Managing asset risks at Sydney South substation

RIT-T – Project Assessment Draft Report

Region: Greater Sydney

Date of issue: 3 December 2019

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Executive summary

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for mitigating asset risks caused by corroding gantries at Sydney South substation. Publication of this Project Assessment Draft Report (PADR) represents the second step in the RIT-T process.

Sydney South substation:

> supplies most of the load in Sydney CBD, Eastern suburbs and South Sydney
> is the largest bulk supply point for Ausgrid's distribution network with growing summer maximum demand at approximately 1,177 MW in 2019/20[1]
> must meet redundancy category 3 reliability standards with only 0.6 minutes of expected unserved energy (EUE) allowed each year across Inner Sydney.

At Sydney South substation, gantries support high voltage connections between switchbays and busbars. They are mainly used to support the power conductor in both directions between the transmission tower closest to the substation and the equipment within the substation. Gantries are connected to concrete footings by concrete plinths, holding down bolts and baseplates. They also support overhead earthwires that protect the substation equipment from direct lightning strikes and are essential for the safe and reliable operation of the substation.

Corrosion has been found on a large portion of gantries at Sydney South substation. The corrosion of holding down bolts and structural components, or 'members', ranges from initial development through to loss of steel thickness (cross-sectional area).

TransGrid's analysis indicates that the holding down bolts and several of the gantry members will reach the end of serviceable life by 2021. After this time, the loss of physical cross-sectional area from corrosion will decrease their capacity to provide structural support. This reduces structural integrity and significantly increases their probability of structural failure, especially during high wind events. Deterioration of holding down bolts has occurred across the site and action is required on the majority of structure footings. If unaddressed, these issues may cause failure of steelwork, holding down bolts or baseplates leading to gantry collapse.

Table E-1 outlines the condition issues identified at Sydney South substation and the potential consequences if not remediated.

Table E-1 Consequences of condition issues

Issue	Consequences if not remediated
Corrosion of gantry steel members	Structural failure
Corrosion of holding down bolts and base plates	Structural failure
Corroded fasteners	Structural failure
Corrosion of earth wire attachment fittings	Conductor drop

[1] Summer maximum demand is estimated to increase to 1,317 MW by 2028/29. TransGrid. "*Transmission Annual Planning Report 2019*." Sydney: TransGrid, 2019. 81. Accessed 13 November, 2019. https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning/Documents/2019%20Transmission%20Annual%20Planning%20Report.pdf

Identified need: managing asset risks to avoid potentially significant unserved energy

The proposed investment to address the corroded gantries has significant 'market benefits' as the proposed investment will help to avoid involuntary load shedding. Options considered under this RIT-T have been assessed relative to a base case. Under the base case, no proactive capital investment is made and the condition of Sydney South substation will continue to deteriorate. The investment will also assist TransGrid to manage and mitigate safety risks that would otherwise arise from a failure in substation gantries.[2]

The purpose of the proposed investment has similarities to those made under a reliability corrective action identified need (ie, to avoid involuntary load shedding), however the scope of the current reliability standards applicable to TransGrid do not extend to multiple failures of transmission network elements that would be expected to result from a failure of substation gantries (eg, damage to and failure of multiple busbar sections at the same substation). It follows that the proposed investment is driven by a 'market benefits' due to the lack of externally imposed obligations relating to multiple failures of transmission network elements.

No submissions received in response to the Project Specification Consultation Report

TransGrid published a Project Specification Consultation report (PSCR) on 3 September 2018 and invited written submissions on the material presented within the document. In the PSCR TransGrid put forward for consideration one technically and commercially feasible option: replacing and refurbishing the identified corroded components in a single project. This option (Option 1) involves in-situ renewal of the steelwork by removing corrosion, painting and replacement of components, where required. No submissions were received in response to the PSCR.

Developments since publication of the PSCR

At the time the PSCR was published, TransGrid's cost estimate for refurbishing the Sydney South substation gantries was primarily based on a desktop assessment of the activity required to refurbish the gantries. TransGrid has since undertaken additional investigations and onsite trials, in particular testing different blasting techniques. The field trials demonstrated that:

> blasting in a live switchyard takes significantly longer than originally anticipated in primarily due to outage/system constraints
> blasting requires extensive outages of all nearby high voltage plant due to garnet overspray, these risks were not considered in PSCR
> there are safety risks and cost impacts of blasting steelwork with lead contaminated paint which were also not considered in the PSCR.

