible contingency events occurring at the same time.

Despite these arrangements, major supply disruptions and black system events can potentially occur, which would require generation in an affected part of the power system to be restarted and customer load re-connected. To manage the consequences of such an event if it did occur, AEMO's power system security responsibilities also include a requirement to procure sufficient SRAS in accordance with the Standard to allow for the restarting of generating units and subsequent restoration of load following a major supply disruption.[5]

This consultation paper considers changes to the settings prescribed in the Standard to account for changes to the SRAS frameworks in the NER made by the Commission in its recent *System restart services, standards and testing Rule* (SRAS rule)[6] and AEMO's draft determination to combine the two existing Queensland electrical sub-networks. [7] This chapter introduces the review and its elements including the:

- terms of reference and scope of the review
- SRAS rule and AEMO SRAS Guideline consultation
- interaction between the Panel's review and AEMO's SRAS Guideline consultation
- timetable for the review
- structure of the consultation paper
- submission process.

2 Clause 3.11.7(a1) of the NER.
3 Clause 4.2.4 of the NER.
4 Clause 4.3.2(h) of the NER.
5 Clause 4.2.6(e) of the NER.
6 Further information is available at: https://www.aemc.gov.au/rule-changes/system-restart-services-standards-and-testing
7 For more information see: https://aemo.com.au/en/consultations/current-and-closed-consultations/sras-guideline-2020

1.1 Terms of Reference and scope of the review

On 24 June 2020, the Commission provided terms of reference to the Panel to initiate a review of the Standard.[8] This section summarises the terms of reference and resulting scope of the review.

The Commission has requested the Panel undertake a limited review of the Standard on this occasion. The scope of the Panel's review is limited by the need to conclude the review prior to AEMO commencing its next round of SRAS procurement in late 2020/early 2021. This timeline is not conducive to the Panel conducting a fulsome review of all aspects of the Standard, including the quantitative settings relating to restoration levels, time frames and aggregate reliability of SRAS sources for each electrical sub-network. As a result, the scope of the review is limited to the changes required to facilitate AEMO's next SRAS procurement round.

Given that the review needs to occur as soon as practicable,[9] the Commission's terms of reference requested that the Panel limit the scope of the review to the following issues:

- To provide guidance to AEMO in its procurement of SRAS for all electrical sub-networks, the Commission recommends the Panel publish an interim Standard by 2 November 2020 updating relevant qualitative elements of the Standard to reflect changes made in the SRAS rule to include system restoration support services in the definition of SRAS under the NER as a consequence of the recent SRAS rule.
- The Commission recommends the Panel consider amending relevant quantitative Standard settings to account for any decision by AEMO to combine the two existing Queensland electrical sub-networks into a single sub-network. In particular, if the two existing Queensland sub-networks are combined into a single sub-network, the Panel would need to determine and publish restoration timeframes, levels of restoration and aggregate reliability requirements for a single Queensland sub-network in a final Standard, which would likely occur in early 2021.

The two elements being considered in the review, along with the relevant timeframes, are further introduced in the following sections.

1.1.1 SRAS Rule

The Commission's SRAS rule made a number of changes to the SRAS frameworks in the NER, including changes to the definitions of SRAS and black start capability, implementing a framework for physical testing of system restart paths, and providing for greater transparency and certainty about participant roles and responsibilities in system restoration. Of these changes, the Commission's terms of reference for this Review specifically identifies

8 Clause 8.8.3(c) of the NER requires the Commission to issue terms of reference to the Panel prior to it commencing a review of the System Restart Standard.

9 The final SRAS rule included transitional arrangements that require the Panel to review the Standard as soon as practicable following 2 April 2020 to take into account the changes made in the amending rule.

the changes to the definition of SRAS as being materially relevant to the Standard, and so this project.[10] The amended definition of SRAS:

- allows for black start capability to be provided by plant other than generating units. This may include new technologies such as batteries combined with grid forming inverters which may be capable of providing this service.
- allows AEMO to procure system restoration support services. These are a new type of SRAS that support the stable re-energisation of the grid, in support of black start services. These services will be specified by AEMO in the SRAS Guideline and procured under the SRAS procurement framework.

These changes necessitate changes to the Standard. The Panel considers that qualitative aspects of the Standard need to be updated to provide guidance for AEMO's procurement of SRAS from these new sources. This may include amending any technology specific terminology in the Standard that acts as a barrier to AEMO procuring these services. Chapter 4 presents the Panel's approach to amending the qualitative aspects of the Standard.

In addition to changes made to the definition of SRAS, which are the primary focus of this review, the Panel also considers a number of other elements in the SRAS rule constitute important improvements to the SRAS frameworks which will enhance preparations for a system restoration scenario. In particular:

- The Panel considers that the changes to the SRAS communication protocols to clarify the roles and responsibilities of AEMO and NSPs with respect to the testing of SRAS provide greater clarity regarding the processes that apply in relation to both SRAS testing and the preparation and implementation of the system restart plan. [11] The Panel notes this change to the rules addresses learnings from the performance of contracted SRAS in South Australia following the system black on 26 September 2016.
- The Panel supports the introduction of a regulatory framework for the physical testing of system restart paths which clarifies the roles and responsibilities of AEMO, NSPs and affected participants. Under this framework, AEMO is responsible for designing and implementing such tests and must consult with affected participants and incorporate their feedback into the design of the test program. The Panel considers that physical testing of system restart paths is a valuable tool for AEMO, and other market participants, to be able to adequately prepare for a system restoration scenario and have confidence that such restoration will succeed based on the system restart plan. The Panel expects that AEMO will conduct such testing, along with the annual testing of individual SRAS providers, as necessary to ensure that contracted SRAS can perform as expected when required.

10 Black start services are provided by generating units or other types of plant which are able to restart without drawing supply from the network. Further explanation of black start is provided in Chapter 2.

11 The Panel also notes that AEMO has a clear set of existing obligations to actively analyse, validate and report on the ability of the system restart plan to achieve the system restart standard as the power system evolves. This is included as part of AEMO's annual reporting obligations in relation to SRAS under the NER).

1.1.2 AEMO consultation on combining Queensland sub-networks

The NEM is divided into electrical sub-networks for the purposes of AEMO's preparations for system restoration and procurement of SRAS. Under the NER, AEMO has the responsibility to determine the boundaries of the sub-networks following consultation with stakeholders.[12] The Standard specifies quantitative requirements for each sub-network, including restoration timeframes, levels and aggregate reliability requirements for SRAS in that sub-network.

On 3 August 2020, AEMO published a draft decision to combine the two existing Queensland sub-networks into a single sub-network incorporating the entire state.[13]

As the existing Standard specifies settings for two separate Queensland sub-networks, the quantitative settings in the Standard need to be amended to allow AEMO to procure SRAS for a combined Queensland sub-network in its next procurement round. AEMO is currently consulting on its draft decision to combine the sub-networks. The Panel understands that AEMO anticipates making a final decision on combining the Queensland sub-networks by 16 October 2020.

The Panel intends to consult on matters relevant to the quantitative settings in the Standard for a combined Queensland sub-network in parallel to AEMO's process for updating the SRAS Guideline. This approach will allow the Panel to make any required amendments to the quantitative settings in the Standard prior to AEMO's next round of SRAS procurement for Queensland. Chapter 5 presents further details on AEMO's proposal and the Panel's proposed approach to determining quantitative settings for a single Queensland sub-network.

The Panel is working closely with AEMO in order to manage the coordination of these matters, most notably through AEMO's representation on the Panel.

1.2 Interaction between SRS review and AEMO SRAS Guideline consultation

There is a close relationship between AEMO's SRAS Guideline review and the Panel's review of the Standard. This section describes this relationship and sets out how the alignment between the two reviews has informed the scope of the Panel's review of the Standard discussed in Section 1.1.

The Panel considers a two stage review process to be required, consistent with the ToR from the AEMC. Specifically, the Panel intends to publish:

- an interim Standard prior to 2 November 2020, which will update relevant qualitative elements of the Standard to reflect changes made in the SRAS rule
- a final Standard in January 2021, which will update quantitative Standard settings for a combined Queensland sub-network.

The dependencies and timeline issues which justify this two stage process are set out below.

Amended definition of SRAS

12 Clause 3.11.8 of the NER.

13 Queensland is currently divided into North and South Queensland sub-networks. Further information is provided in Chapter 5.

The SRAS rule requires AEMO to make changes to the SRAS Guideline to, amongst other things, describe the capabilities of system restoration support services. AEMO is currently in the process of updating its SRAS Guideline to specify these capabilities and published a draft determination on 3 August 2020. The SRAS rule requires AEMO to finalise the changes to its SRAS Guideline by 2 November 2020.[14]

The NER also requires the SRAS Guideline to be designed to ensure that the Standard is met at the lowest cost.[15] AEMO therefore requires any necessary changes to the Standard to precede its changes to the SRAS Guideline, in order to allow it to determine a guideline that meets the Standard requirements at lowest cost.

The Panel is therefore intending to publish an interim Standard setting out changes specific to the amended definition of SRAS in October 2020, prior to AEMO's 2 November 2020 deadline for publication of its updated SRAS Guideline.

Settings for a combined Queensland sub-network

AEMO is currently consulting on the consolidation of the two Queensland sub-networks. Should AEMO determine to combine the sub-networks, the Panel intends to publish draft quantitative Standard settings for a combined Queensland sub-network in October 2020 at the same time as it publishes the interim Standard. The Panel will then consult on the draft quantitative Standard settings for the Queensland sub-network and publish a final Standard in January 2021.

The Panel notes that its review and AEMO's SRAS Guideline consultation will be proceeding in parallel. The Panel intends to work in close collaboration with AEMO through this process to allow for effective development of both AEMO's SRAS Guideline and a revised Standard.

1.3 Timetable for the Review

The AEMC's terms of reference require the Panel to carry out the review to develop the Standard in accordance with the process set out in Table 1.1.

Table 1.1: **Review timetable**

MILESTONES	DETAILS	KEY DATES
Publish a consultation paper	Publish a consultation paper giving notice to all registered participants of commencement of this review and invite submissions on the key issues and questions set out therein for a period of at least four weeks.	20 August 2020

14 Clause 11.123.2 of the NER.

15 Clause 3.11.7(c) of the NER.

MILESTONES	DETAILS	KEY DATES
Submissions close	Submissions close on the issues raised in this consultation paper	18 September 2020
Publish an interim Standard and final report on changes to qualitative elements of the standard.	Publish an interim Standard updating relevant qualitative elements of the Standard to reflect the inclusion of system restoration support services in the definition of SRAS, along with a final report on these changes.	October 2020
Publish a draft report on changes to quantitative Standard settings for a combined Queensland sub-network.	If AEMO determines to combine the two existing Queensland sub-networks into a single sub-network, publish a draft report setting out proposed restoration time frames, levels of restoration and aggregate reliability requirements for a combined Queensland sub-network. This draft report will be published at the same time as the interim Standard.	October 2020
Submissions close	Submissions close on the draft report on quantitative Standard settings for a combined Queensland sub-network.	November 2020
Publish a final standard and final report on changes to quantitative Standard settings for a combined Queensland sub-network.	If AEMO determines to combine the two existing Queensland sub-networks into a single sub-network, publish a final report and final Standard setting out proposed restoration time frames, levels of restoration and aggregate reliability requirements for a combined Queensland sub-network.	January 2021

The Panel considers that a single stage of consultation is adequate to obtain feedback on the changes to the Standard needed to account for the expansion of the definition of SRAS, and is consistent with its obligatoins under the NER and the ToR issued by the AEMC. As such, an interim Standard incorporating these changes is proposed to be published in October 2020.

However, the Panel considers that the complexity associated with determining quantitative Standard settings for a combined Queensland sub-network requires an additional round of consultation following publication of the interim Standard. This additional consultation will provide stakeholders with the opportunity to provide input into the final Standard settings for the Queensland sub-network.

1.4 Structure of the paper

The remainder of this consultation paper is structured as follows:

- Chapter 2 describes the background of how system restart operates in the NEM, and how the Standard fits into the overall governance arrangements for the restoration of the power system
- Chapter 3 sets out the assessment criteria the Panel proposes to apply to its review of the Standard
- Chapter 4 present issues for stakeholder feedback on qualitative changes to the Standard to address changes made in the Commission's SRAS rule
- Chapter 5 presents issues for stakeholder feedback on quantitative changes to the Standard to provide for a single sub-network in Queensland.

1.5 Submission

The Panel invites written submissions on this consultation paper from interested parties by no later than 18 September. All submissions received will be published on the AEMC's website (www.aemc.gov.au), subject to any claims for confidentiality.

Submissions must be lodged in accordance with the instructions on the AEMC website. Any questions regarding the consultation process should be directed to Graham Mills, graham.mills@aemc.gov.au

2 BACKGROUND

Mechanisms established in the NER are used to maintain the power system in a secure operating state. However, certain rare and severe events have the potential to disturb the power system to an extent that cannot be managed by these mechanisms. These rare events can potentially result in a major supply disruption, or black system event,[16] which can shut down entire sections of the power system with significant economic and social costs due to the loss of supply to affected customers. Major supply disruptions and black system events are rare but not impossible events. The most recent black system event was in South Australia in September 2016. Prior to that event, two more occurred in; northern Queensland in 2009; and New South Wales in 1964.[17] As an example of the severity of the economic and social costs of black system events, the economic costs of the South Australian black system event have been estimated at 376 million dollars.[18]

This chapter provides background and context to the issues being considered by the Panel in its review of the Standard. It introduces:

- the process of responding to a major supply disruption and the role of SRAS in this process
- Governance arrangements relating to SRAS and the role of the Standard in this framework
- the different elements comprising the Standard.

2.1 Introduction to SRAS and the process of responding to a major supply disruption

The section introduces the process of responding to a major supply disruption or black system event and the role of SRAS in that process.

2.1.1 What are SRAS

SRAS are resources that AEMO procures to re-energise parts of the power system affected by a major supply disruption or black system event. SRAS can be likened to an "insurance policy" which AEMO procures to minimise the impact of a rare but possible disruption to the power system.

