Transgrid

People. Power. Possibilities.

Maintaining compliance with performance standards applicable to Broken Hill substation secondary systems

RIT-T Project Assessment Conclusions Report

Region: South Western NSW

Date of issue: 15 November 2021

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Executive summary

Transgrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for maintaining reliable secondary systems at Broken Hill substation. Publication of this Project Assessment Conclusions Report (PACR) represents the final step in the RIT-T process.

Broken Hill 220/22kV substation is a customer connection point supplying the Essential Energy networks in the area. Silverton Wind Farm also connects at Broken Hill substation, as well as Broken Hill Solar Plant. It forms part of the wider South Western NSW network which supports renewable energy zone development and will continue to play a central role in supporting the flow of energy to the Far West region of NSW.[1]

Transgrid has identified that the secondary systems at Broken Hill substation have reached a condition that reflects the end of serviceable life. As it is superseded by new technology at the manufacturer level and the existing technology becomes obsolete, spare parts become scarce and the ability of any primary asset connected to the substation to reliably operate will be at risk.

The 220kV and 22kV secondary systems need has been considered in the context that the associated 22kV primary equipment is also reaching a condition that reflects the end of serviceable life.

The outcome of this RIT-T is not influenced by the outcome of the active "Maintaining a reliable supply to Broken Hill" RIT-T.

Identified need: meet the service level required under the National Electricity Rules for protection schemes

Secondary systems are used to control, monitor, protect and secure communication to facilitate safe and reliable network operation.[2] They are necessary to operate the transmission network and prevent damage to primary assets when adverse events occur.

Provision of redundant protection schemes to ensure the transmission system is adequately protected is a Network Performance Requirement under Schedule 5.1 of the National Electricity Rules (NER), therefore the condition issues affecting the secondary systems at Broken Hill substation must be addressed.

The Network Performance Requirements, set out in Schedule 5.1 of the NER, place an obligation on Transmission Network Service Providers (TNSPs) to provide redundant protection schemes to ensure the transmission system is adequately protected. Schedule 5.1.9(c) of the NER requires a TNSP to provide sufficient primary and back-up protection systems, including any communications facilities and breaker fail protection systems, to ensure that a fault of any type anywhere on its transmission system is automatically disconnected.

Additionally, TNSPs are required to disconnect the unprotected primary systems where secondary systems fault lasts for more than eight hours (for planned maintenance) or 24 hours (for unplanned outages). TNSPs must also ensure that all protection systems for lines at a voltage above 66 kV are well-maintained so as to be available at all times other than for short periods (less than eight hours), while the maintenance

[1] There is over 5GW of potential wind and solar generation connections in South Western NSW and the Barrier Ranges. Transgrid. "*Transmission Annual Planning Report 2021*." Sydney: Transgrid, 2021. 69. Accessed 2 September, 2021. https://www.transgrid.com.au/news-views/publications/Documents/TAPR_2021.pdf

[2] As per Schedule 5.1 of the NER.

of protection systems is being carried out.[3] In the event of an unplanned outage, AEMO's Power System Security Guidelines require that the primary network assets must be taken out of service within 24 hours.[4]

Furthermore, as per clause 4.11.1 of the NER, remote monitoring and control systems are required to be maintained in accordance with the standards and protocols determined and advised by AEMO.

A failure of the secondary systems would involve replacement of the failed component or taking the affected primary assets, such as lines and transformers, out of service.

Though replacement of failed secondary systems component is a possible interim measure, the approach is not sustainable as the stock of spare components will deplete due to the technology no longer being manufactured or supported. Once all spares are used, replacement will cease to be a viable option to meet performance standards stipulated in clause 4.6.1 of the NER.

If the failure to provide functional secondary systems due to technology obsolescence is not addressed by a technically and commercially feasible credible option in sufficient time (by 2022/23), the likelihood of not recovering from secondary systems faults and not maintaining compliance with NER performance requirements will increase.

The proposed investment will enable Transgrid to continue to meet the standards for secondary systems availability set out in the NER, and to avoid the impacts of taking primary assets out of service. Consequently, it is considered a reliability corrective action under the RIT-T.

A reliability corrective action differs from a 'market benefits'-driven RIT-T in that the preferred option is permitted to have negative net economic benefits on account of it being required to meet an externally imposed obligation on the network business.

Submissions received in response to the Project Assessment Draft Report

Transgrid published a Project Assessment Draft Report (PADR) on 16 March 2021 and invited written submissions on the material presented within the document. One formal submission was received on the PADR and with permission from the submitter — the Public Interest Advocacy Centre — it is available on Transgrid's website.

The submission covered two topics regarding the efficiencies when considering the secondary and primary systems, specifically for Transgrid to ensure that the proposed timing of the works is in the interests of consumers and to provide more clarity regarding cost comparison between the credible options presented in the PADR to demonstrate that Option 4 is the most efficient and prudent way to achieve these efficiencies.

Transgrid values the feedback raised in the submission and met with representatives from PIAC to better understand and discuss these topics in more detail ahead of preparing this PACR. Feedback from the submission has been taken into account in undertaking the PACR analysis and in preparing this report.

[3] As per S5.1.2.1(d) of the NER.

[4] Australian Energy Market Operator. "*Power System Security Guidelines, 7 April 2021*." Melbourne: Australian Energy Market Operator, 2021.35. Accessed 22 June 2021. https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/procedures/so_op_3715-power-system-security-guidelines.pdf?la=en

No material developments since publication of the PADR

Transgrid published a Project Specification Consultation Report (PSCR) on 17 December 2019 which presented four credible options that would meet the Identified Need from a technical, commercial, and project delivery perspective[5].The options included: complete replacement with Secondary Systems Buildings (SSBs) (Option 1); complete in-situ replacement (Option 2); strategic asset replacement (Option 3); and a complete upgrade and renewal with 22 kV switchroom and 220 kV Secondary Systems Building (SSBs) (Option 4). No submissions were received on the PSCR.

Following publication of the PSCR, Transgrid identified a need to re-scope one of the credible options (Option 4- complete upgrade and renewal with 22 kV switchroom and 220 kV in-situ secondary systems replacement), and identified one additional credible option (Option 5- complete in-situ secondary systems and 22 kV AIS replacement). Consequently, as a result of this material change, Transgrid re-ran the NPV analysis including Options 1, 2 and 3[6], Option 4 (re-scoped) and the new Option 5. In the NPV analysis, Transgrid used updated costs where applicable, as well as the latest inflation and discount rates.

Transgrid presented this analysis and revised assessment, including identification of Option 4 as the proposed preferred option, in a Project Assessment Draft Report (PADR) on 16 March 2021. Transgrid invited written submissions on the materials contained within the PADR and received one submission from the Public Interest Advocacy Centre. The submission highlighted some opportunities to improve the clarity of this PACR, specifically regarding the efficiencies provided by the timing of the works and clearer cost comparison of all credible options to better demonstrate that Option 4 (preferred option) is the most efficient and prudent way forward. Further detail in relation to these points is provided in Section 3 of this PACR.

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

The following changes have occurred since the PADR which have not made an impact on the preferred option:

- updated the substation primary equipment investment cost in the base case and Options 1, 2, 3 and 5 to include remediating fault level limitations on the busbar to allow comparable assessment with Option 4,
- updated operations and maintenance costs,
- updated phasing of risk cost benefits to align with the timing of substation primary equipment investment; and
- removed unserved energy benefits from the NPV analysis.

Option 4 remains the preferred option at this stage of the RIT-T process.

Complete replacement with 22 kV switchroom and 220 kV in-situ secondary systems remains the most prudent and economically efficient option to meet regulatory obligations

In the PADR Transgrid put forward for consideration five technically and commercially feasible options:

- Option 1 – Complete replacement with Secondary Systems Building

[5] As per clause 5.15.2(a) of the NER.

[6] Including $12.1m of investment costs in 2025 to allow comparable assessment of the base case, Option 1, 2 and 3 with the revised Option 4 and new Option 5.

- Option 2 – Complete in-situ replacement
- Option 3 – Strategic asset replacement
- Option 4 – Complete replacement with 22 kV switchroom and 220 kV in-situ secondary systems
- Option 5 – Complete in-situ secondary systems and 22 kV AIS replacement

Option 4 remains the most prudent and economically efficient option to address the identified need. Implementation of Option 4 will enable Transgrid to continue meeting its regulatory obligations set out in clauses 4.11.1, 4.6.1(b),[7] and Schedule 5.1 of the NER. Consequently, it will ensure the performance standards applicable to Broken Hill substation secondary systems are met and is therefore the preferred option for this RIT-T.

Transgrid expects coronavirus (COVID-19) to impact suppliers and disrupt their supply chains, although at this time the extent of the current or future impact is unknown. Consequently, some of the costs associated with the works outlined in this document may be affected.

All costs presented in this PACR are in 2020/21 dollars. The options are summarised in the table below.

Table E-1 Options considered

Option	Description	Capital cost ($m 2020/21)	Operating costs ($ per year)	Remarks
Option 1	Complete replacement with Secondary Systems Building	13.8 (+/- 25%) by 2022/23 (additional $12.1 million by 2024/25*)	~ 172,000	Technically and commercially feasible but less efficient.
Option 2	Complete in-situ replacement	8.0 (+/- 25%) by 2022/23 (additional $12.1 million by 2024/25*)	~ 172,000	Technically and commercially feasible but less efficient.
Option 3	Strategic asset replacement	6.2 (+/- 25%) by 2024/25 and ~ 1.6 in 2029/30 (additional $12.1 million by 2024/25*)	~ 172,000	Technically and commercially feasible but does not address technological obsolescence beyond 2023.
Option 4	Complete replacement with 22 kV switchroom and 220 kV in-situ secondary systems	18.3 (+/- 25%) by 2022/23	~ 23,000	Preferred option, provides efficiencies in combining primary works with secondary works and provides the most benefit to consumers.