Due to the issues described above, the cost estimate of refurbishing the existing gantries in the PSCR is not adequate to cover the scope of Option 1. The risk that the cost estimates could be too low was noted in the PSCR:

The estimated capital cost is between $18 million and $24 million depending on the extent of work required to address corrosion and the final selected remediation methods across the site. Where corrosion is pervasive, more extensive and costly remediation works will be necessary. It is expected

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[2] TransGrid manages and mitigates safety risk to ensure they are below risk 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). In particular, risks for TransGrid and its consumers 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.

that more accurate cost estimates will be provided in the Project Assessment Conclusions Report (PACR) as detailed scoping is progressed.[3]

As the cost estimate of refurbishing the gantries outlined in the PSCR was much lower than the current estimates, more time has been spent developing better ways to address the need. In this PADR, TransGrid has updated the cost estimates and developed a new option to replace the gantries, which would result in a 45-year life extension.

Replacing gantries provides the most enduring benefits

TransGrid considers that there are two feasible options from a technical and project delivery perspective, which are replacing or refurbishing the gantries. Both options would involve removal of gantries that are not essential to the future operation of the substation resulting in fewer gantry structures being required at the site. Both options effectively address the risk of outages due to gantry failure, however the option to replace the gantries results in structures with a 45-year life but the option to refurbish the structures would result in the existing assets being extended only 20 years. Both options include refurbishment of the holding down bolts.

The difference in asset life is the key reason why option 2 to replace the gantries results in far greater benefits than option 1 to refurbish the existing assets and why option 2 is the preferred option. In other words, replacing the gantries will reduce the risk of outages due to asset failure for an additional 25 years when compared to the option to only refurbish the gantries, which significantly reduces the expected cost of unserved energy. Further, under option 1, refurbished assets will likely have a slightly higher expected failure rate and therefore a higher expected unserved energy for the initial 20 years.

It is expected that the remediation works will be undertaken in various stages. The two broad stages to replacing all corroded elements are:

> Stage 1 (2018/19 to 2020/21) – Planning and procurement (including completion of the RIT-T)

> Stage 2 (2020/21 to 2023/24) – Project delivery and construction.

The estimated capital cost is $42.5 million (-/+ 25%) in 2019/20 dollars. It is expected that more accurate cost estimates will be provided in the Project Assessment Conclusion Report (PACR) as detailed scoping is progressed.

Planned operating costs are not expected to materially differ from the base case once remediation of corroded members and bolts has been completed. There are expected to be significantly lower unplanned maintenance costs associated with this option, though the work is designed to eliminate gantry failures due to corrosion.

Extensive planned outages and staging will be necessary in order to complete the construction works.

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

The PSCR 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. This is driven by the fundamental role that the identified gantries play in the transmission of electricity at a substation; the enduring need for Sydney South substation.

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[3] TransGrid. *"Managing the Sydney South Substation's Asset Risks RIT-T – Project Specification Consultation Report."* Sydney: TransGrid, 2018.4. Accessed 13 November, 2019. https://www.transgrid.com.au/what-we-do/projects/regulatory-investment-tests/Documents/TransGrid%20PSCR%20-%20Managing%20the%20Sydney%20South%20Substation%27s%20Asset%20Risks.pdf

Net benefits have been estimated across three different 'scenarios'

TransGrid has considered three alternative scenarios in this PADR:

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. The scenarios include:

> A 'low benefit' scenario, involving a number of assumptions that give rise to a lower bound Net Present Value (NPV) estimate for the options, in order to represent a conservative future state of the world with respect to potential benefits that could be realised.

> A 'central' scenario, which consists of assumptions that reflect TransGrid's central set of variable estimates which TransGrid considers to be the most likely scenario.

> A 'high benefit' scenario – this scenario reflects an optimistic set of assumptions, which have been selected to investigate an upper bound on reasonably expected net benefits.

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

Table E-2 Summary of the three scenarios investigated

Variable / Scenario	Central	Low benefit scenario	High benefit scenario
Scenario weighting	50%	25%	25%
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Value of customer reliability (VCR)	$90/kWh	$40/kWh	$90/kWh
Demand forecast	POE 50	POE 90	POE 10
Discount rate	5.90%	8.95%	2.85%
Safety and Financial risk costs	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%, with the other two scenarios being weighted equally with 25% each.