Traditionally, SRAS are services provided by generating units with "black start" capability which allows them to start, or remain in service, without electricity being provided from the

16 A major supply disruption occurs when voltage is lost on part of the transmission network affecting one or more generators leading to the loss of supply to customers. The NER defines a black system condition as the absence of voltage on all or a significant part of the transmission system or within a region during a major supply disruption affecting a significant number of customers. It should be noted that not all major supply disruptions involve black system conditions, and therefore require SRAS to restore affected customers.

17 Reliability Panel, Fact Sheet - Black system events. https://www.aemc.gov.au/sites/default/files/content/b705e0e4-afd3-47ef-bc41-32ea3393629c/Fact-Sheet-Black-system-events.pdf

18 Business South Australia - https://www.business-sa.com/Commercial-Content/Media-Centre/Latest-Media-Releases/September-Blackout-Cost-State-$367-Million

network. In the event of a major supply disruption or black system event SRAS are the first resources to restart and commence the re-energisation process.[19]

SRAS providers commence the re-energisation process by supplying power to auxiliary loads at non-SRAS generating systems. Generating units require some machinery to operate, such as conveyor belts, compressors, fans, pumps and coal pulverisers, which are known as auxiliaries. Non-SRAS generating systems are unable to start without an external source of supply for their auxiliary loads. SRAS generators provide this initial supply, which allows non-SRAS generating systems to re-start and contribute to power system re-energisation.

A number of different technologies have traditionally provided SRAS in the NEM. These include:

- generating units that can restart without being connected to the grid, such as hydro or various gas turbine generating units
- 'trip to house load' schemes, which include large generating units that can disconnect from the grid in the event of a major supply disruption and continue to supply their own auxiliaries, and
- combination system restart sources, which are large generating units that can be started from a nearby small power station, such as a thermal power station with a gas turbine generating unit that is capable of starting without grid supply.

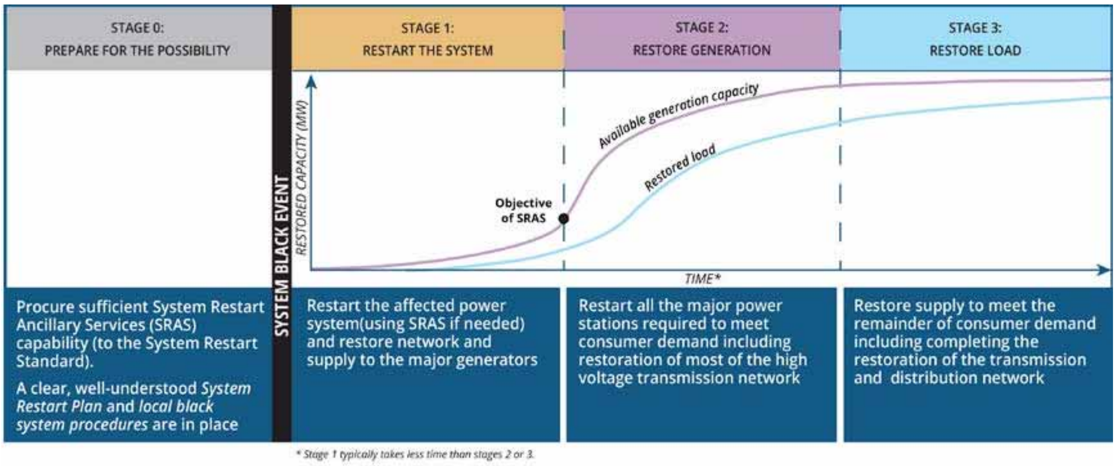
In addition to traditional SRAS providers, a number of non-traditional providers of "black start" capability are emerging. These include technologies such as batteries combined with grid forming inverters. SRAS may also be provided by facilities which have the capability to assist the re-energisation process. The Commission's SRAS rule included changes to allow for restoration support services and non-traditional technologies capable of providing black start services to be captured by the SRAS frameworks. More detail on these changes is provided in Chapter 5.

2.1.2 Process of responding to a black system event

Frameworks in the NER set out a process for restoring the power system following a major supply disruption or black system event. This process has several stages and involves AEMO, transmission and distribution network service providers and generators each coordinating in their respective roles. An overview of the stages involved in preparing for and responding to a black system event is illustrated in Figure 2.1

19 Re-energisation can also occur from neighbouring regions.

Figure 2.1: Power system restoration process



Stage zero - Prepare for the possibility: AEMO procures SRAS during stage zero in preparation for a possible major supply disruption or black system event. The Standard is primarily relevant to stage zero as it provides qualitative guidance and quantitative settings to guide AEMO's procurement of SRAS. During this period AEMO enters into contracts with SRAS providers and develops a system restart plan to guide restoration of the system.

Stage one - Restart the system: immediately following the occurrence of a major supply disruption or black system event AEMO will consider its options for restoring the power system. These may include calling upon SRAS procured during stage zero and, if available, requesting the provision of energy from unaffected parts of the power system. The objective of stage 1 is to re-start a critical number of major power stations necessary to stably restore remaining generation and load.

Stages two and three - Restore generation and load: Remaining generation will be restarted with supply to consumers restored progressively during stages two and three. The Rules set out requirements relating to the restoration of sensitive loads which AEMO must meet.

The speed of customer restoration during these stages is dependent on a range of factors, including network conditions. In accordance with their local black system procedures and instructions from AEMO, it is the responsibility of network operators to restore power to individual consumers. Restoration of supply to consumers may not occur until a number of hours after the restoration of capability for generators as contemplated in the Standard.

2.2 Governance arrangements and the role of the Standard

The Panel, AEMO, networks, and generators all have obligations under the frameworks for system restoration in the NEM. The Standard is a central element in this overall framework. This section introduces the role of the Standard in the context of governance arrangements and roles and responsibilities applying to the different parties responsible for system restoration in the NEM.

The Reliability Panel

The Standard is set by the Panel[20] in accordance with the SRAS Objective and the requirements for the Standard set out in the NER.[21] The NER requires the Standard to include quantitative settings relating to system restoration and qualitative guidance for AEMO to follow in its procurement of SRAS. The specific elements of the standard are introduced in section 2.3.

The Standard is used to set requirements for AEMO's procurement of SRAS, help inform AEMO's system restart plan, and guide AEMO's determination of sub-networks. The Standard is therefore an overarching element of the governance arrangements for system restoration in the NEM.

While the Standard informs AEMO's actions in stage one of the restart process, it is primarily a document applying to stage zero and AEMO's procurement of SRAS and preparations for restoration following a major supply disruption or black system event.

AEMO

AEMO has overall authority for procuring SRAS and coordinating power system restoration following a major supply disruption or black system event.[22] Other parties being network service providers, generators, and jurisdictional system security coordinators (JSSCs) are obliged to provide relevant information and assist AEMO with the restoration process. AEMO publishes three key coordinating documents being the SRAS Guideline, system restart plan, and guidelines for preparing local black system procedures for this purpose.

The SRAS Guideline sets out details of AEMO's technical requirements for SRAS, modelling and testing requirements for SRAS providers, and details of its SRAS procurement processes. It is therefore a significant document in stage zero of the restart process, which is to prepare for the possibility of a major supply disruption or black system event. The Rules require AEMO to publish its SRAS Guidelines in accordance with the relevant guidance provided in the Standard.[23]

The NEM is sub-divided into electrical sub-networks both for acquiring SRAS and developing operational plans to manage major supply disruptions. AEMO is responsible for determining the boundaries of the electrical sub-networks,[24] using criteria specified in the Standard by the Panel.[25] Currently AEMO has determined that there are six electrical sub-networks. These are Queensland North, Queensland South, New South Wales, Victoria, South Australia and

20 The Reliability Panel, which forms part of the AEMC's institutional arrangements, reviews and reports on the safety, security and reliability of the national electricity system. The Panel is comprised of members who represent a range of participants in the national electricity market, including consumer groups, generators, network businesses, retailers and AEMO.

21 Clause 8.8.3(aa) of the NER.

22 Clauses 3.11.7(a1) and 4.3.1(p) of the NER.

23 Clause 3.11.7(c) of the NER.

24 Clause 3.11.8 of the NER.

25 Clause 8.8.3(aa)(6) of the Rules.

Tasmania. With the exception of Queensland, the sub-networks follow the NEM region boundaries.

AEMO also develops a system restart plan for the purpose of managing and coordinating system restoration activities following any major supply disruption or black system event. The system restart plan contains all relevant procedures that would be expected to be followed by generators, including those contracted to provide SRAS, network service providers, and JSSCs in restoring an electrical sub-network following a major supply disruption, including a black system event.[26] The system restart plan is required to be consistent with the Standard.[27]

AEMO also develops guidelines for use by networks and generators to develop their local black system procedures, which are discussed further below.[28]

Networks and generators

The networks are responsible for providing AEMO with any information which AEMO reasonably requires in order for AEMO to assess the capability of an SRAS provider to meet the Standard. They are also required to participate in, or facilitate, testing of SRAS to be provided by a prospective SRAS Provider.[29]

Generators with the relevant specialised equipment are able to offer to provide SRAS. Generators that receive payment for the provision of SRAS are required to maintain their restart capacity and undertake regular testing as set out in the SRAS guidelines.

Networks and generators are both required to develop local black system procedures conforming with AEMO's guideline and setting out the technical characteristics of their plant under black system conditions. These procedures are approved by AEMO.

2.3 The Standard

The NER sets out requirements for the Standard including the elements that the Panel must include when determining the Standard.[30] The elements of the Standard can be divided into qualitative guidance and quantitative settings. This section introduces the quantitative and qualitative elements of the standard as context for the issues to be considered by the Panel in this review.

Quantitative standard settings

The quantitative Standard settings represent targets for AEMO's procurement of SRAS in each sub-region of the NEM. These include the following:

26 A JSSC is a person appointed by the Minister of a participating jurisdiction who must prepare, maintain, and if necessary, update guidelines in relation to the shedding, and restoration, of loads

27 Clause 4.8.12(c) of the NER.

28 Clause 4.8.12(e) of the NER.

29 Clause 3.11.9(i) of the NER.

30 Clauses 8.8.3(a)(5) and (aa) of the NER.

- **Level of restoration -** The level of restoration represents the minimum level (MW) of generation that must be restored for the continued stable restoration of the power system.
- **Restoration time -** The Panel is required to specify the maximum amount of time within which procured SRAS is required to restore supply to a sub-network to a specific level. The Panel considers the costs and benefits of requiring a particular speed of restoration such that Standard settings are economically efficient.
- **Required aggregate reliability -** Aggregate reliability is the probability that the generation and transmission in a sub-network is restored to the specified restoration level within the specified restoration time. The aggregate reliability of the procured SRAS in each electrical sub-network is determined considering the combination of the individual reliabilities of the SRAS procured in that electrical sub-network, together with an assessment of the impact of the points of failure.

The quantitative elements of the Standard provide settings for AEMO's procurement of SRAS. While AEMO would aim to restore the power system to the requirements of the Standard following a major supply disruption, the Standard does not set operational targets to be achieved during an actual restoration event. AEMO is taken to have complied with the quantitative settings in the Standard in respect of the modelled outcomes from its procurement of SRAS rather than operational outcomes during an actual restoration event.

It should also be noted that the Standard's quantitative settings do not specify the level of load that needs to be restored. This is because it is network service providers who are responsible for reconnecting consumers, the level of which can be dependent on a range of issues (such as network damage) that are beyond AEMO's ability to control.

The existing quantitative Standard settings for each sub-network in the NEM are set out in Table 2.1 below:

Table 2.1: **Quantitative Standard settings**

ELECTRICAL SUB-NETWORK	LEVEL OF RESTORATION (MW)	RESTORATION TIME (HOURS)	REQUIRED AGGREGATE RELIABILITY
North Queensland	825	3.5	90%
South Queensland	825	3.0	90%
New South Wales	1500	2.0	90%
Victoria	1100	3.0	90%
South Australia	330	2.5	90%
Tasmania	300	2.5	95%

Specific details of the method used by the Panel to determine the Standard's quantitative settings for each electrical sub-network are provided in Chapter 5 and Appendix A.

Qualitative guidance and guidelines

In addition to the quantitative settings for restoration level, time and aggregate reliability, the Standard also provides qualitative guidance on the interpretation of the quantitative settings, including:

- **Guidelines for the determination of electrical sub-networks** - In determining the boundaries for electrical sub-networks, AEMO must consider the technical characteristics that would facilitate the achievement of AEMO's power system security responsibility of procuring adequate system restart ancillary services to enable it to co-ordinate a response to a major supply disruption. These technical characteristics would include, without limitation, consideration of the number and strength of transmission corridors, electrical distance between generation centres, and the extent to which the sub-network can be kept in a satisfactory (stable) state during restoration.
- **Guidelines for assessing the diversity of services** - In determining the aggregate reliability of SRAS in an electrical sub-network, AEMO shall incorporate an assessment of the impact of diversity of the services by taking into account electrical, geographical, and energy source diversity.
- **Guidelines for the strategic location of services** - AEMO shall determine the strategic location of SRAS based on an assessment of how the geographical and electrical location of those services best facilitates the power system restoration. The locational value of SRAS relates to its ability to energise the transmission network and assist other generating units to restart.

Specific additional requirements applying to certain sub-networks

The existing Standard sets out quantitative requirements that apply uniformly across a sub-network. The selection of locations for SRAS within a sub-networks is left to AEMO's discretion, which is guided by the qualitative guidance on assessing diversity of services and strategic location of services.

The existing Standard determines an additional requirement applying to the NSW sub-network. This requirement is for AEMO to procure SRAS north of Sydney, sufficient to also independently restart, without drawing power from the power system, at least 500 MW of generation capacity within four hours of a major supply disruption with an aggregate reliability of at least 75 per cent.

This additional requirement reflects the importance of an SRAS resource being located north of Sydney for the restoration of generation in the Hunter Valley. This requirement avoids the potential time delays in restarting Hunter valley generation from SRAS located in the south of the state.