[7] As per clause 4.6.1(b) of the NER, AEMO must ensure that there are processes in place, which will allow the determination of fault levels for normal operation of the power system and in anticipation of all credible contingency events and protected events that AEMO considers may affect the configuration of the power system, so that AEMO can identify any busbar which could potentially be exposed to a fault level which exceeds the fault current ratings of the circuit breakers associated with that busbar.

Option	Description	Capital cost ($m 2020/21)	Operating costs ($ per year)	Remarks
Option 5	Complete in-situ secondary systems and 22 kV AIS replacement	18.2 (+/- 25%) by 2022/23	~ 169,000	Provides efficiencies in combining primary works with secondary works but does not address unique site conditions.

* Future expenditure for 22kV primary plant renewal.

Renewal of the 22kV primary plant has been included in the upfront capital cost of Options 4 and 5 to allow efficiencies to be achieved by combining the replacement of both the secondary and primary assets as an integrated solution by 2022/23. Options 1, 2 and 3 only include the secondary systems renewal in their upfront capital cost by 2022/23, but have included subsequent expenditure in 2024/25 for the 22kV primary system renewal as part of the economic assessment to allow 'life-for-like' assessment of all options.

Non-network options are not able to assist with this RIT-T

Transgrid does not consider non-network options to be commercially and technically feasible to assist with meeting the identified need for this RIT-T. Non-network options are not able to meet NER obligations to provide redundant secondary systems and ensure that the transmission system is adequately protected.

Option 4 delivers highest net economic benefits

In all scenarios, highest net economic benefits result from implementing Option 4. Option 4 is the most efficient option to ensure reliability of the secondary systems at Broken Hill substation and mitigate its risks of prolonged failure while also considering the efficiency and benefits achieved through delivering it as an integrated renewal with the primary system. Sensitivity testing finds that Option 4 delivers the most net economic benefits under all sensitivities undertaken by Transgrid.

Option 4 delivers the most benefit to consumers

In this PACR Transgrid has considered five credible options which have been assessed relative to the base case. Of the credible options considered, Option 4 delivers the most benefit to consumers. This includes renewal of 22 kV switchgear which, although not part of the secondary systems need being addressed by this RIT-T, has been discussed in some sections of this PACR as it maximises the benefit to consumers when considered as an integrated solution.

While all options consider renewal of the 220kV and 22kV secondary systems, the renewal of the 22kV primary systems are considered as either future expenditure scheduled by 2024/25 for Options 1, 2 and 3, or undertaken at the same time as the secondary systems renewal by 2022/23 in Options 4 and 5. Options 4 and 5 consider the efficiency achieved through bundling the renewal works given the remote location challenges of Broken Hill.

Option 4 offers an additional benefit as the 22kV secondary and primary systems are renewed using a 'switchroom' solution, whereby the secondary and primary systems are integrated. This solution represents

the modern day practice for this type of equipment, such as would be seen at new renewable generator sites. This 'switchroom' solution will also have lower operational expenditure associated with responding to supply reliability interruptions caused by birds and vermin which is a known issue at Broken Hill substation. It will also provide an unserved energy benefit by addressing this issue, which has not been included in the analysis as it is within the reliability standard.

The efficiency and risk benefits offered by Option 4 result in it having the highest net economic benefit, making it the preferred option.

Conclusion: complete replacement with 22 kV switchroom and 220 kV in-situ secondary systems is optimal

The optimal commercially and technically feasible option presented in the PACR – Option 4 (complete replacement with 22 kV switchroom and 220 kV in-situ secondary systems at the Broken Hill substation) – remains the preferred option to meet the identified need.

Option 4 addresses the identified secondary systems need and scheduled primary system renewals in an efficient manner with additional reliability benefits. This option offers the most benefit to consumers (highest net economic benefits) and can be implemented in sufficient time to meet the identified need by 2022/23. It is therefore the preferred option presented in this PACR.

Moving forward with this option is the most prudent and economically efficient solution to enable Transgrid to continue meeting its regulatory obligations set out in clauses 4.11.1, 4.6.1(b),[8] and Schedule 5.1 of the NER. Consequently, it will ensure the performance standards applicable to Broken Hill substation secondary systems are met.

This option results in efficient renewal of the primary systems as an integrated solution with the secondary systems, maximising the benefit to consumers. This has been assessed through the assessment of Options 1, 2 and 3 whereby the secondary systems are renewed by 2022/23 and the primary systems separately by 2024/25. Option 4 has the highest net economic benefit, making it the preferred option.

The estimated capital cost of this option is approximately $18.3 million. Routine operating and maintenance costs are approximately $23,000 per year.

The works will be undertaken between 2020/21 and 2022/23. Planning (including commencement of the RIT-T) commenced in 2019/20 and is due to conclude in 2020/21. The detailed design will commence in 2021/22 with procurement and delivery of the identified assets planned to occur during 2021/22. All works will be completed by 2022/23.

Necessary outages of relevant existing assets will be planned appropriately in order to complete the works with minimal impact on the network.

The analysis undertaken and the identification of Option 4 as the preferred option satisfies the RIT-T. Option 4 is the preferred option in accordance with NER clause 5.16.1(b) because it is the credible option

[8] As per clause 4.6.1(b) of the NER, AEMO must ensure that there are processes in place, which will allow the determination of fault levels for normal operation of the power system and in anticipation of all credible contingency events and protected events that AEMO considers may affect the configuration of the power system, so that AEMO can identify any busbar which could potentially be exposed to a fault level which exceeds the fault current ratings of the circuit breakers associated with that busbar.

that maximises the net present value of the net economic benefit to all those who produce, consume and transport electricity in the market. This preferred option, Option 4, was found to have the highest net economic benefit while also maintaining compliance with regulatory and safety obligations. Transgrid also conducted sensitivity analysis on the net economic benefit to investigate the robustness of the conclusion to key assumptions. Transgrid finds that under all sensitivities, Option 4 delivers the most net benefit.

Next steps

This PACR represents the third and final step of the consultation process in relation to the application of the Regulatory Investment Test for Transmission (RIT-T) process undertaken by Transgrid. It follows a Project Specification Consultation Report (PSCR) and Project Assessment Draft Report (PADR) published in December 2019 and March 2021, respectively.

Parties wishing to raise a dispute notice with the AER may do so prior to 14 December 2021 (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.

Further details on the RIT-T can be obtained from Transgrid's Regulation team via RIT-TConsultations@transgrid.com.au. In the subject field, please reference 'Broken Hill Secondary Systems PACR'.

Contents

List of Tables

List of Figures

1. Introduction

Transgrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for maintaining a reliable secondary systems at Broken Hill substation. Transgrid has commenced this RIT-T to examine and consult on options to address the need - mitigate and alleviate the deterioration of the secondary systems at Broken Hill substation and the risk from technology obsolescence. As investment is intended to maintain compliance with NER requirement, Transgrid considers this a reliability corrective action RIT-T.

1.1. Purpose of this report

The purpose of this PACR[9] is to:

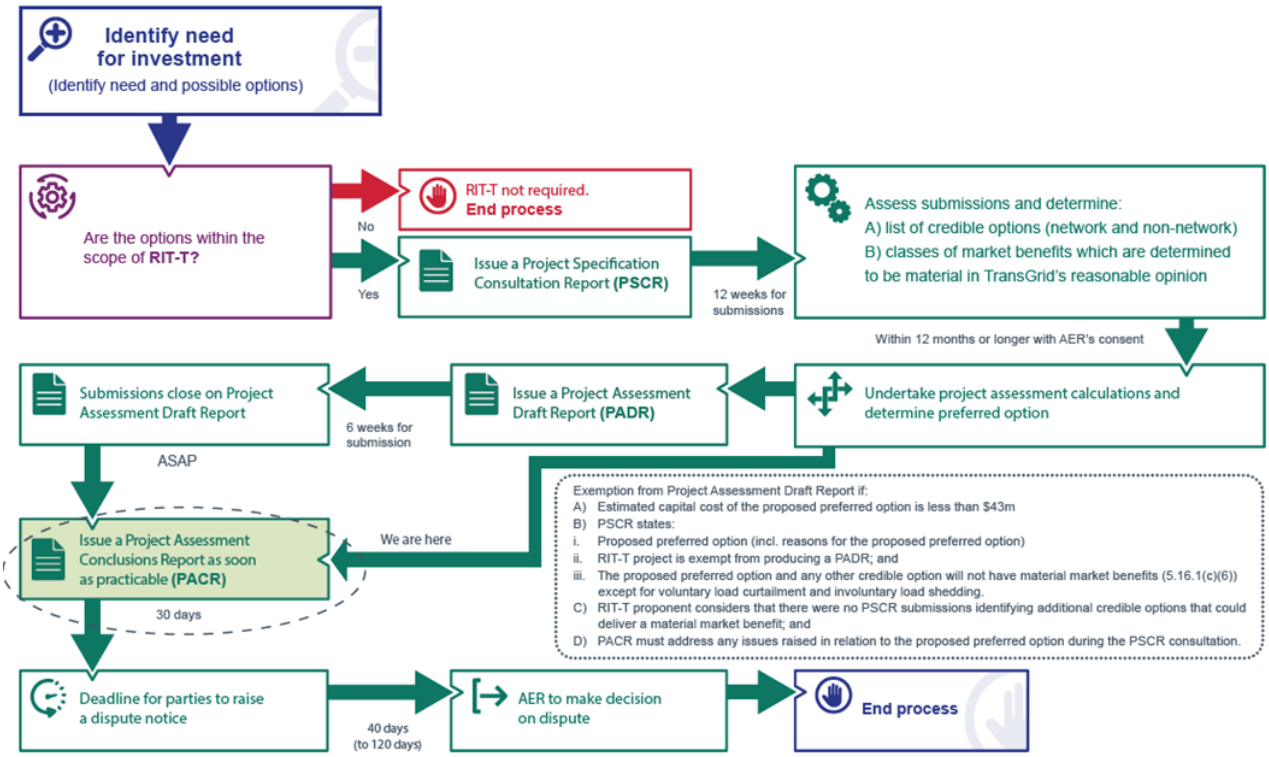
- describe the identified need
- describe and assess credible options to meet the identified need
- describe the assessment approach used
- provide details of the proposed preferred option to meet the identified need

1.2. Next steps

This PACR represents the third and final step of the consultation process in relation to the application of the Regulatory Investment Test for Transmission (RIT-T) process undertaken by Transgrid. It follows a Project Specification Consultation Report (PSCR) released in December 2019 and a Project Assessment Draft Report (PADR) released in March 2021. No submissions were received in response to the PSCR and one submission was received in response to the PADR. With permission from the submitter — the Public Interest Advocacy Centre — the submission is available on Transgrid's website. Transgrid has taken feedback raised in the submission into account in preparing the PACR.

