NOVEMBER 2024

Addressing System Strength Requirements in Queensland from December 2025

Project Assessment Draft Report

Preface

Powerlink Queensland is a Transmission Network Service Provider (TNSP) that owns, develops, operates and maintains Queensland's high-voltage electricity transmission network. The network transfers bulk power from Queensland generators to electricity distributors Energex and Ergon Energy (part of the Energy Queensland Group), and to a range of large industrial customers.

This Project Assessment Draft Report has been prepared in accordance with version 217 of the National Electricity Rules (NER), and the Regulatory Investment Test for Transmission (RIT-T) Instrument (August 2020) and RIT-T Application Guidelines (October 2023). The RIT-T Instrument and Application Guidelines are made and administered by the Australian Energy Regulator.

The NER requires Powerlink to carry out forward planning to identify future reliability of supply requirements, which may include replacement of network assets or augmentations of the transmission network. Powerlink must then identify, evaluate and compare network and non-network solutions (including, but not limited to, generation and demand side management) to identify the preferred option which can address future network requirements at the lowest net cost to electricity customers.

Powerlink also has obligations under the NER to address power system security requirements identified by the Australian Energy Market Operator in its annual System Security Reports.

The main purpose of this document is to provide details of the identified need, credible options, and technical and commercial feasibility of the preferred option. In particular, it encourages submissions from potential proponents of feasible non-network solutions to address the identified need.

This document also provides customers, stakeholders and communities with information on the potential investment/s (network and non-network) that are required in the near-term to meet an identified need, and offers the opportunity to provide input into the future development of the transmission network in Queensland.

More information on the RIT-T process and how Powerlink applies it to ensure that safe, reliable and cost -effective solutions are implemented to deliver better outcomes to customers is available on Powerlink's website.

A copy of this report will be made available to any person within three business days of a request being made. Requests should be directed to the Manager Portfolio Planning and Optimisation, by phone ((07) 3860 2111) or email (networkassessments@powerlink.com.au).

Powerlink acknowledges the Traditional Owners and their custodianship of the lands and waters of Queensland and, in particular, the lands on which we operate. We pay our respect to their Ancestors, Elders and knowledge holders and recognise their deep history and ongoing connection to Country.

Contents

1. Introduction

Key Points

- System strength is a measure of the ability of the network to maintain and control the voltage both during steady state operation and in response to a network disturbance, such as a sudden change in generation or load, or fault on the network.
- System strength has traditionally been provided by conventional forms of generation, not because of their fuel source (such as coal, gas and hydro) but because of their 'synchronous' nature.
- Queensland's energy system is transitioning from supply from large synchronous generating units, such as coal-fired power stations, to renewable energy sources. The energy transition means that power system security services, such as system strength, are less freely available and must be planned for and delivered by other means.
- Powerlink is applying the Regulatory Investment Test for Transmission (RIT-T) to assess options to address system strength requirements in Queensland from 2 December 2025.
- Powerlink commenced the System Strength RIT-T in March 2023, and received close to 80 unique non-network solutions for system strength services from more than 20 proponents. Proposals varied in many aspects, including technology types, location, availability, project development status, level of service, delivery timeframe and cost.
- This Project Assessment Draft Report (PADR) is the second step in the RIT-T process, and sets out Powerlink's technical and economic assessment of credible options to address system strength requirements in Queensland.

1.1. What is System Strength?

System strength is a measure of the ability of the network to maintain and control the voltage both during steady state operation and in response to a network disturbance, such as a sudden change in generation or load, or fault on the network.[1] This includes resisting changes in the magnitude, phase angle, and shape of the voltage waveform. If a transmission network location is:

- 'strong', the change in voltage at that location will be relatively unaffected by a nearby disturbance; or
- 'weak', the voltage at that location will be relatively sensitive to a system disturbance, that could result in a more widespread prolonged voltage recovery.

Low system strength in a particular location can adversely affect the security of the broader power system, such as through reducing the ability of generators to operate stably. System strength is also important to support the rapid detection and clearing of system faults, and to ensure acceptable power quality (including harmonics, flicker and negative phase sequence).

The Queensland energy system has historically comprised synchronous generation such as coal-fired generators, gas turbines and hydro-electric plants. These large synchronous generators have also provided various services as a by-product of their dispatch for energy, including system strength, to enable the power system to operate stably. The transition of the energy system to renewable energy, particularly solar and wind generation, means that certain system services are less freely available and must be planned for and delivered by other means.

[1] AEMO, *System Strength in the NEM Explained*, March 2020, page 5.

The increased uptake of renewable inverter-based resources (IBR), such as solar and wind farms and grid-following Battery Energy Storage Systems (BESS), coupled with the retirement of conventional synchronous generation, is creating significant challenges for power system operations in many regions of the world. This includes the National Electricity Market (NEM) in Australia.[2]

Many of these 'non-synchronous' generators do not inherently provide system strength because they use grid-following inverter technologies to generate electricity. Given the scale of the energy transition and the rapid uptake of renewable IBR, finding alternate, safe, reliable and cost-effective solutions to address system strength needs is critical to ensure Queensland's power system remains stable into the future.

1.2. Overview of the Regulatory Investment Test for Transmission

The purpose of a RIT-T is to identify the preferred investment option that meets the 'identified need'. The identified need is essentially the problem that the RIT-T proponent (in this case Powerlink) considers will arise if action is not taken; that is, why investment is considered to be required.[3]

The 'preferred option' is the investment option that maximises the net economic benefits to the NEM, taking into account changes to Australia's greenhouse gas emissions where relevant. If the identified need is for a reliability corrective action, the preferred option may have a net economic cost.[4]

Powerlink applies the RIT-T to potential prescribed (regulated) investments in the transmission network where the estimated capital cost of the most expensive option to address the identified need that is technically and economically feasible exceeds $7 million.[5]

1.3. This System Strength RIT-T

The identified need for this RIT-T – to address system strength requirements in Queensland from December 2025 – is not included in the Australian Energy Market Operator's (AEMO) latest Integrated System Plan (ISP), published in June 2024. As such, this RIT-T is subject to the application and consultation process for RIT-T projects that are not actionable ISP projects.[6]

This RIT-T is a key part of Powerlink's implementation of the Efficient Management of System Strength on the Power System Rule (System Strength Rule), made by the Australian Energy Market Commission (AEMC) in October 2021. In order to meet Powerlink's responsibilities as the System Strength Service Provider (SSSP) for Queensland under the System Strength Rule, Powerlink is required to apply the RIT-T to procure a portfolio of solutions to ensure that minimum fault level requirements are met, and system strength above the minimum levels is available to host projected levels of IBR.[7]

AEMO and Powerlink are responsible for the planning and delivery of power system security services in Queensland. AEMO's annual System Security Reports consider the need for power system security and reliability services in Queensland and other regions of the NEM. The reports assess system strength requirements, inertia

[2] International Council on Large Electric Systems (CIGRE), *System Strength Reference Paper*, February 2021, page 5.
[3] National Electricity Rules (NER), chapter 10 (definition of 'identified need').
[4] NER, clause 5.15A.1(c) and chapter 10 (definition of 'net economic benefit').
[5] NER, clauses 5.15.3(a) and (b)(2) set the threshold at $5 million. The Australian Energy Regulator's (AER) 2021 cost threshold review increased the value to $7 million for three years from 1 January 2022. The AER's draft determination on the 2024 cost threshold review proposes to increase the RIT-T cost threshold to $8 million for three years from 1 January 2025.
[6] NER, rule 5.16.
[7] NER, clause S5.1.14(b); AEMC, *Efficient Management of System Strength on the Power System*, final determination, October 2021, pages 107-116.

shortfalls and Network Support and Control Ancillary Services (NSCAS) needs. Where AEMO declares a gap/shortfall for a power system security service(s) in Queensland, Powerlink is obliged to make services available within the timeframe declared by AEMO.

Powerlink commenced the System Strength RIT-T in March 2023 with publication of a Project Specification Consultation Report (PSCR), which invited proposals from proponents who considered they could offer potential non-network solutions that were both technically and economically feasible by 2030. To assist proponents in preparing submissions, Powerlink subsequently released a proforma for non-network solutions in June 2023. In response to the PSCR and proforma, Powerlink received close to 80 unique non-network solutions from more than 20 proponents. Powerlink thanks proponents for their engagement in the RIT-T process, and for their responses to the information request that further informed and shaped the technical analysis and market modelling for this PADR.

This PADR is the second step in the RIT-T process, and sets out Powerlink's technical and economic assessment of credible options to address system strength requirements from December 2025.[8] See Appendix A for more information on the RIT-T process.

1.4. Submissions and proposals for non-network solutions

Powerlink invites submissions and comments from market participants, AEMO, potential non-network providers, and any other interested parties, on this PADR and the draft preferred option presented. While a number of areas have been flagged in this PADR as key topics Powerlink is seeking stakeholder feedback on, importantly, these are not the only issues Powerlink is seeking feedback on and parties making a submission should review and consider all issues in this PADR document that they consider require comment.

In response to this PADR, Powerlink also requests proponents of non-network solutions provide their best cost proposals to meet the geographical and technical requirements of relevant solution(s). An information request is included at Appendix B, and a copy of the request will be emailed directly from Powerlink's Network Assessments team to proponents who submitted a proposal in response to the PSCR.

Powerlink also invites proposals from proponents of non-network solutions who did not respond to the PSCR, and/or have responded to the provision of system strength element of the identified need for the Gladstone Project Priority Transmission Investment.

Submissions and responses to the information request are due by **Friday, 20 December 2024**. More information on the submission process is in sections 9.2 and 9.3 of this PADR.

[8] This PADR has been prepared in accordance with clause 5.16.4(k) of the NER and AER, *Application Guidelines, Regulatory Investment Test for Transmission*, October 2023.

2. Identified Need

Key Points

- The System Strength Rule reformed the framework for the supply, demand and coordination of system strength in the NEM.
- A key element of the supply component of the System Strength Rule is the System Strength Standard, comprised of the minimum fault level requirement and the efficient level of system strength.
  - The minimum fault level is necessary for power system security.
  - The voltage waveform stability component is required to securely host forecast levels of connected IBR.
- The System Strength Rule also replaced the fault level shortfall process, under which Powerlink addressed a shortfall at the Gin Gin system strength node.
- The level of coal generation in Queensland over the period December 2025 to December 2030 is the primary consideration for Powerlink's ability to meet minimum fault level requirements. AEMO's forecasts of the retirement dates for Queensland coal generators suggest materially different profiles between the 2023 System Strength Report and the 2024 ISP. In particular, the 2023 System Strength Report suggests a more accelerated retirement profile for coal generation in Southern Queensland than did the 2024 ISP, and the 2022 System Strength Report.
- The sensitivity of coal generation forecasts at sub-regional levels is significant for Powerlink's assessment of system strength needs. The magnitude of change in projected coal generation between the 2022 and 2023 System Strength Reports, and six months later in the final 2024 ISP, illustrates how quickly and materially coal unit forecasts can change, and the risk associated with relying on a particular outcome.
- Powerlink is required to use reasonable endeavours to make system strength services available to AEMO. AEMO's declaration of system strength shortfalls is (currently) based on when AEMO forecasts system strength services will fall below the minimum requirements for more than 1% of the time under typical dispatch patterns. Powerlink considers that this approach aligns with the reasonable endeavours standard, and has therefore adopted this approach in developing the credible options for this RIT-T.

2.1. Description of the identified need

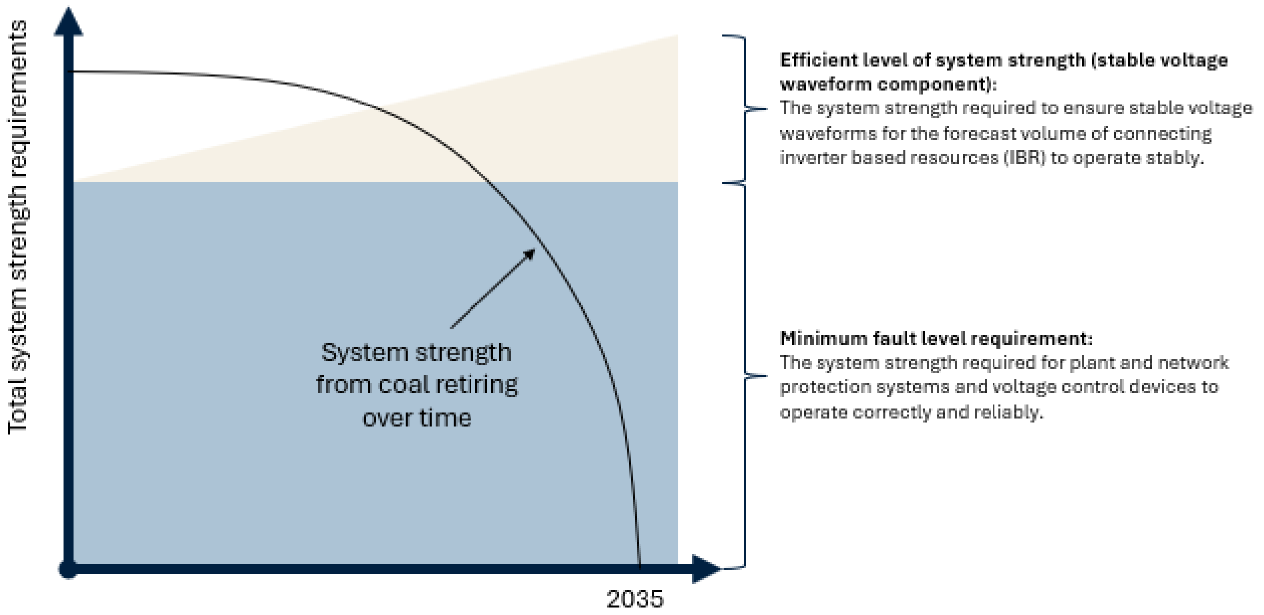
The identified need in this RIT-T is to make system strength services available to AEMO to meet the following requirements in each year from 2 December 2025:

- Maintain the minimum three phase fault level specified by AEMO at each system strength node for the relevant year (**minimum level**); and
- Achieve stable voltage waveforms for the level and type of IBR and market network service facilities projected by AEMO at each system strength node for the relevant year in steady state conditions, and following a credible contingency event or protected event (**efficient level**).[9]

Figure 2.1 is a conceptual illustration of the minimum fault level and stability component elements of system strength requirements.

[9] NER, clause S5.1.14(b).

Figure 2.1: Minimum fault level and stability components of system strength



2.2. System Strength Shortfall at Gin Gin

In December 2021, AEMO declared an immediate system strength shortfall of 44 to 65 megavolt amperes (MVA) at the Gin Gin 275 kilovolt (kV) system strength node for the period 2021/22 to 2026/27, against the minimum (post-contingency) three phase fault level of 2,250 MVA at the node. AEMO declared the shortfall as it projected a decline in the number of synchronous machines online in Central Queensland due to declining minimum demand and increasing variable renewable energy and distributed solar photovoltaic (PV) generation. AEMO declared the shortfall on the basis that it forecast system strength services would fall below the minimum requirements for more than 1% of the time under typical dispatch patterns.[10]

In May 2022, AEMO updated the declaration to account for its replacement of the Progressive Change scenario with the Step Change scenario for the 2022 ISP. AEMO increased the size of the shortfall at Gin Gin from 33 MVA in 2022/23 to 90 MVA in 2026/27, and requested Powerlink provide services from 31 March 2023 until at least 31 December 2026.[11] Also in May 2022, Powerlink commenced an Expression of Interest (EOI) process for non-network solutions to the fault level shortfall at the Gin Gin node.[12] The National Electricity Rules (NER) in force at the time exempted Powerlink from applying the RIT-T to assess options to address the shortfall.[13]

[10] AEMO, *2021 System Security Reports*, December 2021, pages 11, 42 and 102.

[11] AEMO, *Update to 2021 System Security Reports*, May 2022, pages 23 and 48. Note that, on page 48, AEMO indicated that services would be requested from 31 January (rather than March) 2023.

[12] NER, clause 5.20C.3(e).

[13] See NER, clause 5.16.3(a)(11) before it was omitted on 1 December 2022 by *National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021 No. 11*, schedule 2 at [10].

AEMO's System Strength Reports of 2022 and 2023 stated that the shortfall at the Gin Gin node was 64 MVA until 1 December 2025, at which time new requirements for the provision of system strength services would commence.[14]

In late 2023, Powerlink identified the non-network solution of the addition of a clutch to the shaft between the gas turbine and the synchronous generator at the Townsville Power Station was the least-cost option to address the shortfall. The Townsville Power Station is owned by RATCH-Australia, and Powerlink has entered into a contract with RATCH-Australia for the provision of system strength services. The addition of the clutch at the Townsville Power Station is expected to be delivered by mid-2025.[15]

For this RIT-T, Powerlink considers the gas turbine hybrid solution at the Townsville Power Station as a committed project, and has included it in the base case.

2.3. System Strength Rule

Powerlink is the SSSP for Queensland.[16] To provide a clear distinction between Powerlink's role as SSSP for Queensland and proposals for non-network solutions from providers of system strength services, this PADR generally refers to Powerlink as a Transmission Network Service Provider (TNSP) rather than an SSSP.

As stated in section 1.3, in October 2021 the AEMC made the System Strength Rule. The new rule:

- evolved the 'do no harm' framework which required connecting generators to self-assess their impact on the local network's system strength levels, and self-remediate any adverse impacts; and
- established a new framework for the supply, demand and coordination of system strength in the NEM.[17]

A key element of the supply side of the framework is the establishment of the System Strength Standard, comprised of the minimum fault level requirement and the stability requirement. The minimum fault level, forecast by AEMO over a 10-year horizon, is necessary for system security, and the voltage waveform stability component is required to securely host forecast levels of IBR connection. The System Strength Standard is set out in two schedules in Chapter 5 of the NER:

- the system standard in clause S5.1a.9; and
- the network standard in clause S5.1.14 that specifies specific obligations that SSSPs must meet.[18]

The first date by which Powerlink must comply with the standard in clause S5.1.14 of the NER is 2 December 2025.[19] The investment is to ensure Powerlink's compliance with clause S5.1.14 of the NER. This RIT-T is therefore considered a reliability corrective action under the NER.[20]

In the final determination for the System Strength Rule, the AEMC made comments that are directly relevant to Powerlink's response to the rule:

- SSSPs cannot plan to meet the System Strength Standard through the use of constraints or directions given these are operational tools.

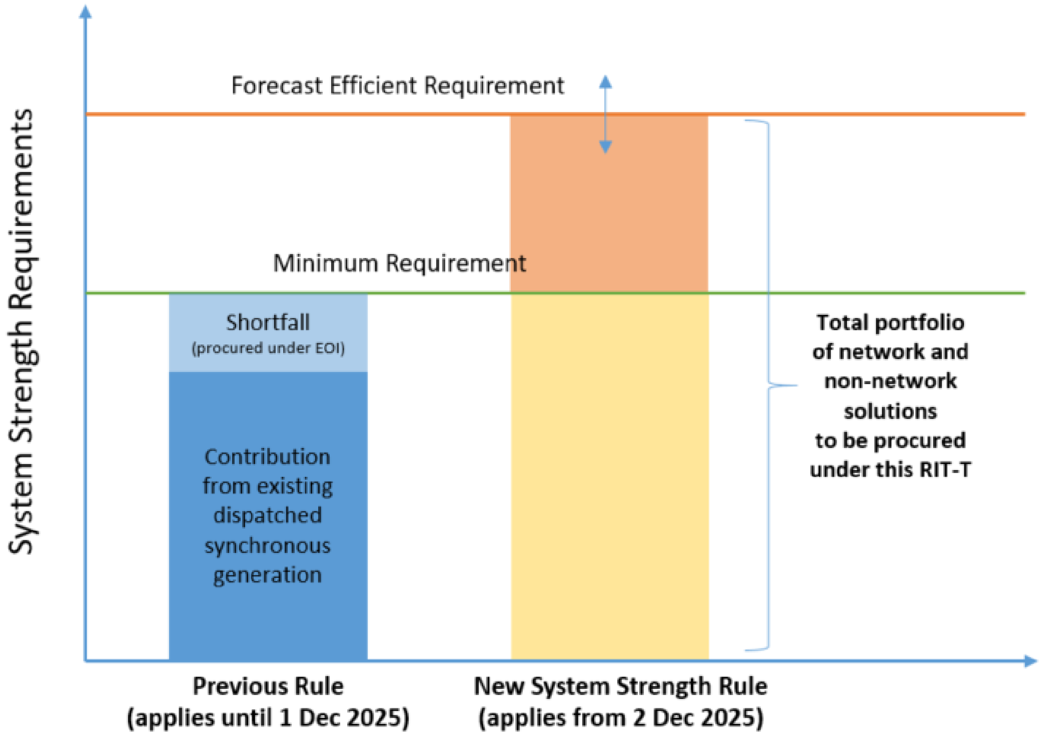
---

[14] AEMO, *2022 System Strength Report*, December 2022, page 41; AEMO, *2023 System Strength Report*, December 2023, pages 28 and 56.
[15] More information on Powerlink's response to the declared shortfall is available on the Power System Security Consultation page of Powerlink's website.
[16] NER, clause 5.20C.3(a).
[17] AEMC, *Efficient Management of System Strength on the Power System*, final determination, October 2021, page 13.
[18] Ibid, page 15.
[19] Ibid, page 107.
[20] NER, clause 5.10.2 (definition of 'reliability corrective action').

- In the operational timeframe, it may be more appropriate to apply constraints to relevant generators to maintain system security when solutions procured by the SSSP are exhausted.
- In the case of planned outages, it may be more efficient to use constraints for the length of the relatively short planned outage than to obtain further services at a significantly higher cost to cover the period.[21]

From December 2022, the System Strength Rule replaced the fault level shortfall process.[22] However, transitional arrangements ensure that Powerlink continues to address the declared shortfall.[23] Figure 2.2 illustrates how the differing approaches of both the shortfall mechanism and System Strength Standard apply to meet system strength requirements.

Figure 2.2: Meeting system strength under the shortfall and standard based approaches



Powerlink is required to use reasonable endeavours to comply with the network standard element of the System Strength Standard.[24] AEMO's declaration of system strength shortfalls is (currently) based on when AEMO forecasts system strength services will fall below the minimum requirements for more than 1% of the time under typical dispatch patterns. Powerlink considers that AEMO's approach aligns with the reasonable endeavours standard, and has therefore adopted this approach in considering the credible options for this RIT-T.

In October 2024, the Australian Energy Regulator (AER) published draft guidance on the System Strength Rule for SSSPs. The final guidance from the AER will be considered as part of the Project Assessment Conclusions Report (PACR), if published by the AER sufficiently ahead of when the PACR (and analysis feeding into it) is finalised.

---

[21] AEMC, *Efficient Management of System Strength on the Power System*, final determination, October 2021, page 16.
[22] See *National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021 No. 11*, schedule 2 at [24] omitting clause 5.20C.2 (Fault Level Shortfalls) from the NER.
[23] NER, clauses 11.143.1 (definition of 'system strength transition period') and 11.143.13(a)(1).
[24] NER, clause S5.1.14(b).

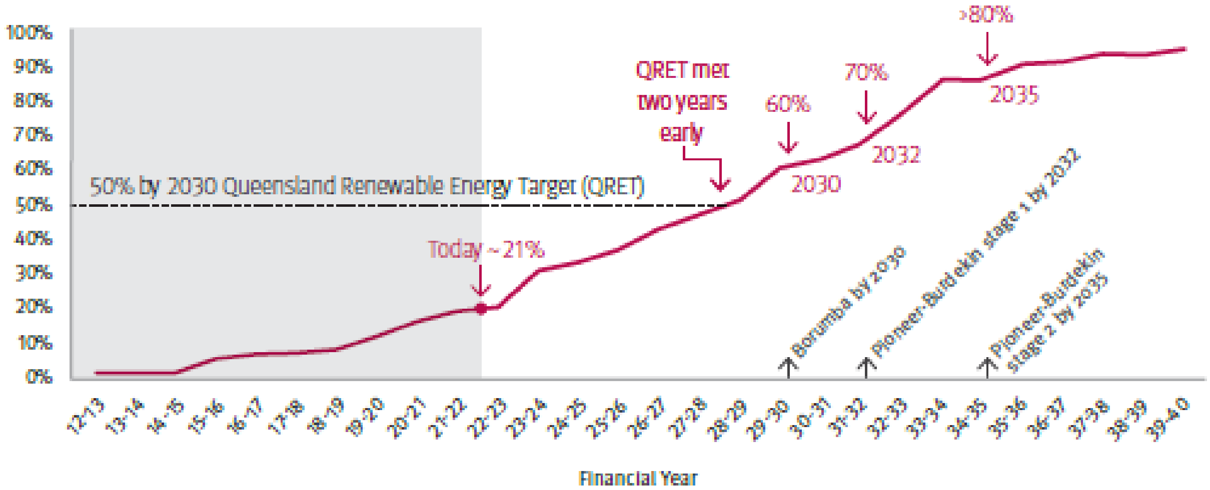
2.4. Queensland Energy and Jobs Plan and SuperGrid Infrastructure Blueprint

In September 2022, the Queensland Government released the Queensland SuperGrid Infrastructure Blueprint (SuperGrid Blueprint). The SuperGrid Blueprint detailed major electricity investments to achieve the 50% Queensland Renewable Energy Target (QRET) by 2030.[25] The SuperGrid Blueprint supports the Queensland Energy and Jobs Plan (QEJP), which outlines the government's plan to meet the QRET of 70% by 2032 and 80% by 2035. The QEJP noted that three gigawatts (GW) of wind and solar generation were already operational in Queensland's energy system, and that Queensland would need at least 25 GW of renewable energy by 2035 to meet the 80% target.[26]

The SuperGrid Blueprint described the optimal infrastructure pathway (OIP) to 2035 to transform Queensland's electricity system across renewable generation, storage and synchronous capacity, transmission network augmentation, and repurposing (government-owned) coal-fired power stations into clean energy hubs.[27] The SuperGrid Blueprint also commented that, until 2029/30 when the Borumba Pumped Hydro Energy Storage (PHES) was expected to be operational, only limited amounts of coal-fired generation could be removed from Queensland's energy system.[28]

Figure 2.3 illustrates the planned trajectory (as of September 2022) to meet the QRET.

Figure 2.3: Queensland Renewable Energy Target



Source: Queensland Government, Queensland Energy and Jobs Plan, September 2022, page 11.

The establishment of the SuperGrid Blueprint and new PHES facilities will support an increase in system strength levels across the network.

To further support system strength and inertia, the SuperGrid Blueprint indicated coal-fired units would be repurposed (where possible) into synchronous condensers.[29] The SuperGrid Blueprint also noted Powerlink's investment in the Central QREZ region would include a new synchronous condenser to provide system strength,

---

[25] Queensland Government, *Queensland SuperGrid Infrastructure Blueprint*, September 2022, pages 3, 7 and 29.
[26] Queensland Government, *Queensland Energy and Jobs Plan*, September 2022, pages 6 and 27. The Renewable Energy Targets are also included in the *Energy (Renewable Transformation and Jobs) Act 2024* (Qld), section 9.
[27] Queensland Government, *Queensland Energy and Jobs Plan*, September 2022, pages 7 and 27.
[28] Queensland Government, *Queensland SuperGrid Infrastructure Blueprint*, September 2022, page 36.
[29] Ibid, page 43.

and a battery connection to support system strength and enable renewable capacity.[30] This RIT-T will address the requirement for system strength services in the Central QREZ region.

Since the Queensland Government is in the process of updating the SuperGrid Blueprint, with the next review expected by May 2025[31], these developments are not explicitly reflected in the modelling assumptions for this PADR. However, Powerlink will reassess this as part of the PACR if these proposals have progressed.

2.5. Assumptions and requirements underpinning the identified need

AEMO 2023 System Strength Report

While the overall characterisation of the identified need for this RIT-T has not changed since the PSCR, the specific detail regarding system strength requirements has been updated. This has been driven by the Draft 2024 ISP process resulting in changes to the AEMO IBR forecasts included in the 2023 System Strength Report, published in December 2023 (which drives Powerlink's obligation). The analysis in this report uses the IBR forecast set out in the 2023 System Strength Report, and so differs from that presented in the PSCR which was based on the 2022 System Strength Report.

For the 2023 System Strength Report, AEMO reviewed minimum system strength requirements in each region of the NEM. The report did not change the minimum pre- or post- contingent fault levels for system strength nodes in Queensland (compared to the 2022 report), but did include estimates of the typical levels of system strength available. In this context, AEMO noted that 'typical' referred to the 99th percentile of availability.[32]

Table 2.1: AEMO minimum three phase fault level expected 99% of the time, December 2023

System Strength Node	Pre-contingent minimum fault level (MVA)	Post-contingent minimum fault level (MVA)	Minimum post contingent three phase fault current (MVA) expected 99% of the time, financial year ending					
			2024	2025	2026	2027	2028	2029
Gin Gin	2,800	2,250	2,192	2,201	2,201	2,195	2,083	2,093
Greenbank	4,350	3,750	4,642	4,590	4,679	4,626	3,126	3,205
Lilyvale	1,400	1,150	1,172	1,182	1,183	1,179	1,146	1,149
Ross	1,350	1,175	1,327	1,321	1,336	1,332	1,306	1,300
Western Downs	4,000	2,550	2,858	2,830	2,863	2,843	2,112	2,144

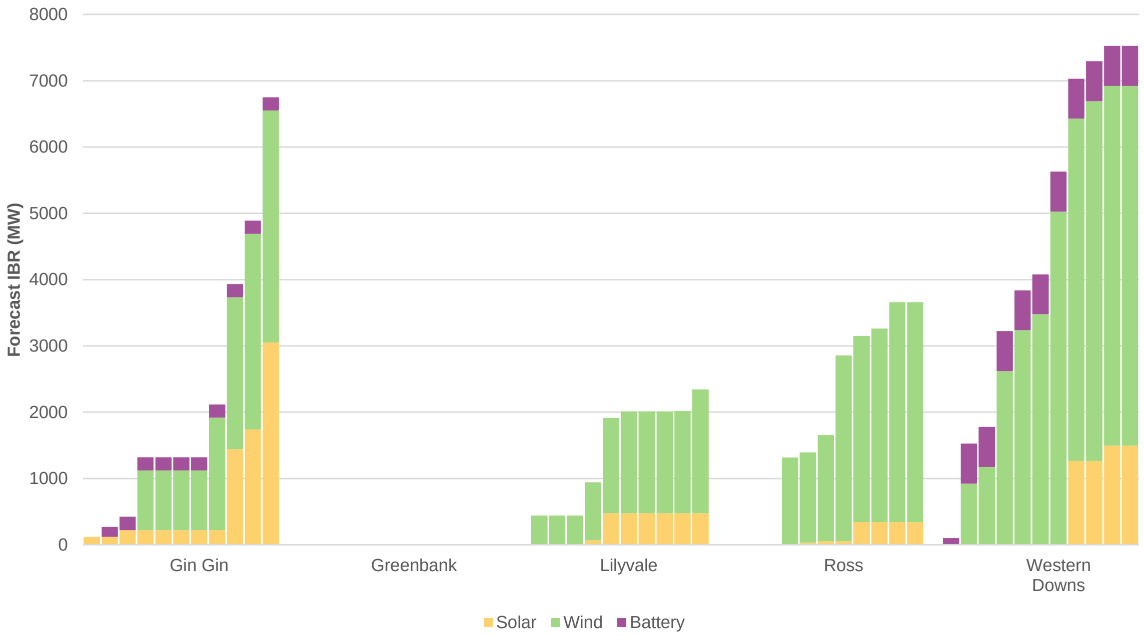
Source: AEMO, 2023 System Strength Report, December 2023, pages 28-32.

AEMO did not identify any new system strength shortfalls, or new system strength nodes, for Queensland in the 2023 report (compared to the 2022 report). However, AEMO identified several potential new nodes in Queensland in the 2023 report.[33]

The 2023 System Strength Report also included updated projections of connected IBR (megawatts (MW)) for Queensland over the 11-year period from 2023/24.

[30] Queensland Government, *Queensland SuperGrid Infrastructure Blueprint*, September 2022, pages 4-5, 25 and 29.
[31] *Energy (Renewable Transformation and Jobs) Act 2024* (Qld), section 16(1)(a).
[32] AEMO, *2023 System Strength Report*, December 2023, page 10.
[33] Ibid, pages 24-26.

Figure 2.4: AEMO 11-year forecast of level and type of IBR at system strength nodes, December 2023



Note: forecasts excluded existing IBR at the time of the report.

Source: AEMO, 2023 System Strength Report, December 2023, page 27.

At an aggregate level, the 2023 forecast shows lower IBR from 2023/24 to 2025/26 than the 2022 forecast, but significantly more megawatts connecting in 2026/27 and over 2,400 more megawatts by the end of 2030/31.