3 ASSESSMENT FRAMEWORK

This chapter sets out the assessment framework proposed by the Panel. This framework includes consideration of:

- the SRAS Objective and National Electricity Objective
- the requirements for the Standard set out in the NER and the terms of reference issued by the Commission
- additional factors relevant to the Panel's assessment of the Standard.

3.1 SRAS Objective and National Electricity Objective

The NER requires the Panel to determine the Standard in accordance with the SRAS Objective set out below:[31]

> *"The objective for system restart ancillary services is to minimise the expected costs of a major supply disruption, to the extent appropriate having regard to the national electricity objective."*

The SRAS Objective requires a Standard that minimises the expected cost of a major supply disruption. This expected cost reflects the cost of providing SRAS plus the costs to society of a prolonged disruption to electricity supply. The SRAS Objective therefore requires the Panel to determine the Standard on the basis of an economic assessment of different levels of, and options for, AEMO's SRAS procurement.

The SRAS objective also requires the Panel to have regard to the National Electricity Objective (NEO) in determining the Standard. The NEO is set out in Section 7 of National Electricity Law as follows:

> *"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 Panel considers that the relevant aspects of the NEO for this review are more efficient investment in, and operation of, electricity services, particularly with respect to the price of SRAS and the reliability, safety and security of supply.

3.2 Requirements of the NER and terms of reference

The NER requires the Panel to determine a Standard that meets the following requirements.[32]

1. identify the maximum amount of time within which system restart ancillary services are required to restore supply in an electrical sub-network to a specified level, under the assumption that supply (other than that provided under a system restart ancillary

31 Clause 8.8.3(aa)(1) of the NER.

32 Clauses 8.8.3(aa)(2) to (7) of the NER

services agreement acquired by AEMO for that electrical sub-network) is not available from any neighbouring electrical sub-network;

2. include the aggregate required reliability of system restart ancillary services for each electrical sub-network;
3. apply equally across all regions, unless the Reliability Panel varies the system restart standard between electrical sub-networks to the extent necessary:
    a. to reflect any technical system limitations or requirements; or
    b. to reflect any specific economic circumstances in an electrical sub-network, including but not limited to the existence of one or more sensitive loads;
4. specify that a system restart ancillary service can only be acquired by AEMO under a system restart ancillary services agreement for one electrical sub-network at any one time;
5. include guidelines to be followed by AEMO in determining electrical sub-networks, including the determination of the appropriate number of electrical sub-networks and the characteristics required within an electrical sub-network (such as the amount of generation or load, or electrical distance between generation centres, within an electrical sub-network); and
6. include guidelines specifying the diversity and strategic locations required of system restart ancillary services.

In this review, the Panel will determine a Standard addressing the necessary elements of the above requirements, having regard to the review's scope as set out in the terms of reference issued by the Commission. Given that the review needs to be completed as soon as practicable, the Commission's terms of reference request that the Panel limit the scope of this review as set out in Chapter 1.

3.3 Factors relevant to the Panel's assessment of the Standard

When determining the Standard, the Panel also intends to consider a number of other factors relevant to addressing the scope of the review. These other factors include:

- in relation to the consideration of any revised Queensland networks, the physical underpinnings of the power system in Queensland, including minimum load levels needed to restore stability on the main transmission flow paths as well as the physical limitations of the system that may be relevant to the minimum technically feasible time frame for system restoration
- more generally:
    - the outcomes of consultation with jurisdictional governments to identify any specific issues or matters relevant to the speed of restoration and the cost of restart services to deliver that speed of restoration in specific jurisdictions
    - feedback received from stakeholders though written submissions and discussions.

QUESTION 1: ASSESSMENT FRAMEWORK

(a) Do Stakeholders agree with the Panel's assessment framework?

(b) Are there other relevant factors the Panel should consider when undertaking the review?

4 CHANGES TO ACCOUNT FOR SRAS RULE

On 2 April 2020, the Commission made the System restart services, standards and testing rule (SRAS rule). This rule was made to address challenges from fewer traditional sources of SRAS being available in some NEM regions, with those remaining potentially less capable of restoring the power system.[33] The SRAS rule made a range of changes to frameworks governing the definition, procurement, testing and deployment of SRAS.

This chapter presents the Panel's approach to amending to the Standard to reflect changes made in the SRAS rule and seeks stakeholder feedback on this issue.

4.1 Changes made by the SRAS rule

The SRAS rule included changes to the definitions of SRAS and black start capability, implemented a framework for physical testing of system restart paths, and provided for greater transparency and certainty about participant roles and responsibilities in system restoration. Of these changes, the Commission's terms of reference specifically identified changes to the definition of SRAS as materially relevant to the Standard.

Changes to implement a framework for physical testing of system restart paths and provide greater transparency and certainty on participant roles and responsibilities are important for wider SRAS frameworks, but are not material to the settings and guidance provided by the Standard for AEMO's procurement of SRAS. The remainder of this chapter will therefore focus on amending the Standard to account for the revised definitions of SRAS and black start capability.

The definition of SRAS was previously limited to facilities with black start capability, with the definition of black start capability being framed as applying specifically to generating units.[34] The Commission's SRAS rule updated both the definition of black start capability, to provide for the provision of this capability by providers other than generating units, and the definition of SRAS, to include a new category of restoration support services.

The current definitions of these terms, as amended by the SRAS rule, are as follows:

- black start capability is defined as a capability that allows a generating unit, facility or a combination of facilities following disconnection from the power system, to be able to deliver electricity to either:(a) a connection point; or (b) a suitable point in the network from which supply can be made available to other generating units, without taking supply from any part of the power system following disconnection.
- SRAS is defined as a service provided by plant or facilities with: (a) black start capability; or (b) the capabilities described in the SRAS Guideline to supply one or more services to sustain the stable energisation of generation and transmission, sufficient to facilitate the

33 AEMC, System restart services, standards and testing rule - final determination, p. ii

34 Black start capability was defined in full in chapter 10 of the NER as: A capability that allows a generating unit, following its disconnection from the power system, to be able to deliver electricity to either: (a) its connection point; or (b) a suitable point in the network from which supply can be made available to other generating units, without taking supply from any part of the power system following disconnection.

restoration and maintenance of power system security and the restart of generating units following a major supply disruption.

The Commission considered that this revised definition will:[35]

- provide for emerging technologies, such as batteries with 'grid forming' inverters, or other combinations of plant to be procured by AEMO to provide black start capability
- increase competition for the provision of black start capability from an expanded range of facilities
- allow AEMO to procure system restoration support services as SRAS, thereby making sure that the capability to support the grid during a restart process is valued and available when required.

In revising the definition of SRAS, the Commission considered whether SRAS should be able to be provided by network service providers (NSPs). In this regard, the Commission considered that procurement of SRAS from NSPs would represent a significant departure from the current design of the SRAS frameworks in the NER and would require a number of complex regulatory issues to be addressed, including the appropriate separation of the regulated and competitive components of the electricity supply chain.[36] As a result, the revised definition of SRAS in the NER does not provide for AEMO to procure SRAS from NSPs or interconnectors. Given that a further rule change would be required to allow SRAS to be provided by NSPs and interconnectors, the Panel does not propose to include consideration of this issue in the scope of this review of the Standard.

The Panel proposes limiting amendments to the Standard to provide for the inclusion of non-traditional providers of black start capability and restoration support services in the above definitions. The scope and type of potential changes to the Standard are discussed in the following section.

The Panel is interested in any stakeholder views on the changes considered in the SRAS rule, and the implication for this review of the Standard.

4.2 Panel's approach to amending the Standard to account for the SRAS rule

As the Standard is currently written to accord with the former definition of SRAS, there is a risk that the qualitative and quantitative elements of the Standard do not fully encompass the expanded technological and service scope of SRAS given the new definition. This section seeks stakeholder feedback on the Panel's approach to amending the Standard to incorporate the revised definition of SRAS.

The Panel's proposed approach to considering changes to the quantitative and qualitative elements of the Standard are set out below.

Changes to quantitative standard settings

35 AEMC, System restart services, standards and testing rule - final determination, p. 19

36 AEMC, System restart services, standards and testing rule - final determination, p. 47.

The Standard specifies quantitative settings for restoration level, time frame, and aggregate reliability for each sub-network in the NEM. The Panel considers the wider scope of technologies that can provide black start and act as restoration support services may, over time, change the economically efficient level of SRAS procured by AEMO for a particular sub-network. Should this occur, the existing quantitative settings in the Standard may no longer reflect economically efficient levels of SRAS given the expanded definition of SRAS.

The Panel however does not consider it possible to identify economically efficient quantitative Standard settings which account for the availability of restoration support services prior to AEMO having defined the technical characteristics of these services in its SRAS Guideline. This is because Panel requires an understanding of the service in order to model its impact on efficient levels of SRAS and resulting quantitative Standard settings. As the Panel's review is being conducted in parallel with AEMO's consultation on its SRAS Guideline, information on the definition of these support services will not be available in sufficient time for consideration in this review.

The Panel also considers it necessary to wait until better information is available prior to adjusting quantitative Standard settings to account for non-traditional providers of SRAS and restoration support services. Information on the actual costs, location, availability and characteristics of restoration support services and non-traditional providers of black start capability will not be available until after AEMO's next SRAS procurement round in 2021. The Panel therefore does not intend to make changes to the quantitative Standard settings to account for the revised definitions of SRAS and black start capability in this review. The Panel considers a fulsome review of the Standard's quantitative settings for each electrical sub-network which accounts for these changes would be appropriate following AEMO's next procurement round.

Changes to qualitative guidance

The Standard provides qualitative guidance to AEMO on the interpretation of the quantitative settings, as well as guidelines for the:

- determination of electrical sub-networks by AEMO
- diversity of services, and
- strategic location of services.

The qualitative guidance currently in the Standard uses language that reflects the former definitions of SRAS and black start capability. An example was provided by AEMO in its submission to the Commission's SRAS rule change. AEMO identified that the system restart standard discusses how the reliability of any individual SRAS provider would be determined, which includes by having regard to "the availability of that service, the expected start-up performance and the reliability of the transmission components between the SRAS source and the first transmission substation to which it is connected.[37] The Panel notes that the use of 'start up performance' in this context may not be applicable to restoration support services.

37 AEMC, System restart services, standards and testing rule (SRAS rule - final determination, p. 48.

This is an example of how the existing qualitative guidance may create barriers to and/or provide insufficient guidance for AEMO's procurement of SRAS of all types from all eligible sources. The Panel will therefore consider revising qualitative guidance in the Standard to:

- address use of language that is inappropriate and/or could act as a barrier to AEMO's procurement of restoration support services and SRAS from non-traditional providers. This approach would focus on amending existing guidance in the Standard.
- provide additional guidance specific to black start capability provided by non-traditional providers and restoration support services. This approach may augment existing guidance in the Standard to clarify how it applies to restoration support services and non-traditional providers of black start capability. This could include, for example, changes to the existing guidance on the diversity and location of SRAS sources.

The Panel's preference is to focus on addressing language in the existing standard that is inappropriate and/or could act as a barrier to AEMO's procurement of restoration support services and SRAS from non-traditional providers. While the Panel may include some additional guidance relevant to black start capability provided by non-traditional providers and restoration support services, the Panel is not proposing to include prescriptive guidance on the procurement of these new services in the amended Standard.

The Panel considers it prudent to augment the Standard with detailed additional guidance specific to SRAS from non-traditional providers and restoration support services once more information is available following AEMO's next procurement round in 2021. This additional information will allow the Panel to add guidance that is accurate, relevant, and appropriately targeted to AEMO's procurement of SRAS of different types from different technologies.

QUESTION 2: CHANGES TO ACCOUNT FOR THE SRAS RULE

(a) Do stakeholders agree with the Panel's proposed approach to amending qualitative guidance in the Standard to remove possible barriers to AEMO's procurement of restoration support services and SRAS from non-traditional providers of black start capability?

(b) Are stakeholders aware of any specific elements of the Standard that require amendment to facilitate this?

(c) Do stakeholders have views on the changes considered and made in the SRAS rule and how this affects this review?

5 STANDARD SETTINGS FOR A COMBINED QUEENSLAND SUB-NETWORK

Sub-networks for the procurement of SRAS are currently defined in line with the NEM regional boundaries, with the exception of Queensland, which is divided into two sub-networks: North Queensland and South Queensland. The existing Standard specifies different quantitative targets for AEMO's procurement of SRAS in each of these two sub-networks.

AEMO is currently consulting on its draft determination to combine the two existing Queensland sub-networks [38] The AEMC's terms of reference recommended that the Panel consider amending relevant Standard settings should AEMO determine to combine the existing Queensland sub-networks. In particular, if AEMO determines to combine the two existing Queensland sub-networks into a single sub-network, the terms of reference suggested that the Panel determine and publish restoration time frames, levels of restoration and aggregate reliability requirements for a single Queensland sub-network in a final Standard.

This section presents the Panel's proposed approach to determining quantitative Standard settings for a combined Queensland sub-network in light of AEMO's draft decision. The following matters are introduced:

- method of determining Standard settings for a combined Queensland sub-network
- approach to valuing unserved energy, and
- additional locational requirements in a single Queensland sub-network

In its draft determination on combining the Queensland sub-networks, AEMO proposed an approach which may involve combining the existing Queensland sub-networks but including a regional requirement for AEMO to procure SRAS in both central and south Queensland. AEMO's proposal is similar to the approach adopted in the existing Standard for New South Wales. This approach is considered further in Section 5.2.

5.1 Method for determining Standard settings for a combined Queensland sub-network

This section presents the Panel's proposed approach to:

- identifying efficient levels of SRAS for a single Queensland sub-network, and
- determining Standard settings arising from those efficient levels.

The Panel proposes to apply the method used to determine quantitative settings for each sub-network in the Panel's 2016 review of the Standard. This section provides a high-level overview of that method for stakeholder feedback. Further details are provided in Appendix A.