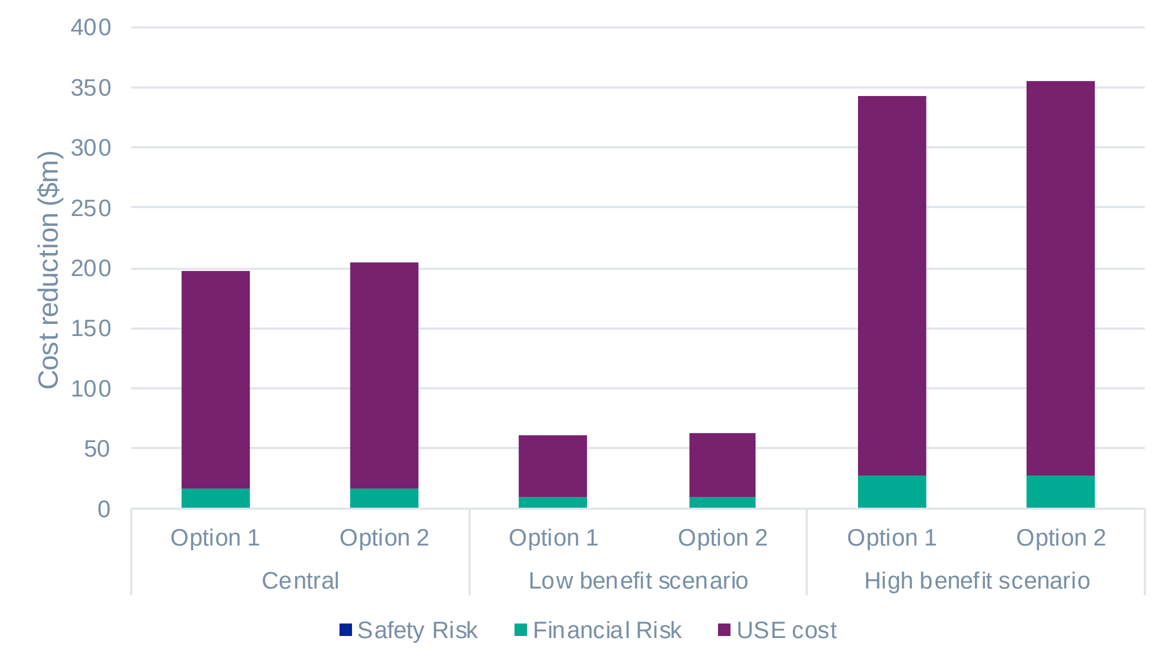
A $90/kWh VCR has been applied in the central and 'high benefits' scenarios since the unserved energy the investment is intended to avoid is in the Inner Sydney region. This is consistent with both the December 2016 Independent Pricing and Regulatory Tribunal's (IPART) Electricity Transmission Reliability Standards review as well as the recent Powering Sydney's Future RIT-T. Noting that there is uncertainty in any estimate of the VCR, we have included a VCR of $40/kWh in the 'low benefits' scenario (consistent with the 2014 AEMO estimates of VCR[4]) and also tested the thresholds for what the VCR would need to be to change the outcome of the RIT-T.

[4] $38.35/kWh adjusted for inflation. Australian Energy Market Operator. "Value of Customer Reliability Review- Final Report." Melbourne: Australian Energy Market Operator, 2014.30. Accessed 14 November 2019. https://www.aemo.com.au/-/media/Files/PDF/VCR-final-report--PDF-update-27-Nov-14.pdf

The proposed investment proposed significant positive net benefits

The figure below provides a breakdown of estimated benefits, showing almost all of the benefits are derived from avoided involuntary load shedding, while other avoided costs contribute relatively small amounts to overall gross benefits.

Figure E-1 Gross benefits for all credible options relative to the base case, present value ($m 2019/20)



The table below summaries the net market benefit in NPV terms across the three scenarios, as well as on a weighted basis. The table shows that the proposed investment is found to have positive net market benefits for all scenarios investigated. On a weighted basis, this investment is expected to deliver approximately $180.3 million in net economic benefits over the life of the investment.