Figure 2.5: AEMO 2022 and 2023 forecasts of level and type of IBR, aggregated across system strength nodes

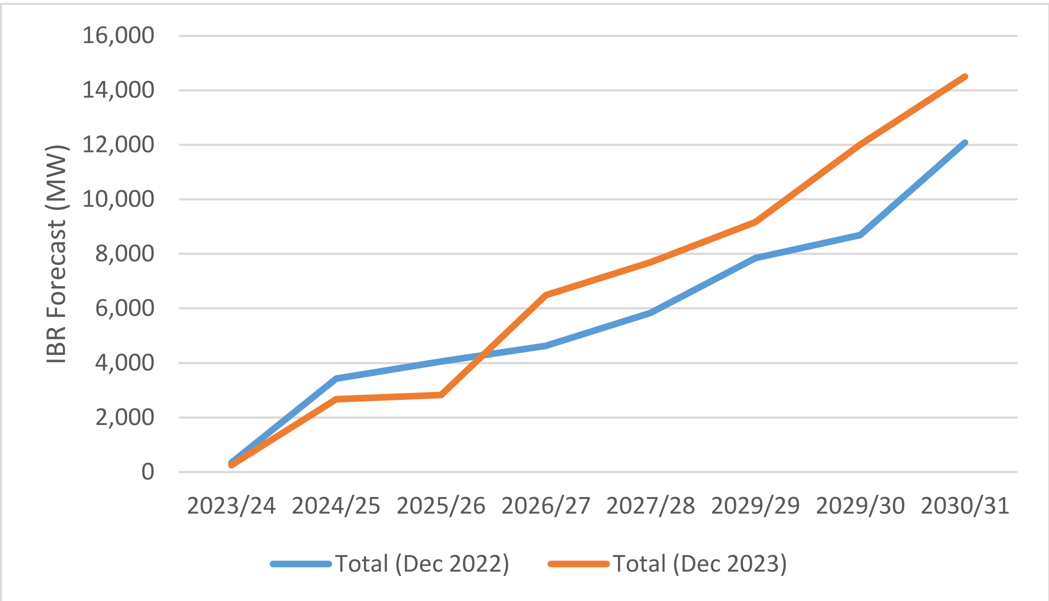
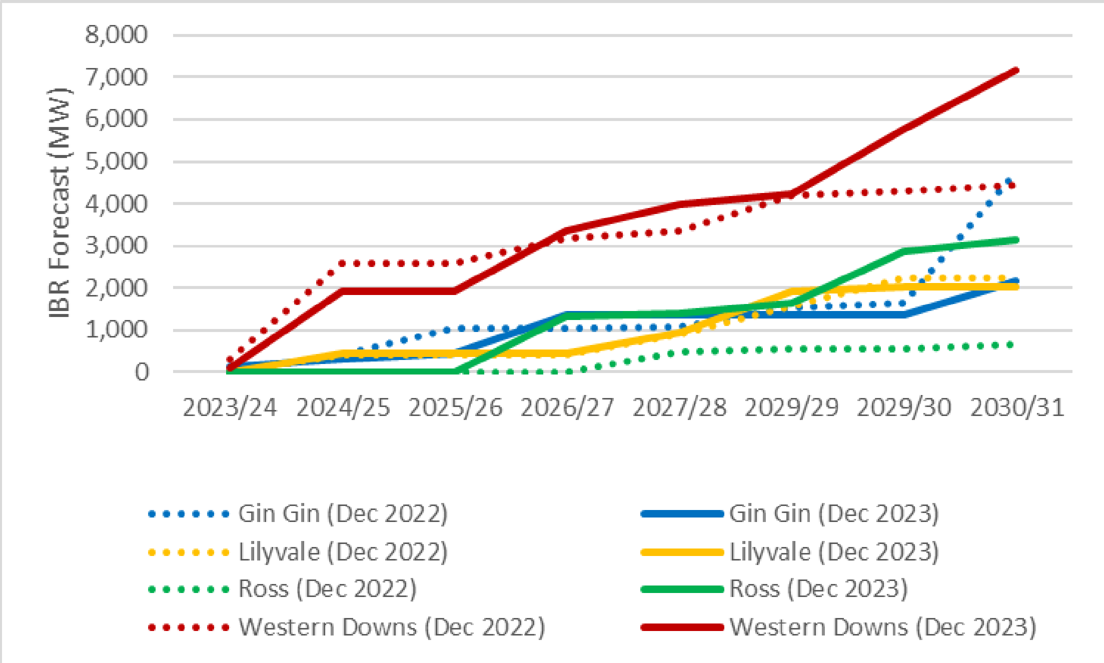


Figure 2.6 shows that the higher IBR forecast for 2030/31 in the 2023 System Strength Report is driven by materially higher forecasts at the Ross and Western Downs nodes, with forecasts at the Gin Gin and Lilyvale nodes lower in the 2023 System Strength Report than the 2022 report.

Figure 2.6: AEMO 2022 and 2023 forecasts of level and type of IBR at each system strength node



AEMO has provided Powerlink with Queensland's (unpublished) IBR forecast for the 2024 System Strength Report. The 2024 forecast aligns with the 2024 ISP and is not materially different to 2030/31 than the 2023 System Strength Report. Powerlink will update the IBR forecast in the PACR for AEMO's forecast in the 2024 System Strength Report.

Timing of retirement/de-commitment of coal generating units

The level of coal generation in Queensland over the period December 2025 to December 2030 is the primary consideration for Powerlink's ability to meet minimum fault level requirements. While all coal is expected to be retired by 2034/35, AEMO's forecasts of the retirement dates for Queensland coal generators suggest materially different retirement profiles before then across the 2024 ISP and the 2023 System Strength Report. In addition, the 2023 System Strength Report (and the 2022 System Strength Report) projects a more accelerated retirement profile for coal generation in Southern compared with Central Queensland than the 2024 ISP. Further detail on AEMO's coal generation projections for Queensland is included in Appendix C.

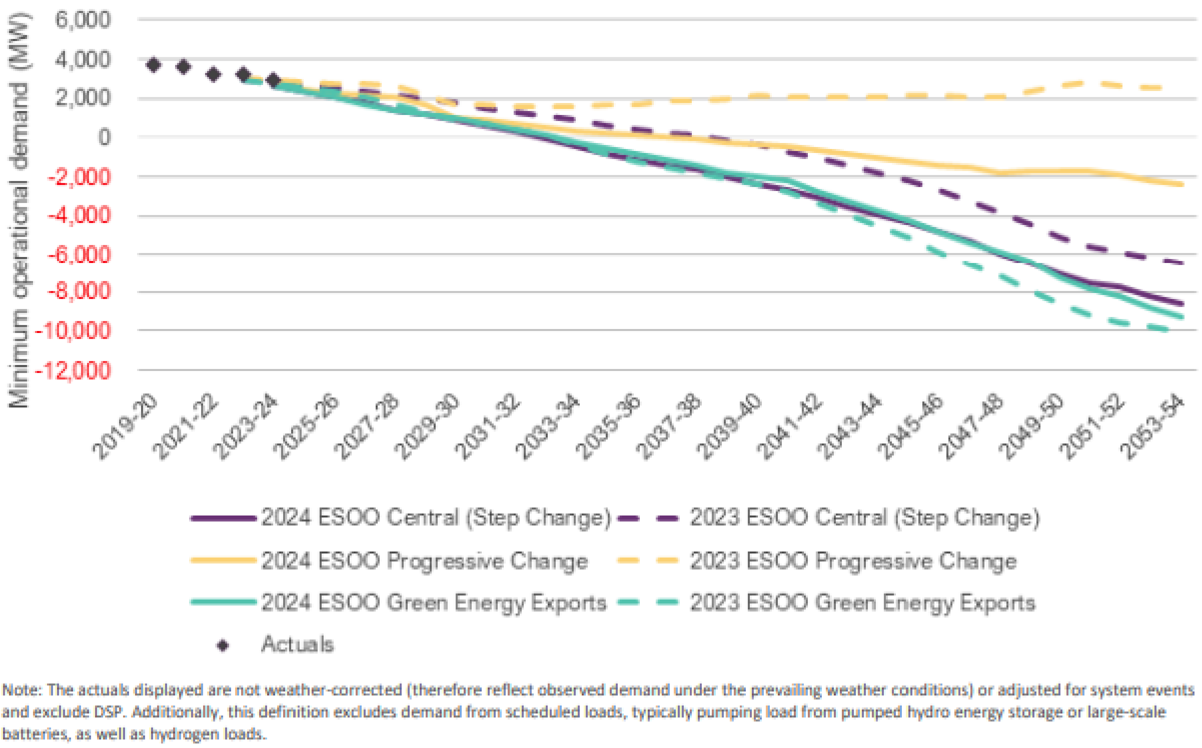
The sensitivity of coal generation forecasts at sub-regional levels is significant for Powerlink's assessment of system strength needs. The magnitude of change in the span of one revision of the System Strength Report, and six months later the 2024 final ISP, illustrates how quickly and materially coal unit forecasts can change at a sub-regional level, and the risk associated with relying on a particular outcome.

The factors determining which coal-fired generation units decommit seasonally are likely to be influenced by factors that are not publicly known, such as economic withdrawal, which is influenced by the asset owner's decision-making across (potentially) a diverse portfolio of assets. Further, as with any integer-based modelling, the specific units chosen for retirement are sensitive to changes in input assumptions. That is, the ISP modelling, and by extension the system strength analysis, could indicate retirements occurring in either Central *or* Southern Queensland. Importantly, the most conservative 2023 System Strength Report forecast predicts one unit in Southern Queensland being online 100% of the time prior to 2029/30 (see Appendix C, Figure 4).

To manage the uncertainty and risk around the number and location of coal generators likely to be dispatched for energy, Powerlink has investigated two key assumed states regarding the retirement of these generators. Specifically, the core PADR analysis (presented in section 6.1) aligns with the final 2024 ISP forecasts, while a separate standalone sensitivity (presented in section 6.2) aligns with the 2023 System Strength Report. The sensitivity includes additional solutions for Southern Queensland to mitigate the risk of shortfalls in system strength should retirement of coal generators in Southern Queensland occur faster than projected in the 2024 ISP.

Low minimum demand conditions may also force more coal generators to retire early and/or be offline more frequently. In the 2023 Electricity Statement of Opportunities (ESOO), AEMO observed that minimum operational demand is declining across the NEM as distributed (rooftop) solar PV erodes daytime operational demand.[34] Figure 2.7 shows historical minimum demand in Queensland from 2019/20 to 2023/24, and AEMO's recent forecasts showing (with one exception) a steady decline in minimum operational demand out to 2053/54.

Figure 2.7: AEMO minimum demand forecasts, August 2024



Source: AEMO, 2024 Electricity Statement of Opportunities, August 2024, page 135 (figure 60).

AEMO stated that the rate of decline in minimum operational demand in the 2024 ESOO is higher than in the 2023 ESOO due to slower relative growth in electric vehicles and a higher relative growth of solar PV.[35]

The continued erosion of daytime operational demand due to solar PV may also make it operationally infeasible for coal generators to run, even if directed by AEMO to do so. That is, daytime demand could get to a level that

[34] AEMO, *2023 Electricity Statement of Opportunities*, May 2023, page 28.
[35] AEMO, *2024 Electricity Statement of Opportunities*, August 2024, page 134.

the number of coal generating units available for AEMO to direct online declines as there is insufficient load for the units to run, in which case parts of the network may have to be de-energised due to insufficient system strength, with significant implications to customer reliability.

3. Credible Options

Key Points

- Powerlink has adopted a portfolio formation approach to develop credible options to address system strength requirements from December 2025 to December 2030.
- Using responses to the PSCR and the accompanying proforma, Powerlink developed a Balanced Technology portfolio (Portfolio 1) that includes a range of different technologies for meeting the **minimum fault level requirements** going forward, such as existing synchronous generation (including hydro generators), adding clutches to existing and future gas generating units and synchronous condensers.
- Powerlink also developed four additional portfolios that assume a greater use of a particular technology for meeting the minimum requirements, namely Portfolio 1A (Balanced Technology with BESS in Minimum), Portfolio 2 (Synchronous Condensers), Portfolio 3 (Clutched Gas Turbines) and Portfolio 4 (Pumped Hydro Energy Storage).
- A key issue Powerlink is considering in this RIT-T is the extent to which grid-forming BESS can be relied on to contribute to minimum fault level requirements. This current uncertainty is the basis for developing Portfolio 1A, which tests how including grid-forming BESS to assist with the minimum fault level requirements would fare, relative to the other technology choices, *if it is found to be technically feasible.*
- For meeting the **stable voltage waveform efficient requirements**, committed and anticipated BESS proposals have been selected as they are relatively low-cost solutions in the cost-benefit analysis and can be contracted as and when required. Given they are independent of solutions to meet the minimum requirements, each portfolio includes the same capacity of grid-forming BESS – both new build and the conversion of existing – to meet the efficient system strength requirements.

3.1. Portfolios of credible options

Powerlink received close to 80 unique non-network solutions from more than 20 proponents in response to the PSCR and the accompanying proforma. Using these responses as a base, Powerlink has adopted a portfolio formation approach to develop five different credible options to address the system strength requirements in Queensland from December 2025. Each of the portfolios meets both the minimum fault level requirements and the stable voltage waveform efficient requirements.

The 'Balanced Technology' portfolio (Portfolio 1) includes investing in or contracting with a range of different technologies for meeting the minimum fault level requirements going forward, such as existing synchronous generation (including hydro generators), adding clutches to existing and future gas generating units and synchronous condensers. Four additional portfolios each assume a greater use of a particular technology for meeting the minimum requirements.

The approach of having portfolios assume a greater use of a particular technology for meeting the minimum requirements enables the PADR assessment to test the relative expected economic benefits of, and interactions between, the different technologies that are able to assist with meeting the minimum system strength requirements.

The outcome of the portfolio formation process is that the portfolios *differ* in terms of the following solutions for meeting the minimum system strength requirements.

Table 3.1: Key differences between the five portfolios

Portfolio	Solutions for minimum requirements
1 (Balanced Technology)	Six new synchronous condensers in Central Queensland. Two future clutched gas turbines in Central Queensland.
1A (Balanced Technology: BESS in Minimum)	Five new synchronous condensers + one (large) grid-forming BESS in Central Queensland. Two future clutched gas turbines in Central Queensland.
2 (Synchronous Condensers)	Eight new synchronous condensers in Central Queensland.
3 (Clutched Gas Turbines)	Four new synchronous condensers in Central Queensland. Four future clutched gas turbines in Central Queensland.
4 (Pumped Hydro Energy Storage)	Three new synchronous condensers in Central Queensland. Two future clutched gas turbines in Central Queensland. Three planned pumped hydro energy storage units in Central Queensland.

While Powerlink has used shorthand labels for each portfolio (such as 'Synchronous Condensers' for Portfolio 2), each portfolio includes a number of solutions, across a range of technologies. The shorthand label has been selected for brevity and to highlight the key difference in focus for each portfolio, compared to Portfolio 1.

Each portfolio also includes a number of *common* solutions for meeting both the minimum and efficient system strength requirements, as summarised in Table 3.2.

Table 3.2: Components common to all five portfolios

Requirements	Solutions
Minimum fault level	One new synchronous condenser in Southern Queensland. Non-network contracts with existing, expected and potential future gas and hydro projects in Southern and Northern Queensland. Powerlink's solution to the system strength shortfall declared by AEMO (in 2021) at the Gin Gin system strength node (being a non-network solution for the installation of a clutch at the Townsville Power Station). A non-network contract with an existing (small) synchronous condenser.
Efficient stable voltage waveform	Each portfolio includes the same quantity (2.15 GW) of grid forming BESS.

For all portfolios, all assumed investment in and or contracting with components is complete by 2033/34. That is, no portfolio involves any new solutions beyond this point.

Figure 3.1 summarises how each portfolio differs in terms of the type and timing of solutions included in Central Queensland for meeting the minimum fault level requirements (which reflects all of the above differences, with the exception of the three planned PHES units in Central Queensland under Portfolio 4).

Figure 3.1: Differences in the timing and type of Central Queensland components included across the portfolios

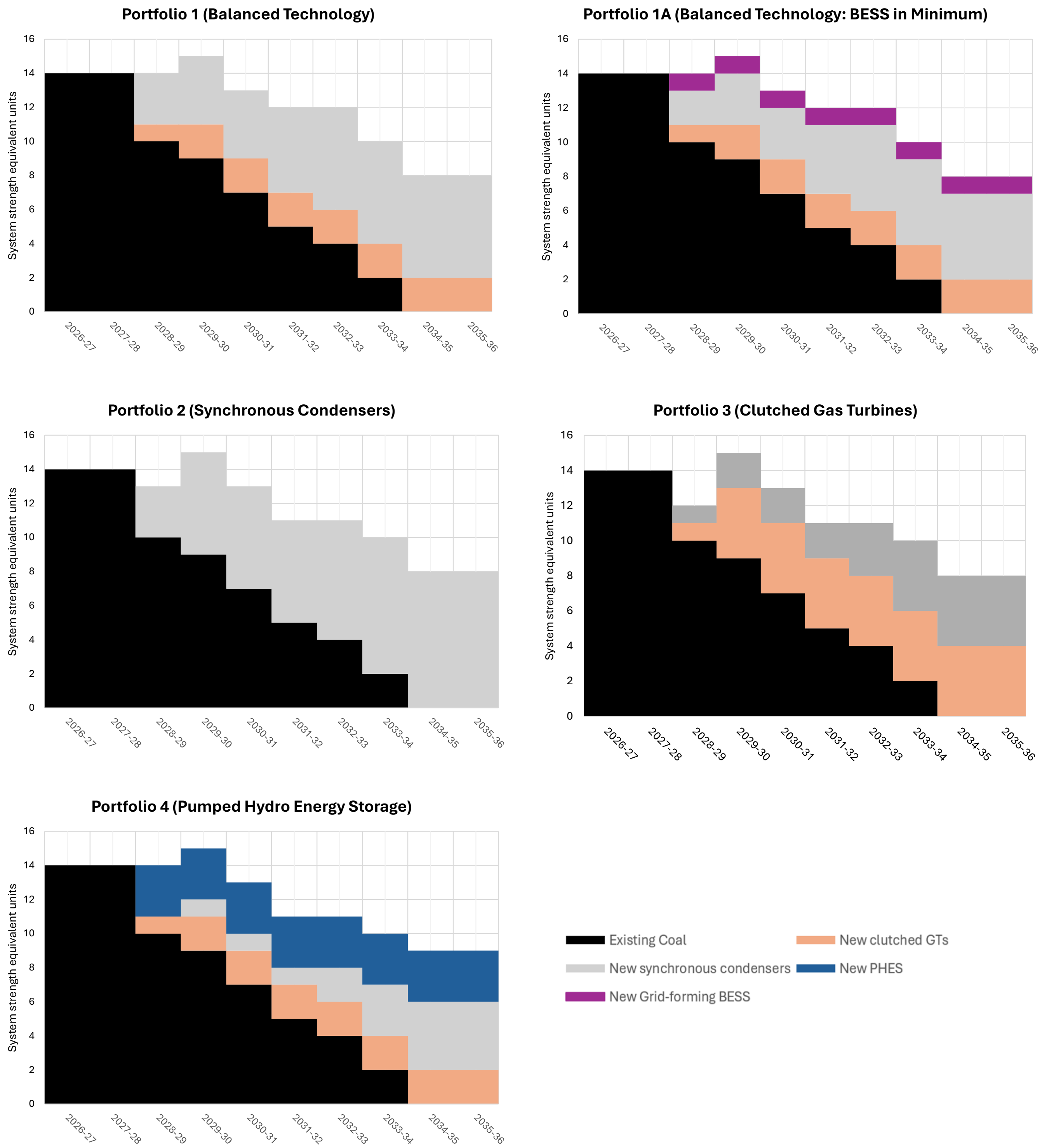
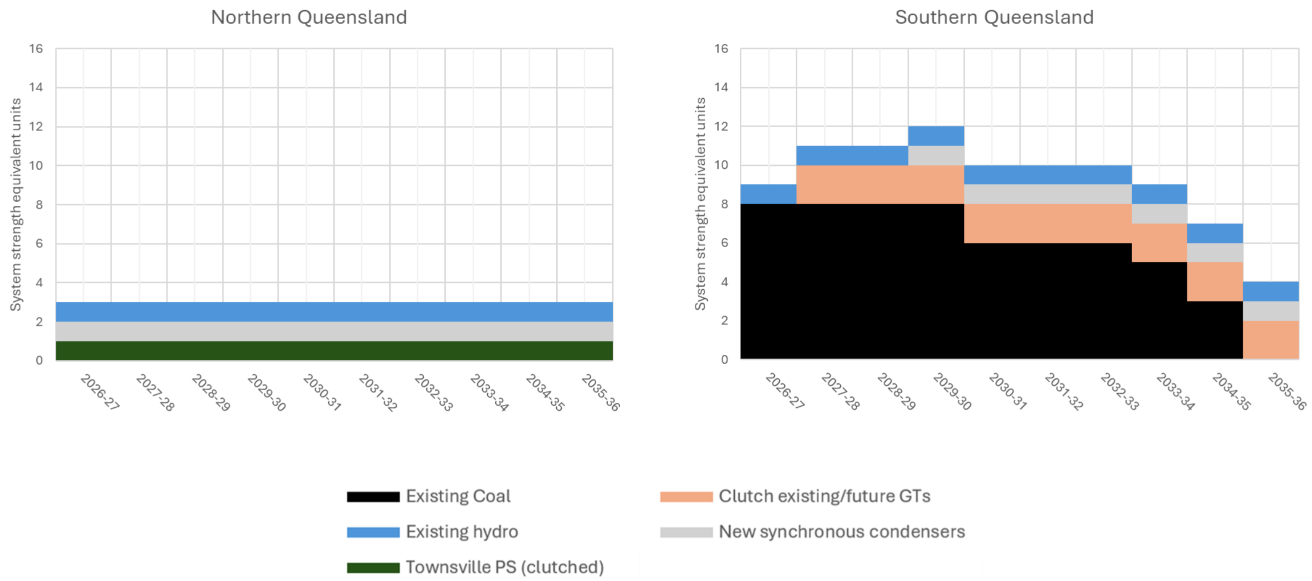


Figure 3.2 summarises the type and timing of the common components included in in Northern and Southern Queensland for meeting the minimum fault level requirements.

Figure 3.2: The timing and type of common solutions in Northern and Southern Queensland



A key issue for Powerlink (and the industry more broadly) is the extent to which grid-forming BESS can be relied on to contribute to minimum fault level requirements. A minimum level of system strength is required to support a number of critical system services, including (but not limited to) maintaining the stability of IBR, satisfactory operation of protection systems, and stable switching of voltage control devices. Powerlink does not have sufficient knowledge or experience of how the power system would behave if grid-forming BESS replace the existing synchronous generators to meet minimum system strength requirements in the near term. As a result, Powerlink does not consider them to be technically feasible for this application at this time. The current uncertainty is the basis for developing Portfolio 1A, which tests how including grid-forming BESS to assist with the minimum fault level requirements would fare, relative to the other technology choices, *if it is found to be technically feasible.*

The portfolios do not differ in terms of how the minimum system strength requirements are met for:

- Southern Queensland, due to:
  - AEMO's 2024 ISP assumptions regarding coal retirement suggesting that there will be sufficient system strength in Southern Queensland over the period December 2025 to December 2030; and
  - proposed non-network contracts with existing, expected and potential future gas and hydro projects being relatively low cost under the RIT-T (meaning that only one new synchronous condenser is assumed to be required in addition to these contracts, as outlined in Table 3.2 above).
- Northern Queensland, due to the dependency of Northern Queensland on Central Queensland for system strength (meaning that these two regions can effectively be considered as one).

Given that the BESS proposals considered to meet the efficient requirements are independent of the solutions to meet the minimum requirements, each portfolio includes the same capacity (2.15 GW) of grid-forming BESS to meet the efficient system strength requirements. This common capacity of grid-forming BESS included in each portfolio is made up of both:

- proposals from committed and anticipated BESS – these represent relatively low-cost solutions under the RIT-T given they are also assumed in the base case and it is only incremental costs, if any, that are included in the portfolios; and
- additional proposals from BESS proponents (both new-build and the conversion of existing to grid-forming) that do not currently meet the RIT-T criteria for committed or anticipated projects – these have been included due to their relatively low costs compared to alternate solutions (such as synchronous condensers). Powerlink is also interested in proposals from other non-network proponents who could also contribute to meeting the efficient level of system strength in a cost-effective manner.

The project status of each solution has been determined by Powerlink using information provided by proponents, AEMO's Generation Information data, and publicly available information for government-backed projects. If a solution is deemed not to meet the RIT-T criteria for committed or anticipated projects at this point in time, then its full cost is included in the assessment, consistent with the RIT-T Application Guidelines.[36]

Detail on Powerlink's approach to estimating costs of network and non-network solutions is in Appendix D.

3.2. Developing portfolio options to meet system strength requirements

Overview of how portfolios have been formed

As noted above, AEMO currently assesses system strength shortfalls based on the 99th percentile of minimum post-contingent fault levels at each system strength node.

Powerlink has implemented a probabilistic approach to assess the likelihood of maintaining sufficient system strength across the grid. This methodology uses binomial probability theory and system modelling, with each power system unit – such as synchronous condensers, gas turbines, and pumped hydro – assigned a reliability value, sourced from AEMO's 2023 Inputs, Assumptions and Scenarios Report (IASR), which reflects the probability of that unit being available when needed. The unit reliability consists of the forced outage rate and maintenance requirements as per AEMO's 2023 IASR.

Each unit's contribution to system strength is also evaluated based on its system strength equivalency – a measure of how much system strength it provides compared to a retiring coal unit in that region, derived from power system modelling and technical analysis of fault level contributions and stability impacts. In this assessment, Powerlink has considered coal retirement projections based on the 2024 ISP retirement outcomes.

While this approach offers robustness, it is sensitive to changes in unit availability, which can lead to notable shifts in the calculated probabilities. Small changes in unit numbers or reliabilities may have disproportionate effects on the outcome. Additionally, assumptions drawn from the IASR and ISP data need to be updated periodically to reflect evolving conditions. External factors, such as policy and market trends, particularly those driven by decarbonisation efforts, will also influence system strength outcomes.

Figures 3.1 and 3.2 above provide a visual representation of the number of system strength equivalent units available in each region, demonstrating the portfolio solutions alongside forecast online coal capacity according to the 2024 ISP Step Change retirement outcomes.

Northern Queensland must have at least two system strength equivalent units online at all times to ensure system strength, while Southern Queensland requires a minimum of four equivalent coal units. Central

[36] AER, *Application Guidelines, Regulatory Investment Test for Transmission*, October 2023, pages 33-35.

Queensland needs at least six equivalent system strength units along with the operation of Townsville Power Station to maintain system strength.

To provide sufficient system strength 99% of the time, it is essential to plan for headroom above the minimum required system strength levels to account for forced outages and maintenance activities, ensuring grid resilience under various operating conditions.

Technological diversity

Powerlink considers technological diversity to be an important feature of the portfolio development process:

- Grid-forming BESS can increase system strength and help to support the operation of IBR in a similar way to synchronous condensers[37], and several grid-forming BESS are currently in the connection application stage. However, as noted above, the technical viability of grid-forming BESS to meet the minimum fault level requirement in a large inter-connected power system is yet to be established.
- Synchronous generation is a proven source of system strength when these units are dispatched in the energy market. However, there is material uncertainty around the number and location of coal generation units that are likely to be online for the period December 2025 to December 2030, and the risks associated with having sufficient operational demand to support the dispatch of this generation.
- Synchronous condensers are capable of providing significant fault current contribution and synchronous inertia. Synchronous condensers can offer system strength support comparable to that provided by large existing synchronous generators. However, achieving the same level of support as large base load synchronous machines (such as Millmerran Power Station) may require a greater number of synchronous condensers due to the larger size of the existing base load units. Further, given the international demand for synchronous condensers, there are delivery risks associated with the technology.
- The addition of clutches to gas turbine units, to enable them to operate in synchronous condenser mode when not generating, could be a cost-effective way to provide system strength. The advantage of a gas turbine, compared, for example, to a coal generating unit, is its ability to start up relatively quickly to generate electricity to meet a sudden increase in demand or to compensate for the variability on renewable sources. Further, as synchronous machines, hybrid gas generation projects should provide inertia and reactive power support when operating in generating mode. However, there are similar risks associated with the installation of the clutches, and operational challenges can arise due to the time required to operate each clutch.
- PHES projects represent a potentially reliable and cost-effective system strength solution. Operating PHES units in synchronous condenser mode ensures continuous provision of system strength.

Powerlink undertook high-level network planning analysis on the Balanced Technology portfolio (Portfolio 1) to be sufficiently confident that it would deliver minimum fault levels and efficient levels of system strength from December 2025. Existing sources of system strength and forecast IBR, combined with the location, size and availability of existing and proposed units, were important factors in determining the technical suitability of the Balanced Technology portfolio. As outlined above, the four additional portfolios assume a greater use of a particular technology for meeting the minimum requirements, namely Portfolio 1A (Balanced Technology with BESS in Minimum), Portfolio 2 (Synchronous Condensers), Portfolio 3 (Clutched Gas Turbines) and Portfolio 4 (Pumped Hydro Energy Storage).

Once the desired technology types and quantities required to address system strength requirements were identified for each region under each portfolio, generic placeholder solutions, such as '2-hour 200 MW

[37] Powerlink, *PSCAD Assessment of the Effectiveness of Grid-forming Batteries*, April 2021, page 3.

grid-forming BESS CQ', were included in the portfolio. These generic placeholders can be described as 'tranches' of technology need that Powerlink will seek to fill via network solutions and contracting with proponents of non-network solutions. This approach:

- allowed Powerlink to use cost estimates from AEMO's IASR to estimate the costs for non-network solutions, thereby providing an independent and comparable basis for comparing solution costs;
- allowed Powerlink to progress the market modelling and detailed planning studies without explicitly selecting unique proponent solutions; and
- provides flexibility for Powerlink to pivot to more technically and/or commercially feasible options in an environment where the status of projects plays a significant role in the cost-benefit analysis of non-network solutions.

None of the portfolios involve additional solutions in Southern Queensland on account of there being sufficient coal generation online as part of the 2024 ISP assumptions. However, and as discussed further in sections 2.5 and 6.2, the level of coal generation in Queensland is the primary consideration for Powerlink's ability to meet minimum fault level requirements, and AEMO's forecasts suggest materially different retirement dates between the 2024 ISP and the 2023 System Strength Report (and the 2022 System Strength Report).

3.3. Ability for grid-forming BESS to contribute to minimum fault level requirements

As noted, the extent to which grid-forming BESS can be relied on to contribute to minimum fault level requirements is a key issue in this RIT-T.

Powerlink's May 2022 EOI for non-network solutions to address the fault level shortfall at the Gin Gin node noted that the contribution of grid-forming BESS toward fault level was 'limited', and that a combination of grid-forming BESS and synchronous machines could form a solution to the shortfall.[38]

More recently, in May 2024 AEMO highlighted the need for minimum fault level requirements across the NEM to be met by devices that can provide protection-quality levels of fault current. AEMO listed synchronous condensers, service contracts with existing hydro or thermal units, or the retrofit of those existing units, as examples of devices suitable for delivering fault level. Further, AEMO noted that remaining system strength needs to accommodate future IBR could be met by a variety of existing or new technologies, including grid-forming inverters, with the ability to stabilise their local voltage waveforms.[39]

Powerlink also acknowledges that, in the PADR for its System Strength RIT-T, Transgrid:

- observed that grid-forming batteries and inverter technologies are relatively novel and are yet to be deployed at significant scale;
- suggested comprehensive power system and protection studies need to be undertaken to confirm the effectiveness of grid-forming battery technology to provide system strength support;
- excluded grid-forming batteries from contributing to minimum fault level requirements until 2032/33; and
- indicated that the portfolio of 4.8 GW of grid-forming batteries supporting stable voltage waveform would provide Transgrid with a measured and safe approach to test and build confidence in the capabilities of grid-forming batteries for fault current support.[40]

[38] Powerlink, *Request for Power System Security Services in Central, Southern and Broader Queensland Regions*, May 2022, page 7.
[39] AEMO, *Update to the 2023 Electricity Statement of Opportunities*, May 2024, page 43.
[40] Transgrid, *Meeting System Strength Requirements in NSW*, PADR, June 2024, pages 35-36. Transgrid also referenced analyses of the ability of grid-forming technologies to provide system strength from Aurecon and Sandia National Laboratories.

Industry-wide actions are underway or have been recommended to progress the use of grid-forming inverter technologies to address system strength needs:

- The Performance of grid-forming BESS activity in AEMO's 2024/25 Engineering Roadmap Priority Actions Report will expand from studying the behaviour patterns of grid-forming BESS to include additional studies for grid-forming BESS Original Equipment Manufacturers (OEMs) not included in the original program.[41]
- AEMO is working with the Australian Renewable Energy Agency (ARENA) on pilot projects that may give further certainty and clarity to grid-forming capabilities implemented by different OEMs. Through joint planning activities, AEMO and SSSPs are also sharing learnings/approaches to the treatment of grid-forming services as a solution to system strength needs.[42]

Powerlink will continue to engage with industry stakeholders on these initiatives as part of its role as SSSP for Queensland.