38 https://aemo.com.au/en/consultations/current-and-closed-consultations/sras-guideline-2020

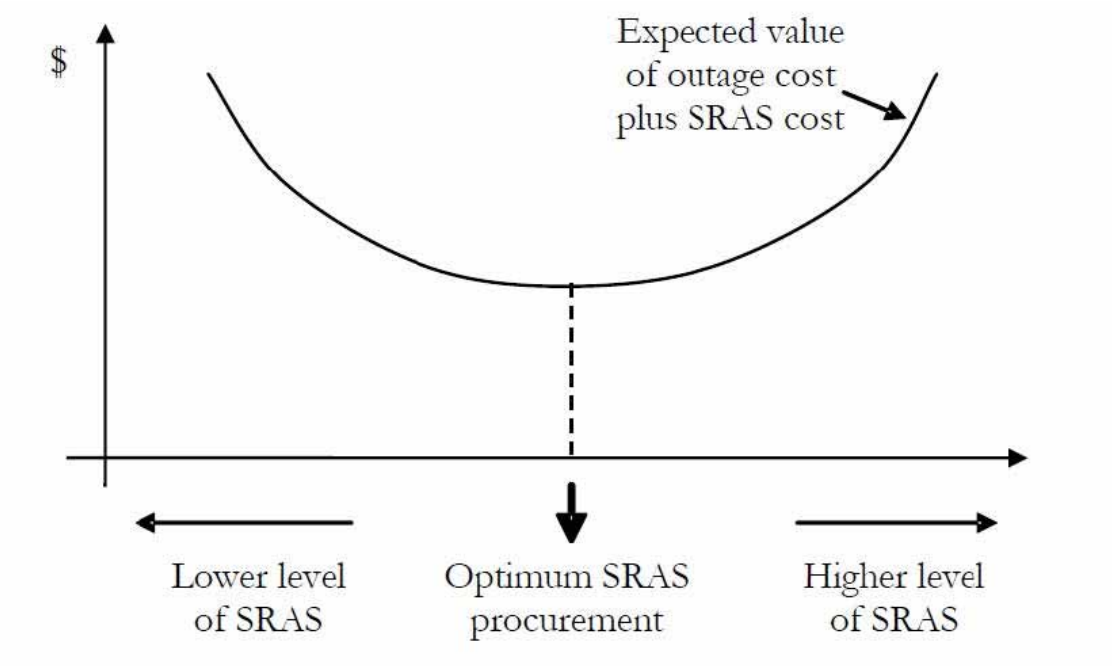
5.1.1 Method for identifying efficient levels of SRAS in a Queensland sub-network

The Panel is required to determine the Standard in accordance with the SRAS Objective, which is to minimise the expected costs of a major supply disruption to the extent appropriate having regard to the national electricity objective. This section sets out the Panel's approach to estimating the level of SRAS is a combined Queensland sub-network that is economically efficient and minimises overall costs for consumers. Following the identification of the efficient level of SRAS, the quantitative Standard settings for restoration levels, restoration timeframes and aggregate reliability would subsequently be determined in accordance with the approach set out in section 5.1.2.

The objective of the Panel's assessment is to identify the efficient level of SRAS in a combined Queensland sub-network. The efficient level is where the probability weighted marginal benefit of procuring an additional restart service is approximately equal to the cost of procuring that additional restart service. Figure 5.1 conceptually identifies this as the level that minimises the total combined cost to consumers of:

- SRAS procurement
- the economic and social costs of a major supply disruption.

Figure 5.1: Identifying the efficient level of SRAS



Source: AEMC

The approach used to identify the efficient level of SRAS involves the steps set out in Table 5.1.

Table 5.1: Summary of steps to identify efficient levels of SRAS

ASSESSMENT STAGE	SUMMARY DESCRIPTION
1) Determining unserved energy for the different SRAS procurement options available	Unserved energy is assessed from the supply restoration curves associated with each SRAS procurement option assessed.
2) Valuing the benefit of different options for SRAS procurement	The economic benefit of avoided unserved energy for each candidate SRAS procurement option is valued using Value of Customer Reliability (VCR).
3) Calculating the annualised benefit of procuring SRAS given the probability of a black system event in the relevant sub-network	The economic benefit of each candidate SRAS procurement option is then annualised using an estimate of the probability of a black system event occurring in a combined Queensland sub-network.
5) Quantifying uncertainty	Uncertainty associated with a set of key variables is accounted for through a sensitivity analysis.
4) Efficient levels of SRAS are identified	Efficient levels of SRAS are identified by comparing the annualised benefit of procuring an additional SRAS with the cost of procurement.

1. Determining unserved energy for different SRAS procurement options

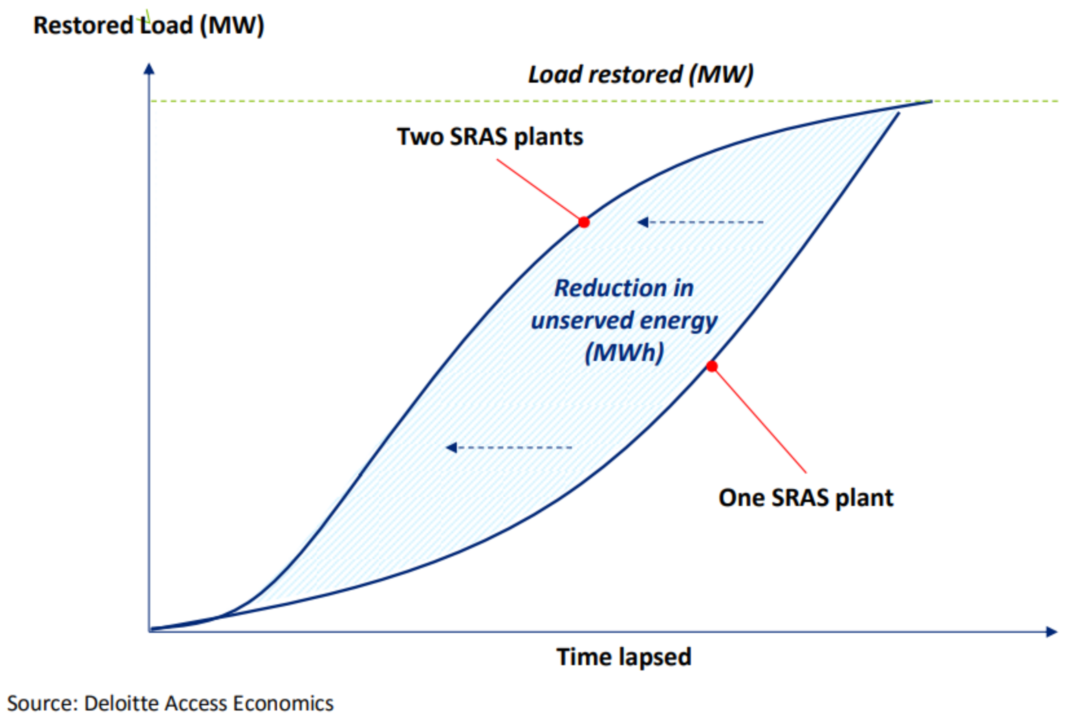
AEMO has a number of SRAS sources it could procure in a combined Queensland sub-network. The first step in identifying the efficient level of SRAS (being the number of restart services procured) involves identifying the unserved energy associated with each potential SRAS procurement option.

In general, procuring additional SRAS in a sub-network reduces the level of unserved energy by allowing for a faster restoration of supply. This means that all else being equal, the procurement of an additional SRAS resource will enable the system to be restarted faster and more reliably, reducing the extent of the system disruption and minimising the economic losses from the resulting unserved energy.

Supply restoration curves are used to describe the speed of restoration for each combination of potential SRAS resources available for procurement. The level of unserved energy associated with each procurement option can be identified from the area under the resulting supply restoration curve. Figure 5.2 conceptually illustrates the unserved energy avoided from the procurement of two SRAS plants relative to one SRAS plant. This reduction in unserved energy represent the benefit of procuring the additional SRAS resource. Appendix A provides further details on this aspect of the Panel’s proposed approach to determining quantitative Standard settings.

The Panel will use supply restoration curves provided by AEMO for a single Queensland sub-network to identify the unserved energy associated with each of the different options for SRAS procurement in order to identify the number of SRAS sources which minimises total costs of both SRAS procurement and the economic and social costs of a major supply disruption.

Figure 5.2: Illustration of supply restoration curves for two alternative SRAS procurement options



Source: Deloitte Access Economics

2. Valuing the benefit provided by SRAS in a combined Queensland sub-network

The economic benefit from procuring additional SRAS is assessed by determining the unserved energy avoided and multiplying this by an estimate of the economic value of that unserved energy. In 2016, the Panel used the Value of Customer Reliability (VCR) published by AEMO as a basis for estimating the economic value of unserved energy.[39]

VCRs seek to reflect the value different types of customers place on a reliable electricity supply under different conditions. VCRs are used in regulatory and network investment decision-making to factor in competing tensions of reliability and affordability. VCR is not a single number but a collection of values across residential and business customer types,

39 Note that the AER now has responsibility for publishing estimates of VCR in the NEM. On 18 December 2019, the AER published its first set of VCR values. https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/values-of-customer-reliability

which need to be selectively applied depending on the context in which they are being used. In 2016, the Panel developed VCR figures for each sub-network in the NEM considering the composition of different customer types in each region. Appendix A provides further details on the Panel's approach.

In addition to VCR values for standard outages, the AER is currently developing a model for estimating the economic costs of Widespread and Long Duration Outages (WALDOs).[40] These are outages of longer duration and/or greater geographical coverage than those considered in the set of VCRs for standard outages. VCRs for WALDOs also include estimates of the social costs arising from long duration and wide area outages such as major supply disruptions and black system events. The AER is developing the WALDO model specifically for use in applications such as the Panel's review of the Standard. [41]

The Panel will consider whether to apply the WALDO model to establish quantitative Standard settings for a combined Queensland sub-network. Further discussion of the Panel's considerations in this regard is provided in section 5.2.

Valuing avoided unserved energy requires consideration of the reliability and availability of the SRAS being considered. Some resources may be highly reliable, such as hydro, while others may be less reliable such as ageing thermal generators. When comparing different options for procurement, AEMO must consider the probability that all, none, or some of the SRAS procured will be available and successfully deliver when called upon.

In 2016, the Panel calculated a reliability weighted total benefit from procuring additional SRAS resources for use in identifying efficient levels of SRAS. This reliability weighted total benefit was established by determining the unserved energy resulting from each combination of resources procured by AEMO failing to start and weighting this by the probability of that outcome occurring. Appendix A provides details on the method of determining reliability weighted total benefit.

3. Calculating the annualised benefit of procuring SRAS given the probability of a black system event

The efficient level of SRAS in a combined Queensland sub-network can be estimated by comparing the annual cost of procuring additional SRAS against the annualised reliability weighted benefit of additional avoided unserved energy. The probability that a black system event will occur in Queensland in a particular year is used to annnualise the reliability weighted benefit of additional avoided unserved energy.

The Panel proposes estimating the probability of a black system event in a single Queensland sub-network by applying the approach used in the Panel's 2016 review of the Standard. This approach used a power law relationship to extrapolate from historic data on lost load in the sub-network to estimate the probability of a black system event occurring. Additional details are available in Appendix A.

40 https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/values-of-customer-reliability/updates

41 AER, Value of Customer Reliability Review - Final Report - December 2019, p. 5.

Estimating the likelihood of high risk, low probability events such as a black system event occurring is difficult as there is often limited data available to inform the assessment. As a result, the Panel will seek to account for this uncertainty by including the calculation of the probability of a black system event in a combined Queensland sub-network in the sensitivity analysis discussed below.

4. Identify efficient levels of SRAS by comparing the annualised benefit with the cost of procurement

The annualised reliability weighted total benefit associated with the different SRAS procurement options available in a combined Queensland sub-network can then be assessed against the annual cost of procurement to identify the efficient number of SRAS sources to procure. The efficient number of SRAS sources to procure is identified by determining the level where the probability weighted marginal benefit of procuring an additional restart service is approximately equal to the marginal cost of procuring that restart service.

5. Quantifying uncertainty

In 2016, the Panel's assessment considered uncertainty associated with the different variables discussed above by conducting a sensitivity analysis. This sensitivity analysis involved estimating upper and lower bounds for a set of parameters to calculate the range (low and high values) of economic costs for each assessed restoration curve. Uncertainty associated with the following key variables were assessed in the 2016 sensitivity analysis:

- VCR ($/MWh) (for each sub-network)
- Probability of a black system event occurring, and
- Composite reliability of restoration curves (for each unique SRAS curve)

The Panel proposes a similar approach to the sensitivity analysis in this review.

