TransGrid

Managing safety and environmental risks from corrosion on Line 959/92Z

RIT-T – Project Assessment Conclusions Report

Region: Greater Sydney

Date of issue: 21 August 2019

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Executive summary

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for mitigating risks caused by corrosion along Line 959/92Z. Publication of this Project Assessment Conclusions Report (PACR) represents the final step in the RIT-T process.

Constructed in 1965, the 23.7 km double circuit 132 kV transmission line is built on 61 steel tower structures between Sydney North and Sydney East 330 kV substations. The majority of the line passes through national parks and certain sections pass through urban areas in Sydney.

The line supplies electricity to the Northern Sydney metropolitan area including North Sydney, Ryde, Macquarie Park, Chatswood, and the suburbs along the Northern Beaches. Line 92Z, which runs on one side of the double circuit transmission line, provides connection to some of Ausgrid's loads through a tee connection at Mt Colah Switching station.

Line 959/92Z plays a critical role in providing back-up transmission supply to areas of Sydney which collectively have a 50% Probability of Exceedance[1] (POE50) summer peak load of about 700 MW – almost as large as the biggest smelter in NSW.

Corrosion-related issues that will impact the safe and reliable operation of the network have been found on Line 959/92Z. The condition issues raise a number of risks associated with asset failure, including safety and environmental (bushfire) risks.

Table E-1 – Condition issues along Line 959/92Z and their consequences

Issue	Consequences if not remediated
Corrosion of tower steel members	Steel corrosion, particularly of critical members, can lead to structural failure of tower
Buried concrete foundations	Accelerated corrosion of critical member
Corrosion of earth straps	Earthing safety hazard
Corroded fasteners	Structural failure
Corroded conductor attachment fittings	Conductor drop
Corrosion of earth wire attachment fittings	Conductor drop
Corroded earth wires	Conductor drop
Conductor dampers	Accelerated conductor fatigue due to vibration

Although the structures were designed to the standards at the time of construction, the towers were designed to a lower set of criteria than the more recent design philosophies and standards.

[1] Probability of Exceedance (POE) demand is a generalised approach to defining the probability of exceedance of electricity demand forecasts. The demand is expressed as the probability the forecast would be met or exceeded, eg a 50% POE demand implies there is a 50% probability of the forecast being met or exceeded. Australian Energy Market Operator, *"Generation and Load,"* accessed 1 February 2019. http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Data/Market-Management-System-MMS/Generation-and-Load

As the asset condition deteriorates over time, the likelihood of failure and subsequent risks may increase should these issues not be addressed.

The identified need for this RIT-T is to mitigate bushfire risks. Categorised as a reliability corrective action under the RIT-T, the proposed investment will enable TransGrid to meet regulatory obligations and standards. The option presented in this PACR will enable TransGrid to appropriately manage and mitigate bushfire and safety risks associated with corrosion on Line 959/92Z.

No submissions received in response to Project Specification Consultation Report

TransGrid published a Project Specification Consultation report (PSCR) on 26 March 2019 and invited written submissions on the material presented within the document. No submissions were received in response to this PSCR.

In the corresponding PSCR for this RIT-T, TransGrid put forward for consideration a range of credible network options that would meet the identified need from a technical, commercial, and project delivery perspective.[2] The options are summarised in the table below.

All costs presented in this PACR are in 2019/20 dollars.

Table E-2 – Summary of the three credible options considered

Option	Description	Capital costs ($m)	Operating costs ($m per year)	Remarks
Option 1	Line Refurbishment	7.08	0.051	Less economical due to higher operating, maintenance and licensing costs
Option 2	Line Refurbishment with Optical Ground Wire (OPGW) Retrofitting	7.28	0.051[3]	Most economical and preferred option
Option 3	New transmission lines from Sydney North to Sydney East	> 75	0.051	Not progressed as uneconomical due to significant costs

In the PSCR, TransGrid noted that non-network options are not considered to be commercially and technically feasible to assist with meeting the identified need for this RIT-T as non-network options will not mitigate safety and environment risk posed as a result of corrosion-related asset deterioration.

Conclusion: refurbishment of Line 959/92Z with Optical Ground Wire is optimal

The optimal commercially and technically feasible option presented in the PSCR, the refurbishment of Line 959/92Z including OPGW retrofitting, remains the preferred option to meet the identified need.

2 As per clause 5.15.2(a) of the NER.

3 Operating costs are incurred for 3 years only under Option 2, compared to 30 years for the base case and Option 1

Moving forward with this option is the most prudent and economically efficient solution to manage and mitigate bushfire and safety risk to the As Low As Reasonably Practical (ALARP) level.

The estimated capital expenditure associated with this option is $7.28 million ± 25%. While this option is $204,328 more expensive than Option 1 as it employs new technology (OPGW), it will provide additional operating cost savings of $51,082 per year from 2021/22 over the life of the asset.