[9] See Appendix A for the National Electricity Rules requirements.

Figure 1-1 This PACR is the third stage of the RIT-T process[10]



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Further details on the RIT-T can be obtained from Transgrid's Regulation team via RIT-TConsultations@transgrid.com.au . In the subject field, please reference 'Broken Hill Secondary Systems PACR'.

[10] Australian Energy Market Commission. "*Replacement expenditure planning arrangements, Rule determination*". Sydney: AEMC, 18 July 2017.65. Accessed 14 May 2020. https://www.aemc.gov.au/sites/default/files/content/89fbf559-2275-4672-b6ef-c2574eb7ce05/Final-rule-determination.pdf

2. The identified need

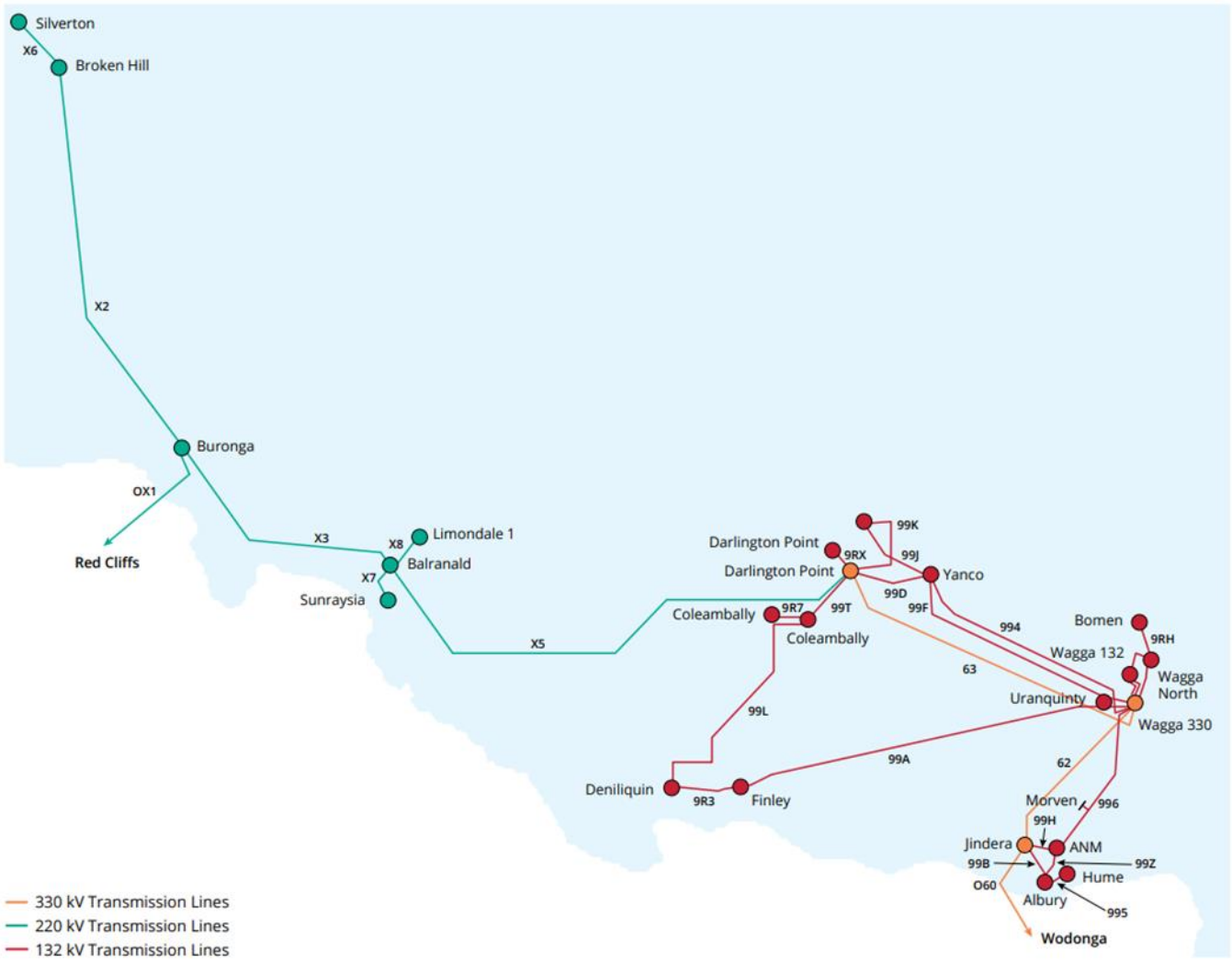
This section outlines the identified need for this RIT-T, as well as the assumptions and data underpinning it. It first sets out background information related to South Western NSW network and existing electricity supply arrangements.

2.1. Background to the identified need

Broken Hill substation was commissioned in 1979 and forms part of Transgrid's network that serves South Western NSW.

The location of Broken Hill substation on the South Western NSW transmission network is provided in Figure 2-1 below.

Figure 2-1 Location of Broken Hill substation on the South Western NSW transmission network



The substation is a customer connection point for nearby generators owned by AGL and Essential Energy. It also supports the flow of electricity to a residential population of more than 17,000[11] in Broken Hill and surrounding areas via the Essential Energy networks.

Broken Hill substation is connected to Buronga substation via a 220 kV transmission line (Line X2) operated by Transgrid. A 220 kV transmission line (Line OX1) runs between Transgrid's Buronga substation and Ausnet's Red Cliffs Terminal Station. Red Cliffs Terminal Station is one of four points of interconnection between the NSW and Victorian transmission systems.

Another two 220 kV transmission lines connect at Broken Hill serving directly connected customers.

A further eight feeders at 22 kV run between Broken Hill substation and connection points in the surrounding area. These connection points include: Broken Hill West, Pinacles Place (three separate connection points), Broken Hill Solar Farm No.1, and Broken Hill Solar Farm No.2.

In addition to the feeders, Broken Hill substation comprises two 220/22 kV transformers, four 22 kV capacitor banks and two 22 kV Static VAr Compensators (SVCs).

The secondary systems components at Broken Hill were installed between 1979 and 2015 to support the safe and reliable operation of the substation. These secondary systems ensure that all electricity users in the Broken Hill area, whether they be large industrial customers directly connected to Transgrid's network or residential consumers connected via Essential Energy's distribution network, are able to receive a safe, secure and reliable electricity supply.

Broken Hill substation will continue to play a central role in supporting the flow of energy to the Far West region of NSW. It forms part of the wider South Western NSW network which supports renewable energy zone development.[12] The maximum load for Broken Hill substation is approximately 54 MW[13] and is currently a mix of residential, commercial[14] and industrial.

2.2. Description of identified need

Secondary systems are used to control, monitor, protect and secure communication to facilitate safe and reliable network operation.[15] They are necessary to ensure the secure operation of the transmission network and prevent damage to primary assets when adverse events occur.

The Network Performance Requirements, set out in Schedule 5.1 of the NER, place an obligation on TNSPs to provide redundant protection schemes to ensure the transmission system is adequately protected. Schedule 5.1.9(c) of the NER requires a TNSP to provide sufficient primary and back-up

[11] The population of Broken Hill is 17,708, as per the 2016 Census. Australian Bureau of Statistics, "*2016 Census QuickStats*", accessed 2 September, 2021. https://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/lga11250

[12] There is over 5GW of potential wind and solar generation connections in South Western NSW and the Barrier Ranges. Transgrid. "*Transmission Annual Planning Report 2021*." Sydney: Transgrid, 2021. 69. Accessed 2 September, 2021. https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning/Documents/2020%20Transmission%20Annual%20Planning%20Report.pdf

[13] Summation of a 17 MW customer load and 37 MW Essential Energy load, based on projections for Essential Energy's Broken Hill 22 kV bulk supply point for summer 2023/24. Transgrid. "*Transmission Annual Planning Report 2021*." Sydney: Transgrid, 2021.120. Accessed 2 September https://www.transgrid.com.au/news-views/publications/Documents/TAPR_2021.pdf

[14] Australian Energy Market Operator, *"AEMO Visualisations Map,"* access 2 September, 2021. http://www.aemo.com.au/aemo/apps/visualisations/map.html

[15] As per Schedule 5.1 of the NER.

protection systems, including any communications facilities and breaker fail protection systems, to ensure that a fault of any type anywhere on its transmission system is automatically disconnected.