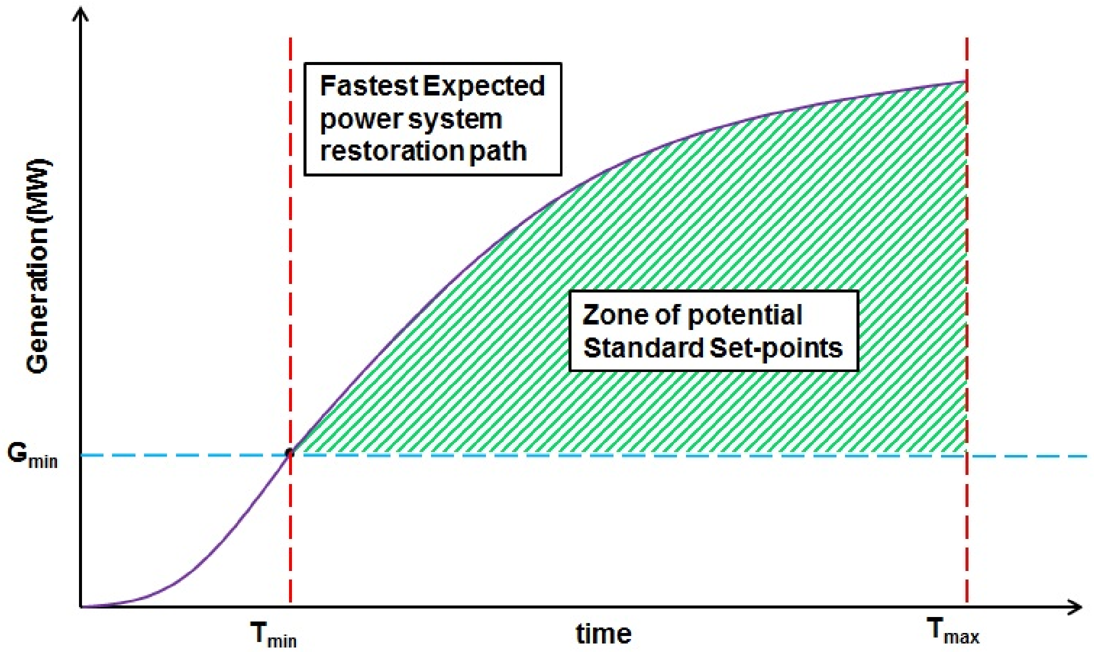
5.1.2 Method for determining Standard settings for a combined Queensland sub-network

Following identification of the efficient number of SRAS resources, the Panel can then identify corresponding Standard settings for the restoration level and time and aggregate reliability of SRAS. The Panel's proposed approach to determining the quantitative Standard settings for a combined Queensland sub-network are summarised below. This approach is consistent with that used by the Panel in 2016.

Restoration level and time

The restoration level in MW represents the minimum online generation capacity required to support ongoing restoration. This level is represented in Figure 5.3 as G_{min} and is a measure of the minimum threshold for generation restoration, beyond which the auxiliary loads of all major power stations can be energised and the ongoing restoration of the power system can proceed without the need for SRAS.

Figure 5.3: Restoration level, time, and the zone of potential Set-points



Source: Reliability Panel

G_{min} is determined by AEMO following technical analysis of power system restoration. In 2016, the Panel determined the level of restoration for each sub-network based on AEMO's advice regarding G_{min}. The Panel proposes determining the minimum restoration level for a combined Queensland sub-network using the same approach for this review.

The restoration time represents the technically feasible time to restore the power system to the level where the available generation exceeds G_{min}, plus a margin to account for uncertainty. The restoration time can be assessed from the supply restoration curves identified for the efficient SRAS procurement option and is conceptually illustrated as Tmin in Figure 5.3. In 2016, the Panel determined Tmin based on the time taken for the slowest procured SRAS resource to re-energise the system to G_{min}. The Standard setting for restoration time was then determined to be T_{min} plus a margin beyond T_{min} equal to 15 minutes, rounding up to the nearest half hour. The Panel included this 15 minute margin because of the inherent uncertainty of the assumptions used to determine the Standard, particularly the assumed VCR and the frequency of black system events. The relationship between T_{min} and the Standard setting for restoration time is illustrated in Appendix B.

The maximum threshold restoration time describes the longest period before which the system must be restarted to avoid a very prolonged restoration. This is used to define very prolonged blackout which is referred to as the default blackout.[42]

Aggregate reliability

The aggregate required reliability of SRAS represents the likelihood that the combined SRAS procured for a given electrical sub-network should be able to restore supply to the minimum capacity required to support ongoing restoration (i.e. G_{min}) within the specified time. In 2016, the Panel determined that the aggregate reliability for each of the electrical sub-networks in the NEM should be 90 per cent. In coming to this decision, the Panel considered that this level achieved a number of objectives, including that it:

- was not so high as to be likely to unduly restrict the potential restart services that AEMO could procure
- met stakeholders' expectations for SRAS reliability
- was consistent with the Panel's economic assessment.

> QUESTION 3: METHOD OF DETERMINING STANDARD SETTINGS FOR A COMBINED QUEENSLAND SUB-NETWORK
>
> (a) Do stakeholders have views on the Panel's proposal to apply the approach used in its 2016 review of the Standard to determine quantitative Standard settings for a combined Queensland sub-network?
>
> (b) Are stakeholders aware of any other approaches that may be considered by the Panel to determine Standard settings for a combined Queensland sub-network that would also satisfy the SRAS Objective?

5.2 Approach to valuing unserved energy

In 2016, the Panel utilised estimates of the VCR published by AEMO for the purpose of valuing unserved energy avoided through the procurement of SRAS. Since 2018, the AER has had responsibility for publishing estimates of VCR. In December 2019, the AER published updated VCR estimates for outages lasting up to 12 hours.[43] On 23 March 2020, the AER published a draft model for estimating the economic costs of Wide Area Long Duration Outages (WALDO).[44] The Panel is considering how the draft WALDO model could be used to inform the Panel's approach to valuing unserved energy in a combined Queensland sub-network in this review of the Standard.

Value of customer reliability

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42 A prolonged restoration is likely to occur as the control and protection systems at the transmission substations rely on emergency supplies (batteries and sometimes backup diesel generator) that only operate for a number of hours without supply from the transmission network

43 AER, Values of customer reliability, Final report, December 2019. Available at: https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/values-of-customer-reliability/updates

44 AER, Widespread and Long Duration Outages - values of customer reliability consultation paper, March 2020.

VCR provides an estimate of the costs associated with unserved energy (assessed in $/MWh). VCR is not a single number, but a collection of values across residential and business customer types, which need to be selectively applied depending on the context in which they are being used. In 2016, the Panel calculated a VCR for each region of the NEM using VCR figures for outage durations of 0-1 hours, 1-3 hours, 3-6 hours and 6-12 hours and accounting for the mix of customer types in each sub-region.[45]

VCRs were developed to compare reliability and affordability in regulatory and network investment decision-making. VCRs are established through contingent valuation and choice experiment survey techniques which assess the direct value for consumers of a more reliable supply.[46] However, VCRs are limited in their inclusion of costs arising from a wide area disruption that may impact consumer utility beyond their immediate ability to consume electricity. Such costs include the social costs arising from the loss of related services and infrastructure systems that may arise from a major supply disruption or black system event. In 2016, the Panel added a confidence interval of 30% to the base case estimates of VCR to provide a first order assessment of possible costs not accounted for in AEMO's VCR estimates.[47].

Wide Area Long Duration Outage (WALDO)

In recognition of the limits of current VCR estimates, the AER is developing a WALDO VCR model for use in applications involving the assessment of the cost of wide area and long duration outages, such as the Panel's review of the Standard. The draft WALDO model estimates the total costs for specified WALDOs by modelling residential, commercial and industrial costs as a result of the outage. The model addresses outages that cover a wider geographical region than localised outages and can have longer durations than those accounted for by the set of standard VCRs. Estimates of economic costs include an allowance for socialcosts for major supply disruptions and black system events resulting in unserved energy ranging from 1 GWh to 15 GWh.[48]

The AER's consultation paper sought stakeholder feedback on the scope of outages to be included in the model, the assumptions and settings present in estimating the additional costs of widespread outages, the assumptions used and the results of the modelling.[49]

The Panel is supportive of the AER's development of the WALDO model. However, in its submission to the AER's consultation paper the Panel acknowledged that estimating WALDO VCRs is difficult and identified a range of areas where additional refinement of the model may be warranted. These included:

- defining a "margin of uncertainty" for the model's outputs to account for uncertainty

45 Deloitte Access Economics, Economic assessment of System Restart Ancillary Services in the NEM - 30 November 2016, p. 61.

46 AER, Value of customer reliability - final report on VCR values, December 2019, p. 23.

47 Deloitte Access Economics, Economic assessment of System Restart Ancillary Services in the NEM, 30 November 2016, p. 17

48 AER, Widespread and long duration outages - values of customer reliability consultation paper, march 2020, p. 6.

49 Ibid, p. 3.

- increasing the upper limit of 15 GWh of unserved energy, which may be too low given unserved energy for the 2016 black system event in the South Queensland region was assessed as exceeding this figure
- providing additional consideration of the Australian context when assessing social costs for inclusion in the model.

The Panel notes that the AER's WALDO model is still under development but likely to be finalised in coming months. Depending on the form of the final model, the Panel is considering how the use of the WALDO can inform and be used in the review of the Standard, noting the issues identified in the Panel's submission to the AER. The Panel is therefore interested in stakeholder feedback on how the AER's WALDO model may inform the Panel's determination of quantitative Standard settings for a combined Queensland sub-network as part of this review.

> QUESTION 4: APPROACH TO VALUING UNSERVED ENERGY
>
> How do stakeholders consider the WALDO VCR estimates may be used in this review to establish quantitative settings for a combined Queensland sub-network?

5.3 Additional locational requirements for a combined Queensland sub-network

The Queensland transmission network is characterised by long transmission flow paths, the presence of large industrial loads in central Queensland and transmission corridors that are vulnerable to cyclone damage in North Queensland. The Panel is interested in stakeholder feedback on how the Standard can effectively address any specific locational needs in the context of a single Queensland sub-network.

This section sets out the relevant considerations and potential approaches to addressing these issues.

AEMO's draft determination to combine the existing Queensland sub-networks

On 3 August 2020, AEMO published a draft determination to combine the two existing Queensland sub-networks. In coming to this decision, AEMO was of the view that combining the sub-networks will reduce any inefficiency created by the need to allocate SRAS exclusively to a single sub-network and will allow increased restoration path flexibility and better access to stabilising loads. AEMO considered this flexibility will be of benefit both under conditions where system restoration is required in any given part of the Queensland power system, or if necessary, to restart the entire system.[50]

50 AEMO considers that maintaining separate sub-networks creates a requirement to identify distinct and separate restoration paths for each sub-network, each with SRAS procured to serve only one of those sub-networks (even though they may all be located in the southern part). AEMO believes that this current Queensland sub-network separation artificially limits the overall restoration capability that could be achieved if the entire Queensland region were a single sub-network, allowing each SRAS source to be procured and planned for concurrent use to energise to the north or south of the region if required. Combining the sub-networks will also help to maximise the available stabilising load required for the SRAS units, potentially facilitating a faster rebuild of transmission corridors.

AEMO's draft determination noted that the procurement of at least one SRAS resource in central Queensland may preserve the perceived benefit of retaining two sub-networks by prescribing specific locational diversity requirements, while also allowing the benefits of combining the sub-networks to be realised. AEMO specifically suggested that the Standard could expressly require sources to be procured in both south and central Queensland (e.g. "north of Bundaberg"), noting that such a requirement would be consistent with existing Standard requirements for geographic diversity. AEMO's suggestion was made to address specific concerns made by stakeholders in their submissions to AEMO's SRAS Guideline review consultation paper.

AEMO's draft determination further notes that this would be similar to the "hybrid" approach the Standard already applies to the New South Wales sub-network, which was adopted in 2016 (as discussed further below). AEMO considers that an approach whereby the entire region is treated as one sub-network but the procurement of SRAS at a particular location (e.g. North of Bundaberg) is prescribed in the Standard may provide stakeholders with additional confidence about the outcomes of AEMO's SRAS procurement.

Panel considerations

In 2016, the Panel determined to include an additional requirement for AEMO to procure SRAS in New South Wales sufficient to independently restart at least 500 MW of generation capacity north of Sydney within four hours of a major supply disruption, with an aggregate reliability of at least 75 per cent. This requirement was imposed to address concerns about the speed of restoration in the region should the New South Wales sub-network be restarted entirely from the fast response hydro-power resources in the south of the state.

The long distance between the large generators in the Hunter Valley and hydro-generation in the south was identified as potentially leading to unacceptably long delays in restarting generators in the Hunter Valley area in the absence of an SRAS generator being located north of Sydney. The requirement in the Standard that AEMO procure SRAS north of Sydney addresses this risk by making sure that auxiliary power is returned to the Hunter Valley generators quickly, as delays of up to 12 hours can result from a cold restart.

As identified by AEMO, existing Standard guidelines on the diversity and strategic location of SRAS require consideration of regional and network issues when deciding where to procure SRAS within a sub-network. These guidelines include guidance on the strategic location of SRAS, based on an assessment of how the geographical and electrical location of an SRAS source best facilitates power system restoration. The guidelines also address diversity of the electrical characteristics and energy sources of SRAS within a sub-network. As noted by AEMO in its draft determination, these existing guidelines are expected to deliver procurement outcomes that account for regional needs specific to a single Queensland sub-network.

The explicit locational requirement prescribed in the Standard for the New South Wales sub-network (as discussed above) was justified on the basis of a significant need identified in respect of that sub-network. The Panel is interested in stakeholder views on:

- whether the existing qualitative guidance on the locational diversity of SRAS in the Standard is insufficient to address the concerns raised by some stakeholders in submissions to AEMO's consultation process in relation to the proposed combination of the existing Queensland sub-networks
- if the Standard were to include an explicit locational requirement relating to the procurement of SRAS in central Queensland, what the appropriate location, level, and aggregate reliability would be for that requirement.

QUESTION 5: ADDITIONAL REQUIREMENTS FOR LOCATIONAL VARIATION IN A QUEENSLAND SUB-NETWORK

(a) Is the existing qualitative guidance in the Standard sufficient to address geographic issues specific to a combined Queensland sub-network?

(b) Do stakeholders consider it necessary to include an explicit locational requirement in the Standard relating to the procurement of SRAS in a combined Queensland sub-network? If so, do stakeholders have views on the specific settings that should apply to this requirement (e.g. location, level and aggregate reliability)?

ABBREVIATIONS

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
Commission	See AEMC
MCE	Ministerial Council on Energy
NEL	National Electricity Law
NEO	National electricity objective
NGL	National Gas Law
NGO	National gas objective
SRAS	System Restart Ancillary Services
NSP	Network Service Provider
MW	Megawatts
MWh	Megawatt-hour
GWh	Gigawatt-hour
VCR	Value of Customer Reliability
WALDO	Wide Area Long Duration Outage

A 2016 METHOD FOR QUANTITATIVE STANDARD SETTING

In 2016, Deloitte Access Economics was engaged by the AEMC on behalf of the Panel to provide an economic assessment of the costs and benefits of SRAS. In particular, Deloitte Access Economics was asked to undertake analysis to estimate the optimal expenditure on SRAS for each sub-network in the NEM, determined by weighing it against the potential benefits of avoided costs associated with a prolonged system outage.

