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Managing the risk of capacitor bank failure

RIT-T Project Assessment Conclusions Report

Issue date: 21 March 2024

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Executive summary

We are applying the Regulatory Investment Test for Transmission (RIT-T) to options for managing the risk of capacitor bank failure. Publication of this Project Assessment Conclusions Report (PACR) represents the final step in the RIT-T process.

Capacitor banks are essential for ensuring that system voltage levels are maintained within +/-10% of nominal volts, as required under the NER.[1]

The likelihood of capacitor can and reactor failure is expected to increase as the units continue to deteriorate. If left unaddressed, this will result in unserved energy for consumers, costs associated with replacements (with long lead times) as well as higher risks relating to safety and environmental issues.

The purpose of this RIT-T is to examine and consult on options to address the deterioration in the conditions of the identified capacitor banks to ensure the safe and secure operation of our network. Given the high population of capacitor banks that fall within this category, the selected capacitor banks for replacement were chosen on the basis that they include sibling units (capacitor cans, reactors or both), are the oldest units in the network and cover a range of voltages and capabilities. The capacitor bank replacement program would apply to the following capacitor banks: Kempsey No 1, Narrabri No 3 and Coffs Harbour No 1 and Narrabri No 2.

Identified need: ensure the safe and reliable operation of our transmission network by managing the risk of capacitor bank failure

The identified need for this project is to ensure the safe and reliable operation of our transmission network by addressing the risk of failure of certain capacitor banks that are approaching, or have passed, the end of their technical life.

In this RIT-T, we have considered four capacitor banks for replacement across our network: Kempsey No 1 Capacitor, Narrabri No 2 Capacitor, Narrabri No 3 Capacitor and Coffs Harbour No 1 Capacitor. In assessing the ongoing viability of the capacitor banks, we have considered several factors:

- existing holdings of spares and the ability to source more spares.
- the general condition of the equipment; and
- age of the asset.

The identified capacitor banks have been in service longer than their expected technical lives, which is 30 years and have limited spare reactors and/or spare cans, which are also expected to deplete quickly. The ability to source additional spares in a reasonable time period may be challenging due to reduced manufacturer support. Ultimately, the selected capacitor banks for replacement were chosen on the basis that they include sibling units (capacitor cans, reactors or both), and cover a range of voltages and capabilities. This will enable us to strategically use these parts to assist with maintenance of other capacitor banks across the network, and to extend the serviceable lives of those assets.

If left unreplaced, the likelihood that the identified capacitor banks will fail is expected to increase significantly as the capacitor banks continue to deteriorate (refer to section 2.3.1). If the capacitor banks are not available during times of high load, load shedding will be required to take place for customers in

[1] Clause S5.1a.4: https://energy-rules.aemc.gov.au/ner/452/229026

NSW to ensure that system voltage levels remain within ±10% as required by the NER. The impact of each capacitor bank failure on lost load varies depending on where the capacitor bank is located on the network and whether viable spare parts are available. Asset failure may also increase the risk of safety and environment issues, and the potential costs of emergency repair and replacements. Given the limited availability of spares, the duration of such outages will also be expected to increase over time. On the basis of this assessment, we consider that replacing the identified capacitor banks would be expected to result in economic benefits for consumers by reducing the risk of load shedding.

We have classified this RIT-T as a 'reliability' driven RIT-T as the economic assessment is being progressed specifically to meet a mandated reliability standard and the net benefits are expected to be generated for end-customers. This replacement will help limit the number of in-service failures that occur (along with the associated interruptions to customer load, as well as safety and environmental consequences).

No submissions received in response to the Project Specification Consultation Report

We published a Project Specification Consultation Report (PSCR) on 8 August 2023 and invited written submissions on the material presented within the document. No submissions were received in response to the PSCR.

No material developments since publication of the PSCR

No additional credible options were identified during the consultation period following publication of the PSCR.

On 21 September 2023, the National Energy Laws were amended to reflect the incorporation of emissions reductions within the National Energy Objectives.[2] Following this the AEMC made harmonising changes to the National Electricity Rules, prompted by a rule change request from energy ministers, to ensure that network investment and planning frameworks are consistent with the new emissions reduction objective. The AEMC's Final Determination, published on 1 February 2024, included introducing a 'changes in Australia's greenhouse gas emissions' as a new class of market benefit to be considered within the RIT-T process.[3]

Transgrid supports greater consideration of emissions reduction within network planning and investment frameworks. These changes ensure network planning and investment frameworks support achievement of the Commonwealth Government's net zero targets. Transgrid has set science-based targets to cut emissions and decarbonise our business. These include:

- Reducing Scope 1 and 2 emissions by 60 per cent by 2030, compared with a base year of 2021 and net zero by 2040.
- Reducing Scope 3 emissions from Purchased Goods and Services, and Capital Goods by 48 per cent for every million dollars that we spend on these two categories by 2030, compared with a base year of 2021, and net zero by 2050.[4]

[2] Statutes Amendment (National Energy Laws) (Emissions Reduction Objectives) Act 2023 (SA)
[3] AEMC, Harmonising the national energy rules with the updated national energy objectives – final determination, 1 February 2024
[4] For more information on Transgrid's planned journey to net zero please see our website here: https://www.transgrid.com.au/about-us/our-approach/our-journey-to-net-zero

The updated National Energy Laws and Rules included transitional provisions that applied these changes to any RIT-T project that was required to publish a PADR where the deadline for doing so was after 21 November 2023.

As the PSCR for this RIT-T was submitted prior to 21 November 2023, and there is no requirement in this project to publish a PADR, this RIT-T is still subject to the old National Electricity Rules which did not consider changes in Australian emissions as a class of market benefit.

Additionally, the identified need for this RIT-T is driven by an externally imposed obligation, and therefore framed as reliability corrective action in which induced market benefits are not the primary objective.

Thus, to ensure timely publication of this RIT-T and delivery of the proposed solution, Transgrid has not assessed the change in Australian emissions tied to the project, as a benefit within this RIT-T.

Option 1 remains the preferred option at this stage of the RIT-T process.

Credible options considered

As indicated above, we have selected four capacitor banks for replacement on the basis that they include sibling units (capacitor cans, reactors or both), are the oldest units in the network and cover a range of voltages and capabilities. The four identified capacitor banks have already exceeded their expected technical lives and the likelihood of failure of the capacitor can and reactor components increases as the capacitor bank units continue to age. The list of capacitor banks which we have selected for replacement across the network are Kempsey No 1 Capacitor, Narrabri No 2 Capacitor, Narrabri No 3 Capacitor, and Coffs Harbour No 1 Capacitor.

On this basis, we consider that there is one credible network option that can meet the identified need. This option is summarised in Table Table E-1.

Table E-1: Summary of the credible options

Option	Description	Estimated capex ($2021-22)	Expected commission date
Option 1		**10.22**	**2028**
Kempsey No 1 Capacitor	Renew the Capacitor Bank Bay	2.80	2027
Narrabri No 2 Capacitor	Replace Capacitor Bank Cans only[5]	1.64	2028
Narrabri No 3 Capacitor	Renew the Capacitor Bank Bay	2.99	2027
Coffs Harbour No 1 Capacitor	Renew the Capacitor Bank Bay	2.79	2027

[5] There are no air core reactors in this bay, and consequently do not need to be replaced. The associated protection and control will be replaced under the secondary systems renewal programs.

No submissions received in relation to non-network options

In the PSCR we noted that we considered non-network options may be able to assist with meeting the identified need, specifically non-network technologies that are able to provide reactive support. We invited parties to make written submissions regarding the potential of non-network options to satisfy, or contribute to satisfying, the identified need for this RIT-T. No submissions were received in response to the PSCR in relation to non-network options.

The options have been assessed against three reasonable scenarios

The credible options have been assessed under three scenarios as part of this PACR assessment, which differ in terms of the key drivers of the estimated net market benefits (ie, the estimated risk costs avoided).

Given that wholesale market benefits are not relevant for this RIT-T, the three scenarios assume the most likely scenario from the Draft 2024 ISP (ie, the 'Step Change' scenario). The scenarios differ by the assumed level of risk costs, given that these are key parameters that may affect the ranking of the credible options. Risk cost assumptions do not form part of AEMO's ISP assumptions and have been based on Transgrid's analysis.

Table E-2 Summary of scenarios

Variable / Scenario	Central	Low risk cost scenario	High risk cost scenario risk
Scenario weighting	1/3	1/3	1/3
Discount rate	7%	7%	7%
VCR ($2021-22)[6]	$46,430/MWh	$46,430/MWh	$46,430/MWh
Network capital costs	Base estimate	Base estimate	Base estimate
Operating and maintenance costs	Base estimate	Base estimate	Base estimate
Environmental, safety and financial risk benefit	Base estimate	Base estimate – 25%	Base estimate +25%
Avoided unserved energy	Base estimate	Base estimate – 25%	Base estimate +25%

The sensitivity analysis has investigated how the NPV results are affected by changes to other variables, including the discount rate and capital costs.

Conclusion

This PACR finds that implementation of Option 1 is the preferred option. Under Option 1, the four capacitor banks identified will be renewed entirely or undergo a replacement of the capacitor can component. These capacitor banks currently exceed their technical life of 30 years and would be exceeding the technical life by at least 15 years in 2027/28. Under this option, Kempsey No 1 Capacitor, Narrabri No 3 Capacitor, and Coffs Harbour No 1 Capacitor would undertake a renewal of the capacitor bank bays i.e., replacement of all components within the capacitor bank, whereas Narrabri No 2 Capacitor would have only its capacitor bank cans and associated steelworks replaced.

[6] The analysis used a $2021-22 VCR value as this was the dollar basis for all costs in the assessment. This was calculated by deflating the VCR $2022-23 amount of $49,216/MWh (as per AEMO's 2023 IASR) by 6% (ABS CPI Jun 22 to Jun 23).

The capital cost of this option is approximately $10.22 million (in $2021-22). The work will be undertaken over a four-year period with all works expected to be completed by 2027/28. Routine operating and maintenance costs are estimated at approximately $4,000 per annum (in $2021-22). All works will be completed in accordance with the relevant standards and components shall be replaced to have minimal modification to the wider transmission network. Necessary outages of relevant assets in service will be planned appropriately in order to complete the works with minimal impact on the network.