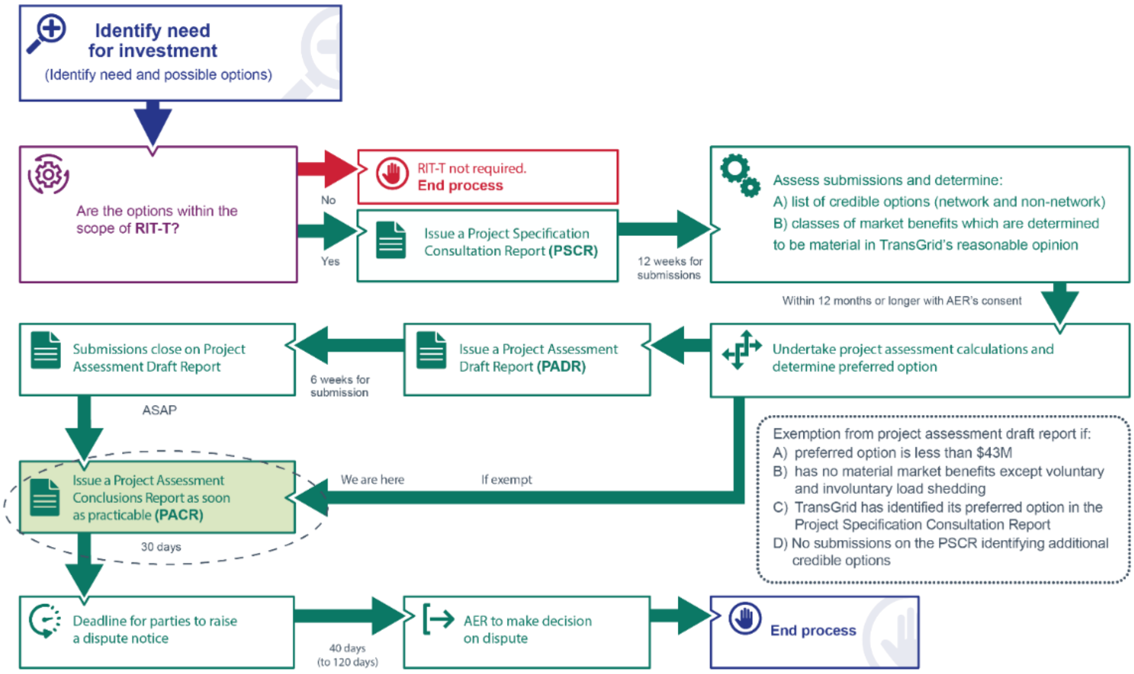
The works will be undertaken between 2018/19 and 2020/21. Planning and procurement (including completion of the RIT-T) will occur between 2018/19 and 2019/20, while project delivery and construction will occur in 2020/21. All works will be completed in accordance with the relevant standards by 2020/21 with minimal modification to the wider transmission assets.

Necessary outages of affected line(s) in service will be planned appropriately in order to complete the works with minimal impact on the network.

Next steps

This PACR represents the third step in a formal Regulatory Investment Test for Transmission (RIT-T) process undertaken by TransGrid. It follows a Project Specification Consultation Report (PSCR) released in March 2019. The second step, production of a Project Assessment Draft Report (PADR), was not required as TransGrid considered its investment in relation to the preferred option to be exempt from this part of the RIT-T process under NER clause 5.16.4(z1).This PACR represents the third stage of the formal consultation process in relation to the application of the RIT-T.

Figure E-1 This PACR is the third stage of the RIT-T process[4]



4 Australian Energy Regulator, *"Final determination on the 2018 cost thresholds review for the regulatory investment tests,"* accessed 15 March 2019. https://www.aer.gov.au/communication/aer-publishes-final-determination-on-the-2018-cost-thresholds-review-for-the-regulatory-investment-tests

Parties wishing to raise a dispute notice with the AER may do so prior to 19 September 2019 (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 project can be obtained from TransGrid's Prescribed Revenue and Pricing team via RIT-TConsultations@transgrid.com.au. In the subject field, please reference "PACR Line 959/92Z project."

TransGrid intends to undertake refurbishment works between 2018/19 and 2020/21. Planning and procurement will occur between 2018/19 and 2019/20 and project delivery and construction will occur in 2020/21. All works will be completed by 2020/21.

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1. Introduction

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for mitigating risks caused by corrosion along Line 959/92Z. Publication of this Project Assessment Conclusions Report (PACR) represents the final step in the RIT-T process.

The corresponding Project Specification Consultation Report (PSCR) released in March 2019 set out the reasons TransGrid proposed that action be taken and the credible options TransGrid considered to address the identified need.

No submissions were received in response to the PSCR.

1.1 Purpose of this report

The purpose of this PACR 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.

2. The identified need

2.1 Background

Constructed in 1965, Line 959/92Z, collectively, is a double circuit 132 kV transmission line built on modified single circuit 330 kV steel towers between Sydney North and Sydney East 330 kV substations.

The line spans a 23.7 km route supported by 61 structures. The majority of the line passes through national parks and certain sections pass through urban areas in Sydney.

The figure below depicts the location of Line 959/92Z in TransGrid's network.

Figure 2-1 TransGrid's Greater Sydney network

A condition assessment performed by TransGrid in January 2016 identified a number of issues with Line 959/92Z. Corrosion-related issues are the biggest factor contributing to deterioration and require rectification in order for TransGrid to continue to safely and reliably operate the assets. Some of the other issues found were:

> corrosion of tower steel members
> buried concrete foundations
> corroded earth straps
> corroded fasteners
> corroded conductor attachment fittings
> corrosion of earth wire attachment fittings
> corroded earth wires
> conductor dampers.

Figure 2-2 below shows the corroded components supporting Line 959/92Z.

Figure 2-2 Corroded components of Line 959/92Z

In addition to the issues identified, the modified single circuit 330 kV transmission line structures on Line 959/92Z have deficiencies due to design philosophies used at the time of installation. Although the structures were designed to the standards at that time, investigations following several structure failures during extreme wind events found that the towers were designed to a lower set of criteria than the more recent design philosophies and standards.

2.2 Description of the identified need

Further deterioration of the condition of the affected assets due to corrosion would mean an increase in bushfire and safety risks along Line 959/92Z. If left untreated, corrosion of some of the vital components of the steel towers could result in incidents such as conductor drop and tower collapse which may cause bushfire and safety risks. Such incidents have serious safety consequences for TransGrid field crew members who may be working on or near the assets, nearby residents and members of the public. As the line traverses national parks and certain sections pass through urban areas in Sydney, the risk of bushfire and on safety caused by structural failure of towers and conductor drop increases substantially.

TransGrid manages and mitigates bushfire and safety risks to ensure they are below tolerance levels or 'As Low As Reasonably Practicable' ('ALARP'), in accordance with TransGrid's obligations under the New South Wales *Electricity Supply (Safety and Network Management) Regulation 2014* and TransGrid's Electricity

Network Safety Management System (ENSMS).[5] In particular, risks are mitigated unless it is possible to demonstrate that the cost involved in further reducing the risk would be grossly disproportionate to the benefit gained.