This appendix provides information on the method applied by Deloitte Access Economics (Deloitte) and presents extracts from its Economic assessment of System Restart Ancillary Services in the NEM final report that are relevant to quantitative standard settings for a combined Queensland sub-network. The full 2016 report by Deloitte Access Economics can be found at: https://www.aemc.gov.au/markets-reviews-advice/review-of-the-system-restart-standard

A.1 Value of unserved energy

The benefit of SRAS can be conceptualised as the avoided costs of a prolonged supply interruption. That is, the costs avoided by enabling economic activity that relies on electricity from the grid to resume earlier than would have otherwise been the case. The key benefit of SRAS is that it provides a mechanism for generation to be brought back online after a system failure, which in turn allows for the restoration of supply. Faster restoration of supply provides clear benefits as it minimises the level of unserved energy, limiting disruption to economic activity that relies on electricity.

In 2016, Deloitte used AEMO's Value of Customer Reliability (VCR) to estimate the benefit of AEMO's procurement of SRAS. VCR represents the value that customers place on a reliable supply of electricity, or the value that they place on avoiding a blackout. VCR is generally used in electricity infrastructure planning and decision-making to determine a level of investment that would deliver a level of reliability that customers' value.

The following sections present extracts from Deloitte's final report relevant to the estimation of VCR for the two Queensland subnetworks.

A.1.1 Estimating a VCR for Queensland

Deloitte used VCR data provided by AEMO which was arranged to estimate the value customers in each State of the NEM place on the reliable supply of electricity. AEMO data provided four duration brackets; 0-1 hours, 1-3 hours, 3-6 hours and 6-12 hours. Each of these brackets has a unique VCR by customer, by State and by time of day/season. For the sake of this analysis, Deloitte used the "Off-peak weekend summer" numbers which were deemed statistically significant by AEMO.

Deloitte's economic model used the generation restoration curves provided by AEMO for each sub-network in the NEM to determine the respective outstanding load restoration in each hour bracket. That value (MW) is then multiplied by the State's VCR (weighted by industry sector) for the respective time bracket. The weights are shown in Table A.1 and were applied to the VCR values for each duration bracket by business sector and size.

Figure A.1: **VCR weight by business customer and size**

Business size	Agriculture	Commercial	Industrial
Small	11%	11%	11%
Medium	6%	6%	6%
Large	83%	83%	83%

Source: AEMO 2016

Source: AEMO

To obtain industrial sector VCRs for direct connect customers (those directly connected to the transmission network), Deloitte averaged the VCR for direct connect customers by industry, as shown in Table A.2. In their analysis, the first hour average was applied up to three hours, the 6 hours average was applied to the 3-6 hours bracket and the 12 hours average was applied to the 6-12 hours bracket.

Figure A.2: **Direct connect VCR for each duration bracket**

Outage duration	Metals ($/kWh)	Wood, Pulp and Paper ($/kWh)	Mining ($/kWh)	Average ($/kWh)
1 hour	0.67	1.51	19.50	7.23
6 hours	15.56	0.32	4.79	6.89
12 hours	7.96	0.23	4.21	4.13

Source: AEMO 2016

Source: AEMO

The values for residential customer VCR were already broken down by State and duration bracket in AEMO's VCR data and did not require adjustment by Deloitte in its analysis. The resulting VCRs for each customer by duration bracket were weighted and summed to produce the VCR estimates by State and for each of the four duration brackets. The results are summarised in Table A.3. Table A.4 provides the resulting VCR assessed for each State for each duration bracket.

Figure A.3: Load weighting by customer class (including direct connect load)

Customer	NEM	NSW	VIC	QLD	SA	TAS
Agriculture	0.01	0.01	0.01	0.01	0.02	0.01
Industrial - DC	0.17	0.13	0.21	0.14	0.13	0.41
Industrial - non DC	0.17	0.18	0.09	0.23	0.14	0.16
Commercial	0.41	0.38	0.48	0.41	0.39	0.24
Residential	0.25	0.30	0.21	0.22	0.32	0.19

Source: AEMO 2016
Source: AEMO

Figure A.4: Value of Customer reliability ($/kWh) by State for each duration bracket

Outage duration	NSW	VIC	QLD	SA	TAS
0-1 hours	47.76	47.57	50.53	46.56	34.18
1-3 hours	40.60	40.47	41.63	40.22	31.14
3-6 hours	27.37	25.96	28.26	27.70	21.37
6-12 hours	17.97	17.00	17.62	17.89	13.53
Average	33.42	32.75	34.51	33.09	25.05

Source: AEMO 2016, Deloitte Access Economics Analysis
Source: AEMO

A.1.2 Social costs

To develop the estimate of VCR used by the Deloitte in 2016, AEMO surveyed almost 3,000 residential and business customers across the NEM.[51] The survey sought to understand customer preferences across a range of outage situations. AEMO used a combination of choice modelling and contingent valuation techniques to derive VCRs for residential and business customers in the NEM.[52]

The contingent valuation questions asked participants about their willingness to pay to avoid experiencing basic outages. The choice modelling, on the other hand, asked participants to consider a series of questions where they chose preferred outage scenarios defined by a set of attributes and compensation amounts for experiencing the outage. The choice modelling results were combined with contingent valuation results to produce the VCR estimates.[53]

The choice modelling explicitly asked both residential and business customers to volunteer a monthly billing discount or rebate that they would be willing to accept for "suffering" an

51 AEMO, Value of Customer Reliability Review Final Report, September 2014, p. 32.
52 Ibid, p. 7.
53 Ibid, p.10-11

outage.[54] How participants responded to this question is likely to be a factor of their own particular circumstances and how frequently they have experienced outages in their recent history. However, without asking these participants to explain the kind of suffering that they considered when formulating an answer to this question, it's difficult to assess the extent to which social costs are captured in the VCR calculation.

For example, one participant may have included an estimate of the inconvenience caused by the local primary school being closed for a period of time and the educational impact that may have on their child. Another participant may have included costs associated with expected crime due to lack of security systems.

Due to the nature of system outages in Australia (i.e. that they are relatively infrequent, quite localised and generally short in duration) Deloitte was of the view that it is unlikely that participants considered these kinds impacts when responding to AEMO's VCR survey. Therefore, it is unlikely that VCR captures the full social costs of a major system outage.

Deliotte considered that a range of indirect tangible costs - The flow-on effects that are not directly caused by the natural disaster itself, but arise from the consequences of the damage and destruction such as business and network disruptions; and intangible costs - direct and indirect damages that cannot be easily priced such as death and injury, impacts on health and wellbeing, and community connectedness were relevant to the costs of a major supply disruption and black system event.

Deloitte considered VCR is likely to incorporate a number of the direct tangible costs and some of the indirect tangible costs. In particular, business participants to the VCR survey likely incorporated some cost of business disruption in their estimate of their willingness to pay or willingness to accept responses. Nevertheless, in Deloitte's view, VCR is unlikely to fully capture indirect tangible costs (particularly disruption of public services) and intangible costs.

To compensate for the uncertainty associated with estimating the VCR, Deloitte included a confidence interval of 30% is set around the base case estimates, a range deemed reasonable by AEMO in its VCR Application Guide.

A.2 Probability of a major outage

In conducting the economic assessment of SRAS, Deloitte estimated the probability that a system black event will occur. Estimating low probability events is difficult as there is often little data to determine the probability distribution function directly. As such, extreme value theory was used, whereby the extrapolation of a trend against known events is used to determine the probability of unknown events. These probabilities are used to weight the economic benefit of providing SRAS in an annualised form, which is compared to the cost of providing SRAS, thereby providing the net benefit of the service.

54 AEMO, Value of Customer Reliability – Application Guide, December 2014, pg. 23, 33

A.2.1 Historic load shedding information

AEMO records observations of events resulting in lost load. Deloitte carried out their analysis under the assumption that an event resulting in lost load prevents a potential blackout from occurring equal to or greater than the amount of energy lost. For example, under this assumption, the 475MW loss that occurred in Victoria in February 2015 is indicative of a blackout equal to, or exceeding 475MW. Deloitte used information provided by AEMO about 26 events. They span a period of 16 years and include all the States of the NEM.

Deloitte used the regional historical average demand (MW) as the indicative value of a major supply disruption in each sub-network in their analysis. Deloitte considered a major supply disruption corresponding to the historical average demand of each sub-network would be of high enough significance to constitute a sub-network system black event.

A.2.2 Using power law to estimate the probability of a major supply disruption

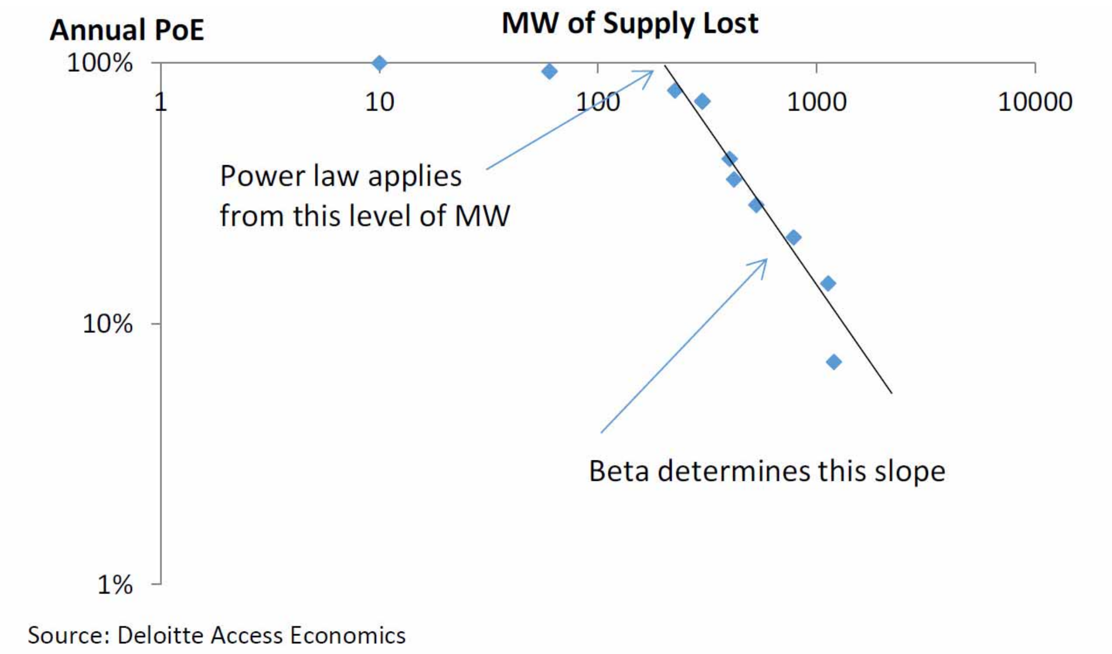
Having established a level of supply disruption that will likely require the use of SRAS, the next step was to estimate how likely such a disruption is to occur. The main challenge in making this estimate is that such large disruptions are very rare. Given the complexity and probabilistic nature of such events, Deloitte utilised an approach which extrapolates from data on historical events to estimate the probability of extreme events. In 2016, Deloitte applied a power law approach to estimating the probability of a black system event in the two Queensland sub-networks.

The power law distribution has been applied to estimate the probability of a major supply disruption in electrical networks internationally, particularly in the US, as well as in Australia. The power law approach is based on the strong correlation between the size of a blackout and its probability of occurrence.

The power law curve can be defined by exponent β, the slope of the line of best fit when load shedding events are plotted on a logarithmic scale. A network with a high β is more stable than one with a low β. The tail of the curve which is characterised by a large number of small events is cut off at the distribution function’s threshold (X-min), the minimum size of a blackout for which the power law applies. Also of importance is the frequency of events (ʎ).

The role of these two parameters can be seen in Figure A.5 below. Beta determines the slope of the line and the point at which the power law begins to affect blackout sizes determines when this slope starts.

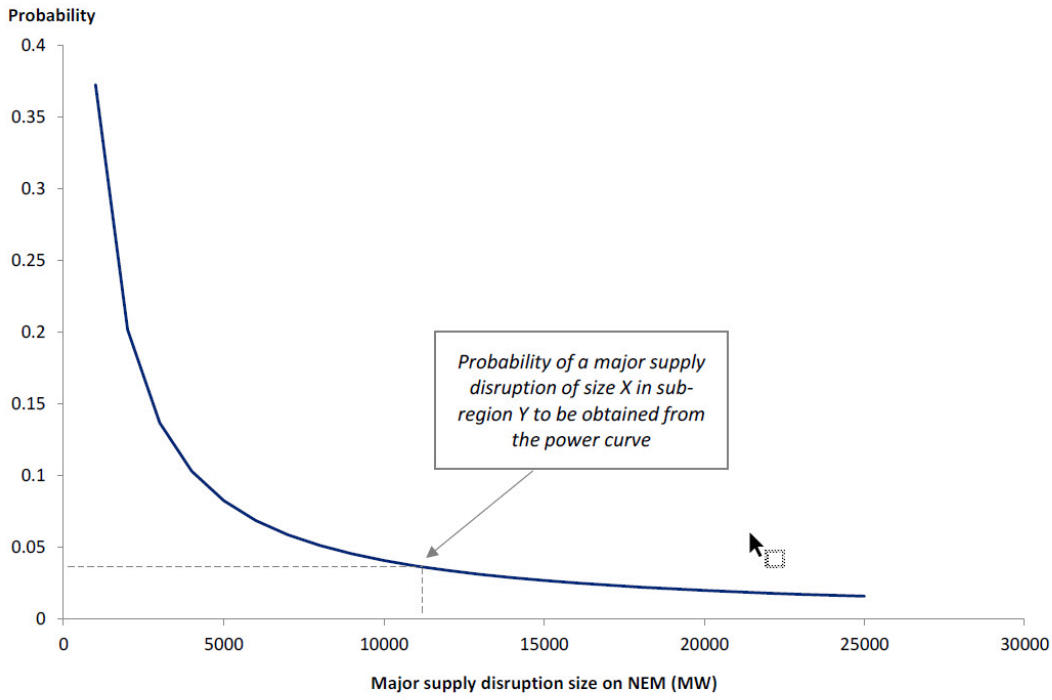
Figure A.5: Power law analysis example



Source: Deloitte Access Economics

After characterising a power law curve for an electrical sub-network, it can be used to estimate probability of extreme values, as illustrated in Figure A.6.