Contents

1. Introduction

We are applying the Regulatory Investment Test for Transmission (RIT-T) to options for ensuring the safe and reliable operation of our transmission network by addressing the risk of failure of certain capacitor banks. Publication of this Project Assessment Conclusions Report (PACR) is the final step in the RIT-T process.

Capacitor banks are essential for ensuring that system voltage levels are maintained within +/-10% of nominal volts, as required under the NER.[7] We have 184 capacitor banks across the network, and in this RIT-T, we have considered four capacitor banks for replacement across our network: Kempsey No 1 Capacitor, Narrabri No 2 Capacitor, Narrabri No 3 Capacitor and Coffs Harbour No 1 Capacitor. The capacitor banks identified in this RIT-T have deteriorated to the point where their condition reflects the end of serviceable life. Additionally, sourcing spares compatible with the existing assets is not commercially feasible compared to the cost of replacement and sourcing spares for those replacements. This will enable us to strategically use these parts to assist with maintenance of other capacitor banks across the network to extend the serviceable lives of those assets.

The likelihood of capacitor can and reactor failure is expected to increase as the units continue to deteriorate. If left unaddressed, this will result in unserved energy for consumers, costs associated with replacements (with long lead times) as well as higher risks relating to safety and environmental issues.

The purpose of this RIT-T is to examine and consult on options to address the deterioration in the conditions of the identified capacitor banks to ensure the safe and secure operation of our network. Given the high population of capacitor banks that fall within this category, the selected capacitor banks for replacement were chosen on the basis that they include sibling units (capacitor cans, reactors or both), are the oldest units in the network and cover a range of voltages and capabilities. The capacitor bank replacement program would apply to the following capacitor banks: Kempsey No 1, Narrabri No 3 and Coffs Harbour No 1 and Narrabri No 2.

1.1. Purpose of this report

The purpose of this PACR[8] is to:

- describe the identified need;
- describe and assess credible options to meet the identified need;
- describe the assessment approach used; and
- provide details of the proposed preferred option to meet the identified need.

Overall, this report provides transparency into the planning considerations for investment options to ensure continuing reliable supply to our customers. A key purpose of this PACR is to provide interested stakeholders the opportunity to review the analysis and assumptions and have certainty and confidence that the preferred option has been robustly identified as optimal.

[7] Clause S5.1a.4: https://energy-rules.aemc.gov.au/ner/452/229026
[8] See Appendix A for the National Electricity Rules requirements.

1.2. No submissions received in response to the Project Specification Consultation Report and there have been no material developments

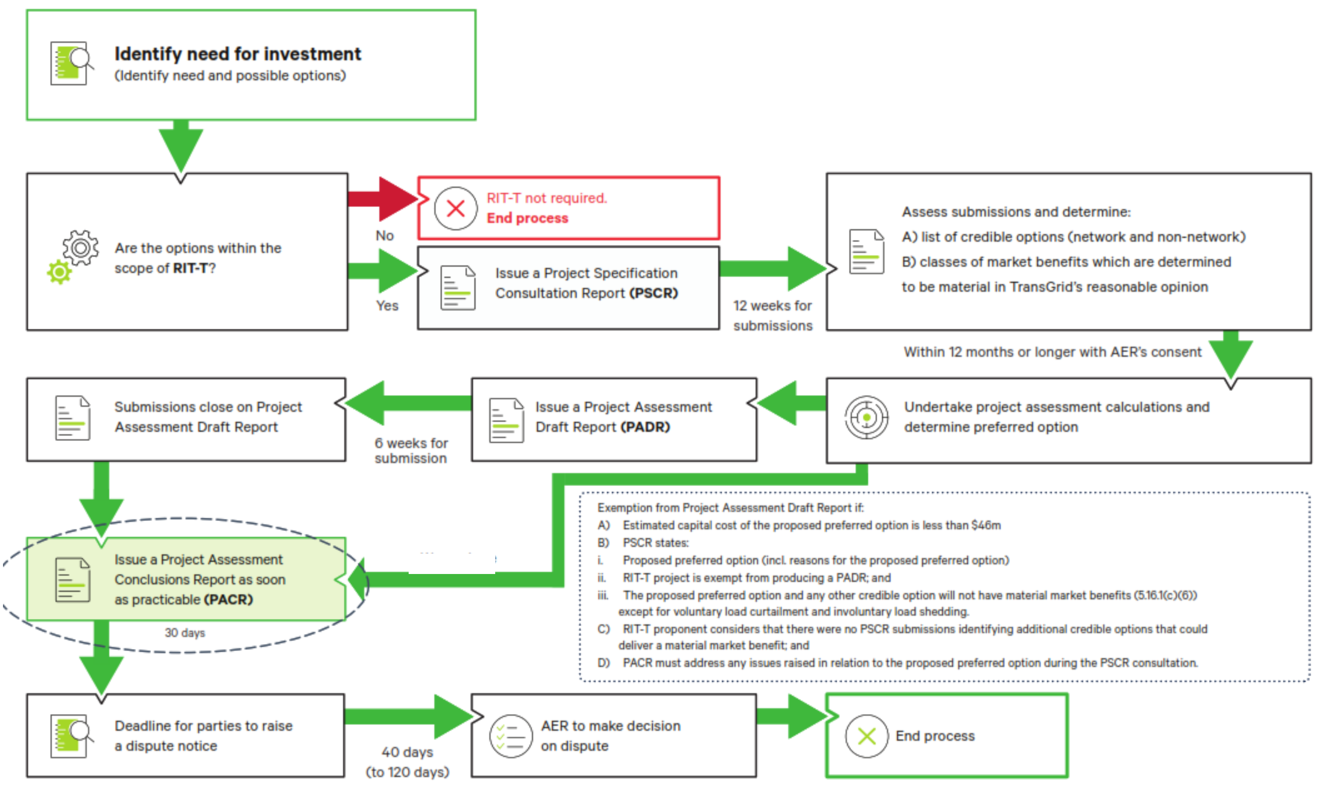
We published a Project Specification Consultation Report (PSCR) on 8 August 2023 and invited written submissions on the material presented within the document. No submissions were received in response to the PSCR.

In addition, no additional credible options were identified during the consultation period following publication of the PSCR. No other material changes have occurred since the PSCR that have made an impact on the preferred option.

1.3. Next steps

This PACR represents the final step of the consultation process in relation to the application of the RIT-T process undertaken by Transgrid. It follows the PSCR released in August 2023. No submissions were received in response to the PSCR.

Figure 1-1 This PACR is the final stage of the RIT-T process[9]



Parties wishing to raise a dispute notice with the AER may do so prior to 24 April 2024 (30 days after publication of this PACR). Any dispute notices raised during this period will be addressed by the AER within 40 to 120 days, after which the formal RIT-T process will conclude.

9 Australian Energy Market Commission. "Replacement expenditure planning arrangements, Rule determination". Sydney: AEMC, 18 July 2017.

Further details on the RIT-T can be obtained from Transgrid's Regulation team via regulatory.consultation@transgrid.com.au . In the subject field, please reference 'Managing risk of capacitor bank failure PACR'.

2. The identified need

2.1. Background to the identified need

Capacitor banks are essential for ensuring that system voltage levels throughout the network are maintained within +/-10% of nominal volts, which is a requirement under the NER.[10] Capacitor banks can provide additional power support by enabling the injection of reactive power into the high voltage grid to provide voltage support and facilitate power system stability in the event of any disturbance or equipment failure.[11]

However, insufficient capacity during high load conditions will lead to system volts dropping below the acceptable level, and force load shedding to occur. Capacitor banks consist of the following components presented in the table below.

Table 2-1: Capacitor bank components and the typical issues experienced as their condition deteriorates

Component	Description	Typical issues
Capacitor cans	Unitised elements providing VARs as part of the overall capacitor bank rating.	Failures of individual cans Expected depletion of remaining spares
Detuning reactors	Reactors to tune the capacitor bank to manage switching current harmonics.	Deterioration of insulation, leading to treeing and flashover
Neutral unbalance current transformers	Utilised to detect failures in the capacitor cans	Deterioration, leaks, corrosion
Control and protection systems	Utilised to detect failures in the capacitor cans and control energising of the capacitor bank based on voltage regulation.	Power supply failures and electronics failures. Inability to clear faults and energise the capacitor banks when required

2.2. Description of the identified need

The identified need for this project is to ensure the safe and reliable operation of our transmission network by addressing the risk of failure of certain capacitor banks that are approaching, or have passed, the end of their technical life.

In this RIT-T, we have considered four capacitor banks for replacement across our network: Kempsey No 1 Capacitor, Narrabri No 2 Capacitor, Narrabri No 3 Capacitor and Coffs Harbour No 1 Capacitor. In assessing the ongoing viability of the capacitor banks, we have considered several factors. This includes existing holdings of spares and the ability to source for more spares; the general condition of the equipment; and age of the asset. The identified capacitor banks have been in service longer than their expected technical lives, which is 30 years and have limited spare reactors and/or spare cans, which are also expected to deplete quickly. Given the age of the capacitor banks, the ability to source additional

[10] Clause S5.1a.4: https://energy-rules.aemc.gov.au/ner/452/229026

[11] https://www.transgrid.com.au/media-publications/news-articles/qni-approaches-completion-as-ninth-capacitor-bank-installed

spares in a reasonable time period may be challenging due to reduced manufacturer support. Ultimately, the selected capacitor banks for replacement were chosen on the basis that they include sibling units (capacitor cans, reactors or both), are the oldest units in the network and cover a range of voltages and capabilities.

The final list of capacitor banks to consider for replacement are provided in the table below.