Additionally, TNSPs are required to disconnect the unprotected primary systems where secondary systems fault lasts for more than eight hours (for planned maintenance) or 24 hours (for unplanned outages). TNSPs must also ensure that all protection systems for lines at a voltage above 66 kV are well-maintained so as to be available at all times other than for short periods (less than eight hours), while the maintenance of protection systems is being carried out[16]. In the event of an unplanned outage, AEMO's Power System Security Guidelines require that the primary network assets must be taken out of service within 24 hours[17].

Furthermore, as per clause 4.11.1 of the NER, remote monitoring and control systems are required to be maintained in accordance with the standards and protocols determined and advised by AEMO.

A failure of the secondary systems would involve replacement of the failed component or taking the affected primary assets, such as lines and transformers, out of service.

Though replacement of failed secondary systems component is a possible interim measure, the approach is not sustainable as spare components will deplete due to the technology no longer being manufactured or supported. Once all spares are used, replacement will cease to be a viable option to meet performance standards applicable to Broken Hill substation secondary systems.

If the failure to provide functional secondary systems due to technology obsolescence is not addressed by a technically and commercially feasible credible option in sufficient time (by 2022/23), the likelihood of not recovering from secondary systems faults and not maintaining compliance with NER performance requirements will increase.

The proposed investment will enable TransGrid to continue to meet the standards for secondary systems availability set out in the NER, and to avoid the impacts of taking primary assets out of service. Consequently, it is considered a reliability corrective action under the RIT-T.

A reliability corrective action differs from a 'market benefits'-driven RIT-T in that the preferred option is permitted to have negative net economic benefits on account of it being required to meet an externally imposed obligation on the network business.

2.3. Assumptions underpinning the identified need

2.3.1. Depletion of available spares due to no manufacturer support for technologically obsolete components

Though like-for-like replacement of a failed secondary systems at Broken Hill substation is possible as an interim measure, the approach is not sustainable as spare components will deplete due to the technology no longer being manufactured or supported. Once all spares are used, repair will cease to be a viable option and will not enable performance standards applicable to Broken Hill substation secondary systems to be met.

[16] As per S5.1.2.1(d) of the NER.

[17] Australian Energy Market Operator. "*Power System Security Guidelines, 20 September 2019*." Melbourne: Australian Energy Market Operator, 2019.39. Accessed 15 May 2020. https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3715---Power-System-Security-Guidelines.pdf

2.3.2. Deterioration of asset condition increases the risk of substation failure

Transgrid has identified several critical issues with the secondary systems at Broken Hill substation. The issues are outlined in Table 2-1 are expected to escalate until the asset is fully inoperable.

Transgrid has also identified that parts of the 22kV primary systems plant have reached a condition that reflects the end of serviceable life as outlined in Table 2-2. This primary plant is scheduled for renewal in a similar timeframe as the secondary systems, and so has been considered in combination with the secondary systems renewal so that costs and potential benefits of combining the secondary and primary renewal works can be assessed.

Appendix B provides an overview of the Risk Assessment Methodology adopted by Transgrid, which has been applied to both the secondary and primary assets to calculate the risk they present for the base case and each credible option.

Table 2-1 Identified condition of Broken Hill substation secondary systems

Asset components	Issues	% of services at site
Line/Feeder Protection Relays	> Component technology obsolescence resulting in a lack of spares and no manufacturer support > Relays known to become trapped in a logic loop, rendering the relay non-auto and initiating the relay inoperative alarm	75% of all line/feeder protection relays on site
Transformer Protection Relays	> Component technology obsolescence resulting in a lack of spares and no manufacturer support > Faulty harmonic bias circuitry due to component failure > Internal wiring connection problems	100% of all transformer protection relays on site
Market Meters	> Microprocessor Energy Meters failing as they approach end of technical service life > Component technology obsolescence resulting in a lack of spares and no manufacturer support	79% of all market meters on site
Capacitor Protection Relays	> Component technology obsolescence resulting in a lack of spares and no manufacturer support > Inaccurate measurement of faults due to deteriorated internal components	100% of all capacitor protection relays on site
SVC Protection Relays	> Component technology obsolescence resulting in a lack of spares and no manufacturer support > Inaccurate measurement of faults due to deteriorated internal components	100% of all SVC protection relays on site

Table 2-2 Identified condition of Broken Hill substation primary systems

Asset components	Issues	% of services at site
22 kV Voltage Transformers	> Deterioration indicating assets nearing end of useful life > Significant risks associated with asset failure	100% of all 22 kV VTs
22 kV Current Transformers	> Deterioration indicating assets nearing end of useful life > Significant risks associated with asset failure	75% of all 22 kV CTs
22 kV Circuit Breakers	> Wear of mechanism components leading to unreliable operation > Low insulation resistance of the high voltage components > Lack of spares availability	50% of all 22 kV CBs
22 kV busbars	> Do not meet fault level rating requirements	100% of all 22kV busbars

3. Consultation on the PADR

Transgrid published a Project Assessment Draft Report (PADR) on 16 March 2021 and invited written submissions on the material presented within the document. One formal submission was received on the PADR and with permission from the submitter — the Public Interest Advocacy Centre (PIAC) — it is available on Transgrid's website.

Transgrid values the feedback raised in the submission and met with representatives from PIAC to better understand and discuss these topics in more detail ahead of preparing this PACR. Feedback from the submission has been taken into account in undertaking the PACR analysis and in preparing this report. The topics raised and how they have been considered in this PACR is summarised in Table 3-1.

Table 3-1 Summary of consultation comments on PADR

Consultation comments	PACR consideration
Transgrid should demonstrate the efficiencies made possible by bringing forward the primary system works are, on balance, worth any increased cost and/or risk consumers will incur as a result.	Transgrid has provided additional details in Sections 4 and 6 of this PACR to demonstrate that the analysis considers the relevant costs and benefits for each credible option. This allows assessment of the options on a like for like basis to determine the most efficient outcome, which is presented in an updated Section 7.
Transgrid should demonstrate Option 4 is the most efficient and prudent way to achieve these efficiencies. This should involve Transgrid providing a clear and consistent cost comparison between the options. The cost estimates for each option in the PADR are for different scope of works as they do not include the primary system replacement costs.	Transgrid has provided additional details in Sections 4 and 6 of this PACR and updated the costs and benefits considered to ensure clear and consistent cost comparison between the options based on the same scope of works over the assessment period. Section 7 demonstrates that Option 4 provides the highest net economic benefits.

4. Potential credible options

This section describes the options explored by Transgrid to address the need, including the scope of each option and the associated costs. Refer to section 6.1 for benefits of each option.

Transgrid considered five technically and commercially feasible options in this PSCR:

- **Option 1** – complete replacement with Secondary Systems Building (SSBs),
- **Option 2** – complete in-situ replacement of protection, market metering and control systems,
- **Option 3** – strategic asset replacement,
- **Option 4** – complete upgrade and renewal with 22 kV switchroom and 220 kV in-situ secondary systems; and
- **Option 5** – complete in-situ secondary systems and 22 kV Air Insulated Switchgear (AIS) replacement.

In this PACR Transgrid has considered five credible options which have been assessed relative to the base case. This includes renewal of 22 kV switchgear which, although not part of the secondary systems need being addressed by this RIT-T, has been discussed in some sections of this PACR as it may offer benefits when considered as an integrated solution.

While all options consider renewal of the 220kV and 22kV secondary systems, the renewal of the 22kV primary systems are considered as either future expenditure scheduled by 2024/25 for Options 1, 2 and 3, or undertaken at the same time as the secondary systems renewal by 2022/23 in Options 4 and 5. Options 4 and 5 consider the efficiency achieved through bundling the renewal works given the remote location challenges of Broken Hill and associated costs of deploying resources to this remote location.

Option 4 offers an additional benefit as the 22kV secondary and primary systems are renewed using a 'switchroom' solution, whereby the secondary and primary systems are integrated. This solution represents the modern day practice for this type of equipment, such as would be seen at new renewable generator sites. This 'switchroom' solution will also have lower operational expenditure associated with responding to supply reliability interruptions caused by birds and vermin which is a known issue at Broken Hill substation. It will also provide an unserved energy benefit by addressing this issue, which has not been included in the analysis as it is within the reliability standard.

Transgrid expects coronavirus (COVID-19) to impact its suppliers and disrupt their supply chains, although at this time the extent of the current or future impact is unknown. Consequently, some of the costs associated with the works outlined in this document may be affected.

All costs presented in this PACR are in 2020/21 dollars.

4.1. Base case

The costs and benefits of each option in this PACR were compared against those of a base case[18]. Under this base case, no proactive capital investment is made to remediate the technological obsolescence,

[18] As per the RIT-T Application Guidelines, the base case provides a clear reference point for comparing the performance of different credible options. Australian Energy Regulator. "*Application guidelines Regulatory Investment Test for Transmission - August 2020*." Melbourne: Australian Energy Regulator. https://www.aer.gov.au/system/files/AER%20-%20Regulatory%20investment%20test%20for%20transmission%20application%20guidelines%20-%2025%20August%202020.pdf

spares unavailability, discontinued manufacturer support, and components deterioration of the secondary systems. The asset will continue to operate and be maintained under the current regime.

The 22kV primary plant reaching end of serviceable life will require intervention by 2024/25 at a capital cost of $12.1 million, which is included into the base case.

Annual maintenance costs are approximately $172,000 per year. Increases to the regular maintenance regime will not be able to mitigate the risk of failure of the secondary systems at Broken Hill substation due to technological obsolescence and reduced reliability.

The table below provides a breakdown of the operating expenditure under the base case.