TransGrid's analysis concludes that the costs of mitigating the bushfire and safety risks is less than the benefit of avoiding those risks. Categorised as a reliability corrective action under the RIT-T, the proposed investment will enable TransGrid to continue to manage and operate this part of the network to a safety and risk mitigation level of ALARP.

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

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5 TransGrid ENSMS follows the ISO31000 risk management framework which requires following hierarchy of hazard mitigation approach.

3. Options that meet the identified need

In identifying the refurbishment of the existing line as a credible option, TransGrid took the following factors into account: energy source; technology; ownership; the extent to which the option enables intra-regional or inter-regional trading of electricity; whether it is a network option or a non-network option; whether the credible option is intended to be regulated; whether the credible option has proponent; and any other factor which TransGrid reasonably considered should be taken into account.[6]

Of the three credible options considered[7] and summarised in Table 3-1, TransGrid considers that the optimal timing for the most efficient option (Option 2: the refurbishment of Line 959/92Z including OPGW retrofitting) that meets the identified need to mitigate the asset risks is before 2020/21.

TransGrid did not receive any responses to the PSCR.

All costs presented in this PACR are in 2019/20 dollars.

Table 3-1 – Summary of the credible options

Option	Description	Capital costs ($m)	Operating costs ($m per year)	Remarks
Option 1	Line Refurbishment	7.08	0.051	Less economical due to higher operating, maintenance and licensing costs
Option 2	Line Refurbishment with Optical Ground Wire (OPGW) Retrofitting	7.28	0.051[8]	Most economical and preferred option
Option 3	New transmission lines from Sydney North to Sydney East	> 75	0.051	Not progressed as uneconomical due to significant costs

3.1 Base case

The costs and benefits of each option in this PACR were compared against those of a base case[9]. Under this base case, no proactive capital investment is made to remediate the deterioration of Line 959/92Z, and the line will continue to operate and be maintained under the current regime.

The regular maintenance regime will not be able to mitigate the risk of tower collapse which will expose TransGrid and end-customers to approximately $514,907 per year in safety and environmental risk costs. The large environmental and safety risk costs are mainly due to the significant consequences of a bushfire event

[6] In accordance with the requirements of NER clause 5.15.2(b).

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

[8] Operating costs are incurred for 3 years only under Option 2, compared to 30 years for the base case and Option 1

[9] 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 - December 2018."* Melbourne: Australian Energy Regulator, 2018. Accessed 1 August 2019. 22. https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf

resulting from conductor drop and risks associated with compromised earthing. Under the base case, all of these risks will continue to increase.

3.2 Option 1 – Refurbishment of the line

Option 1 involves the refurbishment of Line 959/92Z to prevent further corrosion to tower steelwork.

The estimated capital expenditure associated with this option is $7.08 million ± 25%. The routine operating and maintenance costs are the same as in the base case.

Table 3-2 summarises the remediation works under Option 1 to address the key issues on Line 959/92Z.

Table 3-2 Remediation works for Line 959/92Z under Option 1

Issue	Remediation
Buried concrete foundations	On two towers, the following will be implemented: > dig out tower legs > abrasive blast cleaning of steelwork to remove any corrosion product > application of Zinga paint > establish drainage channel where feasible or concrete encase legs to prevent future corrosion. For one tower, in addition to the works mentioned above, concrete scabbling and installation of double plate will also be implemented.
Corrosion of earth straps	Replacement of earth straps in line with current standard
Corrosion of tower steel members	Replacement of tower members, nuts & bolts and structure ladders; works on tower leg earthworks and encasements; and tower leg painting vs asbestos removal; insulator fittings install - tension-climbing
Corrosion of conductor attachment fittings	Replacement of conductor fittings – suspension, conductor fittings – tension
Corrosion of earth wire attachment fittings	Replacement of earth wire fittings
Corrosion of earth wires	Replacement of earth wires, earth wire fittings – suspension, and earth wire fittings – tension
Damaged conductor vibration dampers	Replacement of conductor vibration dampers
Site works	Site establishment and access

3.3 Option 2 – Refurbishment of the line with OPGW Retrofitting

Option 2 involves the refurbishment of Line 959/92Z to prevent further corrosion to tower steelwork. This option includes replacement of one earth wire between Sydney North and Sydney East with OPGW Type A which will improve the communication assets for this section.

This option is considered to address the identified need, be commercially and technically feasible and can be implemented in sufficient time to meet the identified need.[10]

The works will be undertaken between 2018/19 and 2020/21. Planning and procurement (including completion of the RIT-T) will occur between 2018/19 and 2019/20, while project delivery and construction will occur in 2020/21. All works will be completed by 2020/21 with minimal modification to the wider transmission assets and in accordance with the relevant standards.

Necessary outages of affected line(s) 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 $7.28 million ± 25%. While this option is $204,328 more expensive than Option 1 as it employs new technology (OPGW), it will provide additional benefits from reduced maintenance and licensing costs of $30,649 per year and an additional efficiency savings specific to the Sydney East site of $20,433 per year.

Option 2 will enable TransGrid to meet the standard for this part of the network with minimal modification to the wider transmission assets. Driven by reliability corrective action, the refurbishment of Line 959/92Z is categorised as replacement capital expenditure. It is not an expansion of the existing transmission system or an increase in its capacity to transmit electricity and is therefore not categorised as network augmentation capital expenditure.

Table 3-3 summarises the remediation works under Option 2 to address the key issues on Line 959/92Z.