Table 2-2: List of capacitor banks considered for replacement

Capacitor bank	Ratings	Reactors installed	Installation date	Key issues
Kempsey No 1 Capacitor	132 kV 7.5 MVAr	3	1981	Limited spare cans 2 spare reactors
Narrabri No 2 Capacitor	11 kV 4.8 MVAr	0	1981	No spare cans
Narrabri No 3 Capacitor	66 kV 12.4 MVAr	3	1981	Limited spare cans No spare reactors
Coffs Harbour No 1 Capacitor	66 kV 8 MVAr	3	1981	Limited spare cans No spare reactors

If left unreplaced, the likelihood that the identified capacitor banks will fail is expected to increase significantly as the capacitor banks continue to age. If the capacitor banks are not available during times of high load, load shedding will be required to take place for customers in NSW to ensure that system voltage levels remain within ±10% as required by the NER.[12] The impact of each capacitor bank failure on lost load varies depending on where the capacitor bank is located on the network and whether viable spare parts are available. Asset failure may also increase the risk of safety and environment issues, and the potential costs of emergency repair and replacements. Given the limited availability of spares, the duration of such outages will also be expected to increase over time. On the basis of this assessment, we consider that replacing the identified capacitor banks would be expected to result in economic benefits for consumers by reducing the risk of load shedding.

We have classified this RIT-T as a 'reliability' driven RIT-T as the economic assessment is being progressed specifically to meet a mandated reliability standard and the net benefits are expected to be generated for end-customers. This replacement will help limit the number of in-service failures that occur (along with the associated interruptions to customer load, as well as safety and environmental consequences).

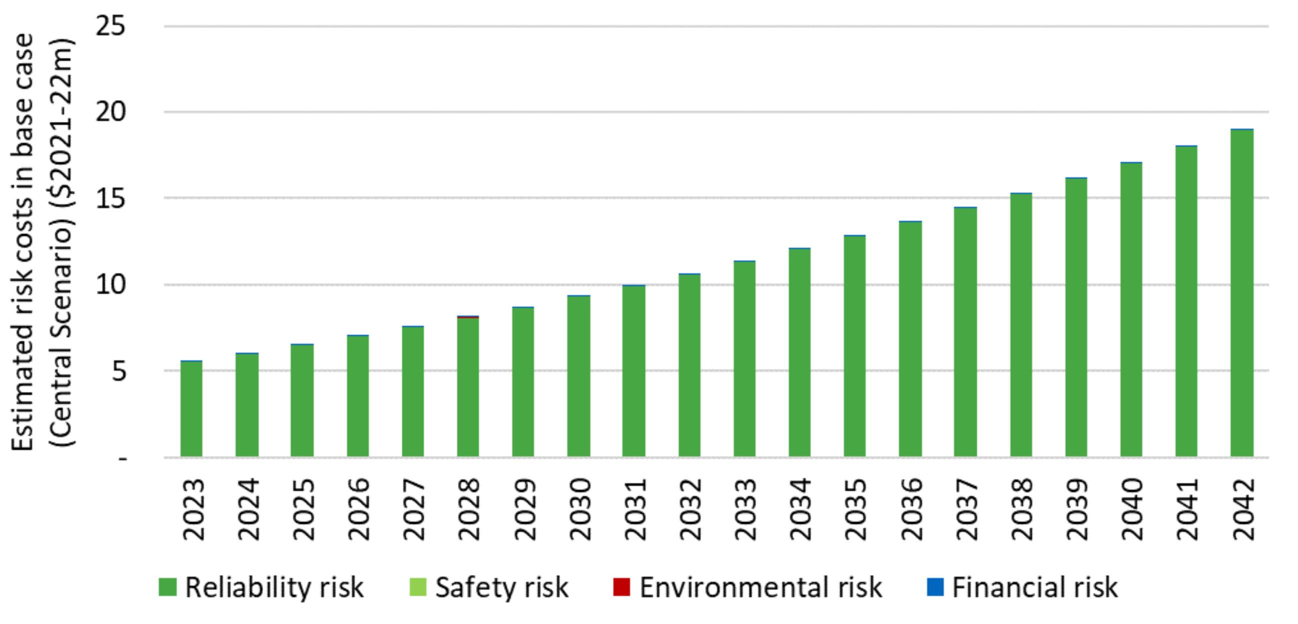
2.3. Assumptions underpinning the identified need

We adopted a risk cost framework to quantify and evaluate the risks and consequences of increased failure rates. Appendix B provides an overview of our Risk Assessment Methodology.

Figure 2-1 summarises the increasing risk costs over the assessment period under the base case and our central scenario of asset failure risk.

[12] Clause S5.1a.4: https://energy-rules.aemc.gov.au/ner/452/229026

Figure 2-1 Estimated risk costs under the base case (central scenario)



This section describes the assumptions underpinning our assessment of the risk costs, i.e., the value of the risk avoided by undertaking each of the credible options. In quantifying the risk costs, it is assumed that the estimated restoration time is one week based on a spare capacitor bank and air core reactor being available. During the restoration period, the capacitor bank will not be in operation, so this could result in load shedding as there will be an amount of energy that would not be supplied to consumers during that time.

The aggregate risk cost under the base case is currently estimated at around $5.58 million in 2022/23, and it is expected to increase going forward if action is not taken (reaching approximately $9.35 million by 2029/30 and $19.05 million by the end of the 20-year assessment period).

2.3.1. Asset health and the probability of failure

A capacitor banks health index score is dependent on age and performance factors.

Factors which determine the capacitor bank's health include:

- **Natural age:** The primary indicator of asset health of a capacitor bank is the natural age of the asset, which is calculated from its first installed date. Capacitor banks typically have an asset life of 30 years, beyond which the asset health is assumed to deteriorate at a faster rate. The capacitor banks under consideration for replacement have been in service for longer than 30 years. Capacitor cans will lose capacitance over their life and can fail through leaks. Both visual inspection and thermography can inform the condition of the capacitor bank. Similarly, for air core reactors, visual and thermographic inspection can provide information with respect to the condition of the reactor. The supporting steelwork also degrades over time and requires renewal.
- **General condition of the equipment:** Given that there is a lack of available failure data for capacitor banks and air core reactors, visual inspection is used to assess the general condition of the asset. This detects the presence of any defects, particularly hot joints and failure of individual capacitor cans and to determine if there is any deterioration in the external reactor insulation.

2.3.2. Difficulty acquiring spare parts for older equipment

There are currently limited spare components available throughout the network to be able to replace a complete capacitor bank. We have identified two spare air core reactors and some spare capacitor cans available.

Given that the current capacitor banks were installed during the 1980s, relying on spares and spares support for these older components to address the identified need is likely to be more challenging. The process of acquiring spares for older equipment involves setting up a bespoke manufacturing run for capacitor cans. This is relatively costly and requires a longer lead time (approximately 12 months) compared to purchasing newer designs (which takes approximately six months). Furthermore, it is often challenging to access spares support for capacitor banks as even with the availability of spares, the risk associated with asset failure remains high.

In a previous instance when multiple capacitor cans had failed to operate, the replacement of the old capacitor can component required a special manufacturing run resulting in extended outages.

2.3.3. Reliability risk

We have considered the risk of unserved energy for customers following a failure of the capacitor banks identified in this PACR. The likelihood of a consequence takes into account the likelihood of contingent planned/unplanned outages, the anticipated load restoration time (based on the expected time to undertake any repair work), and the load at risk (based on forecast demand). The monetary value is based on an assessment of the value of lost load, which measures the economic impact to affected customers of a disruption to their electricity supply.

Reliability risk makes comprises 99.5% of the total estimated risk cost in present value terms.

2.3.4. Safety risk

This refers to the safety consequence to staff, contractors and/or members of the public of an asset failure. The likelihood of a consequence takes into account the frequency of workers on-site, the duration of maintenance and capital work on-site, and the probability and area of effect of an explosive asset failure. The monetary value takes into account the cost associated with fatality or injury compensation, loss of productivity, litigation fees, fines and any other related costs.

Safety risk makes comprises 0.04% of the total estimated risk cost in present value terms.

2.3.5. Bushfire risk

This refers to the environmental consequence (including bushfire risk) to the surrounding community, ecology, flora and fauna of an asset failure. The likelihood of a consequence takes into account the location of the site and sensitivity of surrounding areas, the volume and type of contaminant, the effectiveness of control mechanisms, and the likelihood and impact of bushfires. The monetary value takes into account the cost associated with damage to the environment including compensation, clean-up costs, litigation fees, fines and any other related costs.

Bushfire risk makes comprises 0.01% of the total estimated risk cost in present value terms.

2.3.6. Financial risk

This refers to the financial consequence of an asset failure. The likelihood of a consequence takes into account any compliance and regulatory factors which are not covered by the other categories. The monetary value takes into account the cost associated with disruption to business operations, any third party liability, and the cost of replacement or repair of the asset, including any temporary measures.

Financial risk makes comprises 0.50% of the total estimated risk cost in present value terms.

3. Potential credible options

This section describes the option(s) that we have explored to address the identified need, including the scope of each option and the associated costs.

We have selected four capacitor banks for replacement on the basis that they include sibling units (capacitor cans, reactors or both), are the oldest units in the network and cover a range of voltages and capabilities. The four identified capacitor banks have already exceeded their expected lives and the likelihood of failure of the capacitor can and reactor components increases as the capacitor bank units continue to age. The list of capacitor banks which we have selected for replacement across the network are Kempsey No 1 Capacitor, Narrabri No 2 Capacitor, Narrabri No 3 Capacitor, and Coffs Harbour No 1 Capacitor.

On this basis, we consider that there is one credible network option that can meet the identified need. This option is summarised in Table 3-1. We invited parties to make written submissions regarding the potential of non-network options to satisfy, or contribute to satisfying, the identified need for this RIT-T. No submissions were received in response to the PSCR in relation to non-network options.

Table 3-1: Summary of the credible options

Option	Description	Estimated capex ($2021-22 m)	Expected commission date
Option 1		10.22	2028
Kempsey No 1 Capacitor	Renew the Capacitor Bank Bay	2.80	2027
Narrabri No 2 Capacitor	Replace Capacitor Bank Cans only[13]	1.64	2028
Narrabri No 3 Capacitor	Renew the Capacitor Bank Bay	2.99	2027
Coffs Harbour No 1 Capacitor	Renew the Capacitor Bank Bay	2.79	2027

3.1. Base case

Consistent with the RIT-T requirements, the assessment undertaken in this PACR compares the costs and benefits of each credible option to a 'do nothing' base case. The base case is the (hypothetical) projected case if no action is taken, i.e.,:[14]

> "The base case is where the RIT-T proponent does not implement a credible option to meet the identified need, but rather continues its 'BAU activities'. 'BAU activities' are ongoing, economically prudent activities that occur in absence of a credible option being implemented"

[13] There are no air core reactors in this bay, and consequently do not need to be replaced. The associated protection and control will be replaced under the secondary systems renewal programs.