To provide a potential pathway for the future inclusion of grid-forming BESS into the portfolio of solutions to contribute to minimum fault level requirements, Powerlink intends to investigate as part of the PACR a variant of Portfolio 2, and potentially Portfolio 3, that includes a grid-forming BESS for meeting the minimum system strength requirements (akin to how Portfolio 1A in the PADR is a variant of Portfolio 1). Powerlink also intends to investigate a sensitivity that assumes, not only that grid-forming BESS are technically feasible for assisting with the minimum requirements, but also that one or more reach committed/anticipated status to see whether that affects the overall preferred option for this RIT-T (akin to the sensitivity where the commitment status of proposed clutched gas turbines changes going forward).

To be clear, the additional analysis regarding grid-forming BESS being able to assist with the minimum requirements expected for the PACR is intended to be *economic-only* in nature, and Powerlink is not proposing to present any technical assessment of this potential function at that stage. While Powerlink plans to undertake significant work, and gain general learnings through practical operational experience, to assess and determine the technical feasibility of grid-forming BESS being able to assist with the minimum requirements going forward, Powerlink does not expect to be able to comment on this as part of the PACR as these efforts and learnings will be ongoing at that stage.

[41] AEMO, *Engineering Roadmap, FY2025 Priority Actions Report*, August 2024, pages 24 and 43.
[42] AEMO, *System Strength Framework Status Report*, August 2024, page 3.

4. Base Case

Key Points

- Consistent with the RIT-T requirements, the assessment undertaken in the PADR compares the costs and benefits of each portfolio to a 'do nothing' base case. The base case is the (hypothetical) projected case if no action is taken.
- For this RIT-T, the assumed absence of a credible option would result in significant planned levels of involuntary load shedding to end-use customers during periods of insufficient system strength.
- While these are not situations Powerlink plans to encounter, and the NER obligations and this RIT-T have been initiated specifically to avoid them, the assessment is required under the RIT-T to consider this base case as a common point of reference when estimating the net benefits of each portfolio.
- While the involuntary load shedding has been estimated under the base case, Powerlink has capped its inclusion in the cost-benefit analysis in order to allow for a meaningful comparison of the differences in costs and (other) market benefits across the five portfolio options assessed.[43]

4.1. Regulatory Requirements

The base case is a situation in which the RIT-T proponent does not implement a credible option to meet the identified need, and continues with business-as-usual (BAU) activities. BAU activities are ongoing, economically prudent activities that occur in the absence of a credible option being implemented.[44]

As noted in section 2.3, in the final determination for the System Strength Rule the AEMC indicated that SSSPs could not plan to meet system strength requirements through the use of constraints or AEMO directions given these are operational tools.[45]

4.2. Base Case to address system strength requirements

The base case for this RIT-T has been developed in line with the RIT-T framework and established planning principles for Queensland's power system. In this state of the world, no credible option is implemented to address system strength shortfalls, and BAU activities continue. The base case assumes compliance with key regulatory obligations and follows the stipulation that prevents Powerlink from planning for constraints or AEMO directions in operational timeframes.

In the absence of credible or operational solutions, the estimation of involuntary load shedding considers the following assumptions:

- The network is intact, meaning no significant network failures or planned outages were applied.
- Cross-border synchronous plants are kept at minimum number of units to minimise reliance on inter-network fault level.
- To ensure power system security and safety (requiring fast and reliable fault clearance by protection systems).

[43] The capped avoided involuntary load shedding under the base case from insufficient system strength is estimated to be *at least* $3 billion for each portfolio (and the capping approach is outlined in section 5.3 below).
[44] AER, *Regulatory Investment Test for Transmission*, August 2020, Glossary ('base case'); AER, *Application Guidelines, Regulatory Investment Test for Transmission*, October 2023, page 22.
[45] AEMC, *Efficient Management of System Strength on the Power System*, final determination, October 2021, page 16.

- Minimum synchronous fault levels were calculated for each forecast dispatch interval for the most onerous credible contingency for each system strength node and compared with their respective minimum post-contingent fault level threshold.

Market modelling inputs and assumptions such as generator retirement schedules, as well as associated forced and planned outage rates, are of material importance to the prevalence of minimum fault level violations and, consequently, the estimated involuntary load shedding. As such, AEMO's generator retirement schedules were incorporated from the economic retirement outcomes of the most recent ISP (2024), while forced and planned outage rates were based on the July 2023 IASR generator reliability and maintenance settings. Planned outages were scheduled occur during periods of greatest capacity reserve to minimise market impacts based on a scheduling algorithm developed by Ernst and Young (EY) as part of the market modelling (see chapter 5). Minimum post-contingent fault level thresholds were set by the 2023 AEMO System Strength Report. Involuntary load shedding is valued at the AER's Value of Customer Reliability (VCR) of $46,774 for Queensland per megawatt hour (MWh) in 2023 dollars for native load.

AEMO has a suite of operational tools to mitigate involuntary load shedding due to insufficient system strength, such as:

- reversing planned outages;
- constraining IBR plant;
- constraining non-scheduled generators;
- rooftop PV emergency backstop controls; and
- directing non-dispatched synchronous generators.

Given that these tools are not considered in the base case approach, the base case outcomes present a conservative estimate of system strength shortfalls and potential involuntary load shedding. This base case forms the foundation for assessing the need for additional system strength solutions and serves as a reference point to measure the potential benefits of various credible options in addressing system strength deficiencies.

Section 5.3 outlines how the benefit from avoiding involuntary load shedding under the base case from there being insufficient system strength has been estimated in this PADR. Importantly, the avoided involuntary load shedding from insufficient system strength does not affect the ranking of credible options assessed in this RIT-T.

5. Estimating the Market Benefits

Key Points

- Powerlink engaged EY to undertake market modelling to evaluate the difference in market benefits between each portfolio across seven categories of market benefit under the RIT-T for this PADR, including the recently added category for changes in Australia's greenhouse gas emissions.
- Drawing on hourly market modelling dispatch data from EY, Powerlink also undertook two post-processing modelling exercises to capture the avoided involuntary load shedding under the base case from there being insufficient system strength, and the impact of synchronous condenser losses on Australia's greenhouse gas emissions and NEM fuel costs.
- Only two of the market benefit categories estimated were found to be material in the modelling.
    - The post-processing assessment of avoided unserved energy estimates that all options avoid *at least* $3 billion (in present value terms) of unserved energy.
    - The wholesale market modelling undertaken by EY found that the portfolios provide between $900 million and $2,740 million (in present value terms) of benefits from avoiding or deferring capital and operating costs of generation and storage in the NEM due to the options being in place.
- Competition benefits, option value and changes in ancillary service costs are not expected to be material for this RIT-T and so have not been estimated.

5.1. Modelled market benefits from the portfolio options

The RIT-T requires categories of market benefits to be calculated by comparing the state of the world in the base case where no action is undertaken, with the state of the world with each of the credible portfolio options in place, separately.[46] The state of the world is essentially a description of the NEM outcomes expected in each case, and includes the type, quantity and timing of future generation and storage investment as well as unrelated future transmission investment (for example, that required to connect REZs).

Powerlink engaged EY to undertake wholesale market modelling to evaluate the following seven categories of market benefit under the RIT-T for this PADR:

- changes in involuntary load curtailment;
- changes in costs for other parties in the NEM;
- changes in fuel consumption in the NEM arising through different patterns of generation dispatch;
- changes in Australia's greenhouse gas emissions;
- changes in unrelated network expenditure;
- changes in voluntary load curtailment; and
- changes in network losses.

Drawing on the hourly market modelling dispatch data from EY, Powerlink also undertook two post-processing modelling exercises to capture two additional sources of market benefit in the assessment:

- the avoided involuntary load shedding under the base case from there being insufficient system strength under the base case; and

[46] See AER, *Regulatory Investment Test for Transmission*, August 2020, paragraph 24; AER, *Application Guidelines, Regulatory Investment Test for Transmission*, October 2023, pages 33-35 for a definition and discussion of states of the world in a RIT-T.

- the impact of synchronous condenser losses on Australia's greenhouse gas emissions and NEM fuel costs.

Both of these effects were not captured in the wholesale market modelling undertaken by EY.

Only the two of the market benefit categories estimated were found to be material in the modelling. Specifically:

- the post processing assessment of avoided unserved energy estimates that all options avoid *at least* $3 billion (in present value terms) of unserved energy;[47] and
- the wholesale market modelling undertaken by EY found that the portfolios provide between $900 million and $2,740 million (in present value terms) of benefits from avoiding or deferring capital and operating costs of generation and storage in the NEM due to the options being in place.

While the other five categories of market benefit listed above have been estimated, they are not considered material to the outcome of the assessment.[48]

EY used a wholesale market modelling approach similar to the approach used in the ISP to estimate the market benefits associated with each credible option included in this RIT-T assessment.[49] While section 5.2 below provides further detail on the wholesale market modelling approach taken to estimating the market benefits, it is also discussed in greater detail in EY's market modelling report.

5.2. Market modelling to estimate wholesale market benefits

EY applied a linear optimisation model that performed hourly, time-sequential, long-term modelling for the NEM to estimate categories of wholesale market benefits expected under each of the options. Specifically, EY undertook long-term investment planning to identify the least-cost generation, storage and unrelated transmission infrastructure development schedule, while meeting demand requirements, policy objectives, and technical generator and network performance limitations.

Powerlink undertook analysis of system strength based on the hourly dispatch outcomes from the market modelling to identify load shedding that may be required due to shortfalls in system strength in the base case.

These exercises are consistent with industry-accepted methodology, including within AEMO's ISP.

Figure 5.1 illustrates the interactions between the key modelling exercises, as well as the primary party responsible for each exercise and/or where the key assumptions have been sourced.

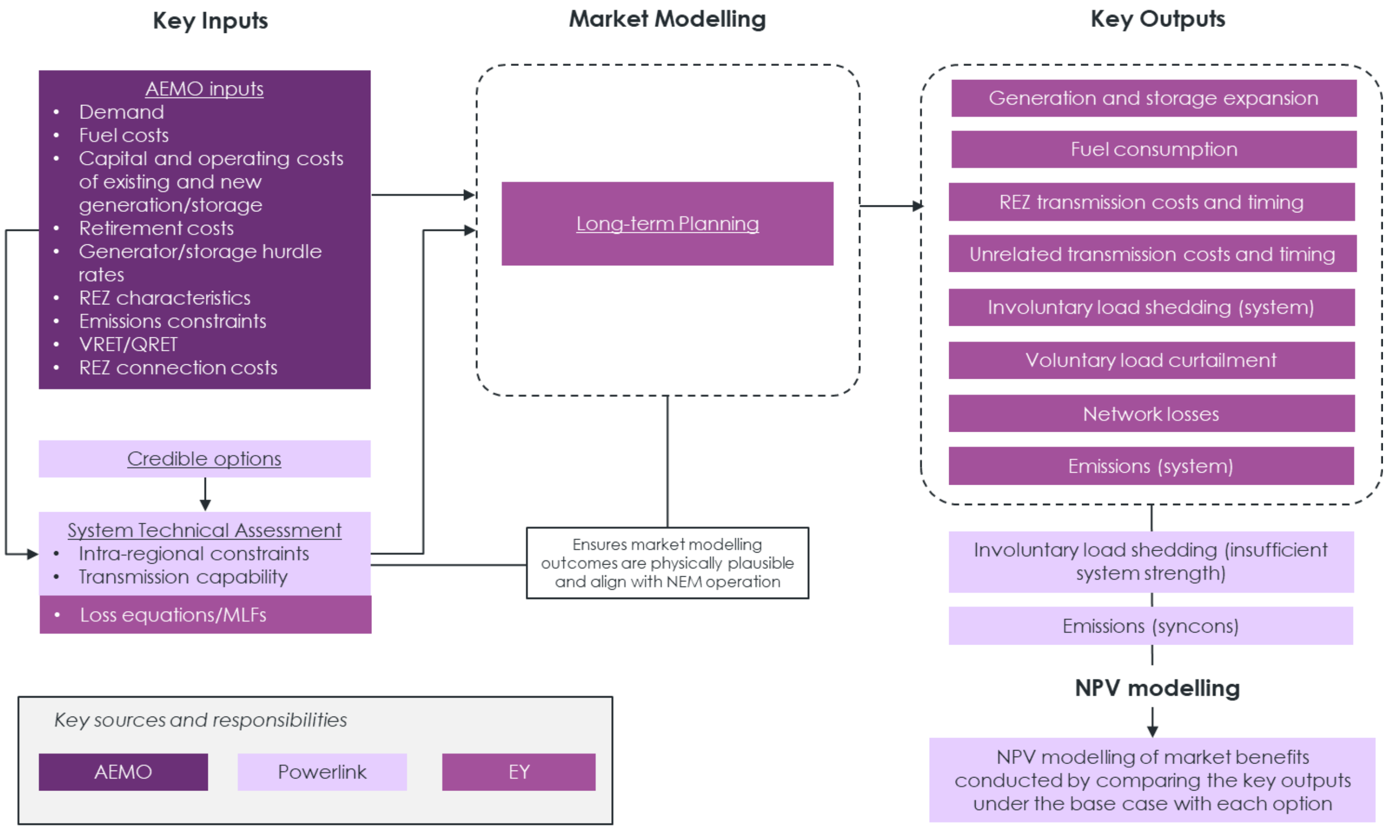
---

[47] Note that 'at least' is used here, and throughout the PADR, on account of the approach taken to capping the avoided unserved energy in the assessment in order to allow for a meaningful comparison across options (as outlined in section 5.3). If the full unserved energy is added to the analysis, the expected net benefit of all portfolios would be significantly greater.

[48] While, technically, the post-processing assessment of avoided unserved energy is also not material under the RIT-T (since it is the same for all portfolios), it is mentioned above as it is such a significant source of market benefit for this RIT-T and should be considered material from the perspective of Queensland electricity consumers.

[49] The RIT-T requires that in estimating the magnitude of market benefits, a market dispatch modelling methodology must be used, unless the TNSP can provide reasons why this methodology is not relevant. See AER, *Regulatory Investment Test for Transmission*, August 2020, paragraph 15(b).

Figure 5.1: Overview of the modelling processes and methodologies



The accompanying market modelling report provides additional detail on these modelling exercises, as well as the key modelling assumptions and approach adopted more generally.

5.3. Post-processing modelling to estimate two sources of market benefit

The approach to the two post-processing modelling exercises undertaken by Powerlink is outlined in the sections below.

Avoided involuntary load shedding under the base case from there being insufficient system strength

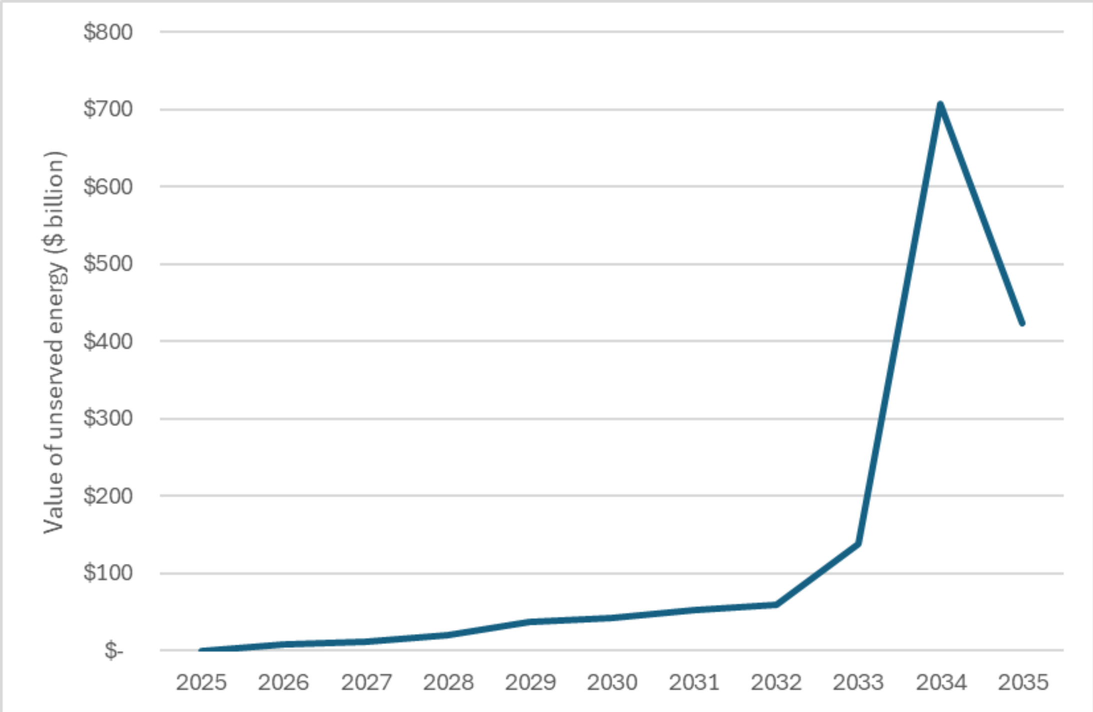
Under the base case where no action is taken to meet Queensland's minimum fault level and efficient level system strength requirements, there would be a significant deficit in system strength because of retiring coal generation and growing renewable connections.

In this hypothetical future, it is expected that AEMO would use operational tools to minimise market impacts; however, as directed by the AEMC these operational tools are not to be assumed at this planning stage (see section 2.3). If the minimum level of system strength is not met, voltage control and protection systems may not operate correctly, which would lead to public safety concerns, cascading failures in the transmission network and, potentially, widespread and extensive power outages. The analysis continues to assume that AEMO would require the safe and secure operation of the power system, thereby requiring the disconnection of parts of the network imposing safety and security risks.

Powerlink has not included in the assessment the substantial unserved energy that would be expected to arise under the base case if no action is taken; for example, the unserved energy associated with catastrophic failure of not meeting the minimum level, or significant breaches in the efficient level. This is due to not knowing exactly how it would unfold and all portfolio options being explicitly designed to avoid it in the same way; that is, it is not material to the RIT-T assessment.

A summary of the exponentially increasing expected involuntary load shedding costs (in undiscounted 2022/23 dollars) under the base case, until 2035, is shown below.[50,51]

Figure 5.2: Value of involuntary load curtailment under base case (undiscounted $2022/23)



The small amount of unserved energy in the early years, before coal exits, is due to an assumption that existing units would only provide system strength under the base case when incentivised to do so via the wholesale energy market. Powerlink considers this consistent with the system strength framework and that it is immaterial to the assessment since all portfolios avoid this unserved energy equally.

While all portfolio options are designed to avoid these outcomes under the base case equally, only the avoided unserved energy for the portfolios until (and including) September 2026 was included. This approach has been developed to demonstrate that the portfolios are expected to have strongly positive net benefits (primarily from avoiding this substantial expected unserved energy under the base case), whilst also allowing for a meaningful comparison across options; that is, by not allowing the common value of avoided unserved energy to swamp the

[50] While the base case level of valued unserved energy is very high, it would not be proportionate for Powerlink to try to estimate it with any greater degree of accuracy as it does not have a material impact on the analysis since all options avoid this unserved energy equally. Further, the *value* of unserved energy under the base case is so high in part due to the general statewide VCR being designed to capture the cost of shorter duration outages, resulting in an over-estimate of the true value, when there are broad-based system level issues such as system strength that result in mass load-shedding for longer durations.
[51] Note that the decrease shown for 2035 is because only 7 months of data is shown.

other benefit (and cost) differences across the portfolios. Powerlink considers this is consistent with the approach adopted in other RIT-Ts, the Energy Networks Australia (ENA) RIT-T Handbook and advice provided to the AER.[52]

The modelling estimates the MWh of unserved energy in each modelling interval over the modelling period as a result in violations in minimum fault level requirements, and then applies a VCR (expressed in $/MWh) to quantify the estimated value of avoided unserved energy for each option (subject to the approach to capping the avoided unserved energy outlined above). Powerlink has adopted the AER's most recent assumptions for the Queensland VCR for the purposes of this assessment. The capped avoided involuntary load shedding under the base case from insufficient system strength is estimated to be *at least* $3 billion for each portfolio.[53]

The assessment focussed on the expected level of involuntary load shedding under the base case and did not attempt to also model the costs of AEMO directing existing synchronous generators to operate, or to constrain renewable generation to maintain system security. While Powerlink considers that, on a per modelling interval basis, this means that the estimated amount of involuntary load shedding is overestimated, this is a proportionate approach and not material to this RIT-T due to the majority of the avoided involuntary shedding being excluded from the analysis (as outlined above).

The impact of synchronous condenser losses on Australia's greenhouse gas emissions and NEM fuel costs

Powerlink also modelled the operational losses arising from the operation of synchronous condensers, as well as hybrid plant operating in synchronous condenser mode, via a post-processing process. The key impact of these losses is the additional greenhouse gas emissions and energy consumption resulting from other sources needing to compensate for the energy use of these plant.

Powerlink valued this impact for synchronous condensers, which is actually a negative market benefit impact (a 'market cost'), using the average Queensland emissions intensity factor combined with the assumed operational losses of these units. Powerlink has also valued the average marginal fuel consumption to compensate for the losses incurred for utilising the synchronous condensers or synchronous condenser mode at approximately $50/MWh (which has been estimated as the volume weighted marginal short-run marginal cost over the year (including coal)).

Powerlink consider this is an overestimate of the impact, as at many times in the year the marginal generating unit will be renewable and have a much lower/zero emissions intensity factor than the state average. However, this a proportionate approach and is not material in the wider PADR assessment. Specifically, Portfolio 2 (Synchronous Condensers) is found to be preferred over the other portfolios at this stage, and so any more refined approach to modelling this impact would be expected to decrease the market cost associated with synchronous condensers and thus further strengthen the conclusion that Portfolio 2 is preferred.

5.4. Market benefits not expected to be material

Given the portfolios considered in this PADR do not address network constraints between competing generators, and all portfolios are expected to meet the system strength requirements equally, competition benefits are not expected to be material for this RIT-T assessment.

---

[52] Darryl Biggar, *An Assessment of the Modelling Conducted by TransGrid and Ausgrid for the 'Powering Sydney's Future' Program*, report for the AER, May 2017, pages 12-16.

[53] Note that 'at least' is used here, and throughout the PADR, on account of the approach taken to capping the avoided unserved energy in the assessment in order to allow for a meaningful comparison across options. If the full unserved energy is added to the analysis, the expected net benefit of all portfolios would be significantly greater.

While option value has not been formally quantified (on account only one scenario being considered relevant for the assessment), each of the portfolios, and the reopening triggers proposed (see section 7.2), provide flexibility to pivot to lower cost solutions if future circumstances change.

While the cost of Frequency Control Ancillary Services (FCAS) may change as a result of changed generation dispatch patterns and changed generation development following any increase to transfer capacity from the portfolios, Powerlink considers that changes in FCAS costs are not likely to be materially *different between the portfolios* under consideration due to:

- the quantity of grid-forming BESS being the same across all portfolios (and only marginally more for Portfolio 1A); and
- any additional market benefits expected for Portfolio 4 (due to the additional PHES) are not expected to outweigh the additional costs associated with that portfolio.

Powerlink does not consider it would be proportionate to develop a model for FCAS for this RIT-T in light of the above two bullet points.

Similarly, it is unlikely there are material changes between portfolio options in relation to NSCAS, or System Restart Ancillary Services (SRAS) costs due to the portfolios being considered.

6. Cost-Benefit Analysis

Key Points

- The Net Present Value (NPV) results find that Portfolio 2 (Synchronous Condensers) has the greatest expected net economic benefit over the assessment period (which extends to 2049/50).
- While Portfolio 2 has the lowest estimated gross benefits, it has significantly lower costs than all other portfolios, which is the key differentiator between the portfolios at this point in time (and total capital and operating costs vary between $2.0 billion and $5.7 billion, in present value terms, across the portfolios).
- The conclusion that Portfolio 2 is the top-ranked option is found to be robust to a range of sensitivity tests, including:
    - a delay to the completion of the Borumba PHES;
    - changes to the assumed cost of gas;
    - changes to the capital costs of BESS;
    - changes to the capital cost of synchronous condensers; and
    - alternate commercial discount rate assumptions.
- However, if the status of clutched gas turbines changes to committed or anticipated going forward, then Portfolio 3 (Clutched Gas Turbines) is the preferred option overall. This highlights the significance of the status of projects to how the costs of solutions are assessed and how, for this RIT-T, the impact this is found to have on the overall preferred option.[54]
- Further, there are additional 'low regret' Southern Queensland solutions that provide prudent insurance against more accelerated coal retirement in Southern Queensland.
- Only the prudent and efficient capital costs of the network components of the preferred option will factor into the Regulatory Asset Base (RAB) following this RIT-T. That is, it is not the total capital costs (across network and non-network solutions), nor the estimated net economic benefits, that factor into the RAB.

6.1. Net Present Value results

Powerlink has undertaken a cost-benefit analysis in accordance with the requirements of the RIT-T Instrument and RIT-T Application Guidelines. Details of the key inputs and assumptions used for the cost-benefit analysis are in Appendix E.

As outlined in section 3.1, the five portfolios *differ* in terms of the following components for meeting the minimum fault level requirements:

- Portfolio 1 (Balanced Technology):
    - Six new synchronous condensers in Central Queensland.
    - Two future clutched gas turbines in Central Queensland.
- Portfolio 1A (Balanced Technology: BESS in Minimum):
    - Five new synchronous condensers + one (large) grid forming BESS in Central Queensland.
    - Two future clutched gas turbines in Central Queensland

[54] This also highlights the difference between the project benefits quantified under the RIT-T and those calculated by the proponent of the project making the investment decision.

- Portfolio 2 (Synchronous Condensers):
    - Eight new synchronous condensers in Central Queensland.
- Portfolio 3 (Clutched Gas Turbines):
    - Four new synchronous condensers in Central Queensland.
    - Four future clutched gas turbines in Central Queensland.
- Portfolio 4 (Pumped Hydro Energy Storage):
    - Three new synchronous condensers in Central Queensland.
    - Two future clutched gas turbines in Central Queensland.
    - Three planned pumped hydro energy storage units in Central Queensland.

Each portfolio also includes a number of *common* solutions for meeting both the minimum and efficient system strength requirements, as summarised in section 3.1 above.

Table 6.1 and Figure 6.1 below detail the NPV components of each portfolio, and show that Portfolio 2 (Synchronous Condensers) has the greatest estimated net benefit of the credible options. Portfolio 2 is found to deliver approximately $128 million greater net benefits than the second ranked option (Portfolio 1).

Network support payments to providers of non-network solutions are treated as a transfer under the RIT-T and are not represented in Table 6.1 in order to preserve confidentiality.

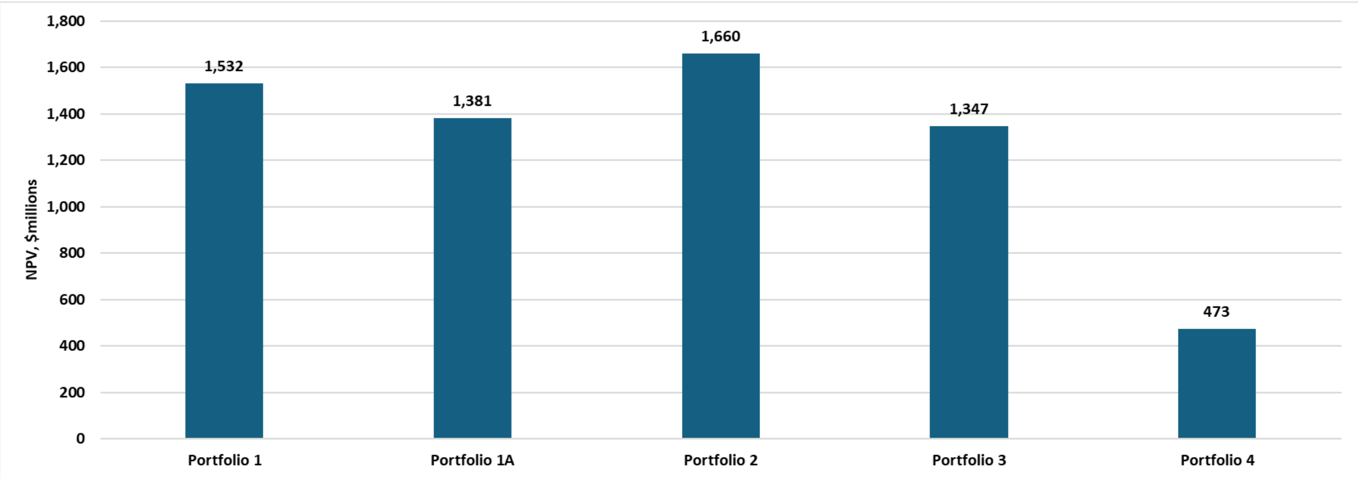
Table 6.1: NPV of the portfolio options (2023 dollars, millions)

Portfolio	Description	Costs		Gross economic benefits			Net economic benefit	Rank
		Capex	Opex	Wholesale Market Benefits + emissions	Avoided USE*	Syncon Losses**		
1	Balanced Technology	-$2,047	-$363	$917	$3,090	-$66	$1,532	2
1A	Balanced Technology (BESS in Min.)	-$2,712	-$445	$1,508	$3,090	-$60	$1,381	3
2	**Synchronous Condensers**	**-$1,720**	**-$282**	**$636**	**$3,090**	**-$65**	**$1,660**	**1**
3	Clutched Gas Turbines	-$2,336	-$433	$1,089	$3,090	-$64	$1,347	4
4	Pumped Hydro Energy Storage	-$5,149	-$530	$3,111	$3,090	-$50	$473	5

** Note that this avoided unserved energy reflects the post-processing assessment by Powerlink of the avoided unserved energy during periods of insufficient system strength under the base case (and has been capped in the analysis). It is separate from the general system unserved energy estimated by EY in the wholesale market modelling (which is immaterial).*

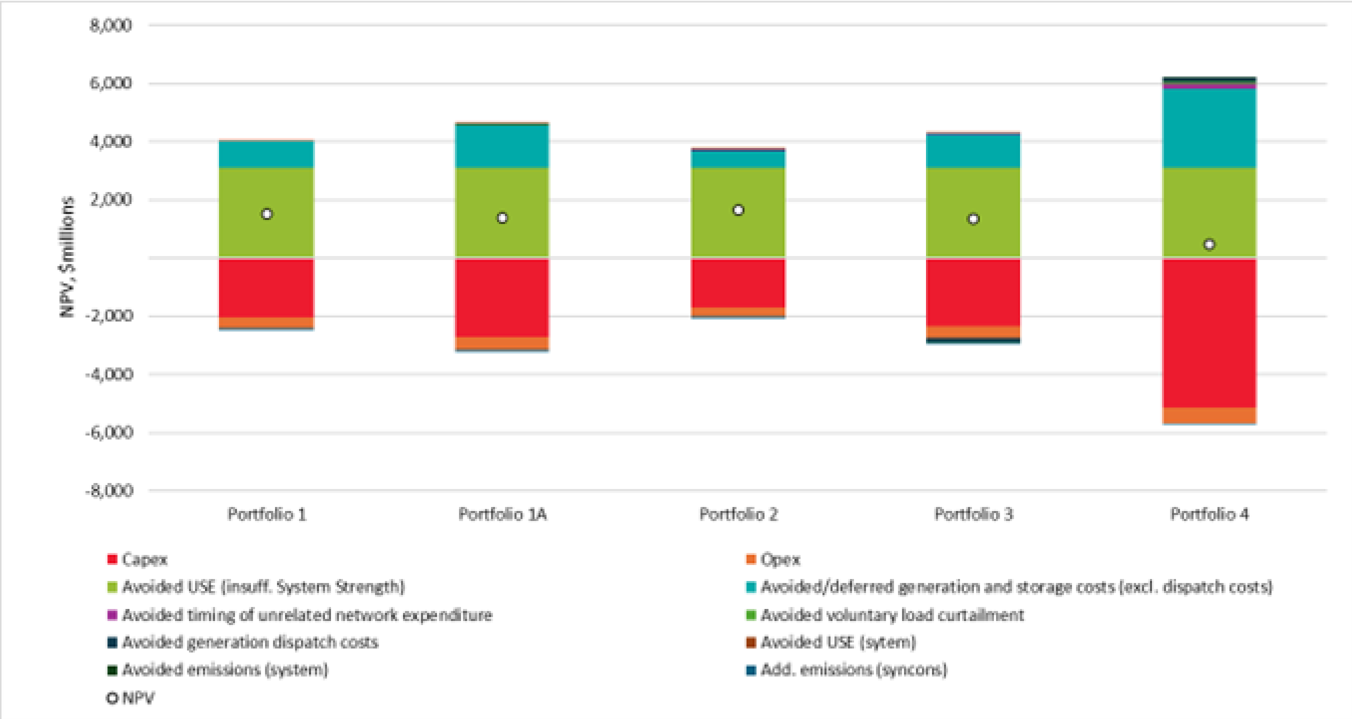
*** This captures the value of the additional emissions from the use of units in synchronous condensers mode due to the energy they consume. It has been estimated via the post-processing assessment by Powerlink, as opposed to as part of the wholesale market modelling undertaken by EY. The value of the additional fuel costs associated with the use of synchronous condensers has been included in the opex column (and is immaterially different between the portfolios).*

Figure 6.1: NPV of portfolio options (2023 dollars, millions)



While Portfolio 2 has the lowest estimated gross economic benefits, it has significantly lower costs than all other portfolios, which is the key differentiator between the portfolios at this point in time.[55]

Figure 6.2: Breakdown of the NPV of the portfolio options (2023 dollars, millions)



The key findings from the NPV assessment of each option portfolio are:

- The cost differences across the portfolios are a key driver of the portfolio rankings, and total capital and operating costs vary between $2.0 billion and $5.7 billion, in present value terms, across the portfolios.
    - Under the RIT-T framework, the full capital and operating costs of solutions is included in the cost-benefit analysis when solutions are not already in service, committed or anticipated. This means, for instance, that the full capital cost of BESS that are not existing, committed or anticipated projects is included in the analysis even though the projects would be used to provide services other than just system strength.
    - Given the criticality of the status of projects to how the costs of solutions are assessed in the RIT-T, Powerlink has investigated a sensitivity that assesses whether the overall preferred portfolio changes if the project status of clutched gas turbines changes going forward (discussed below).
- The avoided involuntary load shedding under the base case from there being insufficient system strength, estimated via the post-processing process, is the largest category of benefit for all portfolios, estimated to be *at least* $3 billion for each portfolio.[56]

[55] While another key differentiator across the portfolios is the significantly greater avoided costs for non-RIT-T proponents for Portfolio 4 (shown in turquoise in the figure above), these are outweighed by its significantly greater capital costs.
[56] Note that 'at least' is used here, and throughout the PADR, on account of the approach taken to capping the avoided unserved energy in the assessment to allow for a meaningful comparison across options (as outlined in section 5.3). If the full unserved energy is added to the analysis, the expected net benefit of all portfolios would be significantly greater.