Table 4-1 Operating expenditure breakdown under the base case ($ 2020/21)

Item	Operating expenditure ($)
Annualised protection maintenance activities	6,000
Annualised primary system maintenance activities	166,000
Total operating cost	**172,000 (+/-25%)**

The majority of protection relays, remote control and monitoring devices at this site have limited spares, no manufacturer support, and will reach end of serviceable life by 2022/23. Repairs will become more difficult due to limited spares and this will lead to periods of unavailability. This increases the asset's risk of failure, difficulty to repair any failures, likelihood of a hazardous event, and periods of unavailability.

TransGrid calculates the annual safety, environmental and operational risk costs associated with the Broken Hill substation secondary and 22kV primary systems under the base case to be approximately $390,000.[19] This reduces to approximately $300,000 from 2025/26 following the 22kV primary plant renewal.

4.2. Option 1 – Secondary Systems Buildings replacement

Option 1 involves a complete upgrade and renewal of secondary systems at Broken Hill substation by using modular Secondary Systems Buildings (SSB) and installing new cable throughout. This option will modernise the automation philosophy to current design standards and practices.

This option assumes that the new secondary systems will be designed to be accommodated within a similar panel arrangement as the existing installation. Redundant panels and tunnel boards in the Auxiliary Services Building's (ASB) relay room will need to be progressively decommissioned and removed as the new secondary systems are cut-over and commissioned.

The work will be undertaken over the three-year period until 2022/23, with all works expected to be completed by 2022/23. All works under all options will be completed in accordance with the relevant

[19] This determination of yearly risk costs is based on Transgrid's Network Asset Risk Assessment Methodology and incorporates variables such as likelihood of failure/exposure, various types of consequence costs and corresponding likelihood of occurrence.

standards and components shall be replaced to have minimal modification to the wider transmission network.

The estimated capital expenditure associated with this option is approximately $13.8 million +/- 25 per cent.

This option does not include works on the 22 kV primary assets as part of the secondary systems renewal works. Under Option 1, an additional capital cost of $12.1 million in primary plant asset renewal program works would need to be incurred in 2024/25.

The table below provides a breakdown.

Table 4-2 Capital expenditure breakdown under Option 1 ($m 2020/21)

Item	Capital expenditure ($m)
FY21	1.4
FY22	7.8
FY23	4.6
FY25 (primary plant)	12.1
Total capital cost	**25.9 (+/- 25%)**

Routine operating and maintenance costs are approximately $172,000 per year. The table below provides a breakdown.

Table 4-3 Operating expenditure breakdown under Option 1 ($ 2020/21)

Item	Operating expenditure ($)
Annualised protection maintenance activities	6,000
Annualised primary system maintenance activities	166,000
Total operating cost	**172,000 (+/- 25%)**

Transgrid calculates the annual safety, environmental and operational risk costs associated with the Broken Hill substation secondary and 22kV primary systems under Option 1 to be $110,000.[20] This reduces to approximately $20,000 from 2025/26 following the 22kV primary plant renewal.

[20] This determination of yearly risk costs is based on Transgrid's Network Asset Risk Assessment Methodology and incorporates variables such as likelihood of failure/exposure, various types of consequence costs and corresponding likelihood of occurrence.

4.3. Option 2 – Complete in-situ replacement of protection and control

Option 2 involves replacement of all secondary systems assets at Broken Hill substation. This option will modernise the automation philosophy to current design standards and practices. This option also includes replacement of Direct Current (DC) supplies to account for an increase in secondary systems power requirements and remediation of the 415V Alternating Current (AC) distribution in the building and the switchyard.

The condition of various categories of automation assets such as protection relays, control systems, AC distribution, DC supply systems, and market meters creates a need for modernisation. This will deliver benefits such as reduced preventative maintenance requirements, improved operational efficiencies, better utilisation of our high speed communications network, improved visibility of all assets using modern technologies and reduced reliance on routine maintenance and testing[21].

There are also additional operational benefits available due to improved remote monitoring, control and interrogation, efficiency gains in responding to faults, and phasing out of obsolete and legacy systems and protocols.

The work will be undertaken over the three-year period with all works expected to be completed by 2022/23. All works under all options 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 existing assets will be planned appropriately in order to complete the works with minimal impact on the network.

The estimated capital expenditure associated with this option is approximately $8.07 million +/- 25 per cent.

This option does not include works on the 22 kV primary assets as part of the secondary systems renewal works. Under Option 2, an additional capital cost of $12.1 million in primary plant asset renewal program works would need to be incurred in 2024/25.

The table below provides a breakdown.

Table 4-4 Capital expenditure breakdown under Option 2 ($m 2020/21)

Item	Capital expenditure ($m)
FY21	1.6
FY22	3.8
FY23	2.6
FY25 (primary plant)	12.1
Total capital cost	**20.1 (+/- 25%)**

[21] International Electrotechnical Commission (IEC), "*IEC 61850 standard for Power Utility Automation*," accessed 14 May, 2020. http://www.iec.ch/smartgrid/standards/

Routine operating and maintenance costs are approximately $172,000 per year. The table below provides a breakdown.

Table 4-5 Operating expenditure breakdown under Option 2 ($ 2020/21)

Item	Operating expenditure ($)
Annualised protection maintenance activities	6,000
Annualised primary system maintenance activities	166,000
Total operating cost	**172,000 (+/- 25%)**

Transgrid calculates the annual safety, environmental and operational risk costs associated with the Broken Hill substation secondary and 22kV primary systems under Option 2 to be approximately $370,000.[22] This reduces to approximately $280,000 from 2025/26 following the 22kV primary plant renewal.

4.4. Option 3 – Strategic asset replacement

Option 3 involves individual replacements of identified assets up to 2024/25. The option is based on a like-for-like approach whereby the asset is replaced by its modern equivalent. Additional system modifications or additional functionalities would not be deployed under this option. This option will lock TransGrid to a system architecture that cannot be expanded to match modern technology capabilities into the future. This option only includes the targeted assets highlighted in Table 2-1. The remaining assets will require additional expenditure in the next 5-10 years.

All works under all options 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 existing assets will be planned appropriately in order to complete the works with minimal impact on the network.

The estimated capital expenditure associated with this option is approximately $6.2 million until 2024/25.

This option does not include works on the 22 kV primary assets as part of the initial secondary systems renewal works. Under Option 3, an additional capital cost of $12.1 million in primary plant asset renewal program works identified under separate needs would need to be incurred in 2024/25. A further $1.57 million in secondary plant asset renewal program works are required by 2030. The table below provides a breakdown.

22 ibid.

Table 4-6 Capital expenditure breakdown under Option 3 ($m 2020/21)

Item	Capital expenditure ($m)
FY21	1.2
FY22	1.2
FY23	1.2
FY24	1.3
FY25	1.3
FY25 (primary plant)	12.1
FY30	1.6
Total capital cost	**19.9 (+/- 25%)**

Routine operating and maintenance costs are approximately $172,000 per year. The table below provides a breakdown.

Table 4-7 Operating expenditure breakdown under Option 3 ($ 2020/21)

Item	Operating expenditure ($)
Annualised protection maintenance activities	6,000
Annualised primary system maintenance activities	166,000
Total operating cost	**172,000**

Transgrid calculates the annual safety, environmental and operational risk costs associated with the Broken Hill substation secondary systems under Option 3 to be approximately $370,000.[23] This reduces to approximately $280,000 from 2025/26 following the 22kV primary plant renewal.

4.5. Option 4 – Complete replacement with 22 kV switchroom and 220 kV in-situ secondary systems

Option 4 involves a complete upgrade and renewal of secondary systems at the Broken Hill substation by using new metal clad 22 kV switchgear in a demountable building inclusive of 22 kV secondary systems. This option will modernise the automation philosophy to current design standards and practices and will

[23] This determination of yearly risk costs is based on Transgrid's Network Asset Risk Assessment Methodology and incorporates variables such as likelihood of failure/exposure, various types of consequence costs and corresponding likelihood of occurrence.

provide additional operational benefits, as well as also renewing the 22kV primary plant as part of an integrated modern solution.

This option assumes that the new 220 kV secondary systems will be designed to be accommodated within a similar panel arrangement as the existing installation. Redundant panels and tunnel boards in the ASB relay room will need to be progressively decommissioned and removed as the new secondary systems are cut-over and commissioned.

This option identified efficiency gains in incorporating planned primary plant renewals to provide the best value for energy consumers by avoiding the need to revisit the site in 2024/25 to address the 22 kV primary plant components. This option also provides a benefit by mitigating unserved energy through addressing an ongoing bird strike and vermin issue resulting in high rates of 22 kV outages causing supply interruptions [24], as well as avoiding response and repair costs when these outages occur. This is achieved through moving the 22kV primary plant to a modern metal clad switchgear arrangement.

The work will be undertaken over the three-year period until 2022/23, with all works expected to be completed by 2022/23. All works under all options 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.

The estimated capital expenditure associated with this option is approximately $18.3 million. The table below provides a breakdown.

Table 4-8 Capital expenditure breakdown under Option 4 ($m 2020/21)

Item	Capital expenditure ($m)
FY21	1.8
FY22	9.9
FY23	6.6
Total capital cost	**18.3 (+/- 25%)**

Routine operating and maintenance costs are approximately $23,000 per year. By renewing the 22kV primary and secondary systems in a modern metal clad switchgear arrangement the operating and maintenance costs will be reduced compared to other options. The table below provides a breakdown.

Table 4-9 Operating expenditure breakdown under Option 4 ($ 2020/21)

Item	Operating expenditure ($)
Annualised protection maintenance activities	6,000
Annualised primary system maintenance activities	17,000
Total operating cost	**23,000 (+/- 25%)**

[24] The expected unserved energy benefit offered by this option has not been included in the analysis as it offers an improvement in reliability within the current reliability standard.