[14] AER, *Regulatory Investment Test for Transmission Application Guidelines,* August 2020, p. 21.

Under the base case, no investment is undertaken to replace existing capacitor banks that are reaching end of life. These assets will continue to be maintained and operated under the current regime, and are essentially run until they fail. The annual routine operating and maintenance is expected to cost $4,000 across the Kempsey No 1 Capacitor, Narrabri No 2 Capacitor, Narrabri No 3 Capacitor, and Coffs Harbour No 1 Capacitor each year from 2022-23 to 2041-42.

The degraded condition of the four capacitor banks that have been identified for replacement under this program will lead to an increase in unplanned outages due to insufficient capacitive capacity during high load conditions. This would result in system volts falling below an acceptable level. In order for the system to maintain its capacity at an acceptable level, load shedding would need to occur. This is expected to result in unserved energy of approximately 120MWh in 2022-23 and 244MWh in 2032-33[15].

It will also lead to higher safety, environmental, and financial risk costs, that are caused by the failure of capacitor banks to operate when required. The aggregate risk cost under the base case is currently estimated at around $5.58 million in 2022-23, and it is expected to increase going forward if action is not taken (reaching approximately $9.35 million by 2029-30 and $19.05 million by the end of the 20-year assessment period).

While this is not a situation we plan to encounter, and this RIT-T has been initiated specifically to avoid it, the assessment is required to use this base case as a common point of reference when estimating the net benefits of each credible option.

3.2. Option 1 – Renew capacitor bays at Kempsey No 1, Narrabri No 3 and Coffs Harbour No 1 and replace capacitor cans at Narrabri No 2

Option 1 involves renewing the capacitor bank bays at Kempsey No 1, Narrabri No 3 and Coffs Harbour No 1 and replacing the capacitor cans only at Narrabri No 2. Under this option, spares will be generated for all sibling sites in our network. Option 1 is detailed as follows:

- **Renewing capacitor bank bays:** This involves a full replacement of all equipment associated with the capacitor bank capability including the following components: capacitor cans and steel work, air core reactors, neutral unbalance current transformers and associated protection and control hardware. This option involves renewing the capacitor bank bays with more updated equipment at Kempsey No 1, Narrabri No 3 and Coffs Harbour No 1. It is estimated that it will take approximately two years to undertake this project. The air core reactors and capacitor cans will be retained as spares under this option.
- **Replacing capacitor cans:** This involves the replacement of the capacitor cans and associated steel work components only. This option only applies to Narrabri No 2. The associated protection and control will be replaced under the secondary systems renewal programs. The remaining equipment within the capacitor bank bays at Narrabri No 2 are not included in this RIT-T due to the absence of air core reactors associated with the asset, so consequently the reactors do not need to be replaced. The protection and control components at Narrabri will be addressed as part of a separate secondary systems renewal program and are therefore not included in this RIT-T. Compared to the version of the capacitor can component currently being used, the new capacitor can is designed to be significantly smaller and lighter, thus reducing safety risk, as well as have greater availability of spare parts.

[15] Yearly figures for unserved energy

The work will be undertaken over a four-year period with all works expected to be completed by 2027/28. The capital cost of this option is approximately $10.22 million (in $2021-22). This expenditure is comprised of:

- $2.11 million in labour costs;
- $2.8 million in materials costs; and
- $5.31 million in expenses.

The table below provides a breakdown of the estimated capital cost by site.

Table 3-2 Option 1 Capital Cost ($2021-22 m)

Capital cost	Description	2024-25	2025-26	2026-27	2027-28	Total capex
Option 1		0.858	4.454	4.250	0.654	10.215
Kempsey No 1 Capacitor	Renew the Capacitor Bank Bay	0.280	1.400	1.120	-	2.800
Narrabri No 2 Capacitor	Replace Capacitor Bank Cans only	-	0.164	0.818	0.654	1.636
Narrabri No 3 Capacitor	Renew the Capacitor Bank Bay	0.299	1.495	1.196	-	2.990
Coffs Harbour No 1 Capacitor	Renew the Capacitor Bank Bay	0.279	1.395	1.116	-	2.790

In addition, routine operating and maintenance costs are estimated at approximately $4,000 per annum (in $2021-22). We expect that the capacitor banks will have an asset life of 30 years. An annual breakdown of the capital and operating expenditure for Option 1 is presented in the table below.

Table 3-3 Annual breakdown of capital and operating costs Option1 ($M, 2021-2022)

Years	Capital cost	Operating cost
2023	-	$0.004
2024	-	$0.004
2025	$0.858	$0.004
2026	$4.454	$0.004
2027	$4.250	$0.004
2028	$0.654	$0.004
2029	-	$0.004
2030	-	$0.004
2031	-	$0.004
2032	-	$0.004
2033	-	$0.004

2034	-	$0.004
2035	-	$0.004
2036	-	$0.004
2037	-	$0.004
2038	-	$0.004
2039	-	$0.004
2040	-	$0.004
2041	-	$0.004
2042	-	$0.004
Total	**$10.215**	**$0.080**

All works will be completed in accordance with the relevant standards and components shall be replaced to have minimal modification to the wider transmission network. Necessary outages of relevant assets in service will be planned appropriately in order to complete the works with minimal impact on the network.

Following the implementation of Option 1, the costs associated with reliability, safety, environmental and financial risks are significantly reduced. A reduction in the risk of failure of the capacitor banks will reduce expected unserved energy and the associated replacements costs.

Transgrid has estimated that there will be no risk costs under Option 1 from 2028/29 onwards, after the above identified capacitor banks have been replaced (in $2021-22).

3.3. Options considered but not progressed

We have also considered whether other options could meet the identified need. Reasons these options were not progressed are summarised in Table 3-4.

Table 3-4: Options considered but not progressed

Option	Reason(s) for not progressing
Increased maintenance or inspections	The condition issues have already been identified and cannot be rectified through increased maintenance or inspections. This option has not been progressed as it is not technically capable of addressing the identified need.
Elimination of all associated risk	This can only be achieved by retiring the assets, which is not technically feasible due to the requirement to maintain the existing network reliability.
Technology substitution	Both Static VAR compensators and synchronous condensers can provide reactive support. Both are significantly more expensive from a capital and operational perspective, and thus were not progressed.

3.4. No material inter-network impact is expected

We have considered whether the credible options listed above is expected to have material inter-regional impact[16]. A 'material inter-network impact' is defined in the NER as:

"A material impact on another Transmission Network Service Provider's network, which impact may include (without limitation): (a) the imposition of power transfer constraints within another Transmission Network Service Provider's network; or (b) an adverse impact on the quality of supply in another Transmission Network Service Provider's network."

By reference to AEMO's screening test for an inter-network impact,[17] a material inter-regional impact may arise if a credible option:

- is expected to change power transfer capability between transmission networks or in another TNSP's network by more than the minimum of 3 per cent of the maximum transfer capability and 50 MW
- is expected to result in an increase in fault level by more than 10 MVA at any substation in another TNSP's network; or
- involves either a series capacitor or modification in the vicinity of an existing series capacitor.

As none of these criteria are satisfied for this RIT-T, we consider that there are no material inter-network impacts associated with any of the credible options considered.

[16] As per clause 5.16.4(b)(6)(ii) of the NER.

[17] Inter-Regional Planning Committee. "*Final Determination: Criteria for Assessing Material Inter-Network Impact of Transmission Augmentations*." Melbourne: Australian Energy Market Operator, 2004. Appendix 2 and 3. Accessed 23 June 2021. https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/170-0035-pdf.pdf

4. Materiality of market benefits

This section outlines the categories of market benefits prescribed in the National Electricity Rules (NER) and whether they are considered material for this RIT-T.[18]

On 21 September 2023, the National Energy Laws were amended to reflect the incorporation of emissions reductions within the National Energy Objectives.[19] Following this the AEMC made harmonising changes to the National Electricity Rules, prompted by a rule change request from energy ministers, to ensure that network investment and planning frameworks are consistent with the new emissions reduction objective. The AEMC's Final Determination, published on 1 February 2024, included introducing a 'changes in Australia's greenhouse gas emissions' as a new class of market benefit to be considered within the RIT-T process.[20]

Transgrid supports greater consideration of emissions reduction within network planning and investment frameworks. These changes ensure network planning and investment frameworks support achievement of the Commonwealth Government's net zero targets. Transgrid has set science-based targets to cut emissions and decarbonise our business. These include:

- Reducing Scope 1 and 2 emissions by 60 per cent by 2030, compared with a base year of 2021 and net zero by 2040.
- Reducing Scope 3 emissions from Purchased Goods and Services, and Capital Goods by 48 per cent for every million dollars that we spend on these two categories by 2030, compared with a base year of 2021, and net zero by 2050.[21]

The updated National Energy Laws and Rules included transitional provisions that applied these changes to any RIT-T project that was required to publish a PADR where the deadline for doing so was after 21 November 2023.

As the PSCR for this RIT-T was submitted prior to 21 November 2023, and there is no requirement in this project to publish a PADR, this RIT-T is still subject to the old National Electricity Rules which did not consider changes in Australian emissions as a class of market benefit.

Additionally, the identified need for this RIT-T is driven by an externally imposed obligation, and therefore framed as reliability corrective action in which induced market benefits are not the primary objective.

Thus, to ensure timely publication of this RIT-T and delivery of the proposed solution, Transgrid has not assessed the change in Australian emissions tied to the project, as a benefit within this RIT-T.

[18] The NER requires that all classes of market benefits identified in relation to the RIT-T are included in the RIT-T assessment, unless the TNSP can demonstrate that a specific class (or classes) is unlikely to be material in relation to the RIT-T assessment for a specific option – NER clause 5.15A.2(b)(5). See Appendix A for requirements applicable to this document.