Table E-3 Present value of net benefits relative to the base case ($m 2019/20)

Option/Scenario	Central	Low benefit scenario	High benefit scenario	Weighted
Option 1 Refurbish gantries	168.5	24.7	321.7	170.8
Option 2 Replace gantries	177.8	27.2	338.4	180.3

TransGrid has also conducted sensitivity analysis on the present value of the net market benefit to investigate the consequences of 'getting it wrong' having committed to a certain investment decision. For all sensitivity tests, the estimated net market benefit of replacing and refurbishing the assets is found to be positive.

The results are found to be most sensitive to the assumed VCR. TransGrid has extended this sensitivity exercise and found that there would need to be a VCR for Inner Sydney of less than $4.91/kWh (assuming no other variables change) to result in no expected net market benefits (NPV of zero) under the central scenario. While acknowledging there is uncertainty in any VCR estimate, TransGrid considers it unlikely that the central estimate has been overestimated to this extent.

Given the life extension offered by Option 2 is a key driver behind this option producing greater benefits than Option 1, TransGrid also modelled the benefits that are likely to be derived if the replacement assets remain in service for only 35 years instead of 45 years. In all scenarios the replacement option (Option 2) results in positive benefits and those benefits are greater than the benefits under Option 1.

Draft Assessment – the preferred option

The preferred option, Option 2, involves the renewal of holding down bolts and replacing the gantries at Sydney South substation. In particular, this involves the remediation of substation gantries at Sydney South substation, in a staged manner:

> treating corroded holding down bolts
> removing and replacing existing corroded gantry structures with new gantries

The resulting structures are expected to have a life of 45 years.

It is expected that the remediation works will be undertaken in various stages. The two broad stages to replacing all corroded elements are:

> Stage 1 (2018/19 to 2020/21) – Planning and procurement (including completion of the RIT-T)

> Stage 2 (2020/21 to 2023/24) – Project delivery and construction.

The estimated capital cost is $42.5 million (-/+ 25%) in 2019/20 dollars. It is expected that more accurate cost estimates will be provided in the Project Assessment Conclusion Report (PACR) as detailed scoping is progressed. Operating expenditure is not expected to be materially different from the base case.

The preferred option reduces the risk of substation gantry failure and this risk reduction outweighs the capital expenditure.

Submissions and next steps

TransGrid welcomes written submissions on material contained in this PADR. Submissions are due on or before 21 January 2020.

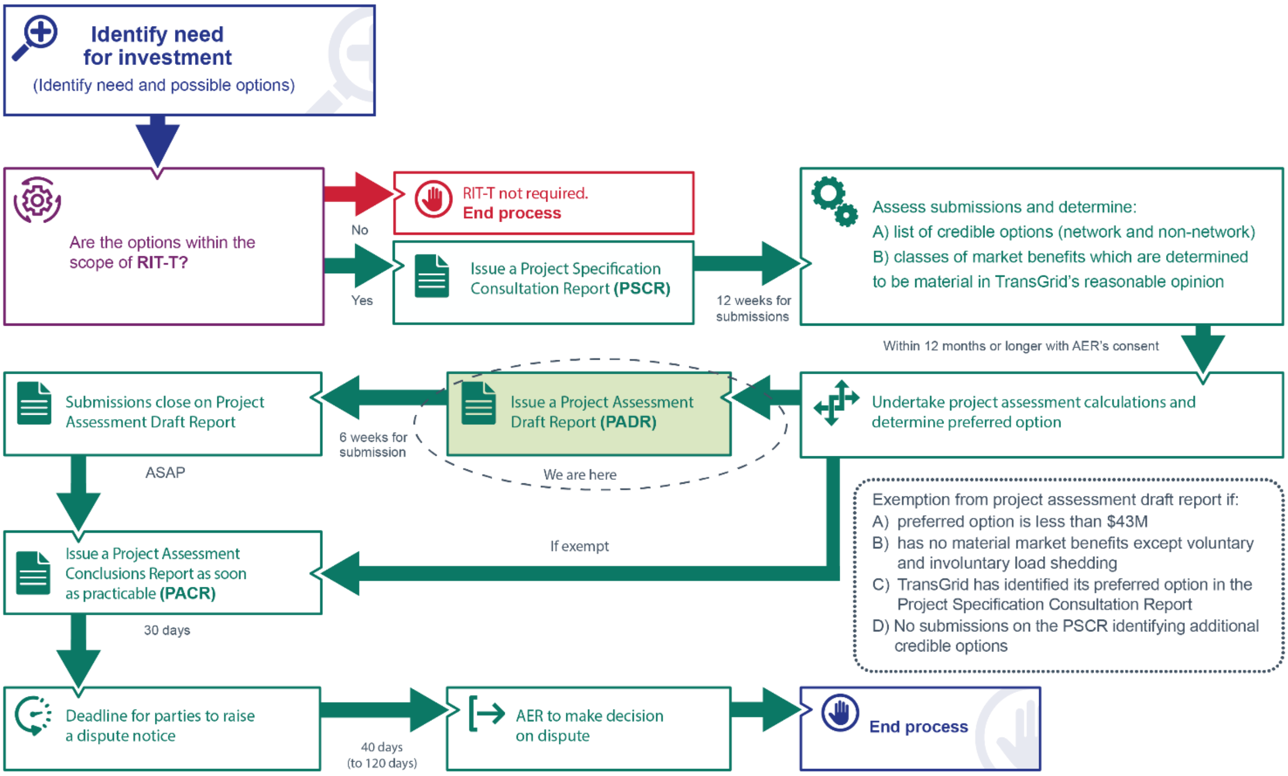
Submissions should be emailed to TransGrid's Regulation team via RIT-TConsultations@transgrid.com.au[5]. In the subject field, please reference 'PADR Sydney South substation steelworks project'.