TransGrid calculates the annual safety, environmental and operational risk costs associated with the Broken Hill substation secondary systems under Option 4 to be approximately $20,000.[25]

4.6. Option 5 – Complete in-situ secondary systems replacement and 22 kV AIS replacement

Option 5 involves an in-situ replacement of the 220kV and 22kV secondary systems at the Broken Hill Substation with in-situ replacement of the 22 kV Air Insulated Switchgear (AIS), and minimal installation of new cable throughout. This option will modernise the automation philosophy to current design standards and practices and will provide additional operational benefits, as well as also renewing the 22kV primary plant in a like for like manner.

This option identified efficiency gains in incorporating planned primary plant renewals to provide the best value for energy consumers by avoiding the need to revisit the site in 2024/25 to address the 22 kV primary plant components. This option does not however address the ongoing bird strike and vermin issue resulting in high rates of 22 kV outages and associated operational expenditure required to restore services, as the 22kV primary plant will remain outdoors. As the new design will be similar to the original, the ongoing issues of bird (and other animals) causing failures in the 22kV equipment will remain.

The work will be undertaken over the three-year period until 2022/23, with all works expected to be completed by 2022/23. All works under all options 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.

The estimated capital expenditure associated with this option is approximately $18.2 million. The table below provides a breakdown.

Table 4-10 Capital expenditure breakdown under Option 5 ($m 2020/21)

Item	Capital expenditure ($m)
FY21	1.8
FY22	9.4
FY23	7.0
Total capital cost	**18.2 (+/- 25%)**

[25] This determination of yearly risk costs is based on Transgrid's Network Asset Risk Assessment Methodology and incorporates variables such as likelihood of failure/exposure, various types of consequence costs and corresponding likelihood of occurrence.

Routine operating and maintenance costs are approximately $169,000 per year. The table below provides a breakdown.

Table 4-11 Operating expenditure breakdown under Option 5 ($ 2020/21)

Item	Operating expenditure ($)
Annualised protection maintenance activities	6,000
Annualised primary system maintenance activities	163,000
Total operating cost	**169,000 (+/- 25%)**

Transgrid calculates the annual safety, environmental and operational risk costs associated with the Broken Hill substation secondary systems under Option 5 to be approximately $20,000.[26]

4.7. Options considered but not progressed

At this stage of the RIT-T process, Transgrid determines that there is no other commercially and technically feasible option to meet the identified need.

4.8. No material inter-network impact is expected

Transgrid has considered whether the credible options listed above is expected to have material inter-regional impact[27]. 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.*"

AEMO's suggested screening test to indicate that a transmission augmentation has no material inter-network impact is that it satisfies the following[28]:

- 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.

[26] This determination of yearly risk costs is based on Transgrid's Network Asset Risk Assessment Methodology and incorporates variables such as likelihood of failure/exposure, various types of consequence costs and corresponding likelihood of occurrence.

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

[28] 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

Transgrid notes that each credible option satisfies these conditions as it does not modify any aspect of electrical or transmission assets. By reference to AEMO's screening criteria, there is no material inter-network impacts associated with any of the credible options considered.

4.9. Non-network options

In the PSCR and the PADR, Transgrid noted that non-network solutions will not enable Transgrid to continue meeting its Rules obligation under Schedule 5.1 and clause 4.11 of the NER to provide redundant secondary systems and ensure that the transmission system is adequately protected. Notwithstanding, as part of this consultation process, interested parties were able to make submissions regarding non-network options that satisfy, or contribute to satisfying, the identified need. Transgrid did not receive any responses from proponents of non-network options to the PSCR or the PADR.

5. 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.[29]

5.1. Wholesale electricity market benefits are not material

The AER has recognised that if the credible options considered 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.[30]

Transgrid determines that the credible options considered in this RIT-T will not address network constraints between competing generating centres and are therefore not expected to result in any change in dispatch outcomes and wholesale market prices. Transgrid therefore considers 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 the RIT-T proponent
- changes in ancillary services costs
- changes in network losses
- competition benefits
- Renewable Energy Target (RET) penalties.

5.2. No other classes of market benefits are material

In addition to the classes of market benefits listed above, NER clause 5.16.1(c)(4) requires Transgrid to consider the following classes of market benefits, listed in Table 4-1, arising from each credible option. Transgrid considers that none of the classes of market benefits listed are material for this RIT-T assessment for the reasons in Table 4-1.

Table 5-1 Reasons non-wholesale electricity market benefits are considered immaterial

Market benefits	Reason
Changes in involuntary load shedding	A failure of secondary systems element results in an extremely low chance of unserved energy.

[29] The NER requires that all classes of market benefit 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 5.16.1(c)(6). See Appendix A for requirements applicable to this document.

[30] Australian Energy Regulator. "*Application guidelines Regulatory Investment Test for Transmission - August 2020*." Melbourne: Australian Energy Regulator, 2020.29-30. Accessed 22 March 2021. https://www.aer.gov.au/system/files/AER%20-%20Regulatory%20investment%20test%20for%20transmission%20application%20guidelines%20-%2025%20August%202020.pdf

Market benefits	Reason
Differences in the timing of expenditure	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. Options are being undertaken to mitigate, in isolation, the rising risk caused by the existing asset nearing its end of serviceable life.
Option value	Transgrid notes 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.[31] Transgrid also notes 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. Transgrid notes that no credible option is sufficiently flexible to respond to change or uncertainty. 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, Transgrid has not estimated additional option value benefit.

[31] Australian Energy Regulator. "*Application guidelines Regulatory Investment Test for Transmission - August 2020*." Melbourne: Australian Energy Regulator, 2020.53. Accessed 22 March 2021. https://www.aer.gov.au/system/files/AER%20-%20Regulatory%20investment%20test%20for%20transmission%20application%20guidelines%20-%2025%20August%202020.pdf

6. Overview of the assessment approach

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

6.1. Description of the base case

The costs and benefits of each option in this document are compared against the base case. Under this base case, no investment is undertaken on the secondary systems and Transgrid incurs regular and reactive maintenance costs, operation and safety related risks costs that are caused by the failure of the secondary systems to operate when required. Transgrid notes 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[32].

Transgrid has assumed an investment of $12.1 million occurs in 2024/25 for renewal of the 22kV primary systems, as this is scheduled to occur separately to the secondary systems need. This has been done to enable a comparison between all feasible secondary system options, compared to those which also include primary plant replacements.

6.2. Assessment period and discount rate

A 15-year post commissioning assessment period from 2023/24 to 2037/38 was considered in this analysis. This period takes into account the size, complexity and expected asset life of the secondary systems. Transgrid took a terminal value approach to ensure that the capital costs of all assets are appropriately captured in the 15-year assessment period.

Transgrid adopted a central real, pre-tax 'commercial' discount rate[33] of 5.90 per cent as the central assumption for the NPV analysis presented in this report. Transgrid considers that this is a reasonable contemporary approximation of a commercial discount rate and it is consistent with the commercial discount rate calculated in the RIT-T Economic Assessment Handbook (Version 2.0) published by Energy Networks Australia (ENA) in October 2020[34].

Transgrid also tested the sensitivity of the results to discount rate assumptions. A lower bound real, pre-tax discount rate of 2.23 per cent equal to the latest AER Final Decision for a TNSP's regulatory proposal at

[32] As per the RIT-T Application Guidelines, 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 defines 'BAU activities' as ongoing, economically prudent activities that occur in the absence of a credible option being implemented. Australian Energy Regulator. *"Application guidelines Regulatory Investment Test for Transmission - August 2020."* Melbourne: Australian Energy Regulator, 2020.21. Accessed 22 March 2021. https://www.aer.gov.au/system/files/AER%20-%20Regulatory%20investment%20test%20for%20transmission%20application%20guidelines%20-%2025%20August%202020.pdf

[33] The use of a 'commercial' discount rate is consistent with the RIT-T and is distinct from the regulated cost of capital (or 'WACC') that applies to network businesses like Transgrid.

[34] Available at https://www.energynetworks.com.au/resources/fact-sheets/ena-rit-t-handbook-2020/ Note the lower bound discount rate of 2.23 per cent is based on the most recent final decision for a TNSP revenue determination which was Directlink in June 2020.

the time of preparing this document[35], and an upper bound discount rate of 9.57 per cent (a symmetrical adjustment upwards) were used.

6.3. Approach to estimating option costs

Transgrid has estimated the capital costs of the options based on the scope of works necessary together with costing experience from previous projects of a similar nature. Transgrid estimates that the actual cost is within +/- 25 per cent of the central capital cost.

Routine and corrective operating and maintenance costs are based on works of similar nature and recent experience at the Broken Hill substation.

6.4. Three different scenarios have been modelled to address uncertainty

The assessment was conducted under three net economic benefits scenarios. These are plausible scenarios which reflect different assumptions about the future market development and other factors that are expected to affect the relative market benefits of the options being considered. All scenarios (low, central and high) involve a number of assumptions that result in the lower bound, the expected, and the upper bound estimates for present value of net economic benefits respectively.

A summary of the key variables in each scenario is provided in the table below.

Table 6-1 Summary of scenarios

Variable / Scenario	Central	Low benefit scenario	High benefit scenario
Scenario weighting	*50%*	*25%*	*25%*
Discount rate	5.90%	9.57%	2.23%
Costs			
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Operating and maintenance costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Benefits (negative benefits)			
Reduction in safety and environmental risk costs	Base estimate	Base estimate - 25%	Base estimate + 25%
Reduction in operational risks	Base estimate	Base estimate - 25%	Base estimate + 25%

Transgrid considered that the central scenario was most likely since it was based primarily on a set of expected assumptions. Transgrid therefore assigned this scenario a weighting of 50 per cent, with the other two scenarios being weighted equally with 25 per cent each.