Figure A.6: Use of power law curve to estimate the probability of a major supply disruption



Source: Deloitte Access Economics
Source: Deloitte Access Economics

Deloitte estimated these parameters based on data on lost load events available from AEMO. To apply the power law, Deloitte:

- determined the lost load threshold;[55]
- ranked the data by size (MW);
- determined the probability of exceeding each event's load loss;
- calculated the log of the MW values and probability of exceedance for each event; and
- ran a regression on those two values for the selected sample.

From this process, for each regression, Deloitte obtained β (inverse of the slope), the threshold applicable to that data set (inverse of the intercept divided by the slope) and C (exponential of the intercept).

55 Unless the dataset was too limited, in which case the entire dataset was used.

Figure A.7: Power law inputs for state based analysis

Sub-network	x-min (MW)	Λ (years)	β	α	C	A
TAS	70.17	0.8	1.04	2.04	33.25	33.89
SA	29.9	0.44	0.5	1.5	5.46	10.93
VIC	115.65	0.75	0.78	1.78	41.11	52.56
QLD	112	0.25	0.72	1.72	30.06	41.68
NSW	260.15	0.44	0.85	1.85	111.09	131.16

Source: Deloitte Access Economics

Source: Deloitte Access Economics

Combining these inputs and entering them into the power law function, Deloitte estimated the base case probability of major supply disruption equal to or exceeding each sub-network's average historical demand as presented for each sub-network in Figure A.8. The probability of a black system event in Queensland was determined using observations limited to Queensland. Due to the lack of data, no threshold was set in this analysis.

Figure A.8: Base case probability of a black system event in each NEM sub-region

Sub-network	Average Historical Demand (MW)	Probability (%)	Return Period (years)
TAS	1,182	4.06%	**24.64**
SA	1,587	5.82%	**17.18**
VIC	5,784	3.45%	**29.02**
N.QLD	2,144	2.97%	**33.63**
S.QLD	3,456	2.07%	**48.39**
NSW	8,577	2.23%	**44.74**

Source: AEMO 2016, Deloitte Access Economics Analysis

Source: Deloitte Access Economics

A.2.3 Base case inputs and uncertainty scenarios

Deloitte's analysis indicated a wide range of possible outcomes depending on the analytical approach and assumptions made. As a result, it was important that uncertainty in the economic assessment be accounted for. Deloitte used a sensitivity analysis for this purpose.

The variance in the return period (62%), the upper and lower bounds, and the base case for the four other states was averaged and applied to the NEM power law values to estimate lower and upper bound return periods and probabilities for the North Queensland and South Queensland sub-networks. The results are summarised in Table A.10.

Figure A.9: upper lower and base case analysis for power law anaysis

		Lower bound		Base case		Upper bound	
Sub-network	**Average Historical Demand (MW)**	**Probability (%)**	**Return Period (years)**	**Probability (%)**	**Return Period (years)**	**Probability (%)**	**Return Period (years)**
TAS	1,182	4.06%	24.64	4.56%	21.92	5.21%	19.20
SA	1,587	5.12%	19.54	5.45%	18.36	5.82%	17.18
N.Qld	2,144	2.97%	33.63	3.34%	29.92	3.82%	26.21
S.Qld	3,456	2.07%	48.39	2.32%	43.05	2.65%	37.70
VIC	5,784	2.63%	38.06	2.98%	33.54	3.45%	29.02
NSW	8,577	2.23%	44.74	2.64%	37.94	3.21%	31.14

Source: Deloitte Access Economics

Source: Deloitte Access Economics

A.3 Composite reliability

Composite reliability represents the probability of a generator starting if dispatch is requested by AEMO. Composite reliability depends on the reliability and availability of a SRAS source determined by using the following formula:

$$CR_{SRAS\ 1} = R_{SRAS\ 1} * A_{SRAS\ 1}$$

Where CR is the composite reliability, R is the reliability ratio and A is the availability of each SRAS plant. These probabilities are summarised for each potential SRAS source in North and South Queensland is presented in Table A.1.

Table A.1: 2016 Composite reliability for each Queensland SRAS source

SRAS SOURCE	RELIABILITY (%)	AVAILABILITY (%)	COMPOSITE RELIABILITY (%)
NQ - 1	90	95	86
NQ - 2	95	95	90
NQ - 3	60	95	57
NQ - 4	60	95	75
SQ - 1	95	95	90
SQ - 2	75	95	71
SQ - 3	90	95	86

Source: AEMO, Deloitte Access Economics

A.3.1 Combining composite reliability curves into SRAS restoration curves

The ability to restore the energy system in a sub-network after a major supply disruption is contingent on the reliability and availability of the procured SRAS plants. Different combinations of SRAS plants will have a different aggregate starting reliabilities and availabilities. That is, different combinations of SRAS plants have different probabilities of providing their contracted load to the grid.

Take a simple example with two generation plants, A and B that can provide SRAS in a sub-network. They both have an availability and reliability set out in Figure A.10.

Figure A.10: Illustrative restoration curve probabilities

Probability driver	SRAS A	SRAS B
Availability (%)	90%	90%
Reliability (%)	80%	90%
Composite reliability	72%	81%
Probability of failure	28%	19%

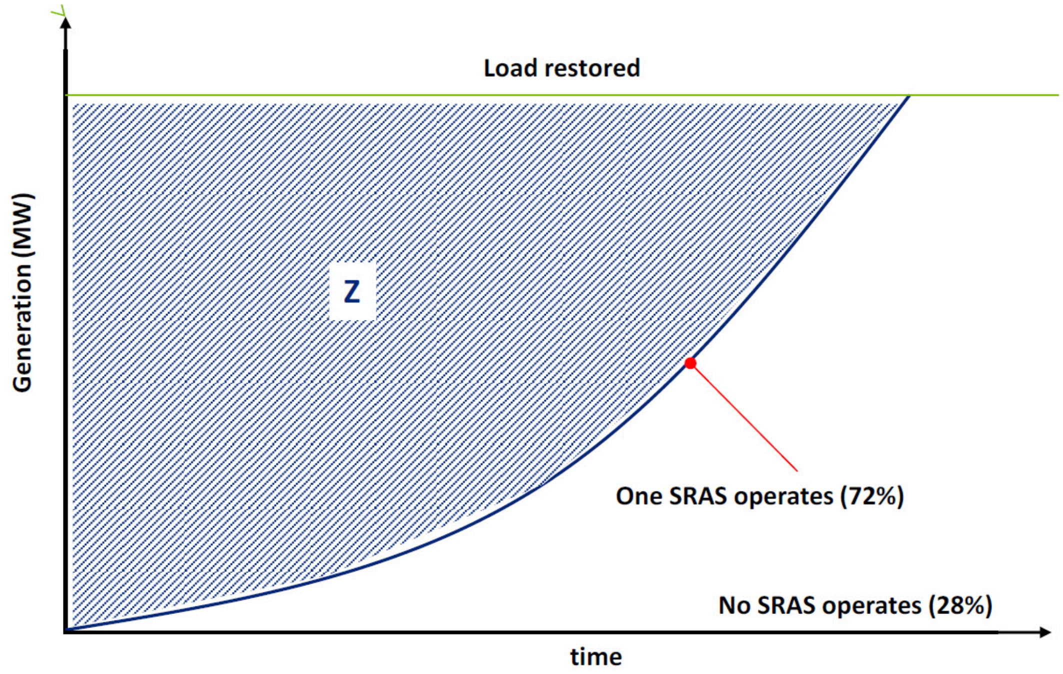
Source: Deloitte Access Economics

The probability of A starting the system as per AEMO's generation restoration curve is 72%. Consequently, there is also a 28% probability that the SRAS plant will fail. Therefore, the economic cost is the weighted sum of both of these outcomes. For our analysis, we assume that the "no SRAS plant successful" outcome will result in an "default blackout" duration, that is, a delayed restoration that restarts the system such that Gmin is reach at least by Tmax.

The weighted economic cost in this example of one procured SRAS plant is calculated by:
$Cost = Z * 0.72 + 0.28 * Default\ Blackout$

Where Z is the estimated economic cost of the major supply disruption.

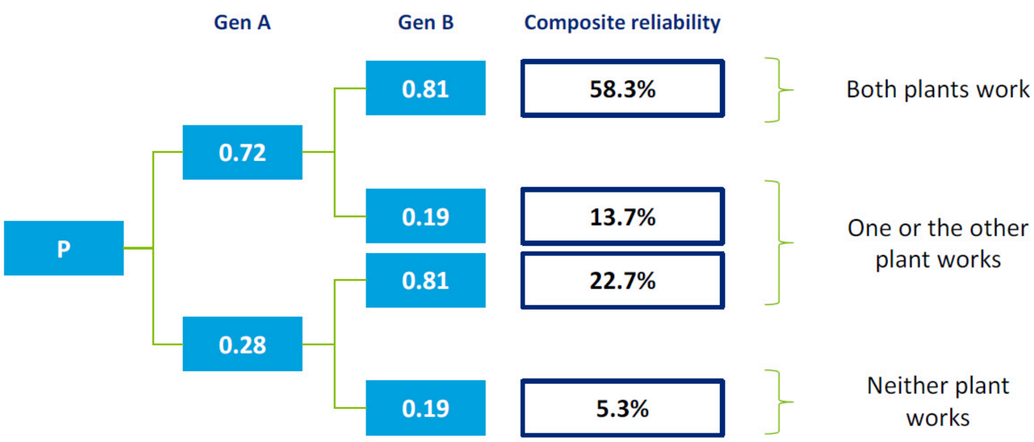
Figure A.11: Probability weighting cost of possible outcomes - 1 SRAS plant



Source: Deloitte Access Economics

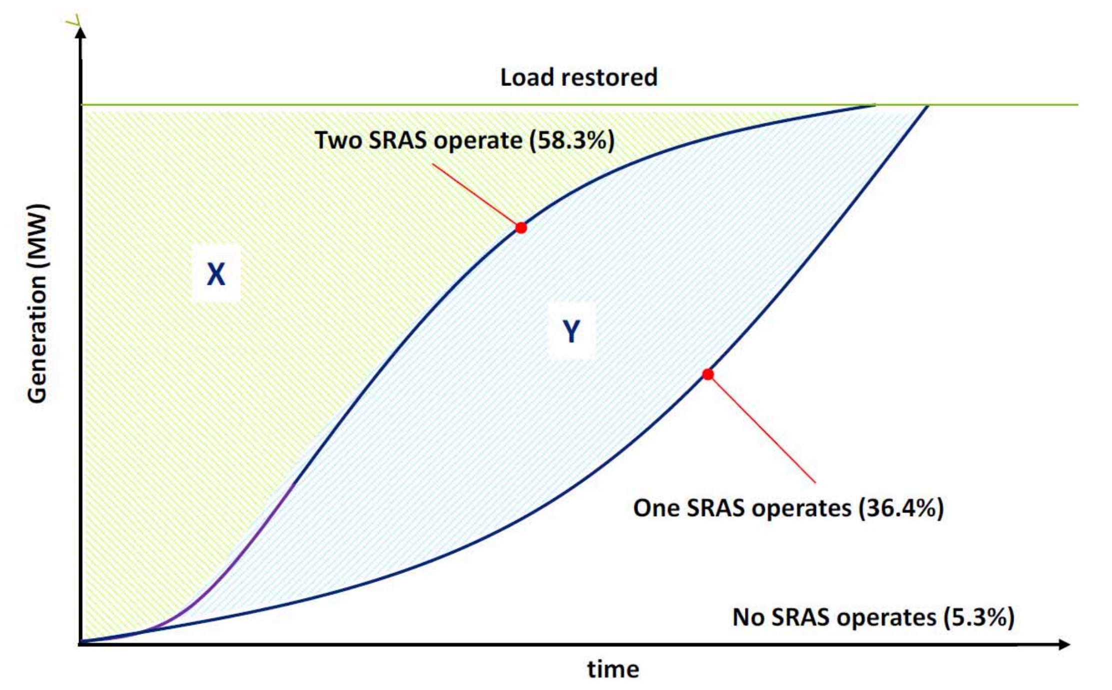
Adding an additional SRAS plant, source B, will result in four possible outcomes, each with different probabilities illustrated in Figure A.11. These possible outcomes have probabilities that are used to weigh the economic cost of unserved energy illustrated in Figure A.12.

Figure A.12: Possible outcomes - 2 SRAS plant case



Source: Deloitte Access Economics

Figure A.13: Probability weighting cost of possible outcomes - 2 SRAS plant



Source: Deloitte Access Economics

The economic cost is therefore expressed as: $Cost = X*0.583 + (X+Y)*0.364 + 0.053*Default\ Blackout$

Clearly, the addition of an SRAS plant will shift the weighing of economic costs such that they decrease. Deloitte's economic assessment applies the above methodology to the restoration curves supplied by AEMO. Deloitte determined the decrease in the cost of unserved energy by incrementally adding SRAS plants from 1 to n in each sub-network.