[19] Statutes Amendment (National Energy Laws) (Emissions Reduction Objectives) Act 2023 (SA)

[20] AEMC, Harmonising the national energy rules with the updated national energy objectives – final determination, 1 February 2024

[21] For more information on Transgrid's planned journey to net zero please see our website here: https://www.transgrid.com.au/about-us/our-approach/our-journey-to-net-zero

4.1. Avoided unserved energy is material

We consider that changes in involuntary load shedding are expected to be material for the credible options outlined in this RIT-T assessment. In the base case, involuntary load shedding would be expected to occur following a failure of capacitor banks on our network. The probability of asset failure is expected or increase over time as the condition of the relevant assets continue to deteriorate.

We have estimated expected load shedding under the base case and each option. These forecasts are based on probabilistic planning studies of failure rates and repair times. The avoided unserved energy for each credible option is calculated as the difference between the expected load shedding under the base case and the expected load shedding under each option.

4.2. Wholesale electricity market benefits are not material

The AER has recognised that if the credible options will not have an impact on the wholesale electricity market, then a number of classes of market benefits will not be material in the RIT-T assessment, and so do not need to be estimated.

We determine that the credible options in this RIT-T will not affect network constraints between competing generating centres and are therefore not expected to result in any change in dispatch outcomes and wholesale market prices. We therefore consider that the following classes of market benefits are not material for this RIT-T assessment:

- changes in fuel consumption arising through different patterns of generation dispatch
- changes in voluntary load curtailment (since there is no impact on pool price)
- changes in costs for parties other than Transgrid
- changes in ancillary services costs
- competition benefits

4.3. No other classes of market benefits are material

In addition to the classes of market benefits listed above, NER clause 5.15A.2(b)(4) requires us to consider the following classes of market benefits, listed in Table 4-1, arising from each credible option. We consider that none of the classes of market benefits listed are material for this RIT-T assessment for the reasons in Table 4-1.

Table 4-1: Reasons non-wholesale electricity market benefits categories are considered not material

Market benefits	Reason
Differences in the timing of unrelated network expenditure	The credible options considered are unlikely to affect decisions to undertake unrelated expenditure in the network. Consequently, material market benefits will neither be gained nor lost due to changes in the timing of expenditure from any of the options considered.
Option value	We note the AER's view that option value is likely to arise where there is uncertainty regarding future outcomes, the information that is available is likely to change in the future, and the credible options considered by the TNSP are sufficiently flexible to respond to that change.

	We also note the AER's view that appropriate identification of credible options and reasonable scenarios captures any option value, thereby meeting the NER requirement to consider option value as a class of market benefit under the RIT-T. We do not consider there to be any option value with the options considered in this RIT-T. Additionally, a significant modelling assessment would be required to estimate the option value benefits but it would be disproportionate to potential additional benefits for this RIT-T. Therefore, we have not estimated additional option value benefit.
Changes in network losses	We do not expect any material difference in transmission losses between options.

5. Overview of the assessment approach

This section outlines the approach that we have applied in assessing the net benefits associated with each of the credible options against the base case.

5.1. Assessment against the base case

The costs and benefits of each option in this document are compared against a 'do nothing' base case. Under this base case, no investment is undertaken to replace existing capacitor banks which will run until they fail.

The degraded condition of the capacitor banks which have been identified for replacement under this program will lead to an increase in unplanned outages due to an increase in the failure rate of capacitor banks and therefore insufficient capacitive capacity during high load conditions. This would result in system volts falling below a level accepted by the NER. It would also lead to higher safety, environmental and financial related risk costs that are caused by the failure of the capacitor banks to operate when required. However, routine operating and maintenance costs are equal under both the base case and the option developed.

We note that this course of action is not expected in practice. However, this approach has been adopted since it is consistent with AER guidance on the base case for RIT-T applications.[22]

5.2. Assessment period and discount rate

A 20-year assessment period from 2022/23 to 2041/42 has been adopted for this RIT-T analysis. This period takes into account the size, complexity and expected asset life of the options.

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. The terminal values have been calculated based on the undepreciated value of capital costs at the end of the analysis period and expected operating and maintenance cost for the remaining asset life. As a conservative assumption, we have effectively assumed that there are no additional cost and benefits after the analysis and period.

A real, pre-tax discount rate of 7 per cent has been adopted as the central assumption for the NPV analysis presented in this PACR, consistent with the assumptions adopted in AEMO's Draft 2024 Integrated System Plan (ISP).[23] The RIT-T requires that sensitivity testing be conducted on the discount rate and that the regulated weighted average cost of capital (WACC) be used as the lower bound. We have therefore tested

[22] The AER RIT-T Guidelines state that the base case is where the RIT–T proponent does not implement a credible option to meet the identified need, but rather continues its 'BAU activities'. The AER define 'BAU activities' as ongoing, economically prudent activities that occur in the absence of a credible option being implemented. (See: AER, *Application guidelines Regulatory Investment Test for Transmission,* August 2020)

[23] AEMO, *2024 Draft Integrated System Plan, December 2023*, p 91.

the sensitivity of the results to a lower bound discount rate of 3 per cent.[24] We have also adopted an upper bound discount rate of 10.5 per cent (ie, AEMO's 2023 Inputs, Assumptions and Scenarios Report).[25]

5.3. Approach to estimating option costs

We have estimated the capital and operating costs of the options based on the scope of works necessary together with costing experience from previous projects of a similar nature.

As the works are being conducted within existing substations, we have assumed normal soil for any civil works, and have no allowance for any additional access work required.

The cost estimates are developed using our 'MTWO' cost estimating system. This system utilises historical average costs, updated by the costs of the most recently implemented project with similar scope. All estimates in MTWO are developed to deliver a 'P50' portfolio value for a total program of works (i.e., there is an equal likelihood of over- or under-spending the estimate total).[26]

We estimate that actual costs will be within +/- 25 per cent of the central capital cost estimate. An accuracy of +/- 25 per cent for cost estimates is consistent with industry best practice and aligns with the accuracy range of a 'Class 4' estimate, as defined in the Association for the Cost Engineering classification system.

All cost estimates are prepared in real, 2021/22 dollars based on the information and pricing history available at the time that they were estimated. The cost estimates do not include or forecast any real cost escalation for materials.

Routine operating and maintenance costs are based on works of similar nature. Given that there is an incremental routine operating and maintenance costs saving in the options compared to the base case, this is a net benefit in the assessment.

5.4. Value of customer reliability

We have applied a NSW-wide VCR value based on the estimates developed and consulted on by the AER.[27] The options considered involve the replacement of capacitor banks across our network. As a result, we consider that a state-wide VCR is likely to reflect the weighted mix of customers that will be affected by these options.

5.5. The options have been assessed against three reasonable scenarios

The RIT-T is focused on identifying the top ranked credible option in terms of expected net benefits. However, uncertainty exists in terms of estimating future inputs and variables (termed future 'states of the world').

[24] This is equal to WACC (pre-tax, real) in the latest final decision for a transmission business in the NEM (Transgrid) as of the date of this analysis, see: https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/transgrid-determination-2023%E2%80%9328/final-decision

[25] AEMO '2023 Inputs, Assumptions and Scenarios Report', July 2023, p 123.

[26] For further detail on our cost estimating approach refer to section 7 of our Augmentation Expenditure Overview Paper submitted with our 2023-28 Revenue Proposal.

[27] The analysis used a $2021-22 VCR value as this was the dollar basis for all costs in the assessment. This was calculated by deflating the VCR $2022-23 amount of $49,216/MWh (as per AEMO's 2023 IASR) by 6% (ABS CPI Jun 22 to Jun 23).

To deal with this uncertainty, the NER requires that costs and market benefits for each credible option are estimated under reasonable scenarios and then weighted based on the likelihood of each scenario to determine a weighted ('expected') net benefit. It is this 'expected' net benefit that is used to rank credible options and identify the preferred option.

The credible options have been assessed under three scenarios as part of this PACR assessment, which differ in terms of the key drivers of the estimated net market benefits (ie, the estimated risk costs avoided).

Given that wholesale market benefits are not relevant for this RIT-T, the three scenarios implicitly assume the most likely scenario from the 2023 ISP (ie, the 'Step Change' scenario). The scenarios differ by the assumed level of risk costs and unserved energy, given that these are key parameters that may affect the ranking of the credible options. Risk cost assumptions do not form part of AEMO's ISP assumptions, and have been based on Transgrid's analysis, as discussed in section 2.

We developed the Central Scenario around a static model of demand scenarios, described further in Section A.3 of our Network Asset Criticality Framework. We consider that this approach is appropriate since it materially reduces the computational effort required, and since differences in demand forecasts will not materially affect the ranking of the credible options.

How the NPV results are affected by changes to other variables (including the discount rate and capital costs) has been investigated in the sensitivity analysis. We consider this is consistent with the latest AER guidance for RIT-Ts of this type (ie, where wholesale market benefits are not expected to be material).[28],[29]

Table 5-1: Summary of scenarios

Variable / Scenario	Central	Low risk cost scenario	High risk cost scenario risk
Scenario weighting	1/3	1/3	1/3
Discount rate	7%	7%	7%
VCR ($2021-22)[30]	$46,430/MWh	$46,430/MWh	$46,430/MWh
Network capital costs	Base estimate	Base estimate	Base estimate
Operating and maintenance costs	Base estimate	Base estimate	Base estimate
Environmental, safety and financial risk benefit	Base estimate	Base estimate – 25%	Base estimate +25%
Avoided unserved energy	Base estimate	Base estimate – 25%	Base estimate +25%

We have weighted the three scenarios equally given there is nothing to suggest an alternate weighting would be more appropriate.

[28] AER, *Application Guidelines Regulatory Investment Test for Transmission*, August 2020, pp. 40-41.

[29] We consider the approach to scenarios and sensitivities to be consistent with the AER guidance provided in November 2022 in the context of the disputes of the North West Slopes and Bathurst, Orange and Parkes RIT-Ts. See: AER, *Decision: North West Slopes and Bathurst, Orange and Parkes Determination on dispute - Application of the regulatory investment test for transmission*, November 2022, pp. 18-20 & 31-32, as well as with the AER's RIT-T Guidelines.

[30] This was calculated by deflating the VCR $2022-23 amount of $49,216/MWh (as per AEMO's 2023 IASR) by 6% (ABS CPI Jun 22 to Jun 23).

5.6. Sensitivity analysis

In addition to the scenario analysis, we have also considered the robustness of the outcome of the cost benefit analysis through undertaking various sensitivity testing.