    - All options are estimated to avoid load shedding due to not meeting minimum levels of system strength under the base case equally.
- Avoided/deferred generation and storage costs are the largest category of benefit estimated via the wholesale market modelling for all portfolios, making up between $0.6 billion and $2.7 billion, in present value terms, across the portfolios.
    - This is driven by the additional storage, gas and/or PHES units (as part of the portfolios) reducing the need to build more capacity to meet demand.
    - The wholesale market modelling finds that under Portfolio 2 wind capacity is primarily deferred or replaced by grid-forming BESS, solar and open cycle gas turbines.
- All other categories of benefits are found to be immaterial in the analysis (as shown in the figure above).

Powerlink notes that only the prudent and efficient capital costs of the network components of the preferred option will factor into the RAB following this RIT-T. That is, it is not the total capital costs (across network and non-network solutions), nor the estimated net economic benefits, that factor into the RAB.

6.2. Sensitivity analysis

Powerlink has tested the robustness of the results of the NPV analysis above to changes in a number of key variables and assumptions. These tests have been designed to investigate whether the preferred portfolio option changes under these alternate key assumptions.

The range of factors tested as part of the sensitivity analysis in this report are:

- Clutched gas turbines becoming committed or anticipated (under the RIT-T) going forward;
- A more accelerated assumed coal retirement schedule for Southern Queensland;
- A delay to the completion of the Borumba PHES;
- Changes to the assumed cost of gas;
- Changes to the capital costs of BESS;
- Changes to the capital cost of synchronous condensers; and
- Alternative commercial discount rate assumptions.

Powerlink has not investigated sensitivities:

- involving higher or lower VCR or Value of Emissions Reduction (VER) values as the value of avoided unserved energy and emissions are not found to be materially different across the portfolios (and thus sensitivities on these variables will not change the ranking of the options); or
- that vary the assumed non-network capital (or operating costs), but intend to do so in the PACR (where it is expected refined costs for solutions will be available, informed by proponents).

Only the sensitivity on the change in timing of retirement/de-commitment for coal generating units was investigated across all portfolios. All other sensitivities were only modelled on Portfolio 1A and tested against the base case in order to gauge the effect on gross benefits (which led to no further portfolios being modelled, as outlined in the sections below).

Clutched gas turbines and/or PHES becoming committed or anticipated (under the RIT-T) going forward

Powerlink also investigated whether the overall preferred portfolio would change *if the project status of proposed clutched gas turbines changes going forward*; that is, assuming that currently proposed projects become committed or anticipated in the future.

Under these assumptions, Portfolio 3 (Clutched Gas Turbines) becomes the preferred option overall. Specifically:

- Portfolio 3 is found to have estimated net benefits of $2.53 billion (in present value terms), which are $388 million more than the second-ranked portfolio under this sensitivity (Portfolio 1) – Portfolio 2 falls to fourth overall and is ranked behind Portfolio 1 (and 1A) due to it involving less clutched gas turbines than those two portfolios.
- This outcome is driven by the costs of the clutched gas turbine component of the options falling significantly if they are considered committed or anticipated – for example, in present value terms the total capital cost of Portfolio 3 falls from approximately $2.34 billion to $1.34 billion.

Given this finding, Powerlink intends to closely monitor the development of the proposed gas turbines, and has proposed reopening triggers (see section 7.2) that would allow us to pivot to these solutions (from synchronous condensers), if they reach committed or anticipated status under the RIT-T.

The above sensitivity has adopted a proportionate assumption for the PADR that the cost of the clutches, in addition to the wider gas turbine plant costs, are committed or anticipated. Powerlink intend to further refine this in the PACR and investigate this sensitivity assuming that only the gas turbine plant costs are assumed to be committed or anticipated under the base case and the clutch cost is included in the portfolio (where appropriate).

While a similar sensitivity for Portfolio 4 (PHES) has not been investigated as part of the PADR, a similar conclusion may hold if these proposals are assumed to become committed or anticipated in the future. However, confirming this position will require significant additional market modelling (which has not been able to be accommodated for the PADR) and so Powerlink intends to investigate it further as part of the PACR, if appropriate to do so.

Similarly, Powerlink has not investigated this type of sensitivity for Portfolio 1A (where grid-forming BESS are assumed to be technically feasible for assisting with the minimum requirements) as part of the PADR and intend to consider this further in the PACR.

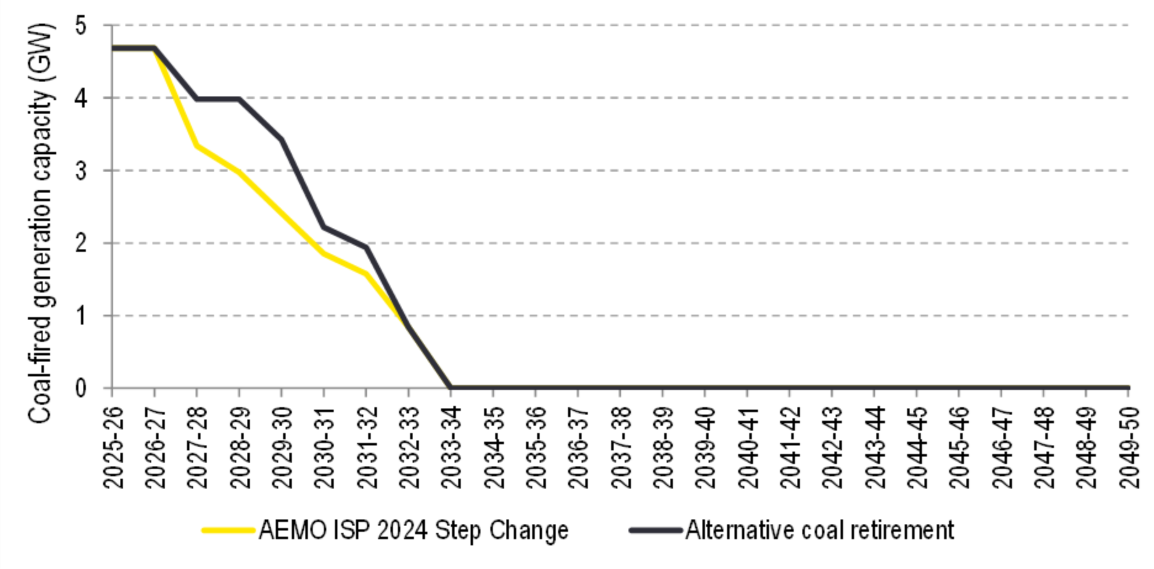
A more accelerated assumed coal retirement schedule for Southern Queensland

The level and location of coal generation in Queensland over the period December 2025 to December 2030 are primary considerations for Powerlink's ability to meet minimum fault level requirements, and AEMO's forecasts suggest materially different retirement dates between the 2024 ISP and the 2023 System Strength Report. Section 2.5 and Appendix C provide additional detail on the two AEMO reports, their respective approaches to forecast coal retirements and why Powerlink considers that the 2023 System Strength Report forecasts are appropriate for also considering as part of this RIT-T.

The core analysis in this PADR (shown in section 6.1 above) aligns its assumptions regarding Queensland coal retirement with the 2024 ISP, as required under the RIT-T framework. Powerlink has also investigated a sensitivity that aligns its assumptions with the 2023 System Strength Report, including the more accelerated retirement profile for coal generation in Southern Queensland, which could occur is Central Queensland coal generators remain online instead of Southern Queensland coal generators going forward.

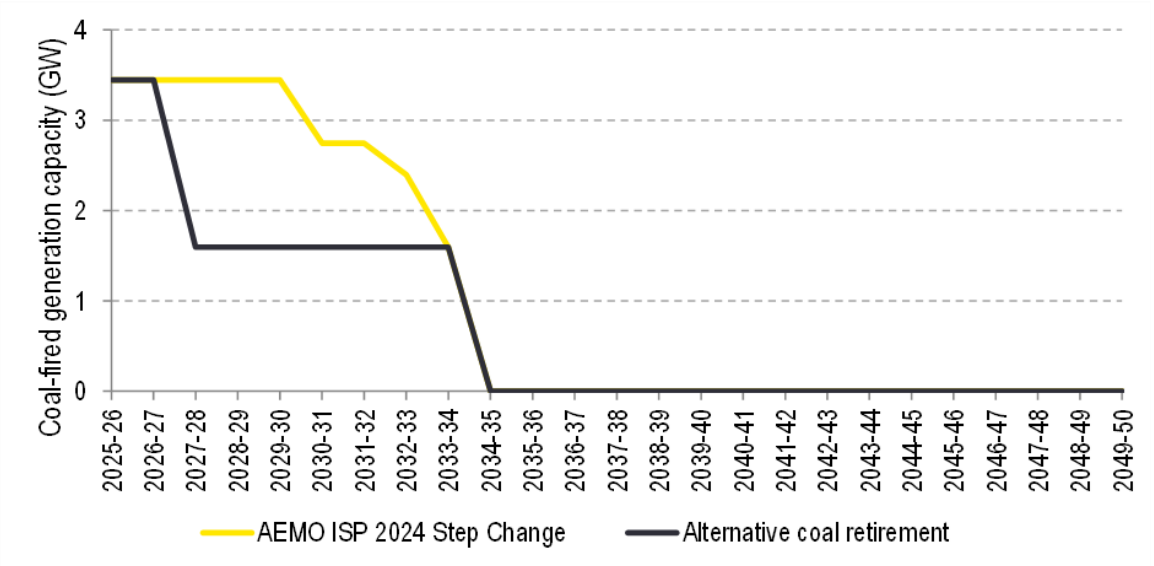
A comparison of the 2024 ISP and 2023 System Strength Report capacity of coal-fired generation for both Central and Southern Queensland is shown in Figures 6.3 and 6.4 below.

Figure 6.3: Coal-fired generation capacity in Central Queensland by year across the 2024 ISP Step Change and the alternative coal retirement sensitivity



Source: EY, Gross Market Benefit Assessment of Queensland System Strength Portfolios, September 2024, page 11 (figure 3).

Figure 6.4: Coal-fired generation capacity in Southern Queensland by year across the 2024 ISP Step Change and the alternative coal retirement sensitivity

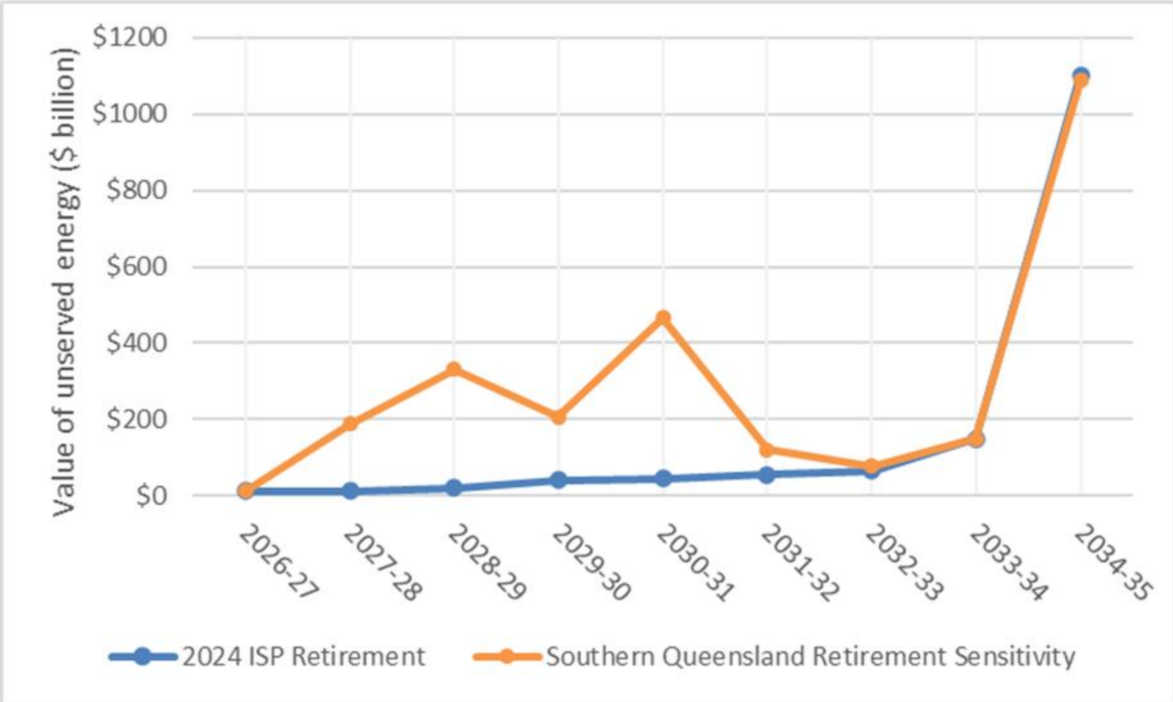


Source: EY, Gross Market Benefit Assessment of Queensland System Strength Portfolios, September 2024, page 11 (figure 4).

A key difference under this sensitivity, compared to the core analysis, is that there is forecast to be a significant amount of unserved energy in Southern Queensland under the base case due to there being insufficient system strength in this region due to the earlier retirement of coal generation under the 2023 System Strength Report assumptions. To avoid this, and ensure that the minimum fault level requirements are met, each of the portfolios need to include contracts for non-network solutions with existing and planned assets in Southern Queensland. The details about which specific projects are assumed to be contracted with have been redacted to preserve confidentiality and to protect commerciality.

Figure 6.5 shows a comparison of estimated unserved energy costs between the 2024 ISP base case and the retirement sensitivity for Southern Queensland. It is clear there is significant amounts of unserved energy between 2027 and 2033 within Southern Queensland under this sensitivity, demonstrating the need for Powerlink to take action in Southern Queensland.

Figure 6.5: Estimated unserved energy in Southern Queensland under the 2024 ISP Step Change and the alternative coal retirement sensitivity



The solutions included for Southern Queensland would not differ by portfolio and are considered independent to the other solutions included for Central and Northern Queensland; that is, their inclusion in the portfolios would not offset any other solutions. The inclusion of these solutions will therefore not affect the ranking of the options, and the wholesale market modelling and post-processing have been limited to the preferred option for this sensitivity to demonstrate that their inclusion is expected to be net beneficial in a state of the world with more accelerated coal retirement than that forecast in the 2024 ISP.

Under these assumptions, contracting with these projects is strongly justified in Southern Queensland to avoid the significant amount of unserved energy that could otherwise occur there.

In present value terms, the additional Southern Queensland components increase the estimated total cost (that is, capital and operating costs) of Portfolio 2 by $83 million (in present value terms), but avoids the extremely high potential value of unserved energy in Southern Queensland (which more than outweighs the increase in costs).

The additional Southern Queensland components required if coal generators retire faster than forecast in the 2024 ISP are both relatively low-cost solutions (both outright and on a $/MVA basis) and only increase the total cost (that is, capital and operating costs) by approximately 4.3% for Portfolio 2 in present value terms.

Given the uncertainty surrounding the retirement, as well as decreased operation during times when it is uneconomic, for coal generators in Queensland, and the consequences of under-investing in system strength solutions, Powerlink considers the addition of these solutions to the ultimately preferred option to be a prudent 'low regrets' decision.

The solutions required in Southern Queensland to meet the meet minimum fault level requirements under this state of the world and their inclusion in the ultimately preferred option for this RIT-T, based on the analysis presented in this sensitivity, is a key aspect Powerlink is seeking stakeholder views on as part of this PADR.

While the 2023 System Strength Report suggests a marginally slower retirement profile for Central Queensland than the 2024 ISP, the scope or timing of components included Central Queensland under this sensitivity has not been amended as this the sensitivity has been designed to test and develop a prudent risk management approach for Southern Queensland. In addition, Powerlink does not consider that any impact on the Central Queensland components would be material in the analysis and would only defer solutions a year or two (and equally across the portfolio).

Sensitivity on the completion of the Borumba PHES

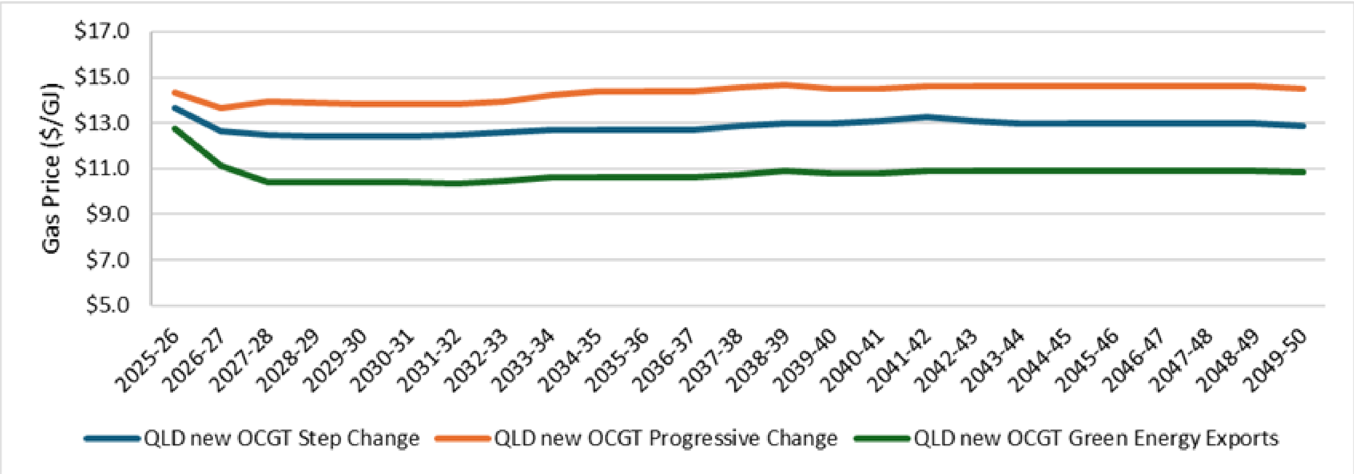
The Borumba PHES is part of the SuperGrid Blueprint (and ISP) and will provide material amounts of system strength. However, being a major project, there is naturally uncertainty surrounding project delivery and ultimate commissioning.

Powerlink has therefore also investigated a sensitivity that delays commissioning by two years. This has been designed as a general test of the impact of the project being delayed. The sensitivity covers Portfolio 1A (and the base case) and finds that the delayed timing of Borumba PHES has an immaterial impact on the overall estimated net benefits (increasing them approximately 4.8%). The sensitivity was consequently not expanded to cover the other portfolios, and it is not expected that doing so would result in a change in the preferred option overall.

Changes to assumed cost of gas

In addition to the core modelling, which used the 2024 ISP Step Change scenario assumptions, Powerlink also investigated sensitivity tests that increase and decrease the assumed cost of gas by adopting the gas cost parameters from the Progressive Change and Green Energy Exports ISP scenarios, respectively.

Figure 6.6: Gas price ($/gigajoule, real July 2023 dollars), comparison of Step, Progressive and Green Energy Export Scenarios

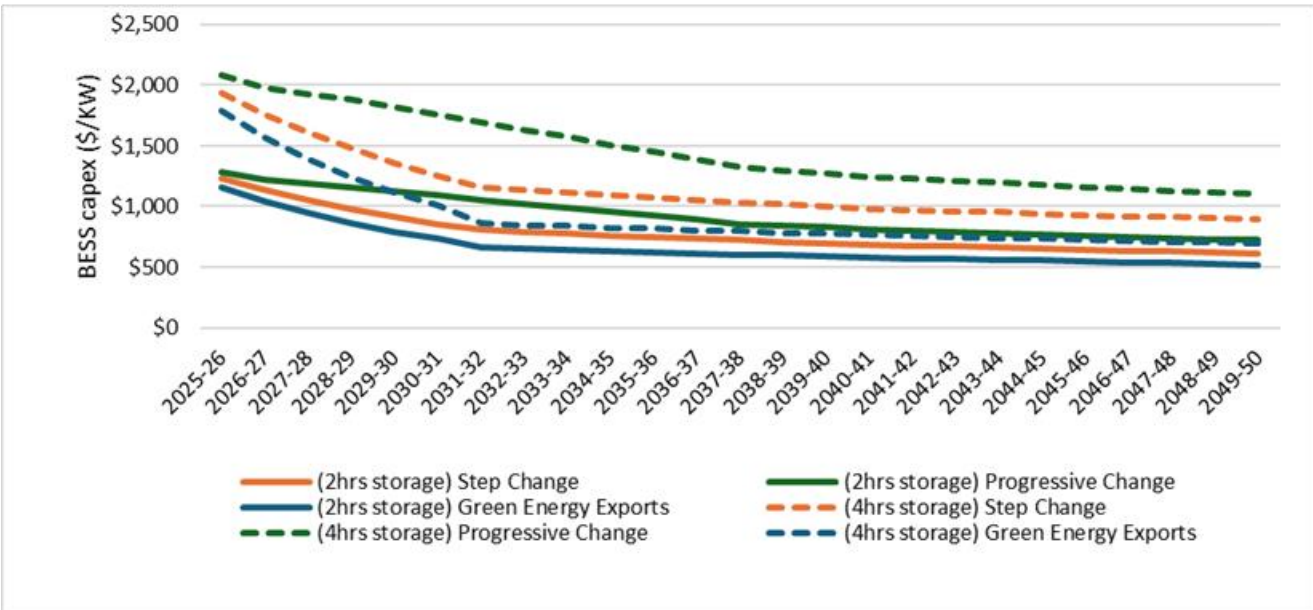


The results of these tests show that the results of the assessment are highly insensitive to the assumed cost of gas given avoided generation dispatch costs are an immaterial category of market benefit in the core analysis. Specifically, adopting the gas cost assumptions from the Green Energy Exports and Progressive Change scenarios resulted in less than a 0.5% change in the overall estimated net benefits of Portfolio 1A. The sensitivity was consequently not expanded to cover the other portfolios, and it is not expected that doing so would result in a change in the preferred option overall.

Changes to capital cost of BESS

Similar to the assumed cost of gas sensitivities, Powerlink also investigated sensitivity tests that increase and decrease the assumed capital cost of BESS in the analysis by adopting the assumed BESS build cost parameters from the Progressive Change and Green Energy Exports ISP scenarios, respectively, for different duration BESS.

Figure 6.7: BESS capital cost ($/kilowatt, real July 2023 dollars), comparison of Step, Progressive and Green Energy Export Scenarios



This sensitivity was undertaken only for Portfolio 1A since it is the only portfolio that includes a BESS within its minimum level portfolio and all portfolios have the same composition of components to meet the efficient level.

The market modelling results showed that for Portfolio 1A:

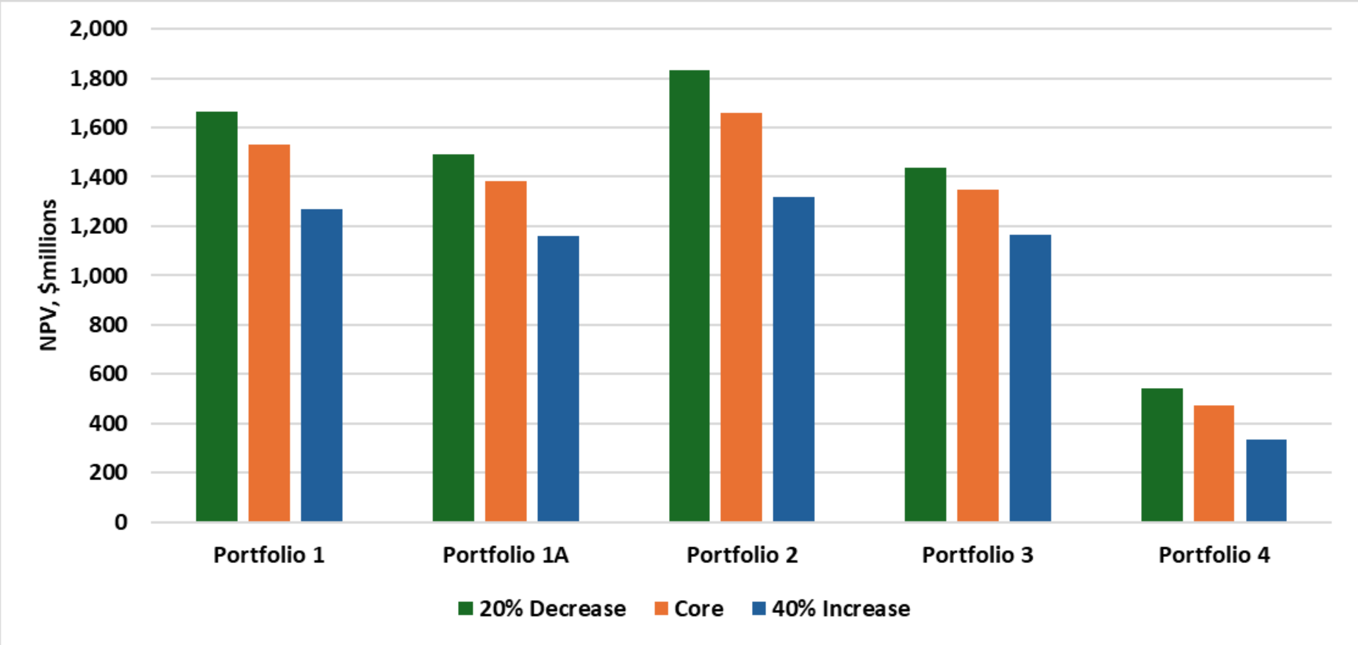
- decreasing BESS build costs to align with the Green Energy Export scenario led to a decrease of $173 million in forecast gross market benefits compared to the core scenario.
- increasing BESS build costs to align with the Progressive Change scenario resulted in only a minor decrease of $2 million in forecast gross market benefits compared to the core scenario.

As BESS are only included in the efficient level (excluding the BESS in Portfolio 1A) which is common across all portfolios the change in the capital expenditure component would consistent across all portfolios. Powerlink does not consider these observations material overall as, even under the low BESS build cost sensitivity, Portfolio 1A would not be ranked ahead of the preferred option (Portfolio 2).

Changes to the capital cost of synchronous condensers

Figure 6.8 presents the results of assuming 40% higher and a 20% lower assumed synchronous condenser costs, consistent with the 'Class 5' nature of the estimates (as outlined in Appendix D). These boundaries align with a class 5 estimate according to the Association for the Advancement of Cost Engineering (AACE) classification system. The results show that Portfolio 2 continues to be preferred, even under higher assumed synchronous condenser costs.

Figure 6.8: NPV of portfolio options – comparison between synchronous condenser costs (2023 dollars, millions)



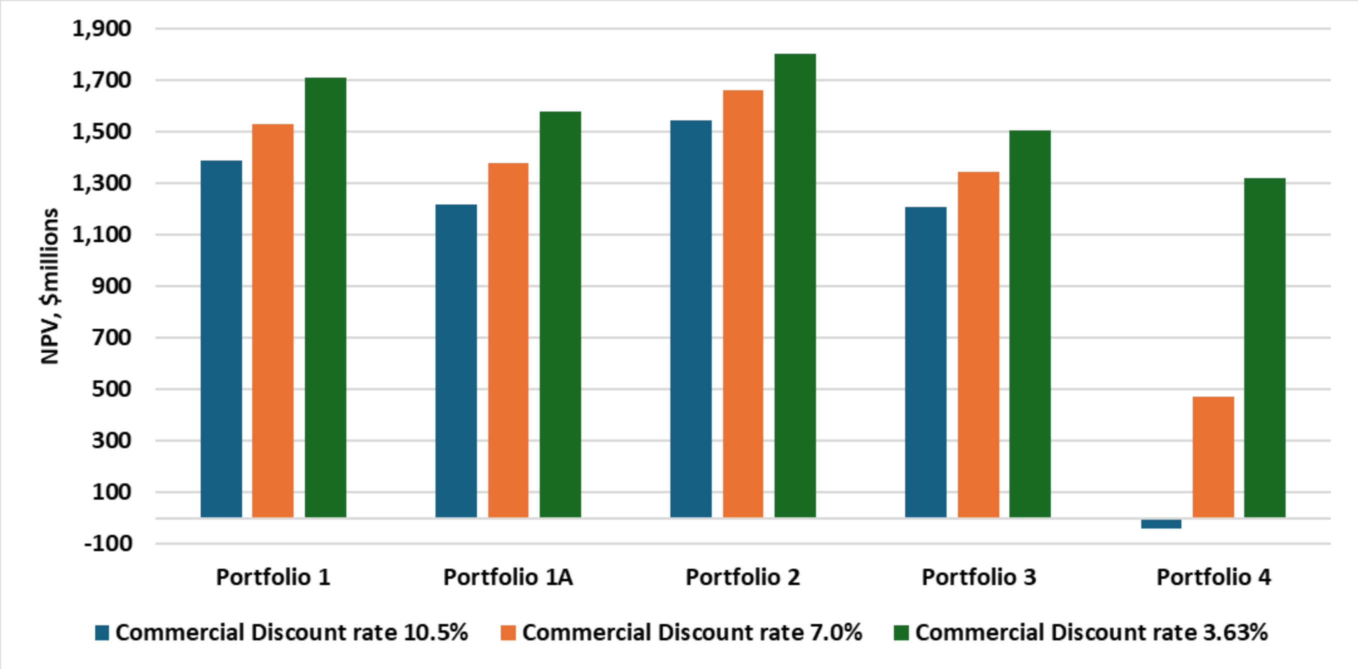
In terms of boundary testing, there would need to be a more than a 72% increase in synchronous condenser costs for Portfolio 2 to no longer be the top-ranked option (and, for all synchronous condenser costs greater than this level, Portfolio 1 would be preferred). As such, the finding that Portfolio 2 is the top-ranked option is robust to the assumed synchronous condenser costs.

Further, and relevant for the proposed reopening trigger covering increased synchronous condenser costs (see section 7.2), while the boundary value testing finds that there would need to be a more than a 72% increase in synchronous condenser costs for Portfolio 2 to no longer be the top-ranked option, at this level, Portfolio 2 would have net economic benefits equal to Portfolio 1. Powerlink therefore rounded up to a 75% increase for the reopening trigger in order to have Portfolio 2 no longer the top-ranked option by a material margin (and, at these assumed costs, Portfolio 1 would have net benefits that are $20 million more than Portfolio 2).

Alternative commercial discount rate assumptions.

Figure 6.9 shows that Portfolio 2 continues to be preferred under lower and higher assumed commercial discount rates.

Figure 6.9: NPV of portfolio options – comparison between lower and higher commercial discount rate (2023 dollars, millions)



In terms of boundary testing, there would need to be a commercial discount rate of less than 2.15% for Portfolio 2 to no longer be the top-ranked option (in which case Portfolio 4 would be preferred). As such, the finding that Portfolio 2 is the top-ranked option is robust to the assumed commercial discount rate.

7. Material Change in Circumstances

Key Points

- Once six months have elapsed after completing the analysis for this RIT-T, Powerlink will be required to monitor developments that could be material to the outcome of this RIT-T and consider whether a material change in circumstances has occurred.
- Powerlink has identified key assumptions that, if they were to change, could alter the preferred option under this RIT-T. In particular,
    - Credible evidence of proposals for synchronous condenser operation of gas turbines (such as adding a clutch) or PHES solutions reaching committed or anticipated status.
    - Credible evidence emerging that grid forming BESS are able to be relied on to contribute to minimum fault level requirements, and proposals reaching anticipated or committed status.
    - Credible evidence that the cost (as considered under the RIT-T) of adding clutches to gas turbines is going to be sufficiently greater than commissioning synchronous condensers that it changes what is considered optimal in Southern Queensland to meet the minimum requirements.
    - Credible evidence of expected real synchronous condenser costs increasing by approximately 75% compared to those used in the RIT-T analysis.
    - Credible evidence of commercial discount rates falling materially below the boundary value identified in this RIT-T.
    - If the demand for system strength requirements for projected IBR plants significantly reduced due to self-remediation and technological advancements in equipment.
    - Delayed availability of, and/or inability to conclude contracts with, proposed solutions, including contracting for solutions in Southern Queensland to meet the minimum requirements.
- Powerlink does not consider that a material change in the location and/or timing of reduced coal generation to form a reopening trigger for this RIT-T. As outlined above, Powerlink proposes to commit to additional, relatively low-cost solutions in Southern Queensland in light of the uncertainty surrounding the retirement/de-commitment of coal generators in Queensland, and the adverse consequences for consumers of under-investing in system strength solutions.