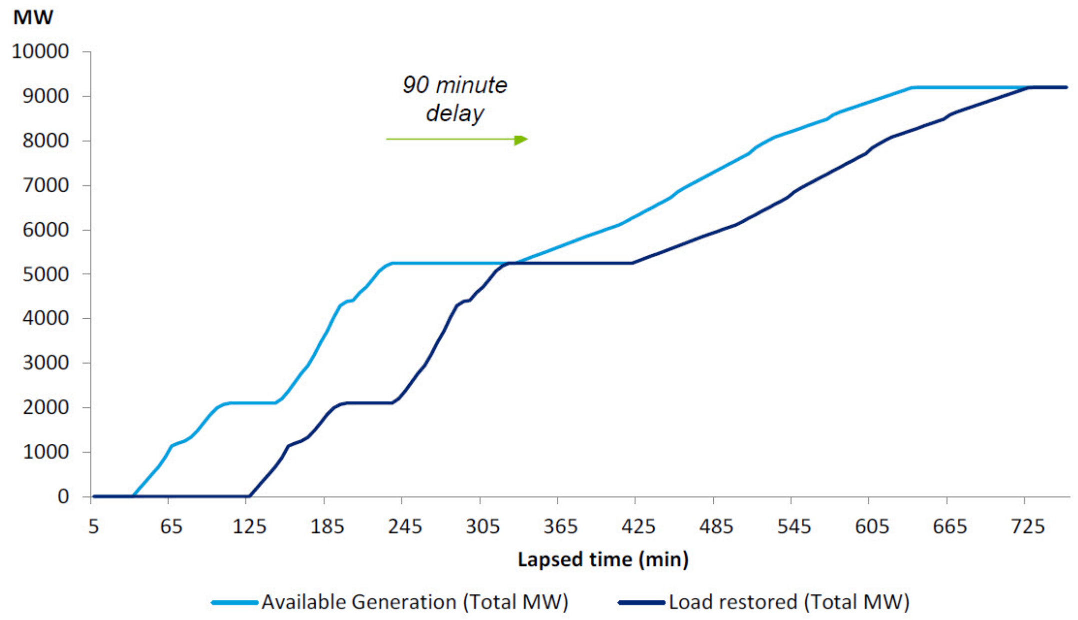
As the above example illustrates, the number of SRAS combinations and permutations increases as more plants are added to the mix. It would not be realistic to have AEMO produce restoration paths for each of these options; as such we make the simplifying assumption that if the curve for a given combination of SRAS plants is not provided, we take the next available curve with the same number of SRAS plants.

A.4 Restoration curves

The restoration of supply after a major supply disruption is unique for each sub-network and for each level of SRAS procured. Given that there is a complex set of interactions that influence the restoration of supply after a major supply disruption, it is difficult to predict the optimal supply restoration path. AEMO does not calculate these curves and as such, Deloitte was required to make a simplifying assumption.

The AEMC received sample load and capacity restoration modelling results from transmission network operators. Based on this, Deloitte made the assumption that there is approximately a 90 minute delay between generation and supply restoration.

Figure A.14: Capacity restoration curves and supply restoration



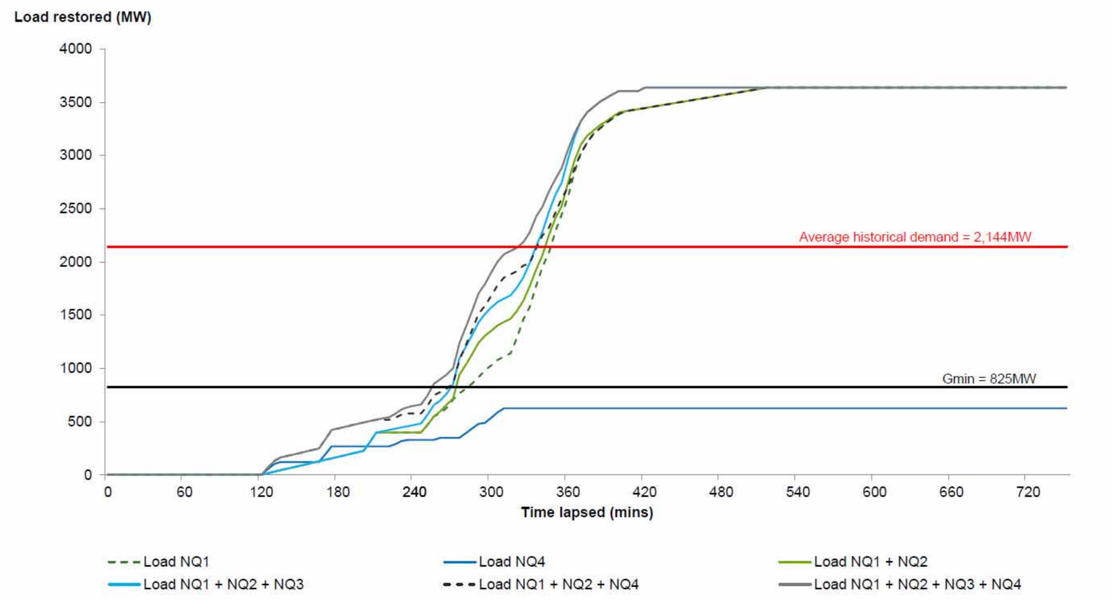
Source: AEMO, Deloitte Access Economics

The capacity restoration curves supplied by AEMO are presented in the following pages.

A.4.1 Queensland Capacity restoration curves - 2016

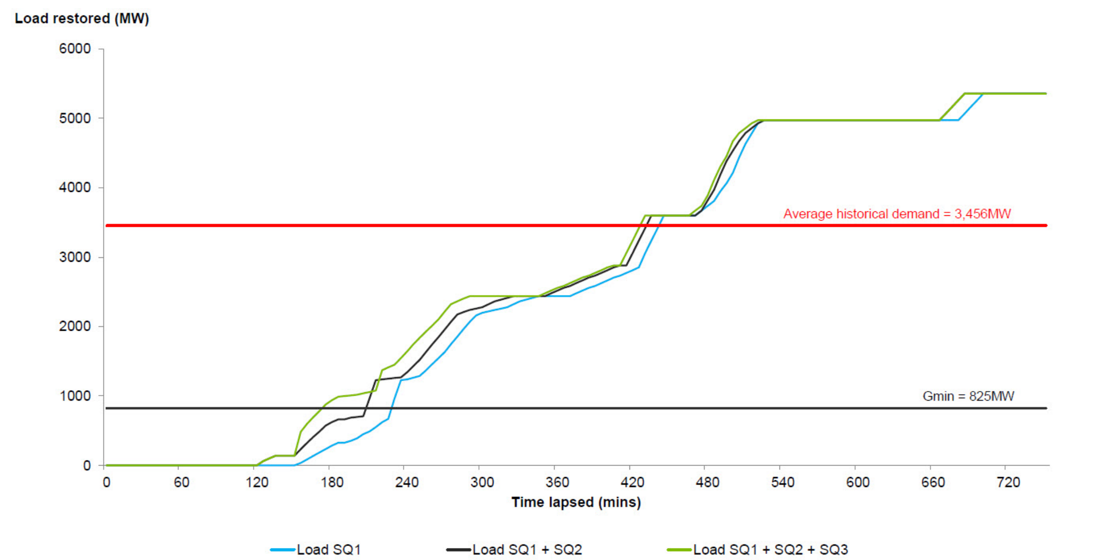
The 2016 capacity restoration curves used to set existing Standard settings are presented below.

Figure A.15: North Queensland restoration curves



Source: AEMO, Deloitte Access Economics

Figure A.16: South Queensland restoration curves



Source: AEMO, Delotte Access Economics

B EXISTING QUEENSLAND STANDARD SETTINGS

Existing Standard settings for restoration level and time in North and South Queensland are presented in the following sections.

B.1 North Queensland

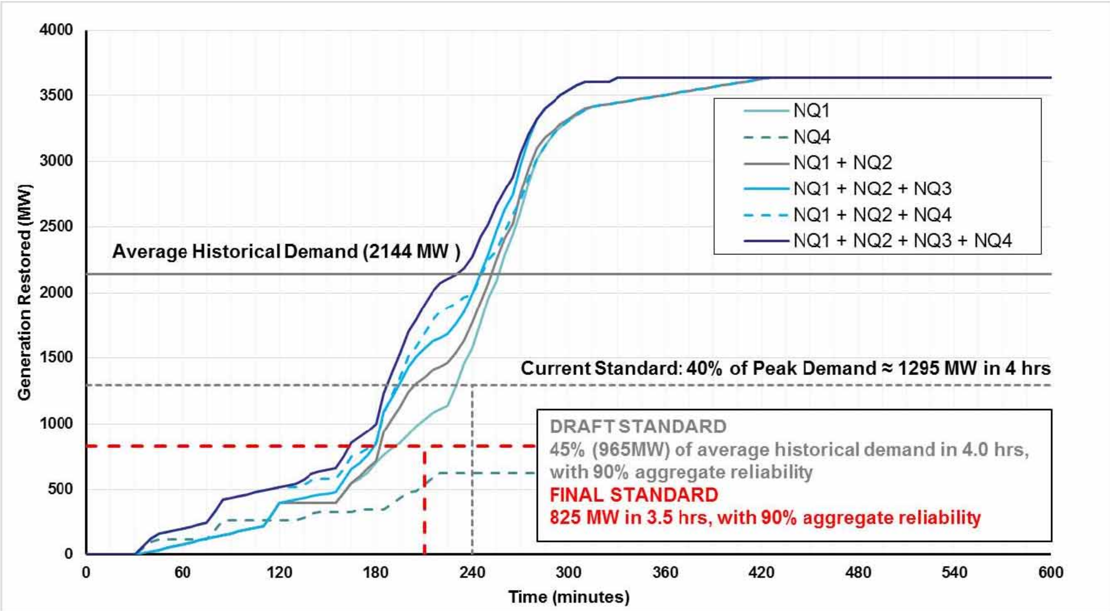
The set-point for the North Queensland electrical sub-network in the Standard is that restart services shall be procured with the target of restoring generation and transmission capability to a level of 825 MW within three and a half hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90 per cent..

In defining this set-point, the Panel has considered the results of the economic assessment and the specific regional characteristics of the North Queensland electrical sub-network. The North Queensland sub-network is a long radial network that lies at the northern extremity of the NEM, and can be exposed to tropical storms. The time and level requirements of the set-point reflect the technical capability and limitations of the available restart services and power system.

The time component of the Final Standard for each electrical sub-network includes a margin to increase the range of potential restart services that could be considered for procurement in the future. For the North Queensland sub-network the value of Tmin is 195 minutes. When a margin of 15 minutes is added and then the result rounded up to the nearest half hour, the time component is three and a half hours (210 minutes). The long distances between the generation centres and relatively low load density in North Queensland, contribute to the longer restoration time of three and a half hours. The long distances between generation centres and lower load density contribute to the initial transmission restoration process being slower than other electrical sub-networks, as generation and load must be progressively balanced during the restoration process.

Figure D.1 shows the restoration curves for the North Queensland electrical sub-network, along with the set-points from the current (pre-2016) draft and final Standard.

Figure B.1: North Queensland Standard settings



Source: AEMC Reliability Panel, 2016 System Restart Standard Review - final report

B.2 South Queensland

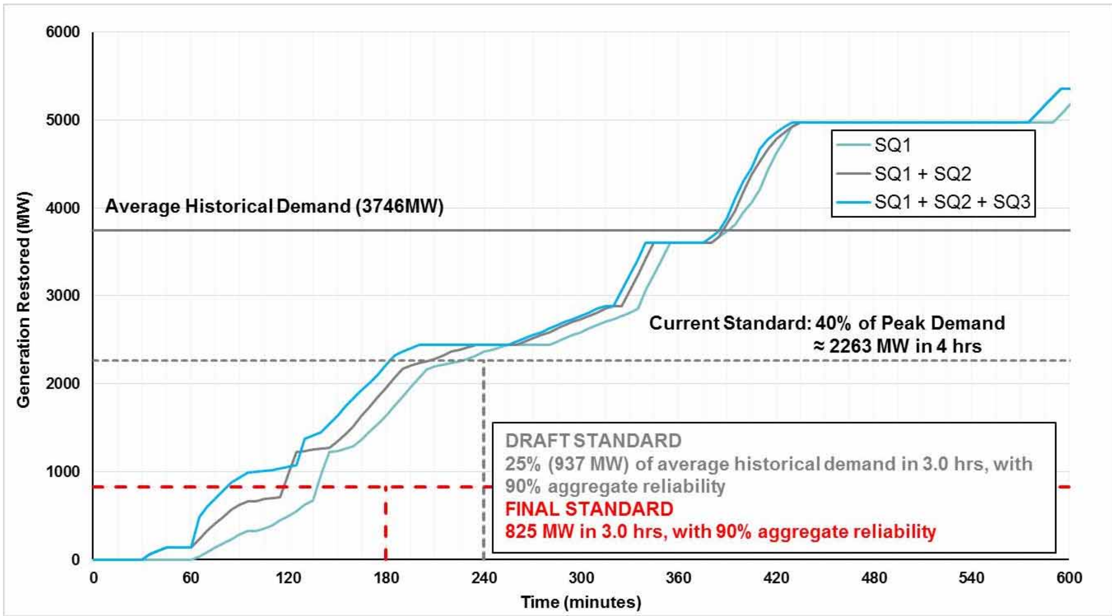
The set-point for the South Queensland electrical sub-network in the Standard is that restart services shall be procured with the target of restoring generation and transmission capacity to a level equal to 825 MW within three hours following a major supply disruption that results in a black system. The associated aggregate reliability for meeting this target is 90 per cent.

In defining this set-point in 2016, the Panel considered the results of the economic assessment and the specific regional characteristics of the South Queensland electrical sub-network. The South Queensland sub-network is a strongly interconnected transmission system with a relatively short electrical distance between the major generation and load centres. The time and level requirements of the set-point reflect the technical capability and limitations of the available restart services and power system.

The time component of the Final Standard for each electrical sub-network includes a margin to increase the range of potential restart services that could be considered for procurement in the future. For the South Queensland sub-network the value of Tmin is 140 minutes. When a margin of 15 minutes is added and then the result rounded up to the nearest half hour, the time component is three hours (180 minutes).

Figure D.2 shows the restoration curves for the South Queensland electrical sub-network, along with the set-points from the current (pre-2016) draft and final Standard.

Figure B.2: South Queensland Standard settings



Source: AEMC Reliability Panel, 2016 System Restart Standard Review - final report