Table 3-3 Remediation works for Line 959/92Z under Option 2

Issue	Remediation
Buried concrete foundations	On two towers, the following will be implemented: > dig out tower legs > abrasive blast cleaning of steelwork to remove any corrosion product > application of Zinga paint > establish drainage channel where feasible or concrete encase legs to prevent future corrosion. For one tower, in addition to the works mentioned above, concrete scabbling and installation of double plate will also be implemented.
Corrosion of earth straps	Replacement of earth straps in line with current standard
Corrosion of tower steel members	Replacement of tower member, nuts & bolts and structure ladder; works on tower leg earthworks and encasement; and tower leg painting vs asbestos removal; insulator fittings install - tension-climbing

10 In accordance with the requirements of NER clause 5.15.2(a).

Issue	Remediation
Corrosion of conductor attachment fittings	Replacement of conductor fittings – suspension, conductor fittings – tension
Corrosion of earth wire attachment fittings	Replacement of earth wire fittings
Corrosion of earth wires	Replacement of earth wires, earth wire fittings – suspension, and earth wire fittings – tension
Damaged conductor vibration dampers	Replacement of conductor vibration dampers
Sydney North Substation works	This includes: > termination of OPGW into non-metallic conductor at substation gantry > non-metallic conductor run to cable trench system in buried conduit > run in conduit to the communications room to be terminated onto new optical distribution frame
Sydney East Substation works	This includes: > termination of OPGW into non-metallic conductor at substation gantry > non-metallic conductor run to cable trench system in buried conduit > run in conduit to the communications room to be terminated onto new optical distribution frame
Site works	Site establishment and access

3.4 Options considered but not progressed

The primary driver for the identified need is to mitigate safety and environmental risks associated with condition issues on the Line 959/92Z caused by corrosion. One other option to address the need was considered but was not progressed further as it was not commercially viable when assessed against the preferred option.

Table 3-4 summarises the reason the following credible option was not progressed further.

Table 3-4 Options considered but not progressed

Option	Description	Reason for not progressing
Option 3	New transmission lines from Sydney North to Sydney East	Due to significant costs of option (> than $75 million), a new set of 132 kV transmission lines from Sydney North to Sydney East is not commercially feasible.

3.5 Non-network options

The PSCR outlined that non-network options cannot assist with meeting the identified need for this RIT-T as non-network options will not mitigate safety and environmental risks posed as a result of corrosion-related asset deterioration.

TransGrid did not receive any responses from proponents of non-network options to the PSCR.

4. Assessment of credible options

There were no material changes since publication of the PSCR that affect the preference of Option 2.

The assessment compares the costs and benefits of the option to a base case where Line 959/92Z will not be remediated, the exiting maintenance regime is continued, and the line will continue to operate with an increasing level or risk.

The analysis presented in the corresponding PSCR for this RIT-T was conducted using an earlier discount rate. The original calculations have been re-done using the base discount rate of 5.9% (real, pre-tax), which is consistent with the commercial discount rate calculated in the RIT-T Economic Assessment Handbook published by Energy Networks Australia (ENA) in March 2019[11].

All costs presented in this PACR are in 2019/20 dollars.

4.1 Assessment under three different scenarios to address uncertainty

RIT-T assessments were based on cost-benefit analysis that includes assessment under reasonable scenarios which were designed to test alternate sets of key assumptions and their impact on the ranking and feasibility of options.

TransGrid considered three alternative scenarios, summarised in Table 4-1, to address uncertainty – namely:

- a low net benefit scenario, involving a number of assumptions that gives a lower bound and conservative estimates of NPV of net economic benefits
- a central scenario which consists of assumptions that reflect TransGrid's central set of variable estimates that provides the most likely scenario
- a high net benefit scenario that reflects a set of assumptions which have been selected to investigate an upper bound of net economic benefits.

Table 4-1 Summary of scenarios

Variable / Scenario	Central	Low net economic benefit	High net economic benefit
Scenario weighting	*50%*	*25%*	*25%*
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Safety and environment risk costs	Base estimate	Base estimate - 25%	Base estimate + 25%
Discount rate[12]	5.9%	4.60%	7.2%

[11] Available at https://www.energynetworks.com.au/rit-t-economic-assessment-handbook Note the lower bound discount rate of 4.60% is based on the most recent final decision for a TNSP revenue determination which was TasNetworks in April 2019.

TransGrid considers that the central scenario is most likely since it is based primarily on a set of expected assumptions. TransGrid therefore assigned this scenario a weighting of 50%, with the other two scenarios being weighted equally with 25% each.

4.2 Estimated gross economic benefits

Table 4-2 summarises the present value of the gross economic benefit estimates for each credible option relative to the base case under the three scenarios.

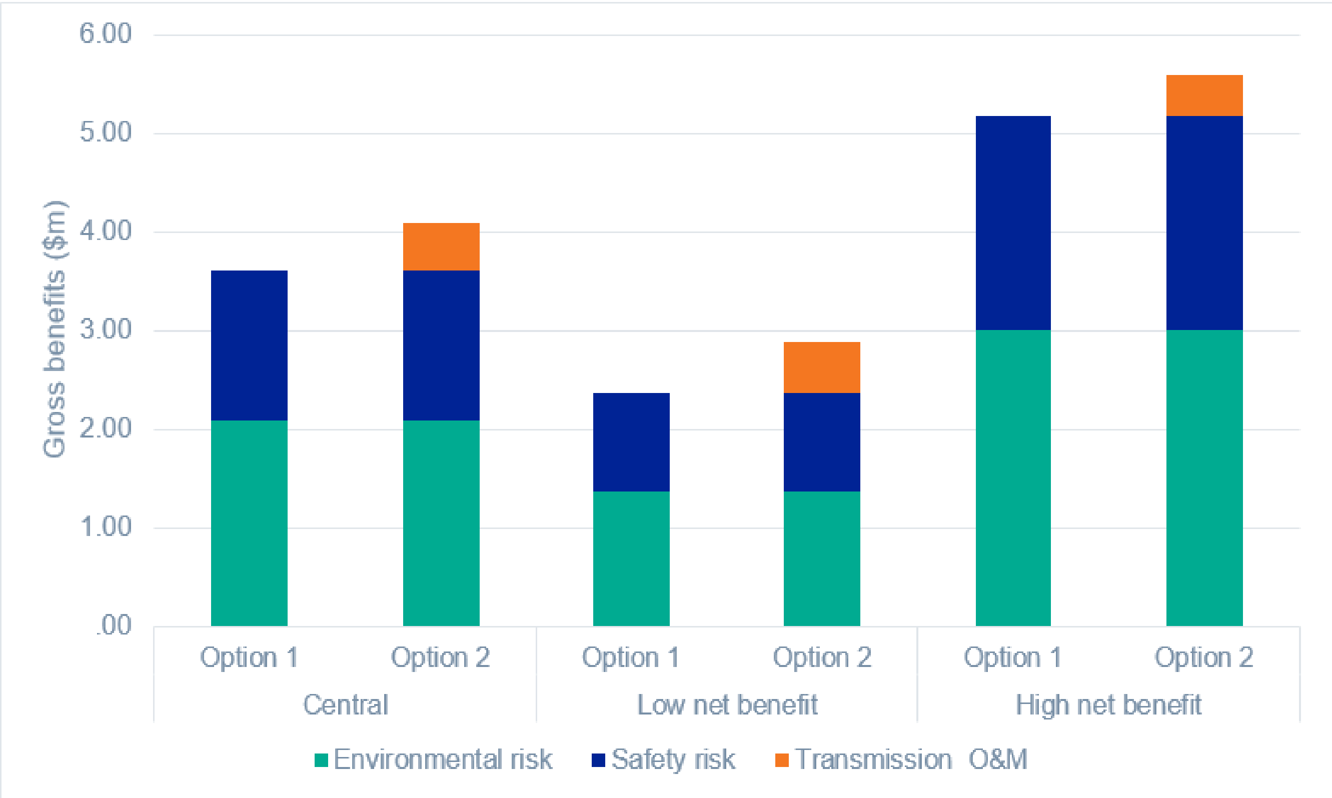
There are benefits from avoided costs associated with safety and environmental risks. These *expected* costs are weighted based on the probability of the event occurring.