[35] See 2020-25 Directlink's Post-tax Revenue Model (PTRM) cashflow derived pre-tax real WACC available at: https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/directlink-determination-2020-25/final-decision

7. Assessment of credible options

This section outlines the assessment Transgrid has 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 reduction in costs or risks compared to the base case.

No changes have occurred since the PADR which have made an impact on the preferred option.

All costs presented in this PACR are in 2020/21 dollars.

7.1. Estimated gross benefits

The table below summarises the present value of the gross benefit estimates for each credible option relative to the base case under the three scenarios.

The benefits included in this assessment are a reduction in safety and environmental risks.

Table 7-1 Estimated gross benefits from credible options relative to the base case, present value ($m 2020/21)

Option/scenario	Central	Low benefit scenario	High benefit scenario	Weighted
Scenario weighting	50%	25%	25%	
Option 1	2.4	1.4	4.2	2.6
Option 2	0.2	0.1	0.3	0.2
Option 3	0.2	0.1	0.3	0.2
Option 4	2.6	1.5	4.4	2.8
Option 5	2.6	1.5	4.4	2.8

7.2. Estimated costs

The table below summarises the capital and operating and maintenance costs of the options, relative to the base case, in present value terms. The cost of each credible option has been calculated for each of the three reasonable scenarios outlined in section 5.4.

Table 7-2 Estimated costs of credible options relative to the base case, present value ($m 2020/21)

Option/Scenario	Central	Low benefit scenario	High benefit scenario	Weighted value
Scenario weighting	50%	25%	25%	
Option 1	15.8	17.5	14.1	15.8
Option 2	10.2	11.0	9.5	10.2
Option 3	8.9	9.1	8.7	8.9
Option 4	5.9	8.6	3.4	5.9
Option 5	7.0	9.6	4.6	7.1

7.3. Estimated net economic benefits

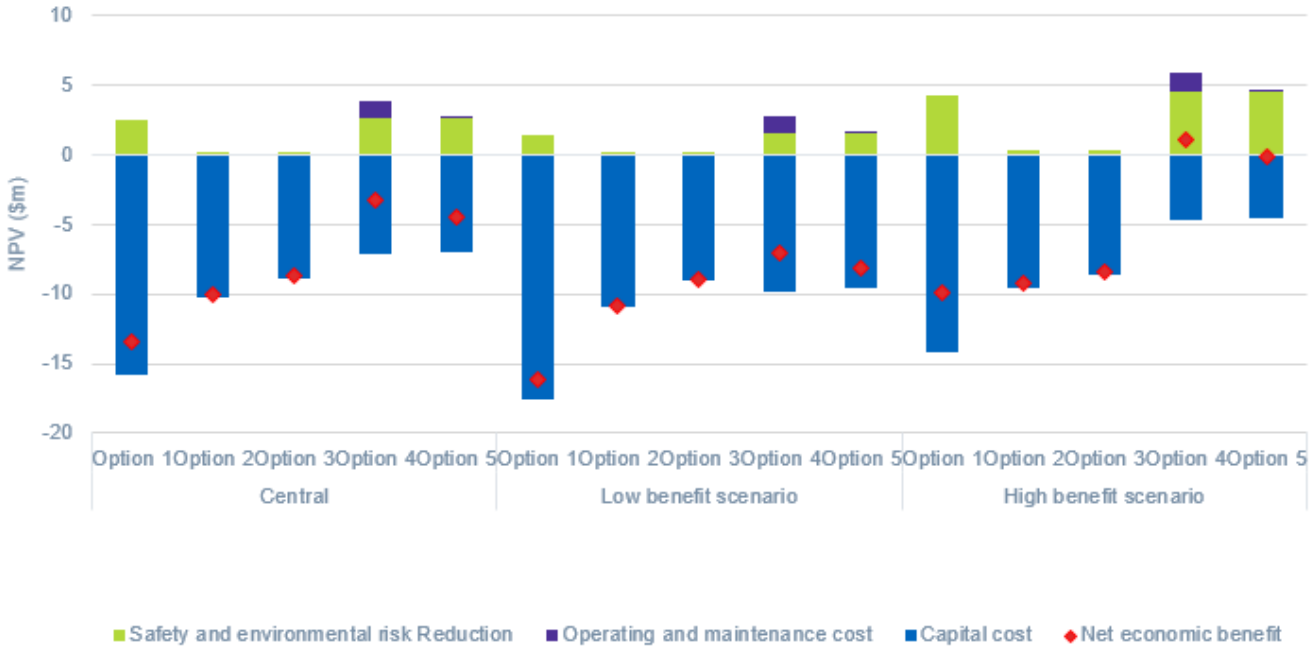
The net economic benefits are the differences between the estimated gross benefits less the estimated costs. The table below summarises the present value of the net economic benefits for each credible option across the three scenarios and the weighted net economic benefits.

As shown in the table and figure below Option 4 has the highest net economic benefit or least cost while also maintaining compliance with regulatory and safety obligations. Transgrid finds that under all sensitivities, Option 4 delivers the highest net economic benefits.

Table 7-3 Estimated net economic benefits relative to the base case, present value ($m 2020/21)

Option	Central	Low benefit scenario	High benefit scenario	Weighted value	Ranking
Scenario weighting	*50%*	*25%*	*25%*		
Option 1	-13.4	-16.1	-9.9	-13.2	5
Option 2	-10.1	-10.9	-9.2	-10.1	4
Option 3	-8.7	-9.0	-8.4	-8.7	3
Option 4	-3.3	-7.1	1.1	-3.2	1
Option 5	-4.4	-8.1	-0.2	-4.3	2

Figure 7-1 Net economic benefits, present value ($m 2020/21)



7.4. Meeting relevant regulatory obligations

Implementation of Option 4 will enable Transgrid to meet regulatory obligations set out under Schedule 5.1 and clauses 4.11.1 and 4.6.1(b)[36] of the NER to provide redundant secondary systems and ensure that the transmission system is adequately protected. Consequently, it will also ensure the performance standards applicable to Broken Hill substation secondary systems are met.

Implementation of Option 4 is the most efficient option to ensure reliability of the secondary systems at Broken Hill and mitigate its risks of prolonged failure.

7.5. Sensitivity testing

Transgrid undertakes sensitivity testing to understand the robustness of the RIT-T assessment to underlying assumptions about key variables. In particular, Transgrid undertakes two sets of sensitivity tests – namely:

- Step 1 – testing the sensitivity of the optimal timing of the project ('trigger year') to different assumptions in relation to key variables
- 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.

Transgrid has not undertaken Step 1 of the sensitivity analysis to determine the optimal timing of the project as the investment is required to be undertaken as reliability corrective action by 2022/23. If the failure to provide functional secondary systems due to technology obsolescence is not addressed by a technically and commercially feasible credible option in sufficient time (by 2022/23), the likelihood of not recovering from secondary systems faults and not maintaining compliance with NER performance requirements will increase. The proposed investment will enable Transgrid to continue to meet the standards for secondary systems availability set out in the NER, and to avoid the impacts of taking primary assets out of service.

Having assumed to have committed to the project by this date, Transgrid has 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 second step to test the sensitivity of the key findings is outlined below.

7.5.1. Step 2 – Sensitivity of the overall net benefit

Transgrid has conducted sensitivity analysis on the present value of the net economic benefit, based on having to undertake the project by 2022/23. Specifically, Transgrid has investigated the following sensitivities:

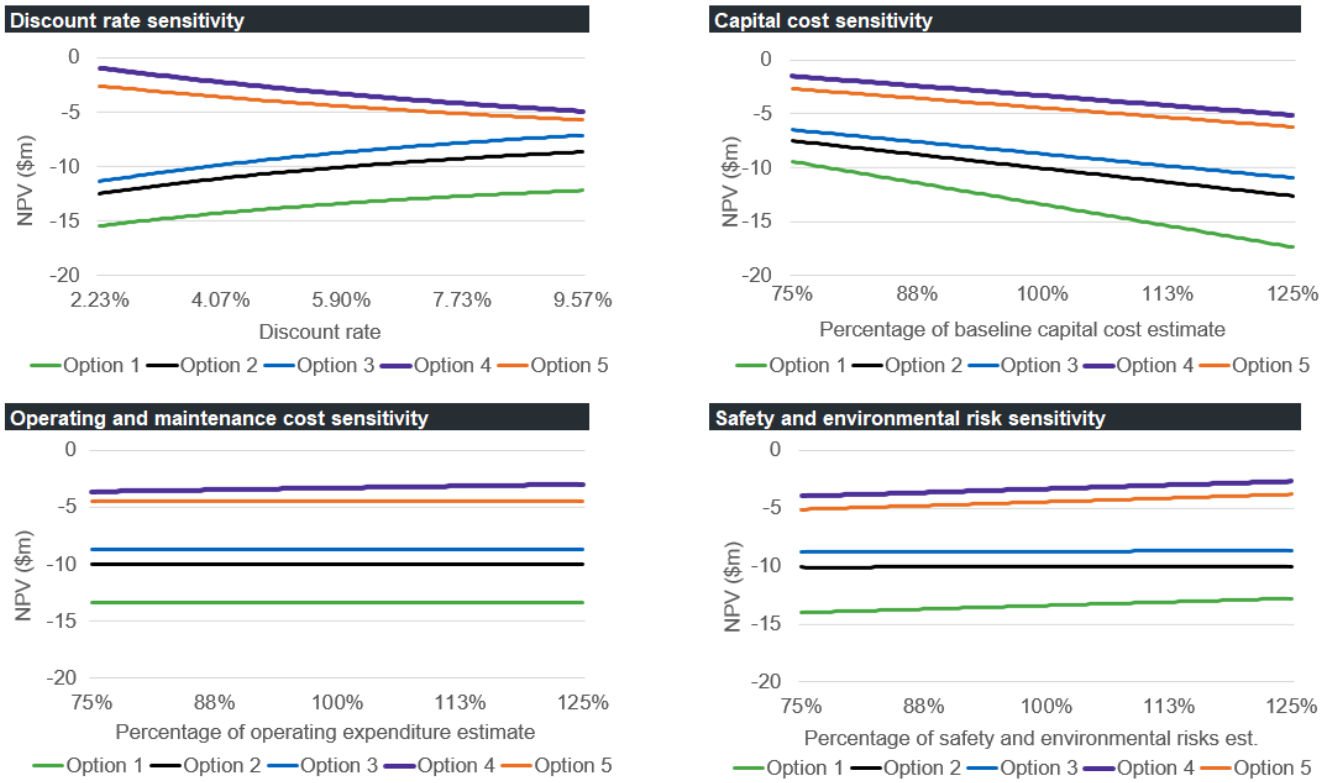
- a 25 per cent increase/decrease in the assumed network capital costs
- lower discount rate of 2.23 per cent as well as a higher rate of 9.57 per cent

[36] As per clause 4.6.1(b) of the NER, AEMO must ensure that there are processes in place, which will allow the determination of fault levels for normal operation of the power system and in anticipation of all credible contingency events and protected events that AEMO considers may affect the configuration of the power system, so that AEMO can identify any busbar which could potentially be exposed to a fault level which exceeds the fault current ratings of the circuit breakers associated with that busbar.