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

- lower and higher assumed capital costs;
- lower and higher assumed Value of Customer Reliability (VCR); and
- alternate commercial discount rate assumptions.

The above list of sensitivities focuses on the key variables that could impact the identified preferred option. The results of the sensitivity tests are set out in section 6.4.

In addition, we have also sought to identify the 'boundary value' for key variables beyond which the outcome of the analysis would change, including the amount by which capital costs would need to increase for the preferred option to no longer be preferred.

6. Assessment of credible options

This section outlines the assessment we have undertaken of the credible network options. The assessment compares the costs and benefits of each credible option to the base case. The benefits of each credible option are represented by a reduction in costs or risks compared to the base case.

All costs and benefits presented in this PACR are in 2021/22 dollars.

6.1. Estimated gross benefits

The table below summarises the present value of the gross benefit estimates for each credible option relative to the base case. The results have been presented separately for each reasonable scenario, and on a weighted basis.

The benefits included in this assessment are:

- avoided involuntary load shedding;
- reduction in safety, environmental and financial risks; and
- avoided routine operating and maintenance costs.

Table 6-1: NPV of gross economic benefits relative to the base case ($2021/22 m)

Option	Central	Low risk cost scenario	High risk cost scenario risk	Weighted scenario
Scenario weighting	1/3	1/3	1/3	
Option 1	73.64	55.23	92.05	73.64

The results show that under all three scenarios, the estimated gross benefits are positive for Option 1 (in NPV terms).

6.2. Estimated costs

The table below summarises the present value of capital costs of each credible option relative to the base case. The results have been presented separately for each reasonable scenario, and on a weighted basis.

Table 6-2: NPV of capital relative to the base case ($2021/22 m)

Option	Central	Low risk cost scenario	High risk cost scenario risk	Weighted scenario
Scenario weighting	1/3	1/3	1/3	
Option 1	7.56	7.56	7.56	7.56

The results show that the estimated cost of implementing Option 1 is equal under each scenario.

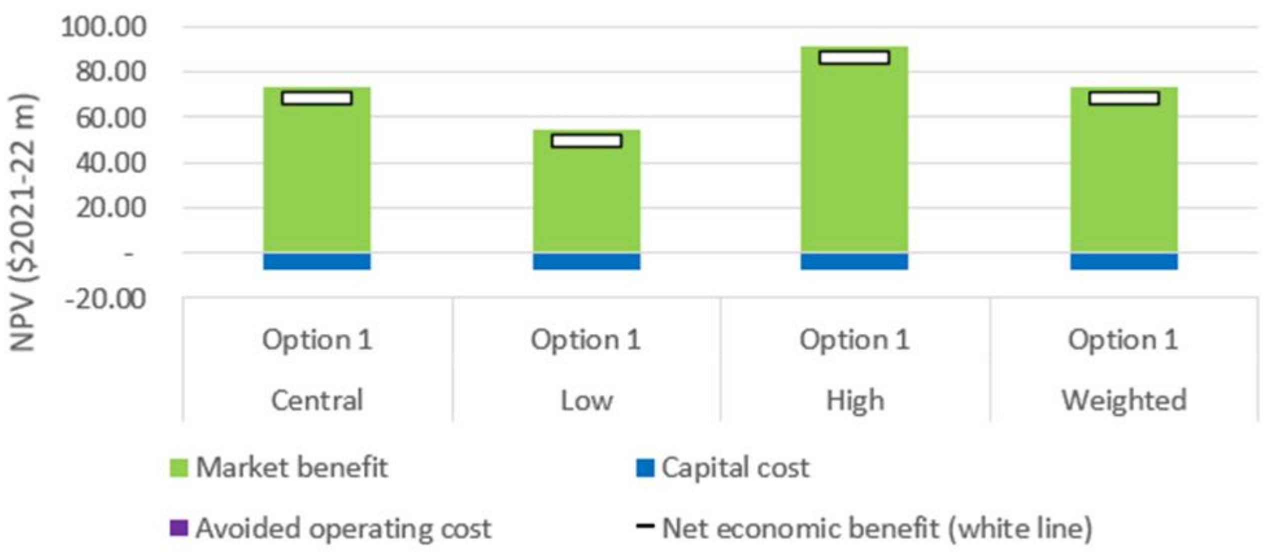
6.3. Estimated net economic benefits

The net economic benefits calculated as the estimated gross benefits less the estimated costs plus the terminal value. The table below summarises the present value of the net economic benefits for each credible option relative to the base case. The results have been presented separately for each reasonable scenario, and on a weighted basis. The table also shows a ranking of the options, where options with a higher net economic benefit under the weighted scenario are accorded a higher rank.

Table 6-3: NPV of net economic benefits relative to the base case ($2021/22 m)

Option	Central	Low risk cost scenario	High risk cost scenario risk	Weighted scenario	Ranking
Scenario weighting	1/3	1/3	1/3		
Option 1	68.35	49.94	86.77	68.35	1

Figure 6-1 Net economic benefits ($m, PV)



6.4. Sensitivity testing

We have undertaken sensitivity testing to understand the robustness of the RIT-T assessment to underlying assumptions about key variables. In particular, we have undertaken two sets of sensitivity tests:

- Step 1 – testing the sensitivity of the optimal timing of the project (‘trigger year’) to different assumptions in relation to key variables; and
- Step 2 – once a trigger year has been determined, testing the sensitivity of the total NPV benefit associated with the investment proceeding in that year, in the event that actual circumstances turn out to be different.

Having assumed to have committed to the project by this date, we have also looked at the consequences of ‘getting it wrong’ under step 2 of the sensitivity testing. That is, if expected safety and environmental risks are not as high as expected, for example, the impact on the net economic benefit associated with the project continuing to go ahead on that date.

The application of the two steps to test the sensitivity of the key findings is outlined below.

6.4.1. Step 1 - Sensitivity testing of the optimal timing

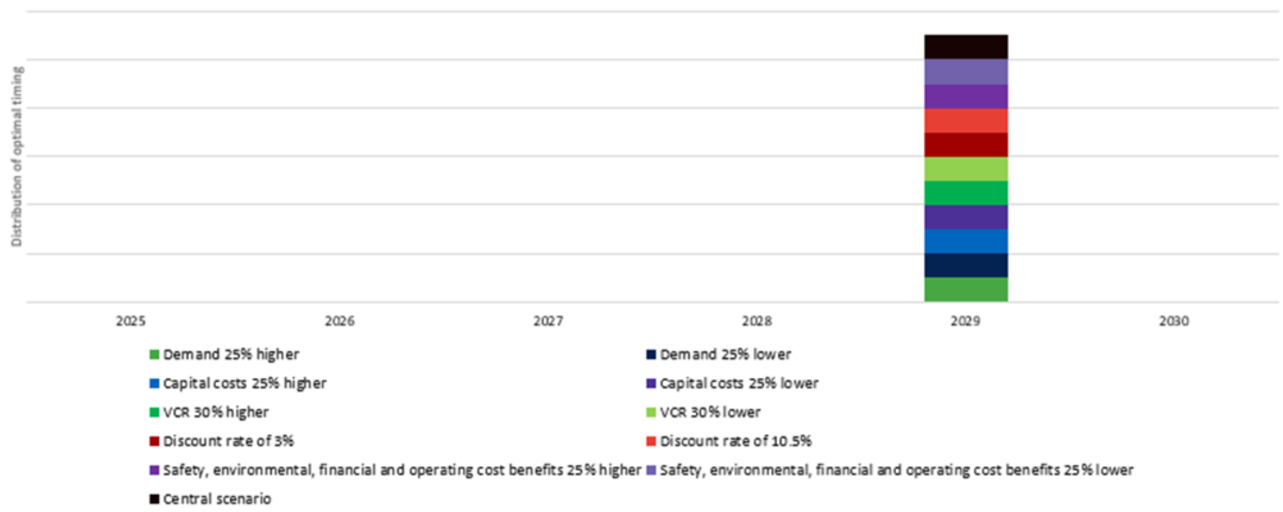
This section outlines the sensitivity of the identification of the commissioning year of Option 1 to changes in the underlying assumptions. In particular, the optimal timing of Option 1 is found to be invariant to the assumptions of:

- a 25 per cent increase/decrease in the assumed network capital costs;
- a 30 per cent increase/decrease in VCR value
- lower discount rate of 3 per cent as well as a higher rate of 10.50 per cent;

Each timing sensitivity has been undertaken on the central scenario.

The figure below outlines the impact on the optimal commissioning year, under a range of alternative assumptions. It illustrates that for Option 1, the optimal commissioning date is found to be in 2027/28, such that the benefits are realised from 2028/29, for all of the sensitivities investigated.

Figure 6-2 Optimal timing of Option 1



6.4.2. Step 2 – Sensitivity of the overall net benefit

We have conducted sensitivity analysis on the present value of the net economic benefit, based on undertaking the project by 2028/29. Specifically, we have investigated the same sensitivities under this step as in the first step:

- a 25 per cent increase/decrease in the assumed network capital costs;
- a 30 per cent increase/decrease in VCR value
- lower discount rate of 3 per cent as well as a higher rate of 10.50 per cent;

All these sensitivities investigate the consequences of 'getting it wrong' having committed to a certain investment decision.

Option 1 delivers positive benefits under all sensitivities.

The sensitivity testing focuses on the central scenario given the ranking of the options is found to be the same across all three scenarios investigated and there are significant expected net market benefits under each scenario. That is, we do not expect the key findings to change for this RIT-T if the sensitivity testing was expanded to cover the low risk and high risk scenarios.