7.1. Regulatory requirements

Once six months have elapsed after completing the analysis for this RIT-T, Powerlink will be required to monitor developments that could be material to the outcome of this RIT-T and consider whether a material change in circumstances has occurred.[57]

A material change in circumstances includes, but is not limited to:

- a change to the key assumptions used to identify the identified need described in the PACR;
- the meeting of any reopening trigger identified in the PACR for this RIT-T;[58] or

[57] NER, clauses 5.16.4(z3) and (z3A). Powerlink is also only required to consider whether a material change in circumstances has occurred if it wishes to proceed with the project. It is not explicitly clear in the NER, RIT-T Instrument or RIT-T Application Guidelines when completion of the analysis that precedes the six-month period commences.

[58] Powerlink is required to identify and consult on reopening triggers for this RIT-T, as the estimated capital cost of the preferred option exceeds $100 million.

- a change in circumstances which, in Powerlink's reasonable opinion, means that the preferred option identified in the PACR may no longer be the preferred option.[59]

The NER state that reopening triggers:

- are the events, factors or circumstances which, if they occur or eventuate, would mean that the RIT-T project may no longer be the preferred option; and
- may include a change in the key assumptions used to identify or rank the credible options.[60]

If Powerlink considers that a material change in circumstances has occurred, it must:

- notify the AER in writing, and advise any actions it proposes to take and timeframes within which it proposes to complete any actions; and
- provide information to the AER to support any actions it proposes to take, having regard to
  - whether, in Powerlink's opinion, reapplication of the RIT-T is justified;
  - the costs and delay that may result from the actions Powerlink proposes to take as a result of the material change in circumstances; and
  - the costs and delay that may result from a full or partial reapplication of the RIT-T.[61]

If Powerlink submits a material change in circumstances notification to the AER, the AER will be required to accept or reject any actions proposed by Powerlink and specify reasonable timeframes for completion of actions. If the AER decides to reject the actions and/or timeframes proposed by Powerlink, the AER would be able to specify actions for Powerlink to take which may include reapplying the RIT-T, in whole or in part.[62]

7.2. Reopening triggers

Powerlink is required to set out in the PADR, for consultation and confirmation in the PACR, reopening triggers for this RIT-T.

The sensitivity analysis in section 6.2 has shown that the outcome of the RIT-T is robust to changes in many of the key underlying assumptions, namely:

- changes in the commercial discount rate;
- assumed synchronous condenser costs;
- a two-year delay to the completion of the Borumba PHES in Southern Queensland;
- real cost changes to the assumed cost of gas; and
- real cost changes to the assumed capital cost of grid-forming BESS.

The NPV analysis also finds that the results are robust to variations to the published VER or VCR (due to the applicable market benefits being found to be immaterial).

The NPV assessment, including the sensitivity and boundary assessment, in this PADR shows that the key findings coming out of this PADR are not sensitive to changes in these variables.

[59] NER, clause 5.16.4(z4). For clarity, TNSPs must consider whether or not a material change in circumstances has occurred for all RIT-T projects, not just those for which the estimated capital cost of the preferred option (at the PADR stage) is greater than $100 million (escalated over time).
[60] NER, chapter 10 (definition of 'reopening trigger').
[61] NER, clauses 5.16.4(z3) and (z4A).
[62] NER, clause 5.16.4(z5A).

Powerlink has also identified key assumptions that, if they were to change, could alter the preferred option under this RIT-T. These have been proposed as reopening triggers, and are a key issue in this PADR on which Powerlink is seeking stakeholder feedback.

Specifically, the proposed reopening triggers include:

- Credible evidence of proposals for synchronous condenser operation of gas turbines (such as adding a clutch) or PHES solutions reaching committed or anticipated status (as defined under the RIT-T).
- Credible evidence emerging that grid-forming BESS are able to be relied on to contribute to minimum fault level requirements, and proposals reaching anticipated or committed status (as defined under the RIT-T).
- Credible evidence that the cost (as considered under the RIT-T) of adding clutches to gas turbines is going to be sufficiently greater than commissioning synchronous condensers that it changes what is considered optimal in Southern Queensland to meet the minimum requirements.
- Credible evidence of expected real synchronous condenser costs approximately doubling compared to those used in the RIT-T analysis.[63]
- Credible evidence of commercial discount rates falling materially below the boundary value identified in this RIT-T.
- If the demand for system strength requirements for projected IBR plants significantly reduced due to self-remediation and technological advancements in equipment.
- Delayed availability of, and/or inability to conclude contracts with, proposed solutions, including contracting for solutions in Southern Queensland to meet the minimum requirements.

In relation to the last trigger, Powerlink intends to include further sensitivity analysis in the PACR on the impact of not being able to contract with key non-network components of the preferred option.

Powerlink also considers that certain changes in future AEMO System Strength Reports may also feed into additional potential reopening triggers at the PACR stage. For example:

- A material change in the IBR forecasts for Queensland published by AEMO;
- Change in the method AEMO uses to quantify gaps for system strength[64]; and/or
- Establishment of new, and/or the removal of existing, system strength nodes.

Similarly, if Queensland coal-fired units are to be repurposed into synchronous condensers, as indicated in the current SuperGrid Blueprint (see section 2.4), Powerlink considers this also may form an additional reopening trigger at the PACR stage.

Powerlink does not consider that a material change in the location and/or timing of reduced coal generation in Southern Queensland to form a reopening trigger for this RIT-T. As outlined above, Powerlink is proposing to commit to additional, relatively low-cost solutions in Southern Queensland in light of the uncertainty surrounding the retirement/de-commitment of coal generators, and the adverse consequences for consumers of under-investing in system strength solutions.

[63] While the boundary value testing above finds that there would need to be a more than a 61.2% increase in synchronous condenser costs for Portfolio 2 to no longer be the top-ranked option, Powerlink notes that, at this level, Portfolio 2 would have net economic benefits equal to Portfolio 1. Powerlink has therefore rounded up to an approximate 75% increase for the reopening trigger in order to have Portfolio 2 no longer the top-ranked option by a material margin.

[64] AEMO proposes to apply a threshold of three standard deviations (which corresponds to approximately the 99.87th percentile) from the mean when considering the quantity of services that can reliably be considered available when comparing against the minimum secure requirements for system strength (and inertia). See AEMO, *Amendments to the NSCAS Description and Quantity Procedure*, draft report, September 2024, pages 10-13.

If there are short-term delays with any of the solutions included the ultimately preferred option that would jeopardise Powerlink's ability to meet its system strength requirements, Powerlink may need to contract with existing synchronous units to ensure customers' reliability is not compromised. Powerlink does not consider this a material change in circumstances given that contracting, in the short-term, with existing synchronous units would be the only solution available to Powerlink to ensure system security.

7.3. Potential responses to a material change in circumstances

Powerlink is not required, in a PADR, to suggest how it intends to respond to a material change in circumstances. However, given the significance of the System Strength Rule to the future operation of Queensland's power system, and the level of interest in this RIT-T, Powerlink seeks stakeholder feedback on its suggested approach to address a material change in circumstances.

To the extent possible, Powerlink contemplates making minimal changes to the preferred option in the System Strength RIT-T should a material change of circumstances occur. It is unlikely that Powerlink would commence a new RIT-T in response to a material change in circumstances, as this would require significant time to complete and may jeopardise our ability to deliver system strength services at the required time. Instead, Powerlink is likely to revert to the sensitivity analysis undertaken (and any other sensitivities identified as part of PACR) to confirm that the action proposed is optimal.

If a material change in circumstances occurs, Powerlink may consider:

- updating the cost-benefit analysis of credible options and publishing a report on the results of the new analysis;
- conducting stakeholder consultation and publishing a report that summarises stakeholders' views and the conclusions from the consultation; and/or
- initiating an EOI for non-network solutions.

In addition, and as stated above, Powerlink would notify the AER of the material change in circumstances, and outline (for the AER's approval) the actions Powerlink proposes to undertake.[65]

7.4. Inertia and system strength

AEMO's 2023 Inertia Report changed the identified inertia shortfall in Queensland from a range of 8,200 to 10,352 megawatt seconds (MWs) from 1 July 2026, to up to 1,660 MWs from 2027/28. The one year delay reflected updates to the delivery timing of several major generation, transmission and REZ development projects which resulted in utilisation of synchronous generation in the near term. AEMO also indicated that the changed assessment represented a deferred onset of the shortfall, rather than a long-term reduction.[66]

The Security Frameworks Rule will align the system strength and inertia procurement frameworks from December 2024, with Powerlink required to ensure sufficient inertia is continuously available to meet projected inertia needs for Queensland from December 2027. The final rule also included transitional provisions to preserve Powerlink's obligation to address the already declared shortfall.[67]

---

[65] NER, clause 5.16.4(z3)(4).
[66] AEMO, *2022 Inertia Report*, December 2022, page 22; AEMO, *2023 Inertia Report*, December 2023, page 26.
[67] AEMC, *Improving Security Frameworks for the Energy Transition*, final determination, March 2024, page 32, and final rule, schedule 3 at [15] amending clause 5.20B.2, and at [17]-[18] amending clause 5.20B.4, of the NER; NER, clause 11.168.9.

If the level of inertia is not met through resources contracted through this System Strength RIT-T, a separate RIT-T may be required to procure services, or Powerlink may initiate a new RIT-T to meet system strength and inertia needs concurrently.

8. Consumer and Stakeholder Engagement

Key Points

- More than five million Queenslanders and 241,000 Queensland businesses depend on Powerlink's performance. Powerlink recognises the importance of engaging with a diverse range of customers and stakeholders who have the potential to affect, or be affected by, Powerlink activities and/or investments
- Through the Powerlink Customer Panel and Transmission Annual Planning Report, industry stakeholders have been kept up-to-date on the System Strength RIT-T.
- Powerlink has met regularly with potential proponents of non-network solutions for the System Strength RIT-T. Further, in December 2023 and May 2024, Powerlink provided formal updates on the technical and economic assessment approaches to proponents.
- The new system strength framework aims to lower the total costs of providing system strength for consumers, and ensure costs are shared and appropriately allocated. The difference between the revenue Powerlink receives from system strength charges from connecting parties who use system strength, and payments Powerlink make to procure system strength resources, will be recovered from or returned to transmission customers.

8.1. Energy Charter

More than five million Queenslanders and 241,000 Queensland businesses depend on Powerlink's performance. Powerlink recognises the importance of engaging with a diverse range of customers and stakeholders who have the potential to affect, or be affected by, Powerlink activities and/or investments.

Together with industry counterparts from across the electricity and gas supply chain, Powerlink has committed to the Energy Charter. The charter is a national CEO-led collaboration that supports the energy sector towards a customer-centric future. Powerlink's Energy Charter Disclosure Statement for 2023/24 shows Powerlink's recent achievements against the principles of the Energy Charter.

8.2. Powerlink Customer Panel

Powerlink's Customer Panel provides a face-to-face opportunity for customers and consumer representatives to give their input and feedback about Powerlink's decision making, processes and methodologies. The panel also provides Powerlink with a valuable avenue to keep customers and stakeholders better informed, and to receive feedback about topics of relevance, including RIT-Ts.

The Customer Panel is regularly advised on the publication of Powerlink's RIT-T documents, and is briefed quarterly on the status of current RIT-T consultations as well as upcoming RIT-Ts. This provides an ongoing opportunity for the Customer Panel to ask questions and provide feedback to further inform RIT-Ts, and for Powerlink to better understand the views of customers when undertaking the RIT-T consultation process.

Powerlink will continue to provide updates to and request input from the Customer Panel throughout the RIT-T consultation process.

8.3. Transparency on future network requirements

Powerlink's annual planning review findings are published in the Transmission Annual Planning Report (TAPR) and TAPR templates (available via the TAPR portal).[68] It provides early information and technical data to customers and stakeholders on potential transmission network needs over a 10-year outlook period. The TAPR plays an important part in planning Queensland's transmission network and helping to ensure it continues to meet the needs of Queensland electricity consumers and participants in the NEM. Powerlink's 2024 TAPR included updated information in relation to system strength locational factors and nodes, and discussed activities undertaken or planned to be undertaken (including the System Strength RIT-T) to meet system strength requirements in Queensland.[69]

Powerlink's annual Transmission Network Forum, held following release of the TAPR, is a primary vehicle used to engage with the community, understand broader customer and industry views and obtain feedback on key topics. It also provides Powerlink with an opportunity to further inform its business network and non-network planning objectives. Forum participants include customers, landholders, environmental groups, Traditional Owners, government agencies, and industry bodies. Engagement activities such as the forum help inform the future development of the transmission network and assist Powerlink in providing services that align with the long-term interests of customers.

8.4. Updates to proponents of non-network solutions

Powerlink has met regularly with potential proponents of non-network solutions for the System Strength RIT-T. Further, in December 2023 and May 2024, Powerlink provided formal updates on the technical and economic assessment approaches to proponents.

8.5. Powerlink applies a considered approach to RIT-T engagement

Powerlink undertakes a considered and consistent approach to ensure an appropriate level of stakeholder engagement is undertaken for each individual RIT-T consultation. The scope of engagement activities is dependent upon various considerations, such as the characteristics and complexity of the identified need and potential credible options.

For all RIT-Ts, members of Powerlink's Non-network Engagement Stakeholder Register receive email notifications of publication of RIT-T reports. For projects where Powerlink identifies material or significant market benefits, additional activities such as webinars or dedicated engagement forums may be appropriate. For more information, see Powerlink's RIT-T stakeholder engagement matrix.

Powerlink intends to hold a webinar in late November 2024 to share the findings of the PADR and next steps with stakeholders.

8.6. Impact of system strength costs to consumers

The System Strength Rule introduced a charging framework for IBR that apply to connect to Powerlink's network. Under the new framework, parties who submit an application on or after 15 March 2023 can choose to remediate their system strength impact, or pay system strength services procured by Powerlink.[70]

[68] See NER, rule 5.12 for requirements.
[69] NER, clauses 5.12.2(c)(8) and (13). See also chapter 4 and Appendix H of Powerlink's 2023 and 2024 TAPRs.
[70] AEMC, *Efficient Management of System Strength on the Power System*, final determination, October 2021, page 23.

System strength charges intend to provide connecting parties with long-run locational and technological signals, and reflect the efficient costs imposed on a TNSP from the connection of a party who uses system strength. To meet the new system strength standard, Powerlink will incur costs to provide and/or procure system strength resources to:

- meet network performance standards with respect to protection system operation and voltage control; and
- host the efficient level of IBR at each system strength node.[71]

The new system strength framework aims to lower total costs of providing system strength for consumers, and ensure costs are shared and appropriately allocated. Powerlink will collect system strength charges from connecting parties who use system strength. The difference between the revenue Powerlink receives from system strength charges and payments we make to procure system strength resources will be recovered from, or returned to, our transmission customers.[72]

The potential magnitude of costs for TNSPs to deliver system strength services, and the complexities involved in forecasting these costs, were discussed in a recent report for ENA by Endgame Economics. Endgame noted that, where TNSPs contract with non-network assets for system strength services, this can expose the TNSP to volatile contract payments due to the volatility in wholesale energy spot prices. Endgame estimated variable 'make-whole' costs, being the difference between spot price revenues and the short-run marginal cost of enabled resources, under system strength contracts in New South Wales, Queensland and South Australia.

For Queensland, Endgame estimated the average annual make-whole cost to be:

- less than $10 million in each of 2025/26 and 2026/27;
- $54 million in 2027/28; and
- $195 million in each of 2028/29 and 2029/30.[73]

Endgame made a number of simplifying assumptions for its analysis, and did not assess the potential cost impacts of synchronous generators bidding unavailable to increase the system strength enablement requirement, market power, or other commercial realities on contractual negotiations. Endgame therefore considered its estimate of make-whole costs to be conservative. Further, the estimate did not include the startup or availability payment components of system strength services contracts.[74]

Appendices F and G include more detail on enablement and the structure of system strength contracts.

8.7. Submissions on PSCR

Powerlink received one (non-confidential) submission, from Energy Australia, in response to the PSCR. A summary of and commentary on each issue in Energy Australia's submission is provided below.[75]

Reasonable endeavours

Energy Australia described Powerlink's interpretation of the reasonable endeavours aspect of the System Strength Standard as pragmatic, and considered it accounted for the potential cost of deterministically addressing any system strength shortfall regardless of the duration or likelihood of the shortfall. Powerlink's interpretation of

---

[71] Powerlink, *System Strength Charges,* Overview, March 2023.
[72] Powerlink, *Rule Change Proposal to Reset System Strength Unit Prices – Consultation,* Overview, January 2024.
[73] Endgame Economics, *Modelling Make-whole Costs for System Strength Enablement*, report for ENA, September 2023, page 9. Note values are in real 2023 dollars.
[74] Ibid, page 3.
[75] NER, clause 5.16.4(k)(2).

the reasonable endeavours standard and approach to applying it to addressing system strength requirements is addressed in section 2.3 of this PADR.

Investment need for minimum system strength

Energy Australia made the following comments on Powerlink's discussion of minimum system strength requirements in the PSCR:

- Powerlink's statement that minimum system strength requirements were met by the operation of a minimum of 13 base load generators in Northern, Central and Southern Queensland suggested Powerlink may expect to pay existing generators for their services, provided a certain pre-determined and acceptable combination of the 13 units was online concurrently.
- The PSCR did not identify the costs of replacing or retaining these plant, nor did it specify assumptions or approaches to market modelling and for base case dispatch patterns, including base load plant operating on a more flexible basis to accommodate cheaper renewable sources and greater reliance on pumped hydro storage.
- The PSCR did not explain how the declared system strength shortfall at Gin Gin affected Powerlink's assessment of need or what action Powerlink was taking to address the shortfall.

In response to Energy Australia:

- the explanation of how minimum system strength requirements have historically been met was meant to articulate the assumptions and requirements underpinning the identified need regarding minimum system strength. Powerlink did not intend for stakeholders and/or non-network proponents to equate the explanation to an intention by Powerlink to contract with particular generators to provide system strength services in the future;
- Powerlink's assumptions for and approaches to market modelling are detailed in chapter 5 of this PADR. Powerlink's PSCR did not set out market modelling approaches in detail (which we consider consistent with the RIT-T framework and guidance); and
- at the time the PSCR was issued, Powerlink was progressing its response to the declared system strength shortfall at Gin Gin and was not in a position to articulate the impact of Powerlink's response to the shortfall on longer-term system strength planning requirements. As noted in section 2.2, for this RIT-T Powerlink considers the non-network solution of a gas turbine hybrid solution at the Townsville Power Station as a committed project, and has included it in the base case for the cost-benefit analysis.

Network solutions to meet efficient system strength requirements

Energy Australia noted that more detail was required on the additional eight 200 MVA synchronous machines, or equivalent, that the PSCR suggested would be needed by 2030 to meet efficient system strength requirements. Specifically, Energy Australia requested Powerlink provide more information on:

- the frequency duration of system strength needs as a time series, at each system strength node from the base case and alternative scenario market modelling;
- how Powerlink determined efficient levels in line with AEMO's four criteria around stable voltage waveforms;
- how Powerlink intends to articulate forecast system strength requirements beyond AEMO's 10-year horizon, given the RIT-T analysis will extend for 20 years;
- how future AEMO IBR forecasts would form part of Powerlink's obligation to meet clause S5.1.14 of the NER, including for any new system strength nodes (such as at Calvale) declared by AEMO over the assessment period; and

- its view of the flexibility that AEMO has provided SSSPs in IBR forecasts, including the potential to adjust near-term forecasts as more information emerges on IBR and MNSF, and treatment of distribution-connected IBR.

In response to Energy Australia:

- Powerlink conducted a detailed technical assessment using electromagnetic transient (EMT) based modelling to identify efficient level of system strength requirements. This analysis incorporates the IBR forecasts presented in AEMO's 2023 System Strength Report for each relevant system strength node on an annual basis. As a result, the identified need for efficient system strength requirements is based on the need arising each year. The expected timeline for solutions is presented in Appendix H of this PADR.
- The technical assessment has not assessed system strength as a detailed time series and Powerlink does not consider this to be practical nor proportionate. The technical assessment is also probabilistic and so a single, time series cannot describe the modelling accurately.
- The technical considerations focused on key criteria related to stable voltage waveforms, with the methodology outlined in Appendix H of this PADR.
- Our technical assessment focused on a five-year timeframe to identify near- to mid-term system strength needs, in accordance with the rule requiring identification three years in advance. Powerlink will review the study data and assumptions each year, following the publication of the AEMO System Strength Report in December, to determine any material impacts on the solutions.
- Powerlink acknowledges that future IBR forecasts and technological advancements may alter the demand for system strength. Powerlink will continuously evaluate any significant impacts on system strength requirements, taking into account changes to the current data and assumptions used in our analysis.

System strength procurement and pricing

Energy Australia requested Powerlink:

- publish and frequently update data on actual system strength levels to help participants understand drivers of investment need;
- provide clarity on how Powerlink translates AEMO's criteria for maintaining a stable voltage waveform into a fault level metric, including how different technologies affect sub-criteria definitions;
- explain assumptions or methods to deal with uncertainties around OSM procurement and inertia markets.

In response to Energy Australia:

- As part of the PADR, Powerlink provided information on the level of system strength services required, along with indicative locations for these services and the expected timelines.
- Powerlink conducted detailed technical assessment using EMT based modelling to identify efficient level of system strength requirements. Therefore, Powerlink has not used fault level metric when determining the requirements.
- It is anticipated that the solutions contracted through the System Strength RIT-T will provide a certain level of inertia. However, a separate RIT-T may be necessary to procure additional services to meet projected inertia needs in Queensland. This topic is discussed in section 7.4 of the PADR.
- As discussed in Appendix F of this PADR, as part the AEMC's simplified OSM rule change, AEMO's scheduling of system security services is a consideration for Powerlink. AEMO will need to consult further on the new Security Enablement Procedures, and Powerlink intend to participate in this consultation as well as engage with AEMO in other industry forums on this topic. For this RIT-T, Powerlink will consider AEMO's Provisional Security Enablement Procedures in system strength contracts.

Sensitivities

Energy Australia suggested Powerlink's modelling of net benefits should encompass credible sensitivities, such as the QEJP and SuperGrid Blueprint, to the extent that these are not reflected in AEMO's approaches for the ISP. Sensitivities are addressed in section 6.2 of this PADR, which includes a brief discussion of the potential for a delay in the Borumba PHES.

9. Conclusion

Key Points

- Portfolio 2, which includes nine synchronous condensers across Central Queensland and Southern Queensland by 2033/34, is found to be the top-ranked option under the RIT-T at this stage. However, this is sensitive to the project status of other potential solutions, such as clutched gas turbines.
- This PADR also shows that there are additional 'low regret' Southern Queensland non-network solutions that provide prudent insurance against more accelerated coal retirement going forward, and Powerlink considers that these should also form part of the preferred option.
- The preferred option recommended in this PADR recognises that action needs to be taken now, but also retains flexibility to refine the specific solutions committed in the future (if optimal). While Powerlink will immediately commit to investing in or contracting with up to three synchronous condensers in Central Queensland by 2028/29, additional investment in up to six further synchronous condensers by 2033/34 can be avoided if alternate solutions reach committed or anticipated status in the next few years.
- To facilitate this flexibility, Powerlink propose a number of reopening triggers which, if activated, would alter the make-up of the preferred option and allow us to pivot to alternate solutions. This includes credible evidence emerging that grid-forming BESS are considered technically feasible for contributing to minimum fault level requirements (and proposals reaching anticipated or committed status). Powerlink expect that the proposed use of BESS to meet the efficient level requirements will provide valuable insights into the technical feasibility of these solutions for meeting the minimum system strength requirements.
- Overall, Powerlink's proposed approach will result in the best outcome for electricity consumers and will avoid Powerlink needing to undertake a new RIT-T, which would require significant time to complete and jeopardise our ability to deliver system strength services to AEMO. Powerlink's approach also supports the development of non-network solutions in being able to provide system strength services.
- Powerlink invites submissions and comments on the material presented in this PADR, as well as new and updated proposals from proponents of non-network solutions. Submissions and proposals are due by **Friday, 20 December 2024**.

9.1. Proposed Preferred Option

The top-ranked option, Portfolio 2 (Synchronous Condensers), involves:

- For the **minimum fault level requirements**:
  - nine synchronous condensers across Central Queensland and Southern Queensland; and
  - contracting with a range of other synchronous units in Southern and Northern Queensland.
- For the **stable voltage waveform efficient requirements**, contracting for:[76]
  - 550 MW of grid-forming BESS in Southern Queensland; and
  - 1,600 MW of grid-forming BESS in Central Queensland/Northern Queensland.

However, Powerlink does not consider it optimal to plan to procure up to nine synchronous condensers for commissioning by 2033/34, particularly as proposals involving adding clutches to gas generating units or PHES

[76] While these bullet points reflect what has been assumed in the PADR assessment for Portfolio 2 for the stable voltage waveform efficient requirements (that is, grid-forming BESS), the ultimately preferred solution may be another technology (such as synchronous condensers). Powerlink has therefore also summarised here the efficient system strength requirements as MVA ranges

solutions could become committed or anticipated in coming years (which would change the preferred option under this RIT-T).

Powerlink will immediately commit to investing in or contracting with up to three synchronous condensers in Central Queensland by 2028/29, in order to meet the minimum standard. This approach takes account of the expected contracting and procurement lead times, with additional synchronous condensers not expected to be required until later. Powerlink will also take into account any additional information between now and the completion of the PACR that could affect this position.

In addition to the three synchronous condensers in Central Queensland from 2028/29, Portfolio 2 also includes the following six synchronous condensers:

- three in Central Queensland by 2029/30;
- one in Southern Queensland by 2029/30;
- one in Central Queensland by 2032/33; and
- one in Central Queensland by 2033/34.

Powerlink is not intending to commit to contracting for the delivery of these additional six synchronous condensers at this time. The assessment in this PADR has shown that the preferred option in this RIT-T would change if alternate solutions became committed or anticipated. Powerlink considers it prudent to allow the opportunity for these alternative solutions to emerge.

However, it is of the utmost importance that Powerlink meets its system strength requirements, as failing to do so could result in material outages for consumers. Given the significant and lengthening lead times associated with procuring synchronous condensers, Powerlink considers that there are 'cut-off' points for alternate technologies being available to avoid future synchronous condenser investment. Powerlink intends to make clear as part of the PACR what we expect these to be for each of the four tranches of synchronous condensers investment outlined above.

Should third-party proponents be able to show credible evidence of their solutions reaching committed or anticipated status ahead of these cut-off points, then Powerlink expects that synchronous condenser investment can be avoided and, instead, these alternate solutions procured. The proposed reopening triggers in this RIT-T will allow Powerlink to pivot to these alternative solutions, should they become available.

The pathway set out in this RIT-T recognises that action needs to be taken now to meet the system strength requirements in the near-term, but retains flexibility to pivot future solutions depending on the project status of proposals, and their (economic) cost under the RIT-T framework. Overall, this will result in the best outcome for electricity consumers and avoid Powerlink needing to undertake a new RIT-T, which would require significant time to complete and jeopardise Powerlink's ability to address system strength requirements in Queensland. It also supports the development of non-network solutions in being able to provide system strength services.

Further, the additional low-regret, and relatively low-cost, Southern Queensland solutions that provide prudent insurance against more accelerated coal retirement should be included in the preferred option as part of this RIT-T, irrespective of the specific option pursued. Powerlink propose to commit to these additional solutions as

---

to reflect the potential for more than one technology type to contribute to meeting the identified need – these are 600 to 1,200 MVA of solutions in Southern Queensland, 400 to 750 MVA of solutions in Central Queensland, and 800 to 1,300 MVA of solutions in Northern Queensland. In addition, as noted in section 3.1, ongoing technical studies have shown that potentially more grid-forming BESS may be required for the efficient requirements (in the order of 10-20% more) and Powerlink intends to review and update this in the PACR.

part of this RIT-T to avoid the adverse consequences for consumers in Southern Queensland of under-investing in system strength solutions.

To provide a potential pathway for the future inclusion of grid-forming BESS into the portfolio of solutions to contribute to minimum fault level requirements, Powerlink intends to investigate as part of the PACR a variant of Portfolio 2, and potentially Portfolio 3, that includes a grid-forming BESS for meeting the minimum system strength requirements (akin to how Portfolio 1A in the PADR is a variant of Portfolio 1). Powerlink also intends to investigate a sensitivity that assumes, not only that grid-forming BESS are technically feasible for assisting with the minimum requirements, but also that one or more reach committed/anticipated status to see whether that affects the overall preferred option for this RIT-T (akin to the sensitivity where the project status of proposed clutched gas turbines changes going forward).

To be clear, the additional analysis regarding grid-forming BESS being able to assist with the minimum requirements expected for the PACR is intended to be *economic-only* in nature, and Powerlink is not proposing to present any technical assessment of this potential function in the PACR. Powerlink plans to undertake significant work, and gain general learnings through practical operational experience, to assess and determine the technical feasibility of grid-forming BESS being able to assist with the minimum requirements going forward. However, Powerlink does not expect to be able to comment on this as part of the PACR as these efforts and learnings will be ongoing.

The proposed use of grid-forming BESS to meet the efficient level requirement will provide valuable insights into the ability of these BESS in the context supporting effective performance of systems within the wider power system in the years following the RIT-T. This should enable Powerlink to gain confidence that the power system will continue to operate effectively as it transitions to new sources of system strength.

Finally, the Security Frameworks Rule will align the system strength and inertia procurement frameworks from December 2024, with Powerlink required to ensure sufficient inertia is continuously available to meet projected inertia needs for Queensland from December 2027.[77] To maximise the value of the synchronous condenser network solutions, Powerlink intends to include flywheels on any network synchronous condensers we procure.

9.2. Submissions

Powerlink invites submissions and comments from market participants, AEMO, potential non-network providers, and any other interested parties, on the preferred option presented and the issues addressed in this PADR.[78]

Submissions should be presented in a written form and should clearly identify the author of the submission, including contact details for subsequent follow-up if required. Parties may request to meet with Powerlink ahead of providing a written response.

To assist stakeholders to prepare submissions, Powerlink will host a webinar on the issues and conclusions in this PADR in late November 2024.

Powerlink will publish submissions on the PADR, subject to any claim of confidentiality by the person making the submission. Where confidentiality over part or all of a submission is made, this should be clearly identified. Powerlink may also explore whether a redacted or non-confidential version of the submission can be made available.[79]

---

[77] AEMC, *Improving Security Frameworks for the Energy Transition*, final determination, March 2024, page 32, and final rule, schedule 3 at [15] amending clause 5.20B.2, and at [17]-[18] amending clause 5.20B.4, of the NER, from 1 December 2024.
[78] NER, clause 5.16.4(q).
[79] AER, *Application Guidelines, Regulatory Investment Test for Transmission*, October 2023, page 69.

Powerlink has a general obligation to use all reasonable endeavours not to disclose any confidential information it receives. The obligation is subject to a number of exceptions, including that disclosure may be made:

- with the consent of the person providing the information; or
- to the AER, AEMC or any other regulator having jurisdiction over Powerlink under the NER or otherwise.[80]

Submissions should be emailed to Powerlink via networkassessments@powerlink.com.au, with 'System Strength RIT-T PADR Submission: <name of submitter>' in the subject field of the email.

Alternatively, submissions can be mailed to Powerlink, addressed to:

Manager, Portfolio Planning and Optimisation
Powerlink Queensland
PO Box 1193
Virginia Qld 4014.

Submissions are due to Powerlink by **Friday, 20 December 2024**.[81]

9.3. Proposals for non-network solutions

This RIT-T is not a tender process. In response to this PADR, Powerlink requests proponents of non-network solutions provide best cost proposals to meet the geographical and technical requirements of relevant solution(s).

Powerlink is particularly interested in receiving new/updated proposals from non-network proponents for near-term solutions expected to be required – namely existing, expected and potential future gas and hydro projects, and grid-forming BESS. Powerlink would also be interested to hear from proponents of longer-term potential non-network solutions as to whether the project status of their proposals has progressed to meet the definition of a committed or anticipated project under the RIT-T (along with supporting evidence). If so, this would support some, or all, of the otherwise expected investment in a further six synchronous condensers between 2029/30 and 2033/34 being avoided.

Powerlink also invites proposals from proponents of non-network solutions who did not respond to the PSCR, and/or have responded to the provision of system strength element of the identified need for the Gladstone Project Priority Transmission Investment.