- lower (or higher) assumed operation and maintenance costs
- lower (or higher) assumed safety and environmental risks

All these sensitivities investigate the consequences of 'getting it wrong' having committed to a certain investment decision. The figures below illustrate the estimated net economic benefits for each option if separate key assumptions in the central scenario are varied individually. Option 4 delivers the most benefit under all scenarios.

Figure 7-2 Sensitivities



8. Final conclusion on the preferred option

The implementation of Option 4, a complete replacement with 22 kV switchroom and 220 kV in-situ secondary systems is the most efficient technically and commercially feasible option to continue meeting NER requirements at this final stage of the RIT-T process. Option 4 addresses the identified secondary systems need and scheduled primary system renewals in an efficient manner with additional reliability benefits, can be implemented in sufficient time to meet the identified need by 2022/23, and is therefore the preferred option presented in this PACR.

Option 4 is the most prudent and economically efficient solution to enable Transgrid to continue meeting its regulatory obligations set out in clauses 4.11.1, 4.6.1(b),[37] and Schedule 5.1 of the NER. Consequently, it will ensure the performance standards applicable to Broken Hill substation secondary systems are met.

The estimated capital cost of this option is approximately $18.3 million. Routine operating and maintenance costs are approximately $23,000 per year.

The works will be undertaken between 2020/21 and 2022/23. Planning (including commencement of the RIT T) commenced in 2019/20 and is due to conclude in 2020/21.The detailed design will commence in 2021/22 with procurement and delivery of the identified assets planned to occur during 2021/22. All works will be completed by 2022/23. Necessary outages of relevant existing assets will be planned appropriately in order to complete the works with minimal impact on the network.

Option 4 is the preferred option in accordance with NER clause 5.16.1(b) 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. This preferred option, Option 4, was found to have the highest net economic benefit while also maintaining compliance with regulatory and safety obligations. Transgrid also conducted sensitivity analysis on the net economic benefit to investigate the robustness of the conclusion to key assumptions. Transgrid finds that under all sensitivities, Option 4 delivers the most benefit. The analysis undertaken and the identification of Option 4 as the preferred option satisfies the RIT-T.

[37] As per clause 4.6.1(b) of the NER, AEMO must ensure that there are processes in place, which will allow the determination of fault levels for normal operation of the power system and in anticipation of all credible contingency events and protected events that AEMO considers may affect the configuration of the power system, so that AEMO can identify any busbar which could potentially be exposed to a fault level which exceeds the fault current ratings of the circuit breakers associated with that busbar.

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 174.

Rules clause	Summary of requirements	Relevant section
5.16.4(v)	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).	3
5.16.4(k)	The project assessment draft report must include:	–
	(1) a description of each credible option assessed;	4
	(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;	4, 5
	(4) a detailed description of the methodologies used in quantifying each class of material market benefit and cost;	6
	(5) reasons why the RIT-T proponent has determined that a class or classes of market benefit are not material;	5
	(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);	4, 5
	(7) the results of a net present value analysis of each credible option and accompanying explanatory statements regarding the results;	7
	(8) the identification of the proposed preferred option;	8
	(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*.	4, 8

Appendix B Risk Assessment Methodology

This appendix summarises the key assumptions and data from the risk assessment methodology that underpin the identified need for this RIT-T and the assessment undertaken for the Revenue Proposal[38].

As part of preparing its Revenue Proposal for the current regulatory control period, Transgrid developed the Network Asset Risk Assessment Methodology to quantify risk for replacement and refurbishment projects. The risk assessment methodology:

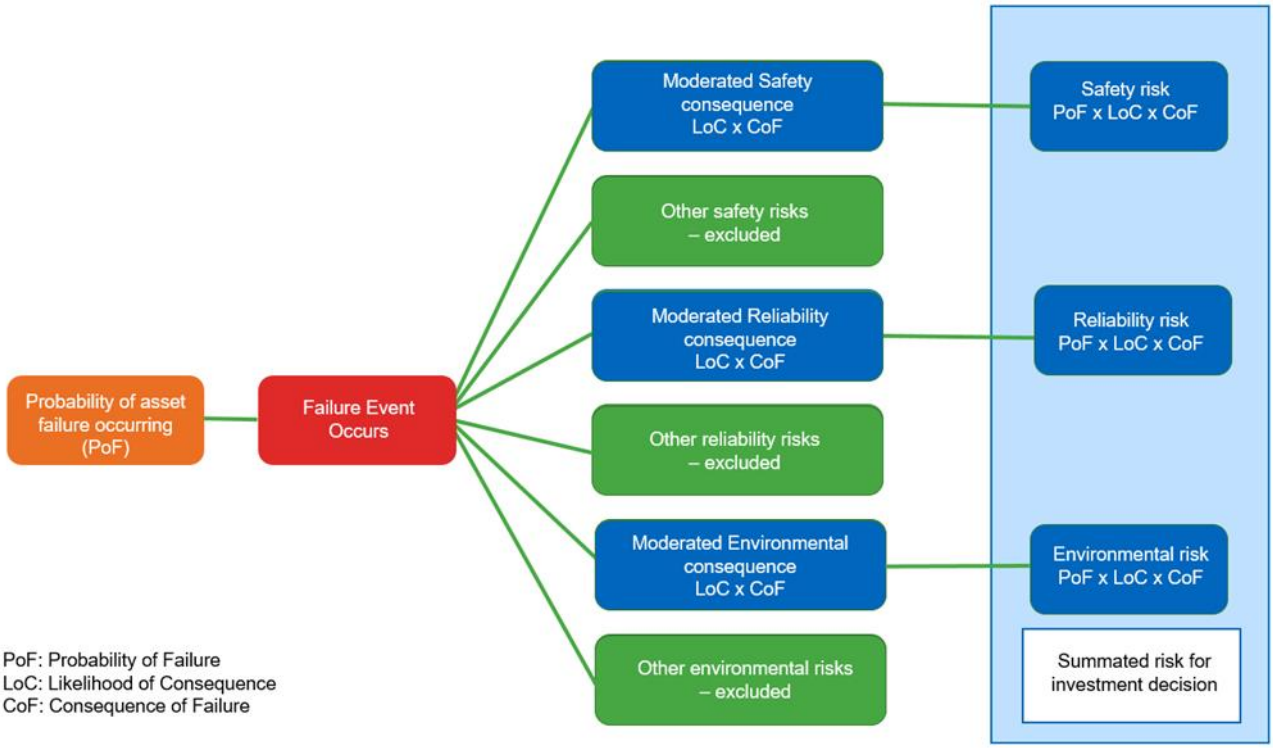
- uses externally verifiable parameters to calculate asset health and failure consequences
- assesses and analyses asset condition to determine remaining life and probability of failure
- applies a worst-case asset failure consequence and significantly moderates this down to reflect the likely consequence in a particular circumstance
- identifies safety and compliance obligations with a linkage to key enterprise risks.

B.1 Overview of the risk assessment methodology

A fundamental part of the risk assessment methodology is calculating the 'risk costs' or the monetised impacts of the reliability, safety, environmental and other risks.

The figure below summarises the framework for calculating the 'risk costs', which has been applied on Transgrid's asset portfolio considered to need replacement or refurbishment.

Figure B-1 Overview of Transgrid's 'risk cost' framework



[38] Transgrid. "*Revised Regulatory Proposal 2018/19-2022/23*." Melbourne: Australian Energy Regulator, 2017. 63-69. Accessed 15 March 2019. https://www.aer.gov.au/system/files/TransGrid%20-%20Revised%20Revenue%20Proposal%20-%201%20December%202017.pdf

The ‘risk costs’ are calculated based on the Probability of Failure (PoF), the Consequence of Failure (CoF), and the corresponding Likelihood of Consequence (LoC).

In calculating the PoF, each failure mode that could result in significant impact is considered. For replacement planning, only life-ending failures are used to calculate the risk costs. PoF is calculated for each failure mode base on ‘conditional age’ (health-adjusted chronological age), failure and defect history, and benchmarking studies. For ‘wear out’ failures, a Weibull curve may be fitted; while for random failures, a static failure rate may be used.

In calculating the CoF, LoC and risks, Transgrid uses a moderated ‘worst case’ consequence. This is an accepted approach in risk management and ensures that high impact, low probability (HILP) events are not discounted. The approach excludes the risk costs of low impact, high probability (LIHP) which would results in lower calculated risk.