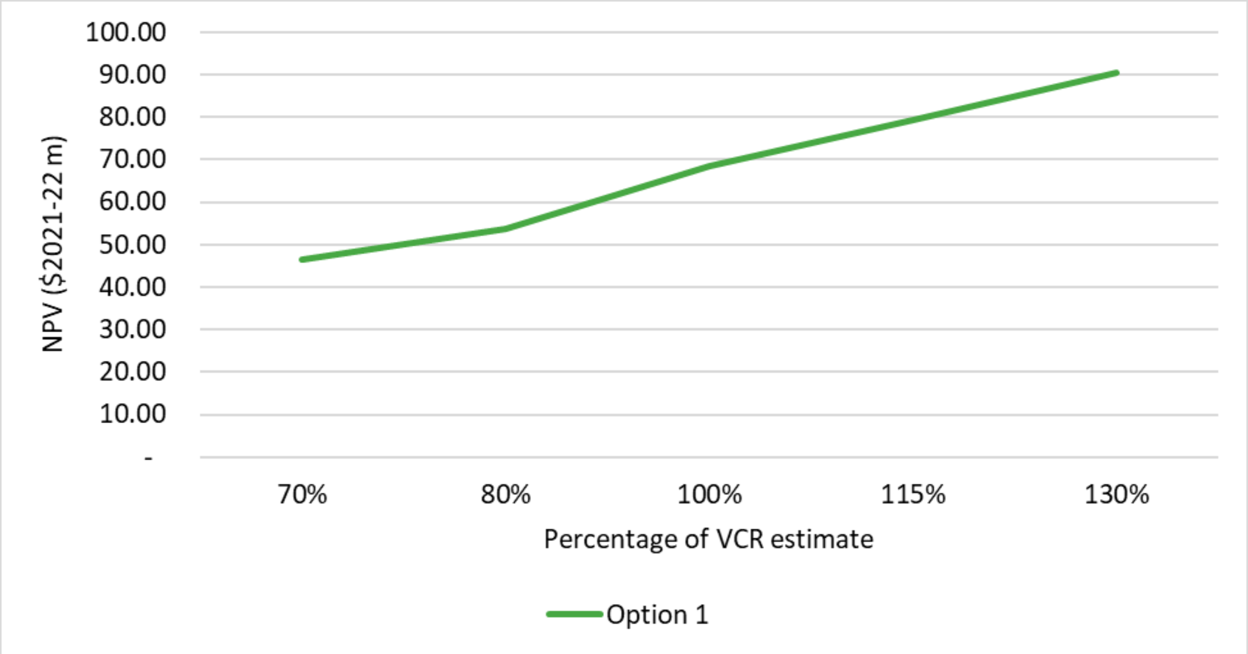
Given that our analysis only considers a single option, we have determined that Option 1 is preferred under all three reasonable scenarios. As such, a threshold analysis to identify whether a change in capital cost estimates would change the RIT-T outcome is not applicable for this RIT-T.

We estimated the net economic benefit of each option by adopting a VCR that is 30% higher (the 'High VCR' scenario) and 30% lower (the 'Low VCR' scenario) than the estimate of VCR adopted in our central scenario. The results of this analysis are presented in the table and figure below.

Table 6-4: NPV of net economic benefits relative to the base case under a lower and higher VCR ($2021/22 m)

Option/scenario	Low VCR	High VCR	Ranking
Sensitivity	Central estimate - 30%	Central estimate + 30%	
Option 1	46.38	90.33	1

Figure 6-3 NPV of net economic benefits relative to the base case under a lower and higher VCR ($2021/22 m)

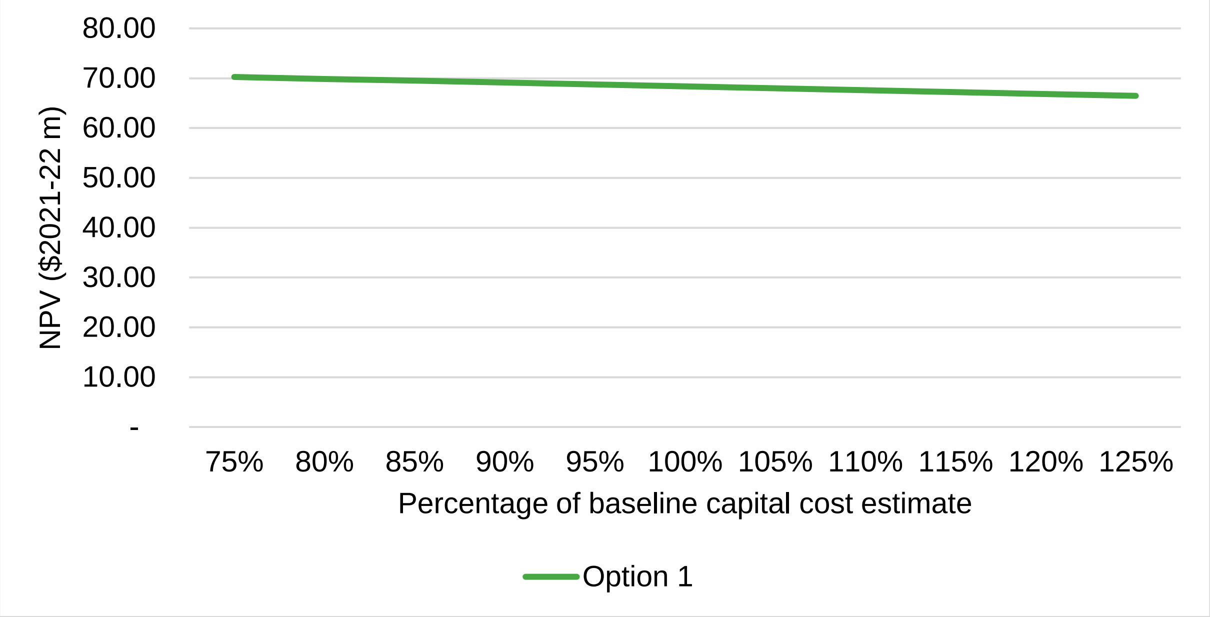


We estimated the net economic benefit of each option by adopting capital costs for each option that are 25% higher (the 'High capex' scenario) and 25% lower (the 'Low capex' scenario) than the capital cost estimates in our central scenario. The results of this analysis are presented in the table and figure below.

Table 6-5: NPV of net economic benefits relative to the base case under lower and higher capital costs ($2021/22 m)

Option/scenario	Low capex	High capex	Ranking
Sensitivity	Central estimate - 25%	Central estimate + 25%	
Option 1	70.25	66.46	1

Figure 6-4: NPV of net economic benefits relative to the base case under lower and higher capital costs ($2021/22 m)



The table and figure below set out the net economic benefits estimated for each credible option relative to the base case by adopting alternative discount rates. Specifically, we considered a low discount rate of 3% which is consistent with the AER's latest final determination for a TNSP (the 'Low discount rate' scenario),[31] and a high discount rate of 10.5% which aligns with the high discount rate scenario in the 2023 IASR (the 'High discount rate' scenario).[32]

Table 6-6: NPV of net economic benefits relative to the base case under a lower and higher discount rates ($2021/22 m)

Option/scenario	Low discount rate	High discount rate	Ranking
Sensitivity	3%	10.5%	
Option 1	120.10	42.89	1

31 This is equal to WACC (pre-tax, real) in the latest final decision for a transmission business in the NEM (Transgrid) as of the date of this analysis, see: https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/transgrid-determination-2023%E2%80%9328/final-decision

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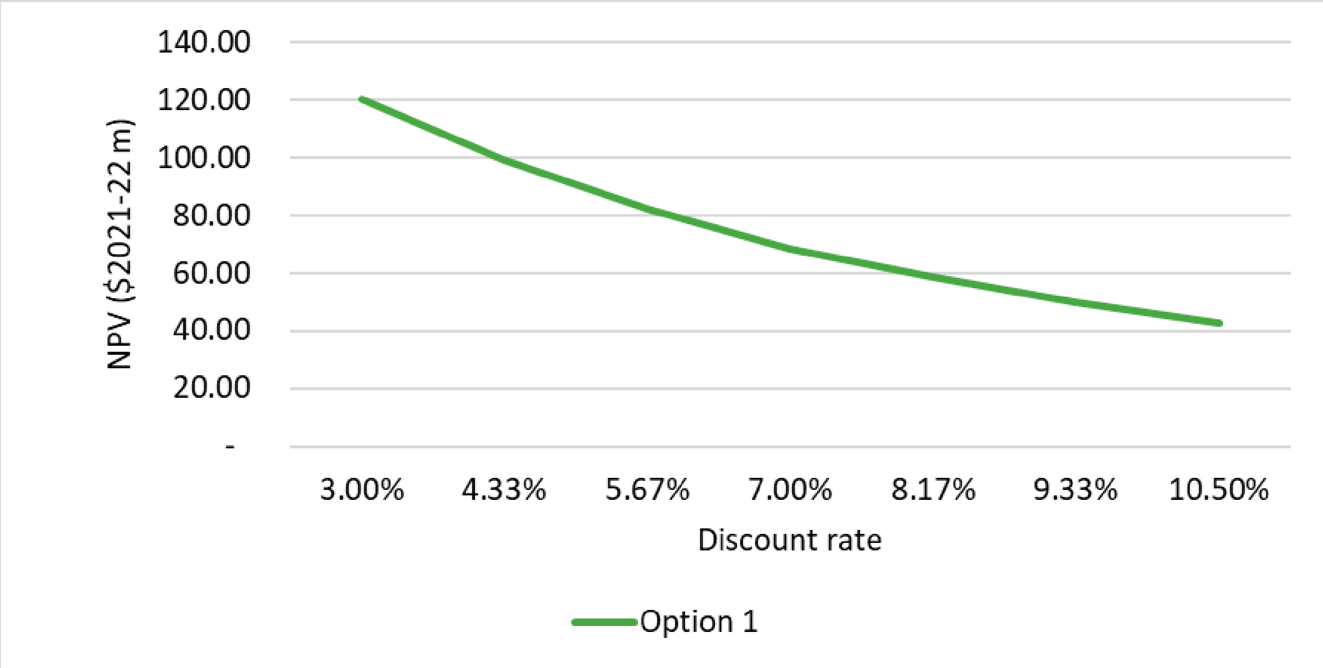
Figure 6-5 Net economic benefits relative to the base case under a lower and higher discount rates ($2021/22 m)



7. Final conclusion on the preferred option

This PACR finds that implementation of Option 1 is the preferred option at this draft stage of the RIT-T process. Under Option 1, the four capacitor banks identified will be renewed entirely or undergo a replacement of the capacitor can component. These capacitor banks currently exceed their technical life of 30 years and would be exceeding the technical life by at least 15 years in 2027/28. Under this option, Kempsey No 1 Capacitor, Narrabri No 3 Capacitor, and Coffs Harbour No 1 Capacitor would undertake a renewal of the capacitor bank bays i.e., replacement of all components, whereas Narrabri No 2 Capacitor would have only its capacitor bank cans and associated steelworks replaced.