Table 4-2 Gross economic benefits from credible options relative to the base case, present value 2019/20 $m

Option/scenario	Central	Low net economic benefit	High net economic benefit	Weighted
Scenario weighting	*50%*	*25%*	*25%*	
Option 1	3.61	2.37	5.18	3.70
Option 2	4.08	2.89	5.59	4.16

Figure 4-1 breaks down these benefits further and shows that most of the benefits are derived from avoided safety and environment (bushfire) risks.

Figure 4-1 Components of gross economic benefits of credible options, present value 2019/20 $m



4.3 Estimated costs

Table 4-3 summarises the present value of costs of credible options relative to the base case under the three reasonable scenarios.

Table 4-3 Costs of credible options relative to the base case, present value 2019/20 $m

Option	Central	Low net economic benefit	High net economic benefit	Weighted
Scenario weighting	*50%*	*25%*	*25%*	
Option 1	5.97	7.20	4.65	5.95
Option 2	6.15	7.41	4.78	6.12

4.4 Estimated net economic benefits

Table 4-4 summarises the present value of the net economic benefits for each credible option across the three scenarios and the weighted net economic benefits. These net economic benefits are the differences between the estimated gross economic benefits less the estimated costs.

While the net economic benefits are only positive under the high net economic benefit scenario, Option 2 is still the cheapest option to maintain compliance with TransGrid's safety obligations. TransGrid also notes that the low net economic scenario is comprised of an extreme combination of low safety and environmental risks estimates and high capital costs.

On a weighted basis, Option 2 will deliver approximately -$1.96 million in net economic benefits. Though the net economic benefits are negative, the investment is still justified as it is intended to mitigate safety and environmental risks using the ALARP principle.

Table 4-4 Net economic benefits relative to the base case, present value 2019/20 $m

Option	Central	Low net economic benefits	High net economic benefits	Weighted value
Scenario weighting	*50%*	*25%*	*25%*	
Option 1	-2.36	-4.83	0.54	-2.25
Option 2	-2.06	-4.52	0.81	-1.96

4.5 Sensitivity testing

TransGrid undertook a thorough sensitivity testing exercise to understand the robustness of the conclusion to underlying assumptions about key variables. These are implemented in stages.

> Step 1 – tests the sensitivity of the optimal timing of the project ('trigger year') to different assumptions on key variables

> Step 2 – once a trigger year is determined, tests the sensitivity of the ALARP test to different assumptions on key variables such as lower or higher bushfire risks.

4.5.1 Step 1 – Sensitivity testing of the optimal timing

The optimal timing for Option 2 is the year in which the safety and environmental risk costs are reasonably mitigated. Shown on Figure 4-2, the optimal timing is 2020/21 and is found to be invariant between the central set of assumptions and a range of alternative assumptions for the following key variables:

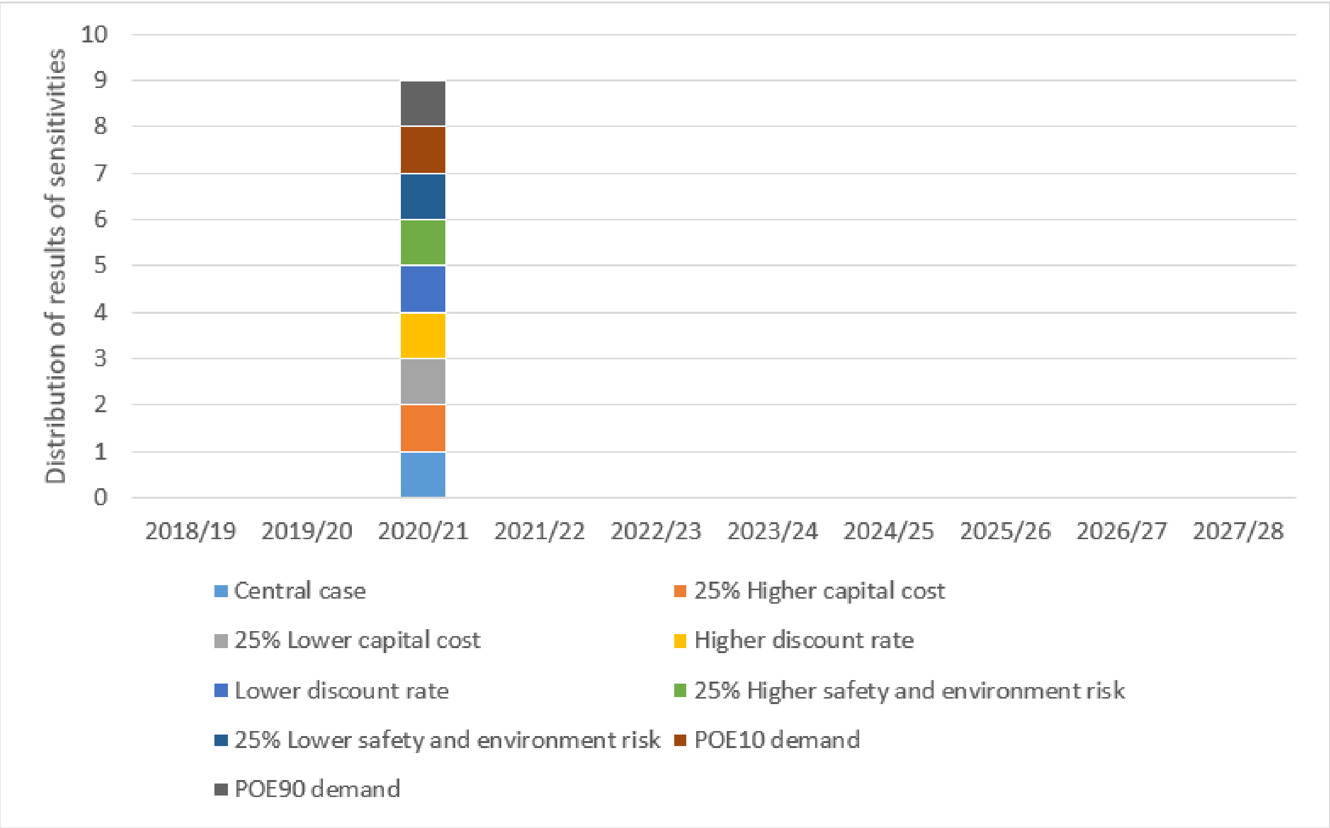
> 25 per cent increase/decrease in the assumed network capital costs
> higher and lower discount rates (7.2% and 4.60%)
> higher and lower assumed safety and environmental risks
> higher and lower demand forecasts (POE 10 and POE 90).

The figure below illustrates that taking into account all sensitivities, the optimal timing for the works is before 2020/21.

TransGrid considers that the sensitivity assessment below demonstrates that planning for any commissioning later than 2020/21 would be inconsistent with the ALARP obligations under the New South Wales Electricity Supply (Safety and Network Management) Regulation 2014. In particular, due to higher risk cost associated with safety and environmental risk, there would be lower expected net market benefits (greater net market cost) if the replacement works were delayed.

No sensitivity tests have been undertaken on load forecasts or VCR as they are immaterial to the identified need.

Figure 4-2 Optimal timing of Option 2 to meet safety regulatory obligations



4.5.2 Step 2 – Sensitivity of the overall net benefit

TransGrid also conducted sensitivity analysis assuming the optimal timing and same sensitivities established in Step 1.

Specifically, TransGrid investigated the same sensitivities under this step:

> 25 per cent increase/decrease in the assumed network capital costs
> higher and lower discount rates (7.2% and 4.60%)
> higher and lower assumed safety and environmental risks
> higher and lower demand forecasts (POE 10 and POE 90).

The figures below illustrate that while the results are most sensitive to the safety and environmental risk cost estimates, it is still reasonable to make investments to mitigate low risk costs estimates.

Figure 4-3 Sensitivities to net present value using the ALARP test

5. Final conclusion on the preferred option

The optimal commercially and technically feasible option presented in the PSCR, the refurbishment of Line 959/92Z including OPGW retrofitting, remains the preferred option to meet the identified need.

Moving forward with this option is the most prudent and economically efficient solution to manage and mitigate safety and environmental risk to ALARP.

The estimated capital expenditure associated with Option 2 is $7.28 million ± 25%. While this option is $204,328 more expensive than Option 1 as it employs new technology (OPGW), it will provide additional operating cost savings of $51,082 per year from 2021/22 onwards over the life of the asset. Routine and operating maintenance costs will be approximately less than 1% of the estimated capital costs.

The works will be undertaken between 2018/19 and 2020/21. Planning and procurement (including completion of the RIT-T) will occur between 2018/19 and 2019/20, while project delivery and construction will occur in 2020/21. All works will be completed in accordance with the relevant standards by 2020/21 with minimal modification to the wider transmission assets.

The analysis undertaken and the identification of Option 2 as the preferred option satisfies the RIT-T.

Appendix A – Compliance checklist

This appendix sets out a compliance checklist which demonstrates the compliance of this PACR with the requirements of clause 5.16.4(b) of the Rules version 123.

Rules clause	Summary of requirements	Relevant section(s) in PACR
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).	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, 4, Appendix C & Appendix D
	(4) a detailed description of the methodologies used in quantifying each class of material market benefit and cost;	4, Appendix C & Appendix D
	(5) reasons why the RIT-T proponent has determined that a class or classes of market benefit are not material;	Appendix C
	(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;	4
	(8) the identification of the proposed preferred option;	5
	(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 & 5, Appendix C

Appendix B – Assumptions underpinning the identified need

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.[13] Appendix D provides further details on the general modelling approaches applied including the commercial discount rate used.