An information request is at Appendix B, and a copy of the request will be emailed directly from Powerlink's Network Assessments team to proponents who submitted a proposal in response to the PSCR. The webinar to support release of this PADR mentioned in section 9.2 will also assist proponents of non-network solutions to prepare their responses to the information request.

Information requests can be requested from, and once completed should be emailed to, Powerlink via networkassessments@powerlink.com.au, with 'System Strength RIT-T PADR Proposal: <name of proponent>' in the subject field of the email.

Proponents are also encouraged to review the:

- AEMC's final determination for the Security Frameworks Rule, and the resources relating to implementation of the rule change on AEMO's website;
- commercial parameters for system strength contracts at Appendix G (which is a key area that Powerlink is seeking stakeholder feedback on in response to this PADR); and

[80] NER, rule 8.6.
[81] NER, clause 5.16.4(r).

- technical performance assessment for grid-forming BESS (if relevant) at Appendix I.

Proponents should clearly indicate whether or not they require Powerlink to treat their proposals as confidential information. It should be noted that Powerlink is required to publish the outcomes of the RIT-T analysis. If proponents making proposals elect not to provide specific project cost data for commercial-in-confidence reasons, Powerlink may rely on cost estimates from independent specialist sources.

Responses to the information request are due by **Friday, 20 December 2024**.

9.4. Next steps

Powerlink is required publish a PACR as soon as practicable after submissions on this PADR close.[82] The PACR will set out the matters covered in this PADR, and summarise and respond to any submissions made on the PADR.[83] Powerlink anticipates the publication of the PACR for this RIT-T by 30 June 2025.

Table 9.1 lists Powerlink's target milestones for completing the System Strength RIT-T.

Table 9.1: Powerlink System Strength RIT-T Milestones

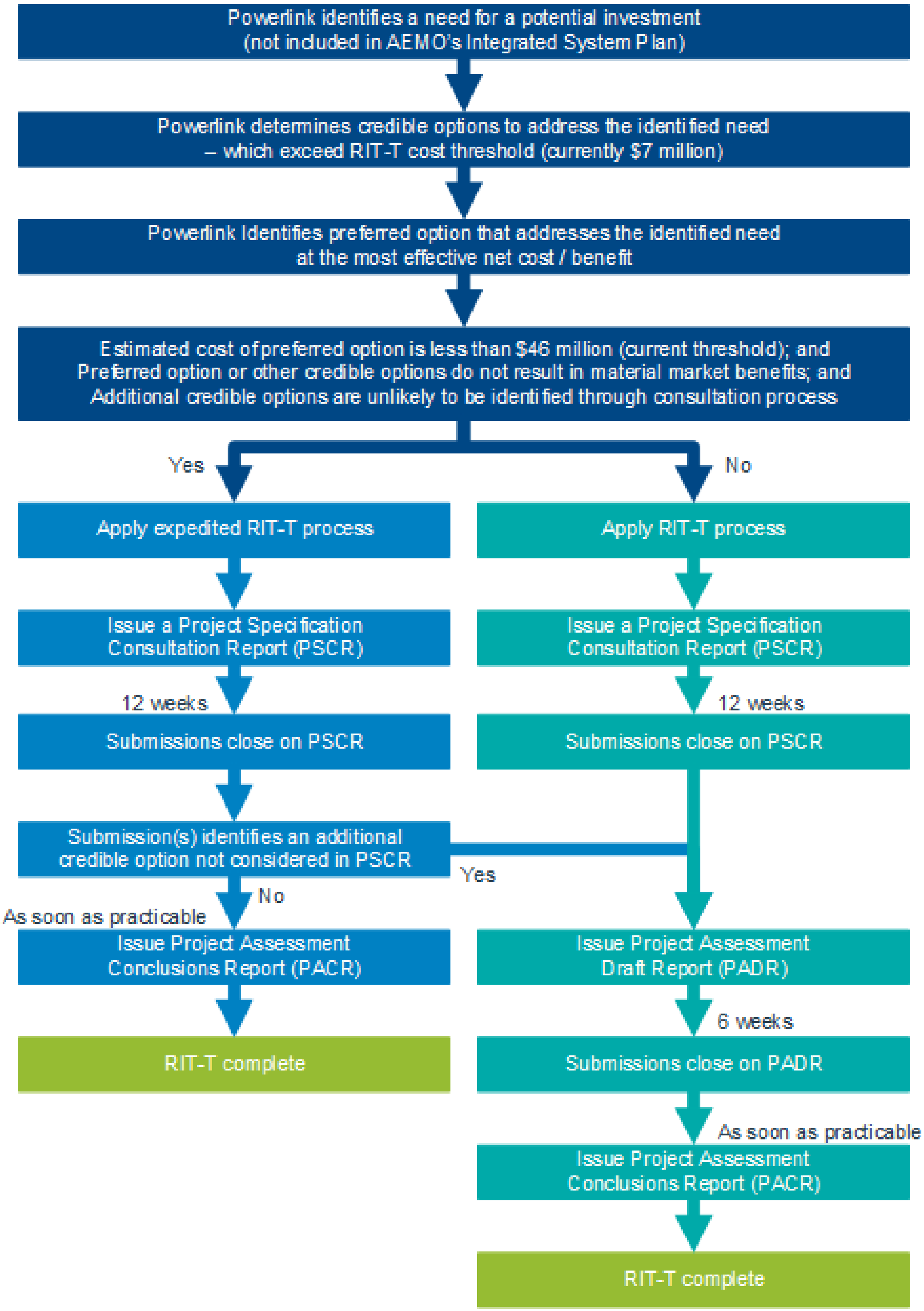
Milestone	Target Date
Publish PADR (Summary and Full Report)	4 November 2024
PADR webinar	Late November 2024
Submissions on PADR due	20 December 2024
Contract negotiations	January to April 2025
Publish PACR (Summary and Full Report)	30 June 2025
PACR Dispute Period ends	31 July 2025
AEMO Final Security Enablement Procedures	31 August 2025
Contract execution	By 30 September 2025
Delivery of system strength services to AEMO	From 2 December 2025

Powerlink reserves the right to amend the timetable at any time.

82 NER, clause 5.16.4(t).
83 NER, clause 5.16.4(v).

Appendix A: RIT-T Process

The flow chart below illustrates the RIT-T process where the need is not identified as an actionable project in AEMO's ISP.



As the first step in the RIT-T process, the PSCR:

- describes the reasons why Powerlink has determined that investment is necessary (the identified need), together with the assumptions used in identifying this need, including whether the need is as an actionable project in AEMO's latest ISP;
- provides potential proponents of non-network solutions with information on the technical characteristics that a non-network solution would need to deliver, in order to assist proponents to consider whether they could offer an alternative solution;
- describes the credible options that Powerlink currently considers may address the identified need;
- discusses why Powerlink does not expect specific categories of market benefit to be material for this RIT-T;
- presents the NPV assessment of each of the credible options compared to a base case, as well as the methodologies and assumptions underlying these results;
- identifies and provides a detailed description of the credible option that satisfies the RIT-T, and is therefore the preferred option;
- provides information about Powerlink's estimation of costs for each credible option;
- describes how customers and stakeholders have been engaged with regarding the identified need; and
- provides stakeholders with the opportunity to comment on this assessment so that Powerlink can refine the analysis (if required) as part of the PACR.[84]

A PADR and a PACR for a RIT-T must include:

- a description of each credible option assessed;
- a summary of and commentary on submissions received in response to the PSCR or PADR (as relevant);
- a quantification of the costs, including a breakdown of operating and capital expenditure, and classes of material market benefit for each credible option;
- reasons why Powerlink has determined that a class or classes of market benefit are not material;
- the results of NPV analysis for each credible option assessed, together with accompanying explanatory statements;
- the identification of the proposed preferred option, including details of the technical characteristics and the estimated construction timetable and commissioning date; and
- RIT-T reopening triggers if the estimated capital cost of the preferred option is greater than $100 million (as varied via AER cost threshold determinations).[85]

[84] NER, clause 5.16.4(b).
[85] NER, clauses 5.16.4(k) and (v).

Appendix B: Information Request for non-network solutions

This System Strength RIT-T is not a tender process. In response to this PADR, Powerlink requests proponents of non-network solutions provide best cost proposals to meet the geographical and technical requirements of relevant solution(s) in the preferred option. This appendix includes Powerlink's information request for new and existing proponents of non-network solutions. The request includes tables for six aspects of proposed solutions:

- Company Details;
- AEMO Fixed and Default Contract Parameters;
- AEMO Variable Parameters;
- Additional Technical Details;
- Commercial Parameters; and
- Status of Projects.

The tables for AEMO's Fixed and Default Contract Parameters, and Variable Contract Parameters, are included in AEMO's Provisional Security Enablement Procedures.

Proponents are also requested, where relevant, to withdraw any projects/solutions that have previously been submitted to Powerlink as part of this RIT-T.

Proponents are requested to complete and submit it to networkassessments@powerlink.com.au by **Friday, 20 December 2024**. See section 9.3 for guidance on responding to the information request.

Powerlink will assess the technical and commercial feasibility of options based on responses to the information request. For shortlisted proponents of grid-forming BESS, Powerlink will request further information to assist Powerlink to undertake further testing based on the technical specification in Appendix I.

Company Details

Table 1: Company Details

Information Requirement	Response
Company Name	
Australian Business Number (ABN)	
Key Contact Name	
Key Contact Phone Number	
Key Contact Email Address	

AEMO Fixed and Default Parameters

See AEMO's Provisional Security Enablement Procedures (Table 1) for guidance.

Table 2: AEMO Fixed and Default Parameters

Information Requirement	Response
Name and type of asset (specific assets, technology connection point, DUID(s) if applicable)	
Asset registration status	
Services	
Auxiliary load	
Default Activation Lead Time	
Default Minimum Dispatch	

AEMO Variable Parameters

See AEMO's Provisional Security Enablement Procedures (Table 2) for guidance.

Table 3: AEMO Variable Parameters

Information Requirement	Response
Availability	
Activation Lead Time	
Minimum Dispatch	

Additional Technical Details

Table 4: Additional Technical Details

Information Requirement	Response
Nameplate rating (MVA)	
Nameplate rating (MW)	
Energy storage capacity (MWh) (if applicable)	
Connection point (nominal voltage and configuration)	

Information Requirement	Response
Inverter size (MVA) (if applicable)	
Number of units	
Reactive power injection capability (capacitive) at the network connection point (MVAr)	
Reactive power absorption capability (inductive) at the network connection point (MVAr)	
Plant overload capability with applicable time duration (MVA or % of rated capacity for t seconds)	
Losses (load/no load), if applicable	
Inertia contribution (MWs), inertia constant H (s)	
Inclusion of flywheel (if applicable)	
Inertia of the flywheel (if applicable)	
Site-specific PSCAD model available (yes or no)	
If using an existing solution, are changes needed to provide the service (e.g. converting from grid-following to grid-forming)?	
Service start date	
Maintenance periods/durations over contract term	
If applicable, the time to switch between modes of operation (e.g., from generation to synchronous condenser, and vice versa)	

Contract Duration

The proforma released in June 2023 to accompany the PSCR requested proponents of non-network solutions indicate preferred contract term options, with 1, 3, 5 and 10 years suggested as options.

In this PADR, Powerlink requests proponents of non-network solutions indicate preferred contract durations up to a maximum length of 10 years.

Table 5: Contract duration

Information Requirement	Response
Preferred contract duration(s) (up to 10 years)	

Commercial Parameters

Powerlink's proposed pricing structure is shown in Table 6 and aligns with AEMO's minimum and recommended requirements for system security contracts. In addition to the minimum requirements, Powerlink's pricing structure allows for an availability payment that will not be taken into consideration by AEMO in its scheduling activities.

It is a minimum AEMO requirement that these payments are stated separately to each other in agreements. This will allow AEMO to establish a consistent and workable scheduling function.

Not all components of the pricing structure will be relevant to each non-network solution and proposed values may be specified as zero.

Proponents should provide prices based on their preferred contract duration, and can create additional versions of Table 6 (e.g., 6A, 6B and 6C etc.) to advise prices for alternate contract durations.

Table 6: Pricing Structure

See AEMO's Provisional Security Enablement Procedures (section 2.3) for guidance.

Information Requirement	Response
Availability Payment ($/month)	
Activation Payment ($/activation)*	
Usage Payment ($/hour)*	
Energy ($)*	

Note: items marked with an asterisk (*) align with AEMO's minimum requirements for the financial structure of system strength contracts.

Energy costs are expected to be a key variable that could significantly change the value of contract payments. Powerlink considers proponents of non-network solutions are best placed to assess the risk associated with this variable, and therefore welcomes feedback on ways to manage this risk. Responses to the Energy row of Table 6 should include whether energy revenue is proposed as part of the contract terms, or alternatively should be specified as $0. Where energy revenue is included in the proposed pricing structure, please indicate options to manage the risk and costs in the best interests of consumers.

Status of Projects

In each of the (five) tables below, update status of your solution(s) against each of the RIT-T criteria used to determine whether projects are committed, anticipated or modelled. See the status of projects sub-section in Appendix E for further guidance on this aspect of the information request.

Table 7A: Status of Projects (Land)

Land: The proponent has purchased/settled/acquired land (or commenced legal proceedings to acquire land) for the purposes of construction
Response:

Table 7B: Status of Projects (Contracts)

Contracts: Contracts for supply and construction of the major components of the necessary plant and equipment (such as generators, turbines, boilers, transmission towers, conductors, terminal station equipment) have been finalised and executed, including any provisions for cancellation payments
Response:

Table 7C: Status of Projects (Planning)

Planning: The proponent has obtained all required planning consents, construction approvals and licences, including completion and acceptance of any necessary environmental impact statement ***To assist Powerlink to compare the status with AEMO's Generation Information, please also indicate what stage of the connection process the solution is at (enquiry/application/5.3.4A received)***
Response:

Table 7D: Status of Projects (Finance)

Finance: The necessary financing arrangements, including any debt plans, have been finalised and contracts executed
Response:

Table 7E: Status of Projects (Construction)

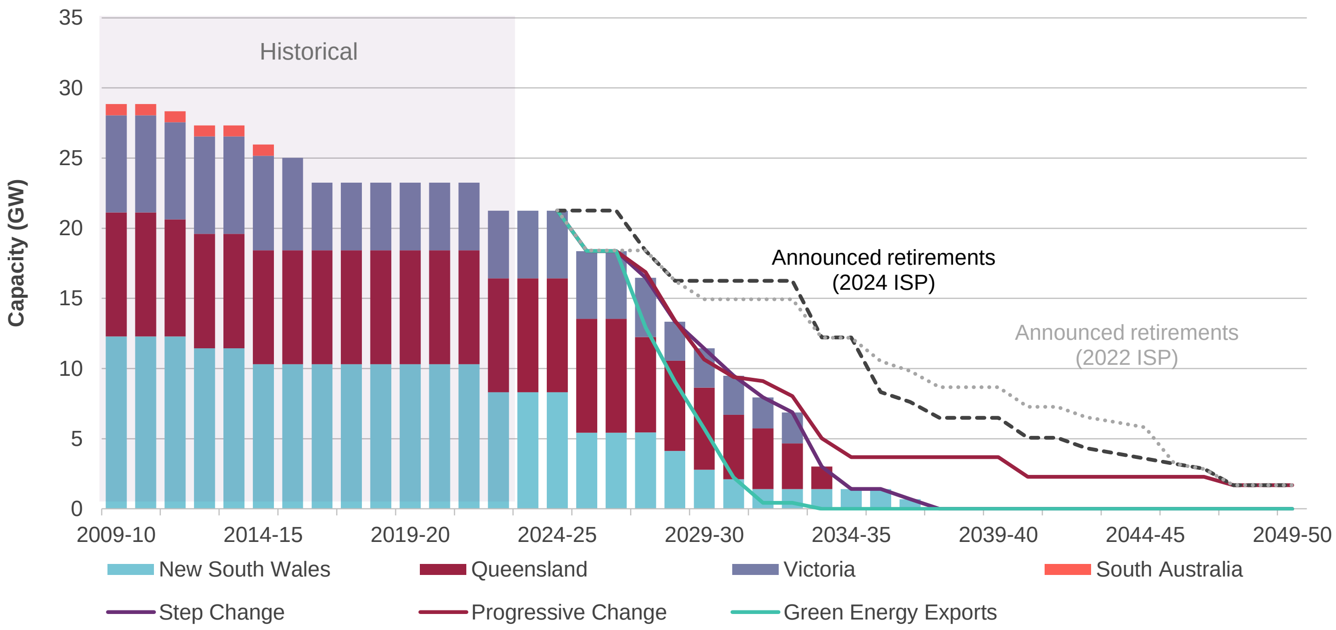
Construction: Construction has either commenced or a firm commencement date has been set
Response:

Appendix C: AEMO Coal Unit Projections for Queensland

AEMO's 2024 ISP noted that, between 2012 and 2023, 10 major coal-fired power stations had retired across the NEM, and owners of all but one plant of the remaining fleet have announced retirements by 2051 with about half announcing retirements by 2035. The ISP forecasts suggest that the coal fleet will close two to three times faster than those announcements, with about 80-90% of the NEM's coal fleet forecast to retire by 2034/35 in both the Step Change and Progressive Change scenarios (with a combined estimated 85% probability). Further, AEMO noted that, in practice, coal retirements may occur earlier than its own forecasts as continued operation of coal-fired generation becomes less attractive due to higher operating costs, reduced fuel security, high maintenance costs and increased competition from renewable generation.[86]

The figure below, from the 2024 ISP, shows coal capacity across the NEM from 2009/10 to 2049/50.

Figure 1: NEM coal capacity 2009/10 to 2049/50, 2024 ISP, June 2024



Source: AEMO, 2024 ISP Chart Data, June 2024 (figure 1).

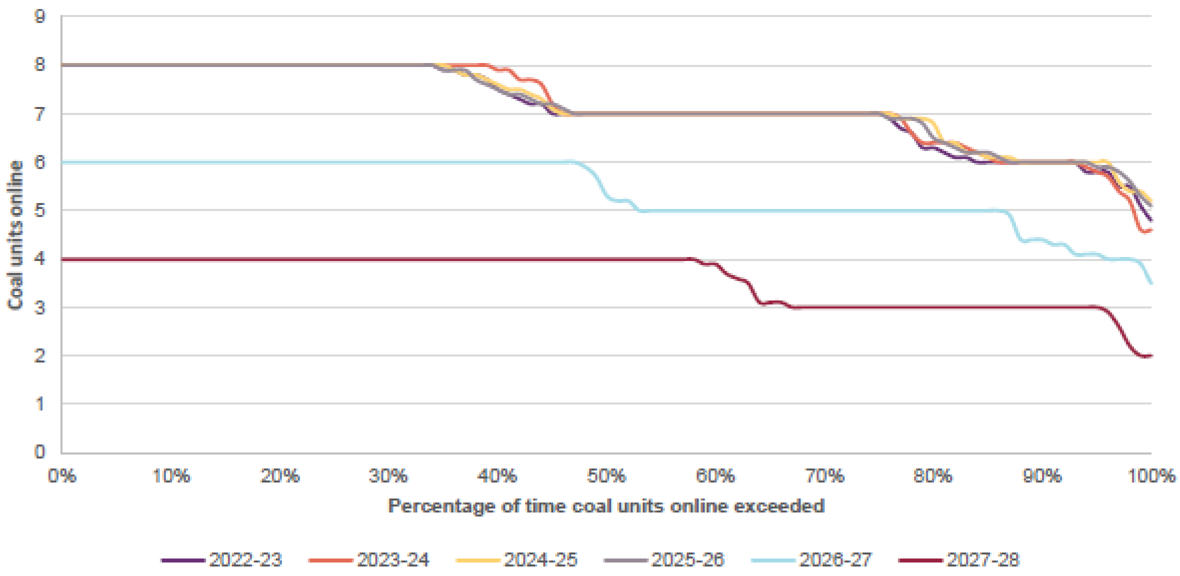
AEMO's 2024 ISP Chart Data shows installed levels of coal generation in Queensland decreasing from 8.13 GW in 2025/26 to 6.785 GW in 2027/28, and to zero GW in 2034/35.[87] Based on the annual changes in coal capacity between 2027/28 and 2034/35, Powerlink has inferred the number of units retired in the 2024 ISP as being four in 2027/28, one in 2028/29, then seven by 2031/32 and the remaining 10 by 2034/35.

For its System Strength Reports, AEMO produces additional duration data to reflect the percentage of each year that certain numbers of coal units are projected to remain online. This allows shortfalls to be identified based on both magnitude and duration, and captures the impact of both changing generator reliability (outage patterns), and periods of economic withdrawal where wholesale spot prices are reduced.

[86] AEMO, *2024 Integrated System Plan*, June 2024, pages 23 and 49.
[87] AEMO, *2024 ISP Chart Data*, June 2024 (figure 1).

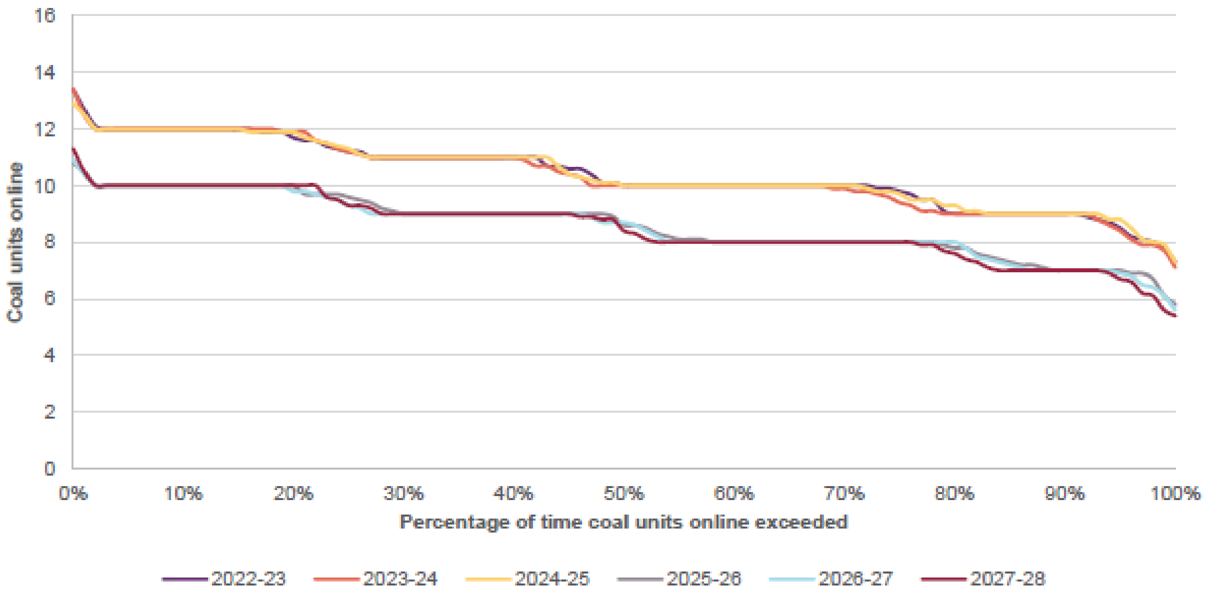
This added detail is critical, since it is the individual periods with low numbers of units online which are of primary concern. Coal generating units may be out of service due to planned outages, forced outages or for economic reasons. These charts reveal the projected number of operational coal units providing system strength in Central and Southern Queensland, based on the Step Change scenario. The three figures below show AEMO's projections in the 2022 and 2023 System Strength Reports.

Figure 2: AEMO projection of coal units online in Southern Queensland, 2022 System Strength Report



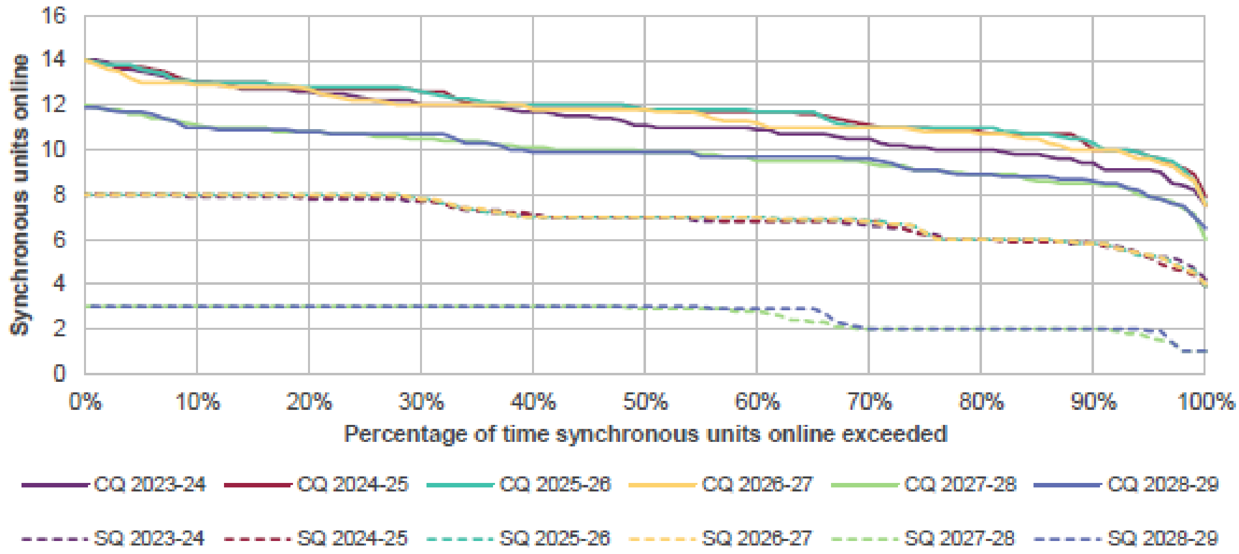
Source: AEMO, 2022 System Strength Report, December 2022, page 35 (figure 14).

Figure 3: AEMO projection of coal units online in Central Queensland, 2022 System Strength Report



Source: AEMO, 2022 System Strength Report, December 2022, page 36 (figure 15).

Figure 4: AEMO projection of coal units online in Central and Southern Queensland, 2023 System Strength Report



Source: AEMO, 2023 System Strength Report, December 2023, page 25 (figure 12).

Powerlink engaged with AEMO to better understand the source of the differences between the ISP and successive System Strength Report forecasts, and understands that:

- ISP modelling calculates and reports economic retirement dates for coal generators as part of the selection of an Optimal Development Path (ODP) for the NEM over the long-term;
- the retirement schedule used as an input to the 2022 System Strength Report was based on the outcomes of the final 2022 ISP;
- the retirement schedule used as an input to the 2023 System Strength Report was based on modelling done as part of the draft 2024 ISP, as was available in November 2023; and
- system strength modelling uses the retirement schedule as an input to further modelling that projects unit commitment decisions based on time-sequential simulation of competitive generator bidding strategies and price outcomes.

The sensitivity of forecast coal unit availability at sub-regional levels is significant for Powerlink's assessment of system strength needs. For Southern Queensland:

- the 2022 System Strength Report projected less than four units online approximately 40% of the time, and less than three units online approximately 5% of the time, in 2027/28; and
- the 2023 System Strength Report projected less than four units online 100% of the time, less than three units approximately 40% of the time and less than two units approximately 5% of the time, in 2027/28.

Appendix D: Cost Estimation

External cost environment

The external environment in which Powerlink operates has become more complex in recent years with challenges such as rising inflation and interest rates, and disruption to supply chains and materials shortages, intensifying.

In a report for the ENA and the Clean Energy Council (CEC), KPMG observed in August 2022 that as Australia constructs more transmission projects to meet the needs of the energy system, the availability of highly-trained engineers and other specialists needed for the projects will become more limited. KPMG also indicated that, for major projects, supply chain pressure was resulting in up to 40% increases in capital expenditure and at least a 5% increase in operational expenditure.[88]

In September 2023, AEMO reported that transmission cost estimates had increased approximately 30% in real terms compared to equivalent cost estimates for the 2022 ISP and, in the 2024 ISP, added that future cost reductions were unlikely. Also in the 2024 ISP, AEMO commented that the investments required by the ISP imply the need for thousands of critical energy assets – including utility-scale generators and batteries, high voltage transmission lines and cables, synchronous condensers and transformers – and the people needed to install and operate them. Further, AEMO noted that international demand for the materials, technologies and expertise to deliver a global energy transformation could increase Australia's exposure to risks associated with competition for investment and skills.[89]

Regulatory requirements

For each credible option, Powerlink is required to quantify:

- costs incurred to construct or provide the option;
- operating and maintenance costs in respect of the credible option; and
- the cost of compliance with laws, regulations and applicable administrative requirements in relation to the construction and operation of the option.[90]

At the PADR and PACR stages of a RIT-T, RIT-T proponents must include a quantification of costs, including a breakdown of operating and capital expenditure for each credible option.[91]

Further, in October 2023, additional information requirements were added to the RIT-T Application Guidelines in cases where the estimated capital cost of the preferred option exceeds $100 million. The guidelines require that, for each credible option, RIT-T must specify to the extent practicable and in a manner that is fit-for-purpose for the stage of the RIT-T:

- key inputs and assumptions adopted to derive the estimate;
- a breakdown of the main components of the cost estimate;
- methodologies and processes applied to derive the cost estimate;
- reasons in support of key inputs and assumptions adopted and methodologies and processes applied; and
- the level of, and basis for, any contingency allowance that has been included in the cost estimate.[92]

---

[88] KPMG, *Market Sounding Report on Transmission*, report for ENA and the CEC, August 2022, page 17.
[89] AEMO, 2023 *Transmission Expansion Options Report*, September 2023, page 3; AEMO, *2024 Integrated System Plan*, final report, page 83.
[90] NER, clause 5.15A.2(b)(8); AER, *Regulatory Investment Test for Transmission*, August 2020, paragraph 5.
[91] NER, clauses 5.16.4(k)(3) and (v)(1).
[92] AER, *Application Guidelines, Regulatory Investment Test for Transmission*, October 2023, page 30.

Powerlink estimates that actual network capital costs will be within a range of +40% and -20% of the central capital cost estimate (consistent with 'Class 5' under the AACE cost estimate classification system).

Updated information from non-network solution proponents

The proforma Powerlink published in June 2023 for non-network solutions requested proponents provide the capital cost, external contributions, and indicative annual availability and hourly run charges for solutions. However, not all proponents provided capital cost information for their proposals and, for those that did, Powerlink could not be confident that the costs were provided in a manner consistent with the RIT-T Application Guidelines. In December 2023, Powerlink requested proponents update/confirm their capital, operating and maintenance, and compliance costs (in accordance with the RIT-T requirements noted above). The information request also asked proponents to update/confirm their availability and/or run charges.

Proposed network support costs for non-network solutions are included in the assessment of costs and benefits, but do not have any impact on the identification of the preferred option as the costs are treated as a wealth transfer between energy market participants under the RIT-T framework.[93] These costs for non-network solutions will ultimately be reviewed by the AER as part of the new Network Support Pass Through process for system security services.[94]

To provide objective estimates of costs of credible options for the cost-benefit analysis, Powerlink used build, fuel, and fixed and variable operating costs, data from AEMO's 2023 IASR to model the incremental costs of non-network solutions.[95] In terms of how the IASR build costs compared to capital cost information from proponents of non-network solutions, Powerlink observed broad alignment between the two sources of data.

A request for updated technical and commercial information from proponents of non-network solutions is at Appendix B of this PADR. The request includes AEMO's minimum and recommended requirements for system strength contracts, as per its Provisional Security Enablement Procedures, and additional information Powerlink requires to complete this RIT-T and conclude contracts with proponents of non-network solutions.

Synchronous condensers

Powerlink has prepared a number of high-level estimates for the installation of network synchronous condensers as part of the System Strength RIT-T. The estimates draw on (confidential) advice from third-party suppliers of synchronous condensers, with the Powerlink portion of the cost based on recent actual projects. The estimates cover the following elements:

- Design, supply, delivery, installation, testing and commissioning;
- Building and civil works;
- Road works; and
- 275kV bay installation and overhead line works.

An escalation factor has also been applied to allow for increases in contract and material costs.

The cost-benefit assessment for the PADR includes a capital cost of $135 million for the supply and installation of network synchronous condensers, which is at the upper-end of our estimates and is site-agnostic across the

[93] AER, *Application Guidelines, Regulatory Investment Test for Transmission*, October 2023, pages 60-62.
[94] See AEMC, *Improving Security Frameworks for the Energy Transition*, final determination, March 2024, pages 49-53.
[95] AEMO, *2023 IASR Assumptions Workbook*, September 2023.

Powerlink network.[96] Land and biodiversity costs are not included in the estimated cost of network synchronous condensers as they are assessed as being co-located on existing Powerlink-owned land.

In terms of operating costs for network synchronous condensers, Powerlink has assumed annual operating and maintenance costs to be 0.6% of capital expenditure, consistent with the AER's August 2019 decision on ElectraNet's Main Grid System Strength Contingent Project.[97] Powerlink also notes that the value is higher than estimates from suppliers of synchronous condensers.