The capital cost of this option is approximately $10.22 million (in $2021-22). The work will be undertaken over a four-year period with all works expected to be completed by 2027/28. Routine operating and maintenance costs are estimated at approximately $4,000 per annum (in $2021-22). All works will be completed in accordance with the relevant standards and components shall be replaced to have minimal modification to the wider transmission network. Necessary outages of relevant assets in service will be planned appropriately in order to complete the works with minimal impact on the network.

Option 1 is the preferred option in accordance with NER clause 5.15A.2(b)(12) because it is the credible option that maximises the net present value of the net economic benefit to all those who produce, consume and transport electricity in the market. The analysis undertaken and the identification of Option 1 as the preferred option satisfies the RIT-T.

Transgrid considers this conclusion to be robust to changes in capital cost inputs, estimated risk costs and underlying discount rates. Transgrid will however continue to monitor these key assumptions and will notify the AER if such changes do occur (or appear likely), which would constitute a material change in circumstance.

Appendix A Compliance checklist

This appendix sets out a checklist which demonstrates the compliance of this PACR with the requirements of the National Electricity Rules version 207.

Rules clause	Summary of requirements	Relevant section(s) in the PACR
5.16.4(i)	The project assessment conclusions report must set out:	–
	(1) the matters detailed in the project assessment draft report as required under paragraph (k); and	See below.
	(2) a summary of, and the RIT-T proponent's response to, submissions received, if any, from interested parties sought under paragraph (q).	NA
5.16.4(k)	The project assessment draft report must include:	–
	(1) a description of each credible option assessed;	3
	(2) a summary of, and commentary on, the submissions to the project specification consultation report;	NA
	(3) a quantification of the costs, including a breakdown of operating and capital expenditure, and classes of material market benefit for each credible option;	3 & 6
	(4) a detailed description of the methodologies used in quantifying each class of material market benefit and cost;	4 & 5
	(5) reasons why the RIT-T proponent has determined that a class or classes of market benefit are not material;	4
	(6) the identification of any class of market benefit estimated to arise outside the region of the Transmission Network Service Provider affected by the RIT-T project, and quantification of the value of such market benefits (in aggregate across all regions);	NA
	(7) the results of a net present value analysis of each credible option and accompanying explanatory statements regarding the results;	6
	(8) the identification of the proposed preferred option;	7
	(9) for the proposed preferred option identified under subparagraph (8), the RIT-T proponent must provide: (i) details of the technical characteristics; (ii) the estimated construction timetable and commissioning date; (iii) if the proposed preferred option is likely to have a material inter-network impact and if the Transmission Network Service Provider affected by the RIT-T project has received an augmentation technical report, that report; and (iv) a statement and the accompanying detailed analysis that the preferred option satisfies the regulatory investment test for transmission.	3 & 7
	(10) if each of the following apply to the RIT-T project: (i) if the estimated capital cost of the proposed preferred option is greater than $100 million (as varied in accordance with a cost threshold determination); and (ii) AEMO is not the sole RIT-T proponent,	N/A

	The RIT-T reopening triggers applying to the RIT-T project.	

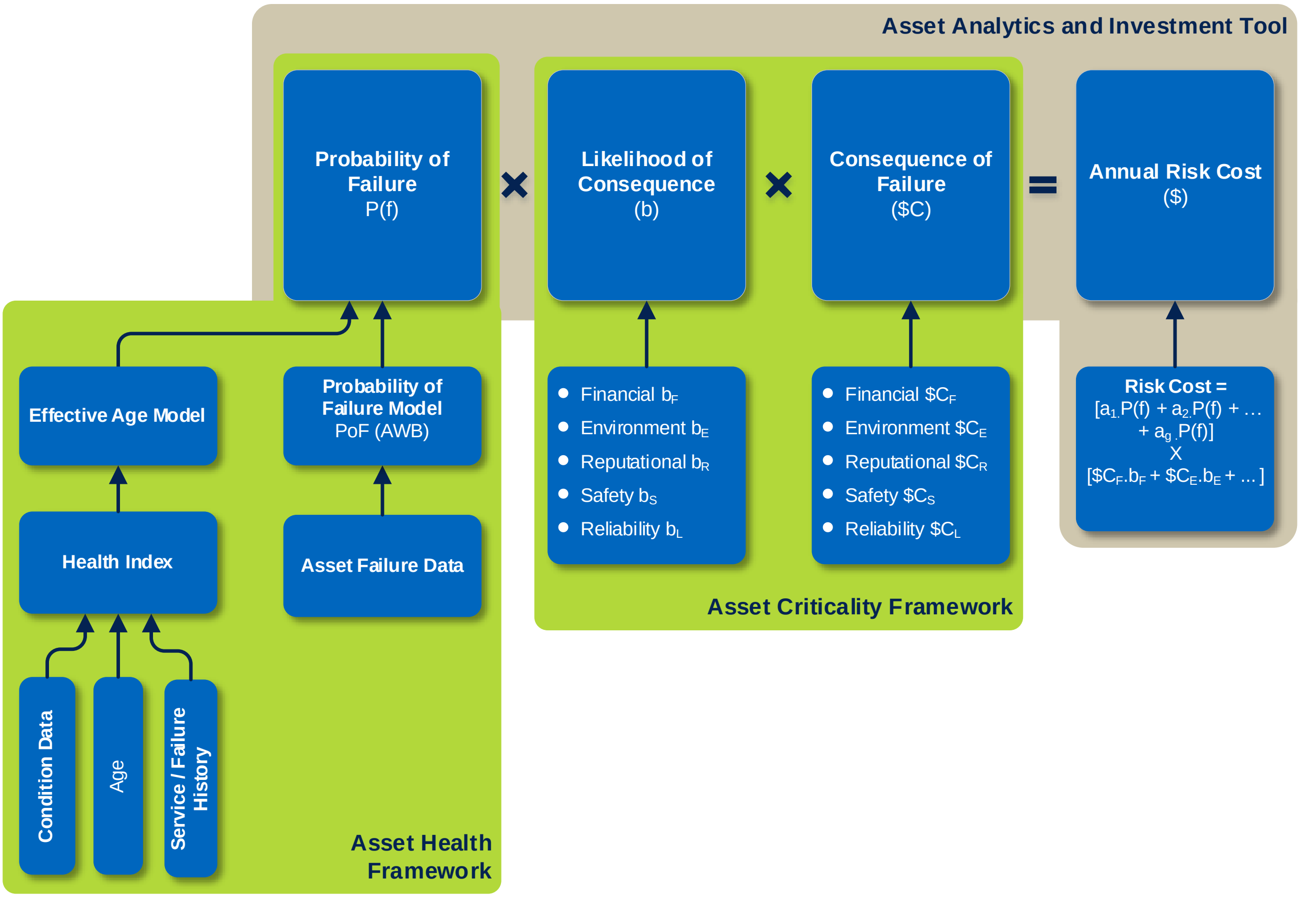
Appendix B Risk Assessment Methodology

Summary of methodology

This appendix summarises our network risk assessment methodology that underpins the identified need for this RIT-T. Our risk assessment methodology is aligned with the AER's Asset Replacement Planning guideline.[33]

A fundamental part of the risk assessment methodology is calculating the annual 'risk costs' or the monetised impacts of reliability, safety, bushfire, environmental and financial risks. The monetary value of risk (per year) for an individual asset failure resulting in an undesired outcome, is the likelihood (probability) of failure (in that year with respect to its age), as determined through modelling the failure behaviour of an asset (Asset Health), multiplied by the consequence (cost of the impact) of the undesired outcome occurring, as determined through the consequence analysis (Asset Criticality). The figure below illustrates the base risk equation that we apply.

Figure B-1 Risk cost calculation



Economic justification for replacement expenditure to address an identified need is provided where the risk reduction benefit (i.e., the value of avoided risks and costs) is greater that the costs of the project or

33 Industry practice application note - Asset replacement planning, AER January 2019

program. The major quantified risks we apply for replacement expenditure justifications include asset failures that materialise as:

- Bushfire risk
- Safety risk
- Environmental risk
- Reliability risk, and
- Financial risk.

The risk categories relevant to this RIT-T are explained in Section 2.3.

Further details are available in our Network Asset Risk Assessment Methodology.

Asset health and probability of failure

The Probability of Failure (PoF) is the likelihood that an asset will fail during a given period resulting in a particular adverse event. The first step in calculating the probability of failure of an asset is determining the Asset Health and associated effective age.[34] This is based on the following considerations:

- An asset consists of different components, each with a particular function, criticality, underlying reliability, life expectancy and remaining life. The overall health of an asset is a compound function of all of these attributes.
- Key asset condition measures and failure data provides vital information on the current health of an asset. The 'current effective age' is derived from asset information and condition data.
- The future health of an asset (health forecasting) is a function of its current health and any factors causing accelerated (or decelerated) degradation or 'age shifting' of one or more of its components. Such moderating factors can represent the cumulative effects arising from continual or discrete exposure to unusual internal stresses, external stresses, overloads and faults. 'Future effective age' is derived by moderating 'current effective age' based on factors such as external environment/influence, expected stress events and operating/loading condition.

The outputs of the PoF calculation are one or more probability of failure time series which provide a mapping between the effective age, discussed above, and the yearly probability of failure value for a given asset class. This analysis is performed by generating statistical failure curves, normally using Weibull analysis, to determine a PoF time series set for each asset that gives a probability of failure for each further year of asset life. This establishes how likely it is that the asset will fail over time.

Further details are available in our Network Asset Health Methodology.

Table B-1 Weibull parameters for assets

Asset	Weibull parameters	
	η	β
Capacitor banks	50	4.5

[34] Apparent age of an asset based on its condition.

Asset criticality

Asset criticality is the relative risk of the consequences of an undesired outcome. Asset criticality considers the severity of the consequences of the asset failure occurring and the likelihood the consequence will eventuate. Our approach to determining these factors for each relevant risk category is set out in our Network Asset Criticality Framework. The analysis leverages data from past events, relevant research / publications and technical insights, to determine an economic value of the impact.