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:

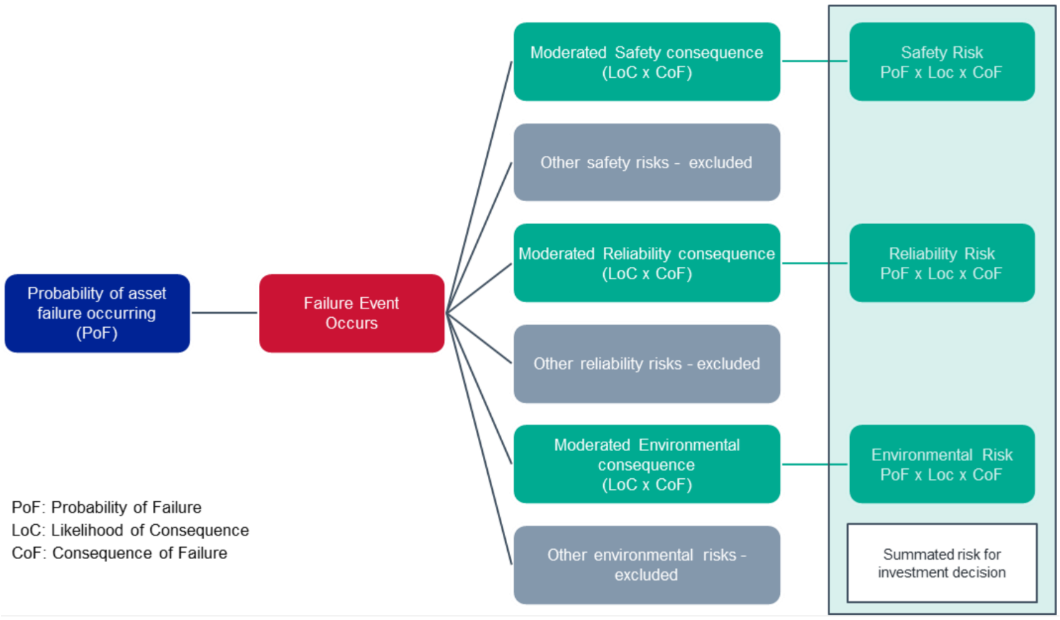
> uses externally verifiable parameters to calculate asset health and failure consequences
> assesses and analyses asset condition to determine remaining life and probability of failure
> applies a worst-case asset failure consequence and significantly moderates this down to reflect the likely consequence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

B.1 Overview risks 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.

Figure B-1 below summarises the framework for calculating the 'risk cost', 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



[13] For additional information on the risk assessment methodology, refer to pages 63-69 of TransGrid's Revised Regulatory Proposal for the period 2018-23, available at: 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 based 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 result in lower calculated risk.

B.2 Line 959/92Z condition issues and their consequences

TransGrid’s asset health assessments have identified a number of corrosion related issues on Line 959/92Z. Details are presented on Tables B-1.

Table B-1 Condition issues along Line 959/92Z and their potential consequences if not remediated

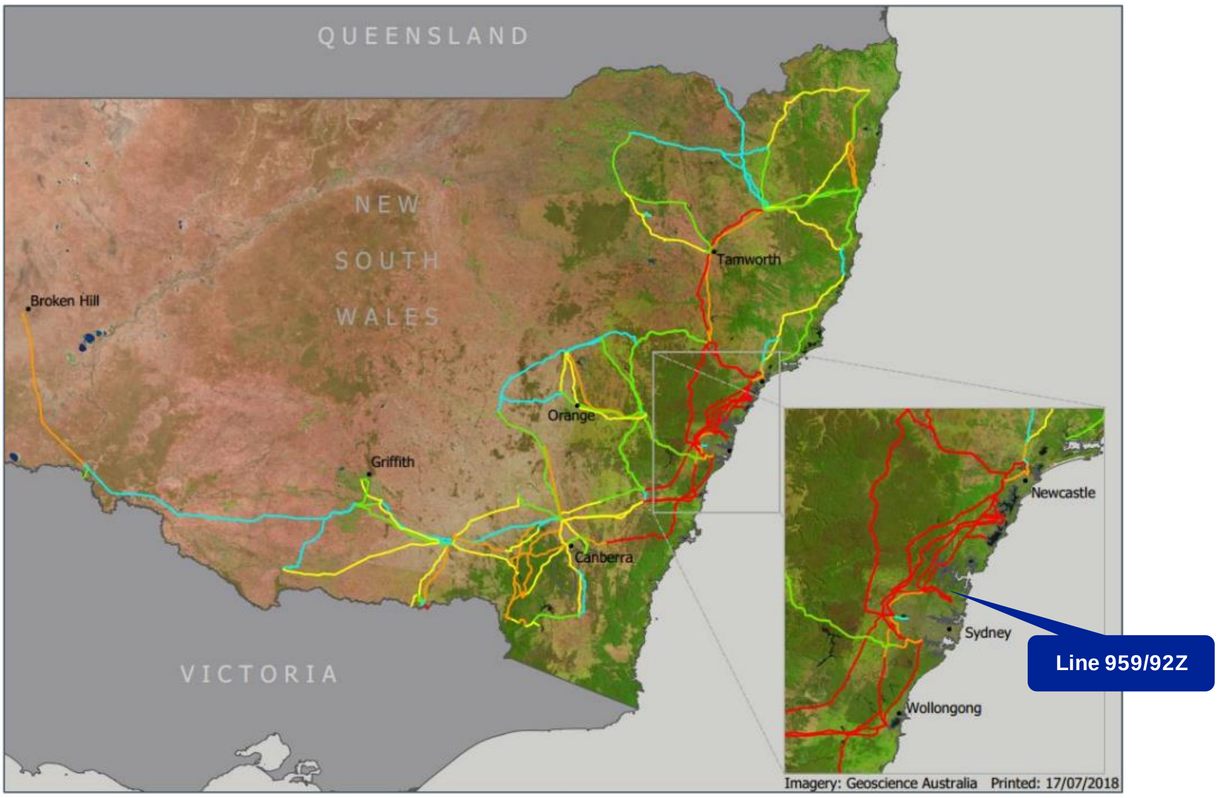
Issue	Consequences if not remediated
Corrosion of tower steel members	Steel corrosion, particularly of critical members, can lead to structural failure of tower
Buried concrete foundations	Accelerated corrosion of critical member
Corrosion of earth straps	Earthing safety hazard
Corroded fasteners	Structural failure
Corroded conductor attachment fittings	Conductor drop
Corrosion of earth wire attachment fittings	Conductor drop
Corroded earth wires	Conductor drop
Conductor dampers	Accelerated conductor fatigue due to vibration

B.3 Avoiding safety and environmental risks is the most substantial driver of this RIT-T

Figure B2 shows a heat map of transmission line risks. As the majority of Line 959/92Z passes through national parks and certain sections pass through urban areas of Sydney, the environmental and safety risks associated with this line are considered to be amongst the highest in TransGrid’s network.