For cost estimation, the active power consumed by running synchronous condensers is translated to network losses based on the operation of the machine. In this regard Powerlink made assumptions on the percentage of time operating at no load, and cost of energy to run (dollars per kilowatt hour).

These assumptions were applied to manufacturer-supplied technical data on losses at different running conditions to derive the cost of losses. The impact of these losses on emissions in the NEM has also been included in the analysis, but is not considered material to the overall outcome of the analysis.

Powerlink has commenced planning studies for potential sites on our 275kV network in Central Queensland for installation of synchronous condensers. As the technical assessment progresses, and updated information from suppliers becomes available, Powerlink will prepare more detailed estimates, in line with our cost estimation methodology, and provide details in the PACR.

For non-network synchronous condensers, the same approach was used as for network synchronous condensers.

Given the current market for synchronous condensers, Powerlink will review the cost estimate as part of the PACR to ensure that the most recent information available at the time is used.

Other network solutions

Powerlink investigated other technology options for addressing system strength, such as using grid-forming STATCOM with supercapacitors or STATCOM with synchronous condensers.

Synchronous condensers offer the benefits of providing system strength via additional short circuit capacity, rotating inertia for network stability, dynamic reactive support, overload capability, voltage support, regulation of voltage during fault conditions, absorption of reactive power during light load conditions to avoid overvoltage, and production of reactive power during high load conditions to avoid under-voltage. Apart from synchronous condensers, no other network solutions have been deemed able to provide system strength and the other mentioned benefits.

Capital costs for non-network BESS

The current ISP investment modelling does not explicitly distinguish between grid-following and grid-forming technology types, and all IBR (including build costs in the IASR) are effectively treated as grid-following.[98]

In undertaking the PADR analysis, there are three 'types' of BESS that have been considered:

- Committed/anticipated BESS;
- Proposed BESS from submissions to Powerlink's PSCR (and the accompanying proforma); and

---

[96] The estimate is based on a 200 MVA synchronous condenser.
[97] AER, *ElectraNet Contingent Project, Main Grid System Strength*, final decision, August 2019, page 29. Transgrid also used the 0.6% value from the AER's decision on ElectraNet's system strength Contingent Project in its PADR (page 29).
[98] AEMO, *System Strength Report*, December 2023, page 11.

- Generic BESS from AEMO's IBR forecast.

The three committed/anticipated BESS included in the cost-benefit analysis (see chapter 7) are the Mount Fox BESS (ARENA), Stanwell BESS and Tarong BESS.[99] These BESS are being built as grid-forming and therefore Powerlink has not added any incremental costs to these assets in the cost-benefit assessment; that is, they are assumed to be included in the same manner/cost under the base case and option cases. While these BESS have been considered in the PADR analysis, they do not feature in any of the option portfolios as they form part of the base case (and not changing their operation in any way under the option cases).

For BESS proposed in response to the PSCR (and the accompanying proforma), the full cost, based on IASR cost assumptions, is included in the cost-benefit assessment, with an additional 5% added to convert the BESS from grid-following to grid-forming (as Powerlink understands that that the IASR cost assumptions relate to grid-following BESS). Proposed BESS make up all of the BESS capacity included in the portfolios, and they are not assumed to go ahead under the base case.

There are also two existing grid-following BESS, which would satisfy the requirements if they were to be upgraded to grid-forming. Similar to the proposed BESS, the cost to convert these BESS from grid-following to grid-forming is calculated at 5% of the total IASR build cost for a BESS of the same size.

Generic BESS included in the AEMO IBR forecasts (that could upgrade from grid-following to grid-forming, if paid to do so) have been considered but ultimately not included in the PADR assessment due to them not being forecast to be available as potential solutions in Queensland. Specifically, the AEMO IBR forecasts for Queensland do not include these 'generic' BESS beyond 2027 and, thus, Powerlink does not consider it appropriate to include any such potential solutions in the formation of our portfolios.[100] Powerlink notes that this is in contrast to Transgrid's recent PADR assessment, which included these BESS in option portfolios due to the significant amount of generic BESS forecast in New South Wales in the AEMO IBR forecasts.

---

[99] AEMO, *Generator Information*, Excel workbook, July 2024. The Mount Fox BESS (ARENA) and Stanwell BESS are listed as anticipated, and the Tarong BESS as committed (highly likely to proceed), in the July workbook.

[100] While the latest AEMO IBR forecasts include a small amount of IBR BESS in the short-term, Powerlink notes that all of this capacity is assumed to be taken up by 2027 by the three committed/anticipated BESS Powerlink has included in the modelling (i.e., the Mount Fox BESS, the Stanwell BESS and the Tarong BESS).

Appendix E: Cost-benefit Analysis Inputs and Assumptions

This appendix outlines the key inputs and assumptions used to inform the cost-benefit analysis detailed in chapter 6.

Reasonable scenarios

In terms of Queensland-specific policies, the 2023 IASR included the following positions:

- Expansion of the QRET to 50% by 2030, 70% by 2032 and 80% by 2035;
- Support for the Borumba PHES as an anticipated project, based on AEMO's generation commitment criteria;
- Support for the Kogan Renewable Hydrogen Project;
- SuperGrid Blueprint and Queensland REZ infrastructure treated as options;
- CopperString 2032 treated as an anticipated project, with the Townsville to Hughenden connection to be modelled as a REZ network expansion;
- Inclusion of the SuperGrid Landholder Payment Framework; and
- Conversion of publicly owned coal-fired generation into clean energy hubs.[101]

AEMO's 10-year forecast IBR at each system strength node is based on the Step Change scenario from the 2022 ISP and the central scenario demand forecast from the 2022 ESOO.[102] Given Powerlink is required to plan for delivering the efficient level of system strength required to host the forecast IBR, Powerlink considers the Green Energy Exports and Progressive Change scenarios are not relevant to this RIT-T.

NPV parameters

Analysis period

To take into account the size and complexity of the system strength services that will be required in Queensland over the long-term, the RIT-T analysis extends to 2049/50.[103] Where the capital components of the credible options have asset lives extending beyond the end of the assessment period, the NPV modelling includes a terminal value to capture the remaining asset life. This ensures that the capital cost of long-lived options over the assessment period is appropriately captured, and that all options have their costs and benefits assessed over a consistent period, irrespective of option type, technology or asset life.

Discount rate

Under the RIT-T Instrument:

- RIT-T proponents must adopt the discount rate from AEMO's most recent IASR unless the proponent can demonstrate why variation is necessary; and
- the present value calculations of the costs and benefits of credible options must use a commercial discount rate appropriate for the analysis of a private enterprise investment in the electricity sector.[104]

---

[101] AEMO, *2023 Inputs, Assumptions and Scenarios Report*, July 2023, pages 7 and 31.
[102] AEMO, *2022 System Strength Report*, December 2022, page 16.
[103] The PSCR indicated the cost-benefit analysis would be conducted over a 20-year period, which is the standard timeframe for Powerlink's RIT-T analysis. The longer period aligns with EY's modelling of market benefits out to 2049/50.
[104] AER, *Regulatory Investment Test for Transmission*, August 2020, paragraphs 18 and 19.

In this RIT-T Powerlink has adopted a real, pre-tax commercial discount rate of 7% as the central assumption for the NPV analysis.[105]

Powerlink has tested the sensitivity of the results to changes in this discount rate assumption, and specifically to the adoption of a lower bound discount rate of 3.63% and an upper bound discount rate of 10.5%.[106]

Status of projects

The status of non-network solutions – that is, whether they are committed, anticipated or modelled – is a key input into the analysis under the RIT-T. The RIT-T Instrument defines a committed project as meeting all of the following criteria:

- *Land* – The proponent has purchased/settled/acquired land (or commenced legal proceedings to acquire land) for the purposes of construction.
- *Contracts* – Contracts for supply and construction of the major components of the necessary plant and equipment (such as generators, turbines, boilers, transmission towers, conductors, terminal station equipment) have been finalised and executed, including any provisions for cancellation payments.
- *Planning* – The proponent has obtained all required planning consents, construction approvals and licenses, including completion and acceptance of any necessary environmental impact statement.
- *Finance* – The necessary financing arrangements, including any debt plans, have been finalised and contracts executed.
- *Construction* – Construction has either commenced or a firm commencement date has been set.[107]

An anticipated project is one that does not meet all the criteria of a committed project, and is in the process of meeting at least three of the criteria of a committed project. A modelled project is a hypothetical project derived from market development modelling in the presence/absence of the credible option.[108]

Committed and anticipated projects are included in the base case for the cost-benefit analysis, while modelled projects are not. The status of projects under the RIT-T has an important bearing on how their costs are included in the analysis. Specifically, the full capital and operating cost of modelled projects are required to be included in the RIT-T assessment (given they are not included in the base case), while existing, committed and anticipated projects are included either at no cost (where they are already grid-forming), or at their incremental cost to become grid-forming.

In the proforma for non-network solutions (June 2023), and in the subsequent information request (December 2023), Powerlink requested proponents to provide advice on the status of their proposed solutions. Overall, the responses were sufficient for Powerlink to form a view on which projects were committed, progressing toward committed status (that is, anticipated) or modelled for the purpose of undertaking cost-benefit analysis. However, proponent responses were not all equal in terms of clarity, level of detail, or addressing each element of the five RIT-T criteria. To ensure the cost-benefit analysis in the PACR is as robust and up-to-date as possible, Powerlink needs all proponents, via their responses to Tables 7A to 7E in Appendix B, to update/confirm the status of their proposals, and include sufficient information on each of the five RIT-T criteria. As Powerlink moves

[105] This indicative commercial discount rate of 7% is based on AEMO, *2023 Inputs, Assumptions and Scenarios Report*, July 2023, page 123.
[106] A discount rate of 3.63% pre-tax Weighted Average Cost of Capital is based on AER, *TasNetworks (Transmission) 2024–29 Final Determination*, April 2024.
[107] AER, *Regulatory Investment Test for Transmission*, August 2020, page 13 (glossary).
[108] Ibid.

toward contracting with non-network providers, it is likely that the quality and reliability of advice on project status will be taken into account in selecting solutions.

Powerlink also compared the non-network solutions with AEMO's Generation Information Excel workbook (in April 2024), and found the status of the majority of solutions was the same. It is worth noting, however, that AEMO's project commitment criteria are slightly different to the RIT-T criteria. For example, AEMO's planning criteria requires connection contracts (including approval of Generator Performance Standards) to be approved whereas the RIT-T criteria do not. Therefore, Powerlink does not expect complete alignment on the status of projects between the System Strength RIT-T and AEMO's Generation Information.

Key parameters

The table below outlines the inputs Powerlink has used for key parameters for the cost-benefit analysis for this RIT-T.

Table 1: Input parameters for cost-benefit analysis

Parameter	Source/Assumption
Fixed Date Asset Retirement – Qld coal	AEMO Final 2024 ISP (Step Change scenario)
Fixed Date Asset Retirement – non-Qld coal	AEMO Final 2024 ISP (Step Change scenario)
Fixed Date Asset Retirement – Gas	AEMO 2023 IASR
Fixed Date Non-thermal Asset Retirement	AEMO 2024 IASR
Borumba PHES Pumped Hydro	AEMO Generation Information (May 2024)
New Entrant Build Limits	AEMO 2023 IASR
Generator Energy Limits	AEMO 2023 IASR
Capital Costs	AEMO 2023 IASR
Fixed operating and maintenance cost (real 2023 dollars)	AEMO 2023 IASR (Qld Medium)
Variable operating and maintenance cost (real 2023 dollars)	AEMO 2023 IASR (Qld Medium)
Weighted average cost of capital (WACC)	AEMO 2023 IASR (central assumption)
Existing generation and storage technical parameters	AEMO 2023 IASR
New entrant generators technical parameters	AEMO 2023 IASR
REZ representation	AEMO 2023 IASR
Capacity Factors for new wind and solar availability	AEMO 2023 IASR
Coal fuel cost	AEMO 2023 IASR (Step Change scenario)
Gas fuel cost	AEMO 2023 IASR (Step Change scenario)
Hydro inflows and storage volumes	AEMO 2023 IASR
Group REZ limits	AEMO 2023 IASR

Parameter	Source/Assumption
Resource limits	AEMO 2023 IASR
Network representation	AEMO 2023 IASR
Transmission development pathway	Final 2022 ISP ODP with updates to align New South Wales flow path augmentations with the NIS central scenario and Queensland with the SuperGrid Blueprint.
Value of emissions	Portfolio formation (excl. VER sensitivity): Emissions analysis using NSW Treasury Cost of Carbon Emissions. Portfolio Formation VER Sensitivity: Emissions analysis using AER Draft Guidance Valuing Emissions Reduction Modelling of Wholesale Market Benefits Analysis: Emissions Analysis using AER Draft Guidance Valuing Emissions Reduction
Demand Side Participation	AEMO 2023 IASR (Step Change scenario)
Underlying consumption	Final 2022 Electricity Statement of Opportunities (Step Change scenario)
NEM carbon budget	630 Mt CO2-e for 2024-25 to 2029-30 681 Mt CO2-e for 2024-25 to 2051-52 2023 IASR v5.3 (Step Change scenario)
Commonwealth Renewable Energy Target	82% renewable generation by 2029/30 2023 IASR v5.3
Queensland Renewable Energy Target	50% renewable energy by 2029/30, 70% by 2031/32 and 80% by 2034/35, as a share of Queensland demand. 2023 IASR v5.3
NSW Electricity Infrastructure Roadmap	At least the same amount of electricity at 8 GW in New England REZ, 3 GW in Central West Orana REZ and 1 GW of additional renewable capacity + 2 GW of long duration storage (8 hours or more) by 2029/30. 2023 IASR v5.3
Victoria Renewable Energy Target	40% by 2025, 65% by 2030 and 95% by 2035 as a percentage of Victorian generation. 2023 IASR v5.3
Victoria Energy Storage Target	2.6 GW by 2030 and 6.3 GW by 2035 2023 IASR v5.3
Victoria Offshore Wind Target	2 GW by 2032, 4 GW by 2035, 9 GW by 2040 2023 IASR v5.3

Appendix F: System Strength Enablement

In September 2022, the AEMC released a draft determination to establish an Operational Security Mechanism (OSM) to value, procure and schedule security services across the NEM in operational timeframes. The AEMC intended that AEMO would define the security services to be procured, and accredit eligible participants, and that the OSM would commence on 1 October 2025. One of the expected advantages of the OSM was that it would address the over-reliance of directions by AEMO to bring generators online, that would otherwise be offline, to provide essential system services.[109]

In August 2023, the AEMC proposed what it described as a simpler solution to managing power system security. The AEMC suggested greater understanding of the engineering and technical capabilities of the energy system was needed before complex market changes could be made. The AEMC's revised approach focused on long-term procurement of power system security services by building on existing frameworks on the NER, rather than operational procurement via an OSM.[110]

In March 2024, the AEMC made the Security Frameworks Rule which aimed to enhance arrangements to value, procure and schedule system security services – which includes system strength, inertia and NSCAS – in the NEM. One element of the Security Frameworks Rule – AEMO's scheduling and dispatch (enablement) of security services – is of particular relevance to Powerlink's implementation of the System Strength Rule.

The AEMC considered that AEMO, rather than TNSPs, was best placed to enable system security contracts due to AEMO's operational security responsibilities and ability to coordinate operational security needs.[111]

From December 2025, AEMO will be required to use reasonable endeavours to:

- enable a combination of contracts to provide security services at least cost;
- enable contracts as close as practicable to the relevant trading interval, and no more than 12 hours ahead of time;
- enable contracts to meet a gap in security services, and to not always enable for the full amount of the required service; that is, enable contracts only when energy spot market outcomes are not expected to provide the required level of security service; and
- not enable contracts that would result in a significant adverse effect on power system emissions or efficiency.[112]

In terms of Powerlink's procurement of system strength services, these enablement principles may reduce Powerlink's ability to contract with generating units that have cold startup times greater than 12 hours. As AEMO will only dispatch for system strength where there is a 'gap' in energy dispatch, variable payments from Powerlink to non-network providers are likely to only be made for the gap, with any plant operating within the merit order not receiving variable payments.

The Security Frameworks Rule also required AEMO to consult on and publish a new Security Enablement Procedures to describe how it will determine and meet the relevant enablement levels for security services.

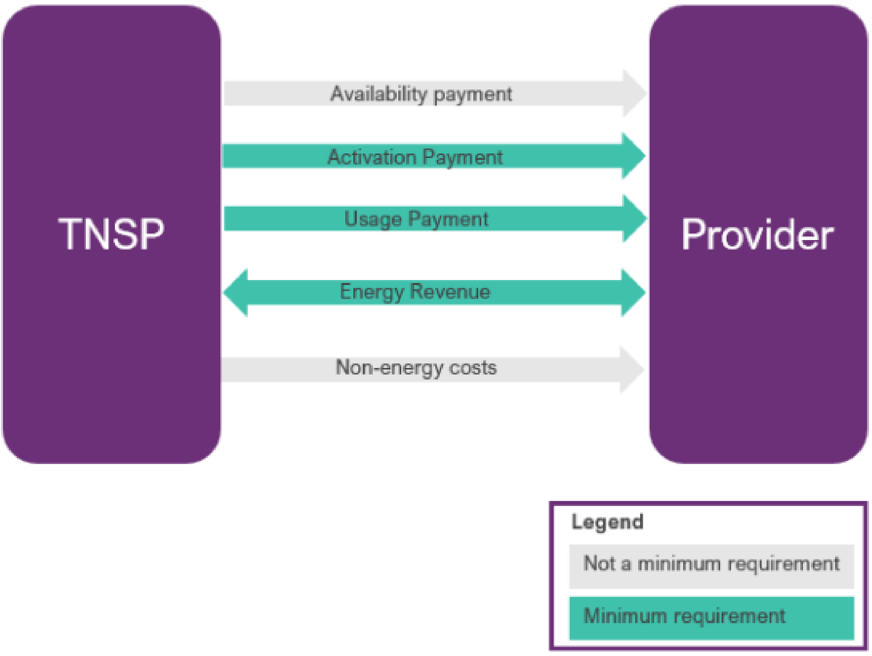
[109] AEMC, *Operational Security Mechanism*, draft determination, September 2022, pages 13, 24 and 27.
[110] AEMC, *Improving Security Frameworks for the Energy Transition*, directions paper, August 2023, pages 1 and 4.
[111] AEMC, *Improving Security Frameworks for the Energy Transition*, final determination, March 2024, pages 84-85.
[112] AEMC, *Improving Security Frameworks for the Energy Transition*, final determination, March 2024, page 90, and final rule, schedule 5 at [14] adding clause 4.4A.4 to the NER from 2 December 2025.

Although the procedures are not due for publication until 31 August 2025, AEMO was required to issue the minimum and recommended requirements for system security contracts by 30 June 2024.[113]

In June 2024, AEMO released Provisional Security Enablement Procedures which included minimum and recommended requirements to be included in contracts entered into by TNSPs for the provision of system security services. The provisional procedures set requirements across five aspects of contracts:

- General agreement structure.
- Defining service provision.
- Financial structure.
- Intended scheduling arrangements.
- General requirements.[114]

The chart below, from AEMO's Provisional Security Enablement Procedures, identifies the minimum and recommended ('not a minimum requirement') elements of the system strength contracts.



Source: AEMO, Provisional Security Enablement Procedure, June 2024, page 10 (figure 1).

Powerlink will implement AEMO's requirements in our system strength contracts, and intends to actively participate in AEMO's consultation on the final version of the Security Enablement Procedures.

[113] AEMC, *Improving Security Frameworks for the Energy Transition*, final determination, March 2024, page 88, and final rule, schedule 5 at [14] adding clause 4.4A.6 to the NER from 2 December 2025; NER, clause 11.168.2.
[114] AEMO, *Provisional Security Enablement Procedure (Improving Security Frameworks)*, June 2024, page 5.

Appendix G: Commercial Parameters

In December 2023, Powerlink published a commercial parameters document to provide proponents of non-network solutions with example terms and conditions for system strength contracts that Powerlink will negotiate with proponents. To inform submissions and responses to the information request from proponents of non-network solutions, this appendix outlines Powerlink's updated commercial parameters.

The scope of these commercial parameters is a key area that Powerlink is seeking stakeholder feedback on in response to this PADR.

Details

The Queensland Electricity Transmission Corporation Limited (ABN 82 078 849 233) (**Powerlink**) provides System Strength Providers (**SSPs**) with high-level terms as an example of the provisions that may be included in a System Strength Services Agreement (**SSSA**). These example terms remain subject to Powerlink's requirements and the specific terms and conditions negotiated between the parties.

Concept	Description
Contract Term	Preferred duration of the SSSA is up to 10 years and may be subject to the following: • The term will be the period for which system strength services are to be provided by the SSP; • The term is subject to termination rights under the SSSA; • Fixed start and/or end dates may apply to align with Powerlink's system strength service needs; and • Options to extend the term may be included.
Form of Contract	Individual SSSA with each SSP.
Conditions Precedent	The SSSA may include customary conditions precedent before commencement of the term, including: • all necessary approvals; • the parties obtaining relevant Board authorisations; • the SSP providing a copy of the notice to proceed (or equivalent) under its construction or supply contracts; • the SSP providing a copy of its connection and access agreement; and • any additional conditions precedent required following due diligence on the SSP. The conditions precedent for the SSSA will depend on the results of Powerlink's due diligence.

Concept	Description
SSP Obligations	During the term, the SSP must comply with customary ISF Asset related obligations, including compliance with the connection and access agreement, all land use arrangements for the ISF Asset, and the National Electricity Rules (NER) (including rule 5.3.9 if applicable for altering a generating system and NER processes for the SSP to become a registered participant in the National Electricity Market). The SSP must, in the form and at the times specified in the Security Enablement Procedures, provide the current Availability and a continuous forecast of Availability to AEMO and the TNSP and must immediately update AEMO and the TNSP if there is any change in current or forecast Availability of the ISF Asset. The ISF Asset must be capable of continuous service provision for at least 2 hours. During the term, the SSP must comply with all instructions from Powerlink and / or AEMO to provide or cease providing system strength services.
Construction Milestones (where appropriate)	The SSSA will contain key information milestones (including procurement, installation, commissioning, testing and validation). Construction milestones and system strength service milestones will be required under SSSA. The SSP will be required to achieve commercial operations by a target date. If commercial operations are not achieved by the target date, liquidated damages may be payable (and with the right to terminate the SSSA if commercial operations are not achieved by the sunset date).
System Strength Services	Description of services, including: • Technology type • Technical characteristics (e.g., fault level (MVA), inertia (MWs)) • Auxiliary load (MW) • Activation lead time (hours and minutes) • Minimum dispatch • Metering points • Performance standards • Limitations (e.g., availability during specific months)
Guaranteed Availability Service Standards	Service levels to be included in the SSSA: Guaranteed Availability ≥ 95% over an aggregate availability period (e.g. rolling 12-month period) subject to permitted periods of non-performance being excluded. The measure of availability will depend on the nature of the ISF Asset providing the service. In determining the availability calculation, planned and unplanned maintenance will be accounted for and permitted periods of non-performance will be excluded. Activation is calculated by reference to the ISF Asset's non-operational state and must be no more than 12 hours Powerlink may require additional service level standards to be maintained by the SSP depending on the nature of the contracted system strength services

Concept	Description
Breach of Guaranteed Availability Service Standards and Remedies for Breach	Where Guaranteed Availability [and/or Guaranteed Activation time] cannot be met, remedies may include the abatement of fee payments, the payment of liquidated damages by the SSP, and/or termination rights for protracted breaches.
Framework for System Strength Charges	**Availability Payment ($/month/year)** Powerlink will make availability payments per month/year (based on the availability period across the proposed term). The availability payments are intended to compensate the SSP's fixed costs for maintaining the availability of the system security service. **Activation Payment ($/activation per unit)** The SSSA will include a 'payment per event' mechanism. This mechanism is intended to compensate the SSP for the costs of commencing operation from a previously inactive state. No activation payment is payable if the unit is already online. **Usage Payment ($/hr per unit)** The SSSA will include a usage payment per hour of operation. The usage payments are intended to compensate the SSP for the variable costs (if applicable) of operating in the manner required to provide the relevant system security service. Note: Settlement will be calculated on a trading interval basis and not payable during activation lead time. **Energy** *Powerlink is seeking feedback from stakeholders regarding options to manage energy revenue risks and the cost associated with energy revenue transfers for system strength services.*
Metering	The SSP will be required to install market meters enabling the separate metering of electricity generated by the ISF Asset or electricity supplied to the ISF Asset.
Information Sharing with AEMO	The SSSA will include a general obligation for the SSP and Powerlink to provide information requested by AEMO relevant to scheduling and enabling the system strength services. If required by AEMO, the SSP and Powerlink will consult with AEMO on any misalignment between the SSSA and AEMO's methodology for scheduling and enabling system strength services and will negotiate in good faith any variations to the SSSA to ensure it operates consistently with AEMO's processes.
Credit support	A bank guarantee, cash retention or insurance bond may be required during the construction phase (if applicable). This may be subject to Powerlink's internal requirements including SSP credit rating/capacity.

Concept	Description
Liability Caps	Contractual liability caps are subject to negotiation. Relevant considerations may include total payment amounts under the SSSA, the capital expenditure estimate of the ISF Asset, amounts recoverable under insurance etc. Uncapped positions for fraud and wilful default reflect those liabilities for which a court may award damages beyond the contractual terms due to their nature or which can be appropriately managed by insurance. The SSP must be willing to accept liability in connection with any failure by it to provide system strength services.
Insurance	The SSP will obtain (from a reputable insurer), and maintain all insurance policies customarily held, and for the coverage amounts customarily held, by an asset operator providing services similar to the Network Support Services, and as reasonably requested by Powerlink.
Prescribed Network Charges	Prescribed network charges may apply to ISF Assets when they are operating as a load. Prescribed charges payable by the SSP will then be passed through to Powerlink under the SSSA.
Change in Law	A change in law regime will be included in the SSSA.
Termination and default	The SSSA will include termination rights for breach. Termination rights may be subject to a remediation/cure plan. Powerlink may terminate for convenience. The SSP will be entitled to payment of its reasonable costs actually and unavoidably incurred that are directly attributable to the termination for convenience, provided that these costs do not exceed a capped amount. The cap will be based on: • non-refundable amounts payable to contractors of the SSP; and • agreed percentage of unrecovered capital costs. Any termination amount for termination for will be subject to adjustment (deduction) (e.g. for any reutilisation, recontracting value, residual or written down value of the ISF Asset).
Dismantling Costs	Dismantling expenses incurred are the responsibility of the SSP and cannot be passed through.
Invoicing	Standard invoicing is monthly in arrears. Standard 30-day payment terms will apply from the date the invoice is received.
Contract schedules	The SSSA will include schedules with contract particulars, including: • ISF Asset/technology specific details • Testing plan • System strength services • Operational protocols

Definitions

Term	Definition
Activation Lead Time	The time required for an ISF Asset to become enabled for a system security service/s after receiving an instruction from AEMO for enablement.
Activation Payment	A payment to reflect the Provider's cost of commencing operation from a previously inactive state.
Activation Period	The period (corresponding to the Activation Lead Time) between an ISF Asset being instructed for enablement and being enabled to provide a system security service.
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
Available	An ISF Asset is considered Available if it is capable of providing system security services after its Activation Period if instructed by AEMO to do so.
Availability Payment	A payment that reflects the Provider's fixed costs for maintaining the Availability of the system security service.
Enabled	A system security service is enabled when an ISF Asset provides the service in accordance with AEMO's instructions. A service commences enablement after the Activation Period ends.
Enablement Period	The period over which an ISF Asset is instructed by AEMO to provide a system security service(s).
ISF	Improving Security Framework refers to the final rule for the Improving Security Frameworks for the Energy Transition rule change
ISF Asset	A production unit, network element, other plant or facility that is under an agreement to provide a system security service(s).
NEM	National Electricity Market
NER	National Electricity Rules
SSSP	System Strength Service Provider
Usage Payment	A payment to compensate for costs of operating in the manner required to provide the relevant system security service.

Appendix H: Technical Considerations

Key Points

- Powerlink conducted comprehensive wide-area EMT studies using the Power Systems Computer Aided Design (PSCAD) software package with detailed models to determine system strength requirements in Queensland for the 2025 to 2030 planning horizon.
- Powerlink also applied AEMO's recommended assessment methods for analysing stable voltage waveforms for the studies.

Methodology

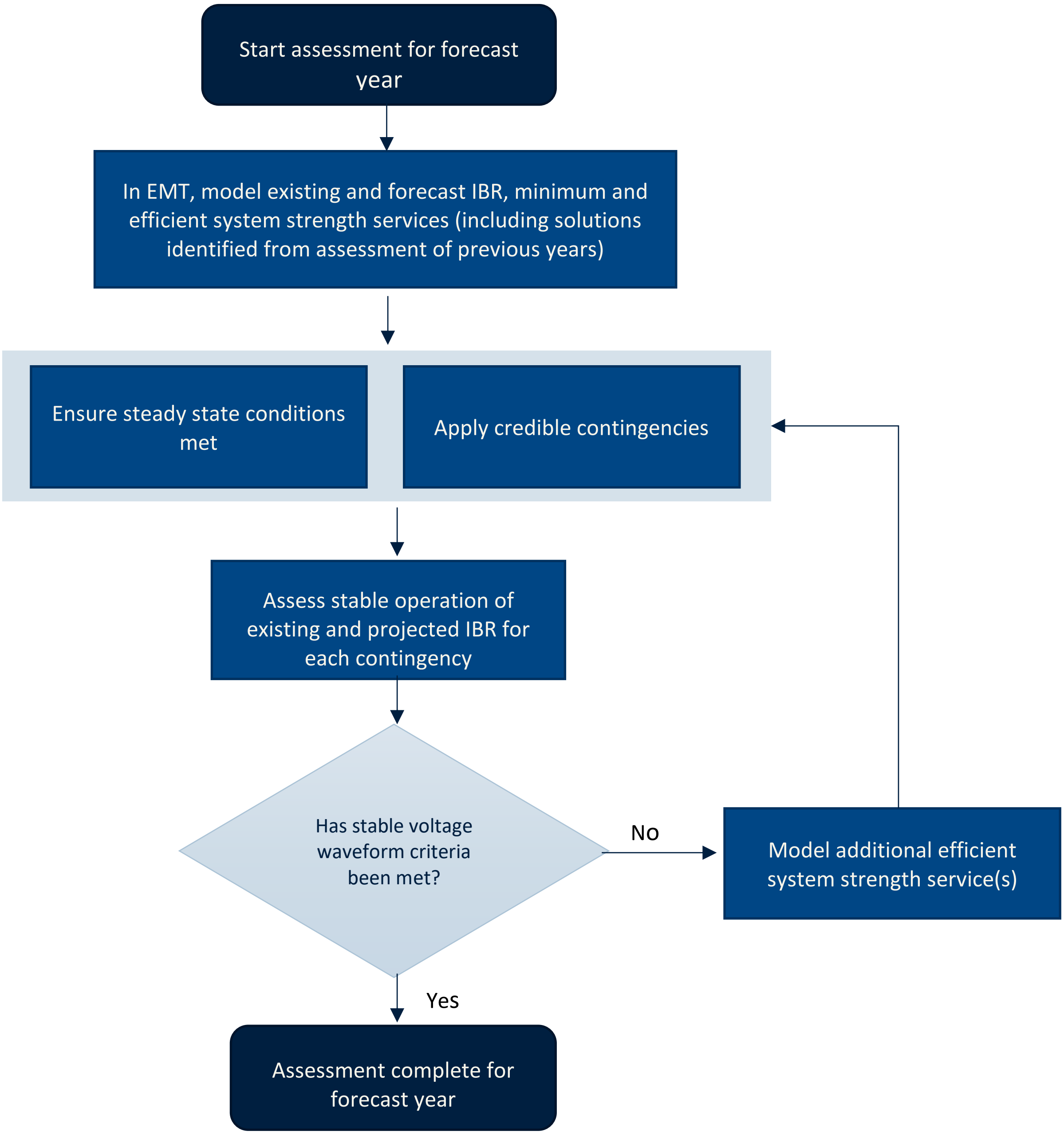
Powerlink conducted comprehensive wide-area EMT studies using the PSCAD software package with detailed models to determine system strength requirements in Queensland for the 2025 to 2030 planning horizon. The high-level methodology included the following elements:

- IBR forecast from the 2023 System Strength Report was considered for modelling. Forecasted IBR projects were mapped to system strength nodes to match the forecast level and type of IBR.
- Detailed PSCAD models, where available, were integrated into the wide-area network model. For cases lacking project-specific models, generic models were used.
- Powerlink's local connection knowledge was factored in to determine the most appropriate way to model the 'typical' performance characteristics of forecast IBR. Specifically, consideration was given to projects at various stages, including:
    - projects that have received connection letters under clause 5.3.4A of the NER;
    - projects in the full impact assessment (FIA) stage of the system strength impact assessment; and
    - active projects that are in the application stage.
- For BESS, information on whether the project was intending to be grid-forming or grid-following was used. For hybrid plants (solar farm plus BESS or wind farm plus BESS), actual project data as at the time of the study was used. For future plants the best available information, such as location and OEM details, were used.
- System strength planning study outcomes were evaluated to ensure stable voltage waveforms, allowing a sufficient amount of IBR to connect and remain stable during steady-state conditions and following credible contingency events.
- Each contingency was assessed for successful fault recovery and post-contingent steady-state voltage at key buses in the system, ensuring the network maintains stable voltage waveforms.
- Evaluation of day and night time conditions was considered.
- Assessment of stable voltage waveform was conducted in accordance with AEMO's System Strength Requirements Methodology (version 2.0) taking into account the following criteria:
    - Voltage magnitude within relevant network limits;
    - Voltage oscillations do not exceed acceptable thresholds; and
    - Change in voltage phase angle is not excessive.
- When conducting detailed modelling for a specific system strength planning year, known committed and anticipated grid-forming BESS projects were initially excluded from detailed PSCAD modelling, as they can provide stable voltage waveform support to the projected IBR. However, when a need is identified for efficient system strength requirements due to projected IBR connections, the grid-forming BESS were gradually incorporated into the model until satisfactory results are achieved for stable voltage waveform

criteria. The required level of efficient system strength for that year is determined based on the amount of grid-forming BESS needed. For the subsequent year, the solutions identified in the previous year remain in place, and detailed modelling continued to assess any additional needs based on the projected IBR for that year.