Figure B2 shows that Line 959/92Z is a high risk line.

Figure B-2 Indication of the relative risk of all of TransGrid's lines



*Line colours on Figure B-2 represent the level of risk from highest risk to lowest risk respectively: red, orange, yellow, green, blue.

The safety and environment risk cost from corrosion related condition issues on the line is $514,907 per year. This figure will likely increase over time as the assets continue to deteriorate.

Categorised as a reliability corrective action under the RIT-T, the proposed investment will enable TransGrid to continue to manage and operate this part of the network to a safety and risk mitigation level of ALARP.

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.

TransGrid manages and mitigates bushfire and safety risks to ensure they are below tolerance levels or 'As Low As Reasonably Practicable' ('ALARP'), in accordance with TransGrid's obligations under the New South Wales *Electricity Supply (Safety and Network Management) Regulation 2014* and TransGrid's Electricity Network Safety Management System (ENSMS).[14] In particular, risks are mitigated unless it is possible to demonstrate that the costs involved in further reducing the risks would be grossly disproportionate to the benefits gained.

In the context of investment decisions, ALARP is tested through the use of disproportionality factors which increase the risk costs to just below the level which the community, government and law would consider risk reduction expenditures to be grossly disproportionate.

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[14] TransGrid ENSMS follows the International Organization for Standardization's ISO31000 risk management framework which requires following hierarchy of hazard mitigation approach.

Appendix C – Materiality of market benefits

The section outlines the categories of market benefits prescribed in the NER and whether they are considered material for this RIT-T.[15]

C.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 therefore do not need to be estimated.[16]

Option 2 outlined above does not impact network constraints between competing generating centres and is not expected to result in any change in dispatch outcomes and wholesale market prices. Therefore, TransGrid 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.

Additionally, as part of the RIT-T process, TransGrid applied AEMO's screening criteria[17] to test whether or not Option 2 has material inter-network impact:

> a decrease in power transfer capability between the 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 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
> the investment does not involve either a series capacitor or modification in the vicinity of an existing series capacitor.

TransGrid concludes that there are no material inter-network impacts associated with Option 2.

[15] The NER requires that all categories 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 category (or categories) is unlikely to be material in relation to the RIT-T assessment for a specific option – NER clause 5.16.1(c)(6). Under NER clause 5.16.4(b)(6)(i), the PSCR should set out the classes of market benefit that the NSP considers are not likely to be material for a particular RIT-T assessment.

[16] AER, *Final Regulatory Investment Test for Transmission Application Guidelines*, 18 September 2017, pp. 13-14. This was also reiterated in the recently updated AER RIT-T Guidelines, see: AER, *Final Regulatory Investment Test for Transmission Application Guidelines*, December 2018, pp.39.

[17] The screening test is set out in Appendix 3 of the Inter-Regional Planning Committee's Final Determination: Criteria for Assessing Material Inter-Network Impact of Transmission Augmentations, Version 1.3, October 2004.

C.2 No other categories 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 classes of market benefits.

Table C-1 sets out the reason TransGrid considers these classes of market benefits to be immaterial.

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

Market benefits	Reason
Changes in involuntary load curtailment	Since Line 959/92Z forms part of a meshed network (N-1 and N-2 redundant) required to supply Sydney, a failure due to the corroded assets results in extremely low chance of unserved energy.
Differences in the timing of expenditure	Options considered will provide an alternative to meeting reliability requirements but 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	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.[18] 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.

18 Australian Energy Regulator. *"Application guidelines Regulatory Investment Test for Transmission - December 2018."* Melbourne: Australian Energy Regulator, 2018. Accessed 15 March 2019. https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf

Appendix D – Overview of the assessment approach

This appendix outlines the approach that TransGrid has applied in assessing the net economic benefits associated with refurbishing Line 959/92Z.

The analysis presented in the corresponding PSCR for this RIT-T was conducted using an earlier discount rate. The original calculations have been re-done using the base discount rate of 5.9% (real, pre-tax), which is consistent with the commercial discount rate calculated in the Energy Network Australia's (ENA) RIT-T Economic Assessment Handbook[19].

D.1 Overview of the assessment framework

As outlined in section 3.1, all costs and benefits considered were measured against a base case.

The analysis presented in this RIT-T considered a 20-year period, from 2019/20 to 2039/40. TransGrid considers that a 20-year period takes into account the size, complexity and expected service life of the options and provides a reasonable indication of the costs and benefits over a long outlook period. Since the capital components have an asset life greater than 20 years, TransGrid took a terminal value approach to ensure that the capital costs of those assets were appropriately captured in the 20-year assessment period.

TransGrid adopted a central real, pre-tax 'commercial'[20] discount rate of 5.9% 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, consistent with the RIT-T.

TransGrid also tested the sensitivity of the results to discount rate assumptions. A lower bound real, pre-tax discount rate of 4.60% equal to the latest AER Final Decision for a TNSP's regulatory proposal at the time of preparing the PACR for this RIT-T, and an upper bound discount rate of 7.2% (a symmetrical adjustment upwards) were investigated.

D.2 Approach to estimating project costs

TransGrid estimated the capital costs of the options by using scope from similar works. TransGrid considers the central capital costs estimates to be within ± 25% of the actual costs.

Routine operating and maintenance costs were based on similar works of similar nature.

Reactive maintenance costs under the base case considered the:

> level of corrective maintenance required to restore assets to working order following a failure
> probability and expected level of network asset faults.

In either credible option, the asset failures were less frequent and restoration costs were reduced.

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[19] Available at https://www.energynetworks.com.au/rit-t-economic-assessment-handbook Note the lower bound discount rate of 4.60% is based on the most recent final decision for a TNSP revenue determination which was TasNetworks in April 2019.

[20] 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.