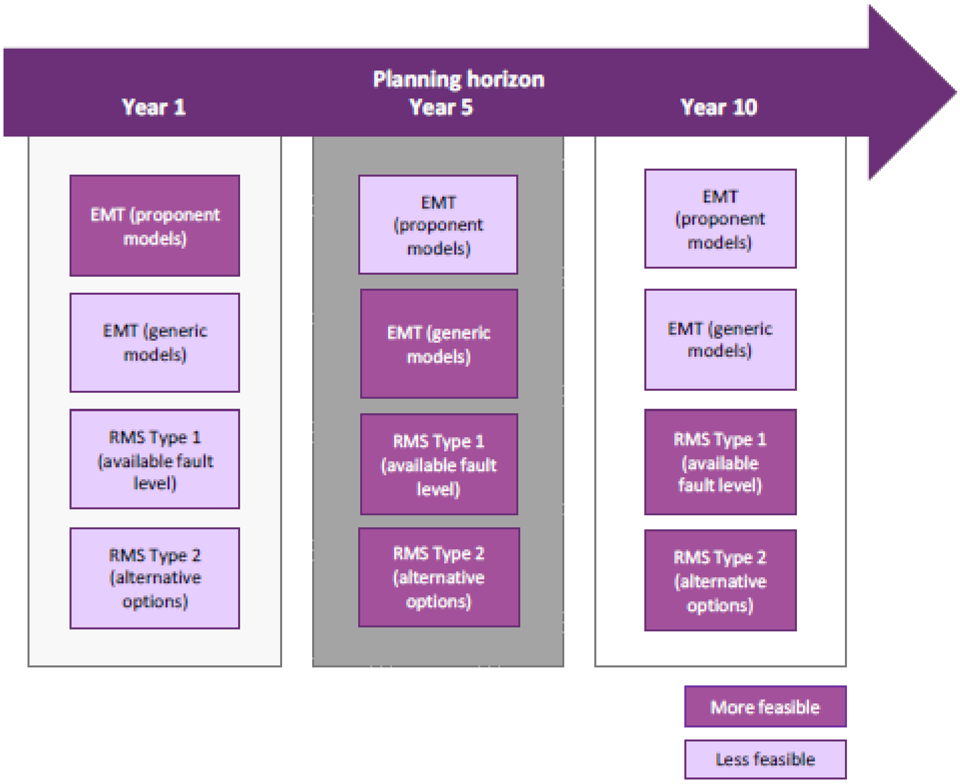
An overview of the technical assessment approach is shown in the figure below.

Figure 1: Technical assessment methodology overview



Powerlink applied AEMO's recommended EMT based analytical option (see figure below) for assessing stable voltage waveforms. Powerlink considered both actual plant and generic EMT models for system strength planning over the five-year period of December 2025 to December 2030.

Figure 2: Determining best assessment for analysing stable voltage waveforms



Source: AEMO, System Strength Requirements Methodology, September 2022, page 22 (figure 6).

Study inputs and assumptions

The table below lists the key inputs and assumptions used for the EMT technical assessment.

Table 1: EMT technical assessment inputs and assumptions

Element	Inputs and Assumptions
Minimum fault level requirement	It is considered that the minimum fault level requirements would primarily be met using synchronous based sources, with the exception of Portfolio 1A. This assumption was also used for the technical assessment. Over time, existing synchronous generators will be replaced by alternative synchronous machines, including but not limited to synchronous condensers, gas generating units, and PHES. Consequently, various combinations and different type of synchronous machines can be utilised to satisfy the minimum fault level requirements across different areas.

Element	Inputs and Assumptions
Grid-forming BESS	Grid-forming BESS has limited short-circuit current contribution capabilities, due to its reliance on semiconductor switching devices. To achieve fault levels comparable to traditional synchronous generators, it is necessary to increase the size of a single grid-forming BESS or deploy multiple units. In the portfolios considered, grid-forming BESS have been excluded from meeting minimum fault level requirements, with the exception of Portfolio 1A which includes a grid-forming BESS in Central Queensland in 2028/29. For Portfolio 1A, Powerlink considered one grid-forming BESS in Central Queensland as part of the combination of minimum solutions in the technical assessment. However, the assessment only considered impacts to stable voltage waveform, and not other aspects to meet minimum fault level requirements (such as impacts to protection system operation). To incorporate grid-forming BESS as part of minimum fault level requirements, Powerlink considers that several key activities are needed in the near future to effectively assess the performance of grid-forming BESS and build confidence in the technology (see section 10.1). Powerlink does however consider that grid-forming BESS will play a crucial role in future power system, providing stable voltage waveform support. As such, grid-forming BESS were included as part of efficient system strength solutions when completing the detailed technical studies.
Synchronous condenser size	As outlined in the portfolios of credible options, existing synchronous generators were included in the modelling for the early years to represent the minimum level of system strength support. However, for later years, where applicable, new synchronous condensers were modelled in place of the existing synchronous generators. For the purpose of the study, these synchronous condensers are sized at approximately 220 to 250 MVA and are expected to provide a fault current of greater than 800 MVA at the high voltage terminal.
Grid-forming BESS sizes	When a need for efficient system strength requirements arises due to projected IBR connections, the grid-forming BESS size was progressively increased in the studies until satisfactory results were achieved for the stable voltage waveform criteria. For the modelling purposes, a starting grid-forming BESS size of 250 MVA was utilised. Powerlink has considered various grid-forming OEM models as part of the sensitivity analysis for this study.
IBR plant list for system strength planning studies	The IBR plants included in the studies were selected based on AEMO's forecast, taking into account both the forecast level and the type of IBR in each area. Most of the IBR plants considered for the early years are progressing under the previous system strength framework (i.e., applications submitted before March 2023) and were included in the study with the assumption that they can connect without requiring system strength remediation. Additionally, new IBR plants that would fall under the new system strength framework are also included, as applicable, to fulfil the forecast IBR levels for the studies.
PSCAD models for future IBR plants	Site-specific PSCAD models were utilised whenever available, which was the case for all existing IBR plants and IBR projects currently in progress. In cases where a site-specific model was not available, particularly for future IBR plants, a generic PSCAD model was used, based on a selected plant type (e.g., wind farm, solar farm or BESS) and the corresponding OEM, if known, to model represent the forecasted IBR plants.
IBR connecting in northern NSW	At this stage, the detailed studies exclude forecast IBR plants connecting on the southern side of the Queensland – New South Wales Interconnector (QNI); that is, in northern NSW.
CopperString 2032	CopperString 2032 was not included in the assessments.

Technical assessment results

For the PSCR, Powerlink estimated the efficient system strength requirements based on AEMO's 2022 System Strength Report. However, following the publication of AEMO's 2023 System Strength Report in December 2023, Powerlink conducted a detailed technical assessment aligned with the IBR forecast given in the 2023 report. Consequently, changes in the IBR forecast levels for certain system strength nodes, including Ross and Western Downs, have led to adjustments to the efficient level requirements identified in the PSCR. The updated results for efficient system strength requirements are detailed in this section.

Minimum system strength requirement

Powerlink has assessed minimum system strength requirements as part of the detailed technical assessment conducted. The analysis primarily relied on synchronous-based sources, with one exception where a grid-forming BESS was included in the minimum generator combinations for Central Queensland.

In the early years, the requirements are largely satisfied by existing synchronous generation across Southern, Central, and Northern Queensland. For the later years, it is assumed that alternative synchronous machines, such as synchronous condensers, clutched gas turbines, and pumped hydro, would replace the currently considered synchronous generation used to meet the minimum requirements.

Two generator combinations have been used in PSCAD studies as potential options for meeting the minimum system strength requirements for the study period.

Minimum generator combination 1 includes:

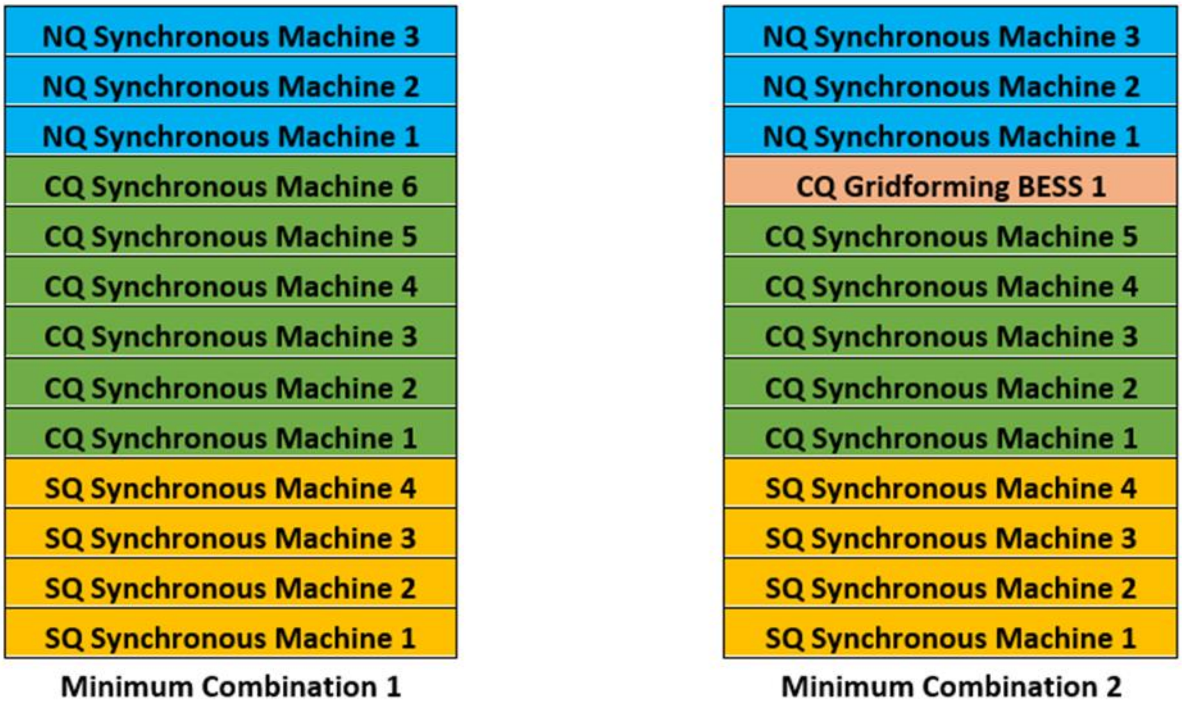
- Two hydro-electric machines or equivalent online in Northern Queensland in the order of 20 MVA each;
- One Townsville gas turbine or equivalent plant online in Northern Queensland in the order of 200 MVA;
- Six synchronous machines online in Central Queensland in the order of 250 – 350 MVA each; and
- Four synchronous machines online in Southern Queensland in the order of 250 – 400 MVA each.

Minimum generator combination 2 includes:

- Two hydro-electric machines or equivalent online in Northern Queensland in the order of 20 MVA each;
- One Townsville gas turbine or equivalent plant online in Northern Queensland in the order of 200 MVA;
- Five synchronous machines online in Central Queensland in the order of 250 – 350 MVA each;
- One grid-forming BESS online in Central Queensland in the order of 400 – 600 MVA; and
- Four synchronous machines online in Southern Queensland in the order of 250 – 400 MVA each.

A simplified illustration of the two minimum generator combinations is shown below.

Figure 3: Minimum generator combinations



The number of synchronous machines depicted corresponds to the minimum number required to meet system strength requirements for any given time period. However, to ensure a satisfactory overall availability (for example greater than 99%), a greater number of machines than indicated by the two combinations above will be necessary as part of the overall portfolio in each geographical area.

Minimum generator combination 2 includes one grid-forming BESS in Central Queensland. However, the technical assessment focused solely on the impacts to stable voltage waveforms and did not address other factors necessary to meet minimum fault level requirements, such as the satisfactory protection system operation. To integrate grid-forming BESS into the minimum fault level requirements, Powerlink considers that several key activities that need to be undertaken in the near future. These activities aim to effectively evaluate the performance of grid-forming BESS and enhance confidence in the technology (refer to sections 3.3 and 9.1).

The figure below illustrates the indicative Southern, Central and Northern Queensland areas related to minimum system strength solutions. It is important to note that a solution in one area also influences adjacent areas; therefore, the solutions cannot be completely decoupled.

Figure 4: Indicative areas for minimum system strength solutions

Note: figure is for illustrative purposes only.

Efficient system strength requirements

For the detailed technical studies, Powerlink considers grid-forming BESS as a key component of efficient system strength solutions, aimed at providing stable voltage waveform support for projected IBR. However, efficient system strength solutions are not restricted to grid-forming BESS only; alternative technologies, such as synchronous condensers and grid-forming STATCOMs, may also be suitable. Consequently, the required level of system strength is defined as a range to allow for various technological solutions. The selection of feasible solutions will take place in the next phase of the system strength RIT-T.

Based on the technical studies conducted, the need for efficient system strength solutions in each area is outlined in the table and map below. The solution size required for efficient system strength support is presented as a range because specific technical details about the actual solution(s) are not yet available.

Table 2: System strength need for efficient level of system strength

Area	Expected timeline	Grid-forming BESS size considered in technical assessment (MW)*	Possible range for solutions considering other technologies including grid-forming BESS (MVA)**
Northern Queensland Area 1	2026	200	180 to 300
Northern Queensland Area 2	2028	200	180 to 300
Northern Queensland Area 3	2028	300	220 to 400
Northern Queensland Area 4	2030	200	180 to 300
Central Queensland Area 1	2028	300	220 to 400
Central Queensland Area 2	2030	300	220 to 400
Southern Queensland Area 1	2029	300	220 to 400
Southern Queensland Area 2	2030	300	220 to 400
Southern Queensland Area 3	2030	300	220 to 400

** Indicative MW size utilised in the studies are given here. The operating MW level of BESS at any given time is not pertinent to the provision of system strength services. Expected technical performance requirements for grid-forming BESS to deliver the system strength services are detailed in Appendix I. Multiple OEM models have been tested which resulted in a satisfactory performance.*

*** A variety of solutions (synchronous condenser, grid-forming STATCOM or grid-forming BESS) can provide the suitable solution. Indicative MVA range for the potential solutions is presented here. This capacity can be made of multiple projects or a single project. The system strength requirement for each solution can be met through multiple technologies, such as a combination of grid-forming STATCOM and BESS.*

Figure 5: System strength need for efficient level of system strength

Note: figure is for illustrative purposes only.

Appendix I: Technical Performance Assessment for Grid-forming BESS

Powerlink will engage with shortlisted proponents of grid-forming BESS solutions on specifications/requirements once the technical and commercial feasibility of responses to the information request has been determined. This appendix outlines Powerlink's approach to the technical performance assessment of grid-forming BESS.

Grid-forming BESS technical requirements

The connection of a grid-forming BESS for providing system strength services to Powerlink will adhere to the standard generator connection process. Compliance with the NER and the specified Generator Performance Standards (GPS) is required.

This section outlines the key technical performance requirements that Powerlink will evaluate to ensure the grid-forming BESS delivers 'stable voltage waveform support' which is vital for achieving the efficient level of system strength service. These requirements are in addition to the technical requirements specified in the GPS.

The key technical performance requirements are developed based on the following three criteria for stable voltage waveform, as outlined in AEMO's System Strength Requirements Methodology (version 2.0, effective 1 December 2022):

- Voltage magnitude;
- Change in voltage phase angle; and
- Voltage oscillations.

Documents and study requirements

Powerlink will request the following technical information from the proponents submitting proposals to provide system strength services using a grid-forming BESS:

- A detailed site-specific PSCAD model that meets the requirements of Power System Model Guidelines, a RUG, and minimum DMAT tests.
    - The quality of the model is critical, as the technical assessment of the grid-forming BESS performance relies heavily on model-based evaluations.
- Model documentation from the OEM describing high level inverter control philosophy.
    - The grid-forming BESS inverters are expected to maintain synchronisation with the grid by continuously controlling an internal voltage phasor, including both the magnitude and the angle. **The inverters must respond instantaneously to changes in the external grid without any controller action, provided that current limits are not exceeded. Switching between grid-following (or any other mode) and grid-forming modes is not considered suitable for providing system strength service.** Furthermore, if a Phase-Locked Loop (PLL) is utilised for monitoring, control or protection functions, detailed information must be provided.
    - Details on the current limiting mechanism are preferred.
    - Hardware-in-the-loop (HIL) test results confirming model response are preferred.
- Documentation demonstrating the inverter's short-term overloading capability, which refers to their ability to handle current beyond the continuous rating, must be provided. The overloading capability can be demonstrated through several ways:
    - The selected inverter is designed to have short-term overloading capability (generally in seconds);

- Plant is sized and designed with an inverter capacity that exceeds the standard requirements (i.e., the plant is oversized); or
- Active power is curtailed to maintain a margin between the operating output and the maximum output of the plant; that is, maintaining a headroom when in service.

The minimum number of tests needed to evaluate the technical performance of a grid-forming BESS providing system strength services is determined by the criteria outlined under the "stable voltage waveform". Table 1 below specifies the key technical performance tests required to understand the characteristics of the grid-forming inverters. These tests will be conducted using the PSCAD SMIB model, and proponents are expected to provide the results to Powerlink. Additionally, Powerlink will conduct detailed PSCAD WAN studies where applicable.

Powerlink will evaluate the transient and oscillatory stability aspects of the grid-forming BESS as part of the standard generator connection process. This assessment will utilise the models provided by the proponent during the GPS studies.

Table 1: PSCAD SMIB tests required as part of providing system strength service

Test #	Test description	Additional requirements and evidence
1	Voltage source behaviour Withstand SCR tests conducted at SCR=1.2	Refer withstand SCR test requirements given in Powerlink's Inverter Based Renewable Plant: GPS Connection Study Process and Expectations (Note 1). PSCAD study results should be provided. Tests need to include balanced and unbalanced faults, as well as phase angle jumps. For the phase angle jump tests, tests should be performed up to ±60°, as per the DMAT grid voltage phase angle change test. Noting the expectation is that BESS can remain connected and stable at a minimum of 40 degrees for provision of system strength. It is expected that grid-forming plant should be able to operate stably at SCR =1.2 subject to the limits of power transfer capability depending on its operating mode (i.e. charging or discharging). Unlike S5.2.5.15 requirements, these tests must be conducted using the settings necessary for the plant to meet the GPS requirements. Note that these tests are not intended to demonstrate performance compliance with GPS. For example, the speed of response is not required to meet GPS performance when tested at a SCR = 1.2. Test results should be analysed considering stable voltage waveform support requirements rather than on voltage stability issues.
2	Speed of response Response to ±5% step change in source voltage magnitude conducted at min and max SCR levels applicable to the connection with site specific X/R ratio.	PSCAD study results should be provided. Zoomed-in plots should be provided as part of the results. It is expected that grid-forming BESS should start its response immediately to oppose the change in voltage from the initiation of the voltage step.

3	Voltage oscillation damping Oscillation rejection tests (ORT) conducted at min and max SCR levels applicable to the connection with site specific X/R ratio. If the minimum SCR is higher than 3, then SCR=3 should be used as minimum SCR.	Refer "Oscillation Rejection" test requirements given in Powerlink's Inverter Based Renewable Plant: GPS Connection Study Process and Expectations (Note 1). Frequency range: 0.1 - 1 Hz with 0.1Hz steps, 1 – 49 Hz with 1Hz step. PSCAD study results should be provided. It is expected that grid-forming BESS provides positive damping to network voltage oscillations in the sub-synchronous frequency range (i.e. attenuation factor less than 1 as per methodology explained in Powerlink's study guide).
4	Response to grid frequency DMAT Test 170 with Pmax (charging) at Qmax and Qmin DMAT Test 174 with Pmax (discharging) at Qmax and Qmin Studies conducted at min and max SCR levels applicable to the connection with site specific X/R ratio.	Test to be conducted with and without PPC frequency control function enabled. PSCAD study results should be provided. It is expected that grid-forming BESS provides an immediate active power response (i.e., inertial response).
5	Short-term overloading capability.	Supporting documents indicating short-term overload capability of inverters to be provided (e.g., xxx% for t1 seconds, yyy% for t2 seconds). Furthermore, PSCAD SMIB study results as indicated below. Phase angle jump tests conducted in PSCAD SMIB model at the maximum SCR applicable to the connection. The following two operating points are to be considered. • Pmax, Qmin • Pmin, Qmax The plant is expected to have sufficient overloading capability to accommodate phase angle jumps of up to ±5° without reaching the inverter's current limit. A short-term overloading duration of up to 1 second is deemed adequate, given the inverter's rapid response to move away from the limit. Zoomed-in plots of three phase instantaneous voltages and currents waveforms at the inverter terminal should also be provided as part of the results. Please refer an example case shown below. Whilst a minimum of ±5° angle jump without reaching the inverter's current limit is to be demonstrated, higher short term overloading capability (~ 1 second) is preferrable.

Note 1: Powerlink's Inverter Based Renewable Plant: GPS Connection Study Process and Expectations document can be provided upon request. Requests should be directed by email to networkassessments@powerlink.com.au.

An illustrative study case is provided in Figure 1 below, demonstrating that the angle jump (initiated at t=40 seconds) caused the inverters to reach their current limit. In this example, the current limitation resulted in a distorted voltage waveform, that impacts stable voltage waveform support criteria. The plant is typically sized to meet the NER clause S5.2.5.4 requirements for GPS, which includes an approximate 10% margin for overloading. Our findings suggest that, in addition to meeting S5.2.5.4, an additional 10% short-term overloading capability may be necessary to accommodate a ±5° phase angle jump without reaching the current limit. Figure 2 illustrates a scenario in which the inverter does not reach its current limit during an angle jump test (initiated at t=20 seconds) demonstrating its ability to provide stable voltage waveform support.

Figure 1: Inverter's voltage and current waveforms during an angle jump test – reaching current limit

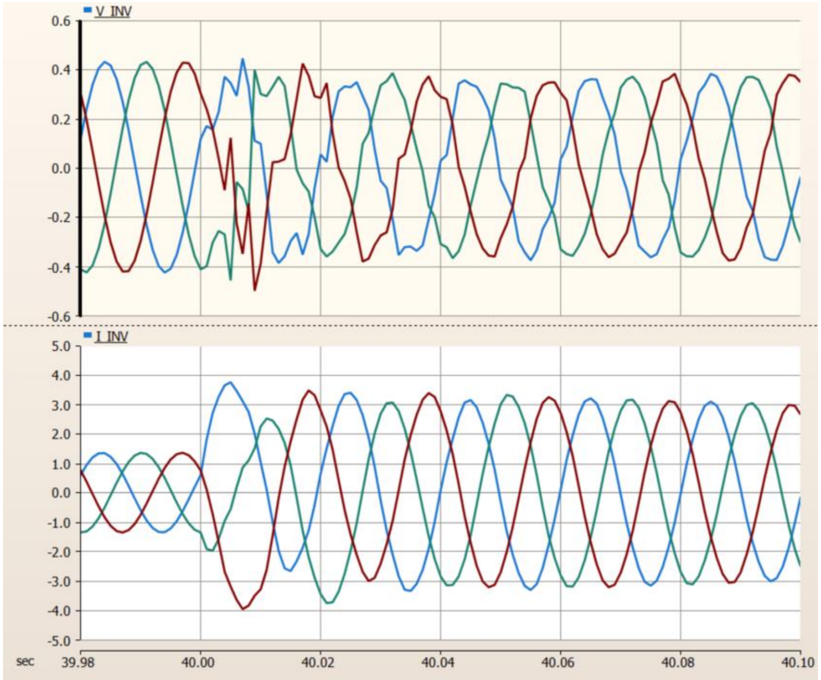
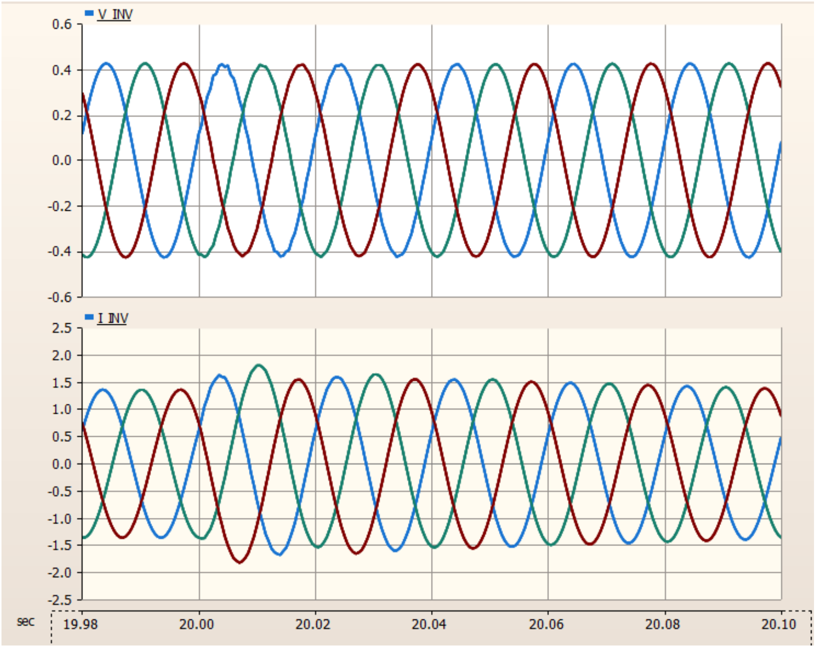


Figure 2: Inverter's voltage and current waveforms during an angle jump test – not reaching current limit



Appendix J: Material Inter-network Impact

Powerlink is required to consider whether the portfolio of credible options is expected to have a material inter-network impact (MINI).[115] A MINI is a material impact on another TNSP's network which may include (without limitation) the imposition of power transfer constraints within another TNSP's network, or an adverse impact on the quality of supply in another TNSP's network.[116]

The PSCR indicated that:

- the credible options had the potential to increase the fault level by at least 10 MVA on the Queensland-New South Wales Interconnector;
- the size of any potential fault level increase in Powerlink's transmission network will depend on the submissions received to the PSCR and the location, size, mix of technologies and/or number of additional plant identified in the credible options in the PADR; and
- if necessary, Powerlink would request an augmentation technical report from AEMO.[117]

AEMO's suggested screening test to indicate that a transmission augmentation has no MINI is that it satisfies the following:

- a decrease in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3 per cent of the maximum transfer capability and 50 MW;
- an increase in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3 per cent of the maximum transfer capability and 50 MW;
- an increase in fault level by less than 10 MVA at any substation in another TNSP's network; and
- the investment does not involve either a series capacitor or modification in the vicinity of an existing series capacitor.[118]

This consideration has been done in the context of the overall energy transformation. The energy transformation will see the ultimate retirement of coal-fired power stations and the replacement of this energy with combinations of renewable energy generation (wind and solar) and firming generation in the form of PHES, BESS and gas peaking plant. This changing mix of generation will materially change not only the patterns of power flow on the interconnected power system, but also the dynamic stability characteristics (transient and oscillatory) of the interconnected power system.

To this end, Powerlink's view is that the changes in the performance characteristics of the power systems are as a result of the combined impacts of all components of the energy transformation, and given these complex interactions, it is not practicable to isolate the impact of only the system strength solutions. Inevitably the dynamic performance (including secure power transfer limits) of the power system will vary across dispatches and also vary as coal is progressively displaced and/or retired.

Powerlink must continue to reassess changes in the secure technical envelope as the power system transforms. If material changes to the secure technical envelope are observed through the trajectory of the energy transformation, then Powerlink will need to also reassess what level of power transfer delivers efficient market outcomes. This needs to be a continuing process through the transformation that includes joint planning with

[115] NER, clause 5.16.4(b)(6)(ii).
[116] NER, chapter 10 (definition of 'material inter-network impact').
[117] Powerlink, *Addressing System Strength Requirements in Queensland from December 2025*, PSCR, March 2023, page 22.
[118] Inter Regional Planning Committee, *Final Determination: Criteria for Assessing Material Inter-Network Impact of Transmission Augmentations*, version 1.3, June 2004, Appendices 2 and 3.

Transgrid. As such, Powerlink does not see the role of this system strength RIT-T to quantify changes in inter-regional power transfer limits.

In addition to the position taken on the impact on limits, Powerlink is also of the view that the proposed portfolio of credible options will not increase the maximum fault levels beyond that already experienced by Transgrid at the jurisdictional border.

For these reasons Powerlink does not intend to do any screening studies against the MINI criteria above or trigger the need for AEMO to complete an augmentation technical report in relation to the options being considered in this RIT-T.

Appendix K: Compliance Checklist

This appendix outlines Powerlink's compliance with PADR content requirements in each sub-paragraph of clause 5.16.4(k) of the NER.

Table 1: Compliance Checklist

Sub-para	Requirement	Section of PADR
(1)	Description of each credible option	3.1
(2)	Summary of and commentary on submissions to the PSCR	9.2
(3)	Quantification of costs, including breakdown of operating and capital expenditure Classes of material market benefit for each credible option	App D 6.1
(4)	Description of methodologies used to quantify each class of material market benefit and cost	5.2 – 5.3
(5)	Reasons why a class/classes of market benefit are not material	5.4
(6)	Identification and quantification of any class of market benefit estimated to arise outside Queensland	N/A
(7)	Results of NPV analysis for each credible option, and explanation of results	6.1
(8)	Identification of preferred option	9.1
(9)	For the preferred option: (i) details of the technical characteristics (ii) the estimated construction timetable and commissioning date (iii) an augmentation technical report from AEMO (iv) a statement that the preferred option satisfies the RIT-T	9.1
(10)	RIT reopening triggers	7.2

In addition, the table below outlines a separate compliance checklist demonstrating compliance with the binding guidance in the RIT-T Application Guidelines relating to cost estimation; that is, the new requirements added to the guidelines following the Material Change in Network Infrastructure Project Costs Rule, made by the AEMC in October 2022.

Table 2: Binding guidance in the RIT-T Application Guidelines relating to cost estimation

Guidelines section	Requirement	Section of PADR

3.5A.1	Where the estimated capital costs of the preferred option exceeds $100 million (as varied in accordance with a cost threshold determination), a RIT-T proponent must, in a RIT-T application:
	• outline the process it has applied, or intends to apply, to ensure that the estimated costs are accurate to the extent practicable having regard to the purpose of that RIT-T stage
	• for all credible options (including the preferred option), either:
	  • apply the cost estimate classification system published by the AACE, or
	  • if it does not apply the AACE cost estimate classification system, identify the alternative cost estimation system or cost estimation arrangements it intends to apply, and provide reasons to explain why applying that alternative system or arrangements is more appropriate or suitable than applying the AACE cost estimate classification system in producing an accurate cost estimate.
		3 and Appendix D

3.5A.2	For each credible option, a RIT-T proponent must specify, to the extent practicable and in a manner which is fit for purpose for that stage of the RIT-T: • all key inputs and assumptions adopted in deriving the cost estimate • a breakdown of the main components of the cost estimate • the methodologies and processes applied in deriving the cost estimate (e.g. market testing, unit costs from recent projects, and engineering-based cost estimates) • the reasons in support of the key inputs and assumptions adopted and methodologies and processes applied • the level of any contingency allowance that have been included in the cost estimate, and the reasons for that level of contingency allowance.	3 and Appendix D
3.8.2	Where the estimated capital cost of the preferred option exceeds $100 million (as varied in accordance with an applicable cost threshold determination), a RIT-T proponent must undertake sensitivity analysis on all credible options, by varying one or more inputs and/or assumptions.	6.2
3.9.4	If a contingency allowance is included in a cost estimate for a credible option, the RIT-T proponent must explain: • the reasons and basis for the contingency allowance, including the particular costs that the contingency allowance may relate to • how the level or quantum of the contingency allowance was determined.	N/A

Contact us

Registered office	33 Harold St Virginia Queensland 4014 ABN 82 078 849 233
Postal address	PO Box 1193 Virginia Queensland 4014
Telephone	+61 7 3860 2111 (during business hours)
Email	pqenquiries@powerlink.com.au
Website	powerlink.com.au
Social	