Submissions will be published on the TransGrid website. If you do not want your submission to be made publicly available, please clearly specify this at the time of lodging your submission.

The next step in this RIT-T, following consideration of submissions received via the six-week consultation period and any further analysis required, will be publication of a Project Assessment Conclusion Report (PACR). TransGrid anticipates publication of a PACR by June 2020.

[5] TransGrid is bound by the Privacy Act 1988 (Cth). In making submissions in response to this consultation process, TransGrid will collect and hold your personal information such as your name, email address, employer and phone number for the purpose of receiving and following up on your submissions. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement. See the Disclaimer section of this PADR for more details.

Figure E-2 This PADR is the second stage of the RIT-T process[6]



6 Australian Energy Market Commission. "*Replacement expenditure planning arrangements, Rule determination*". Sydney: AEMC, 18 July 2017.65. Accessed 19 November 2019. https://www.aemc.gov.au/sites/default/files/content/89fbf559-2275-4672-b6ef-c2574eb7ce05/Final-rule-determination.pdf

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1. Introduction

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for mitigating asset risks caused by corroding gantries at Sydney South substation. Publication of this Project Assessment Draft Report (PADR) represents the second step in the RIT-T process.

At Sydney South substation, gantries support high voltage connections between switchbays and busbars. They are mainly used to support the power conductor in both directions between the transmission tower closest to the substation and the equipment within the substation. Gantries are connected to concrete footings by concrete plinths, holding down bolts and baseplates. They also support overhead earthwires that protect the substation equipment from direct lightning strikes and are essential for the safe and reliable operation of the substation.

TransGrid routinely assesses the condition and timing of replacement of its assets as part of its ongoing asset management processes. Asset condition assessments in the last few years have identified a number of corrosion related issues at the Sydney South substation and a plan has been developed to renew the affected steelwork. An allowance has been made for addressing substation gantry corrosion in TransGrid's 2018-23 Revenue Proposal to the Australian Energy Regulator.

Corrosion has been found on a large portion of gantries at Sydney South substation. The corrosion of holding down bolts and structural components, or 'members', ranges from initial development through to loss of steel thickness (cross-sectional area).

TransGrid's analysis indicates that the holding down bolts and gantry members will reach the end of serviceable life by 2021. After this time, the loss of physical cross-sectional area from corrosion will decrease their capacity to provide structural support. This reduces structural integrity and significantly increases their probability of structural failure, especially during high wind events. Deterioration of holding down bolts has occurred across the site and action is required on the majority of structure footings. If unaddressed, these issues may cause failure of gantries resulting in widespread outages and damage to other substation equipment.

1.1 Purpose of this report

The purpose of this PADR is to:

> Set out the reasons why TransGrid proposes that action be undertaken (the 'Identified Need')

> Present the options that TransGrid currently considers to address the identified need

> Outline the technical characteristics that non-network solutions would need to provide, whilst outlining how these solutions are unlikely to be able to contribute to meeting the identified need for this RIT-T

> Allow interested parties to make submissions and provide input to the RIT-T assessment.

> Provide TransGrid's draft assessment about the preferred option to address the need.

1.2 Submissions

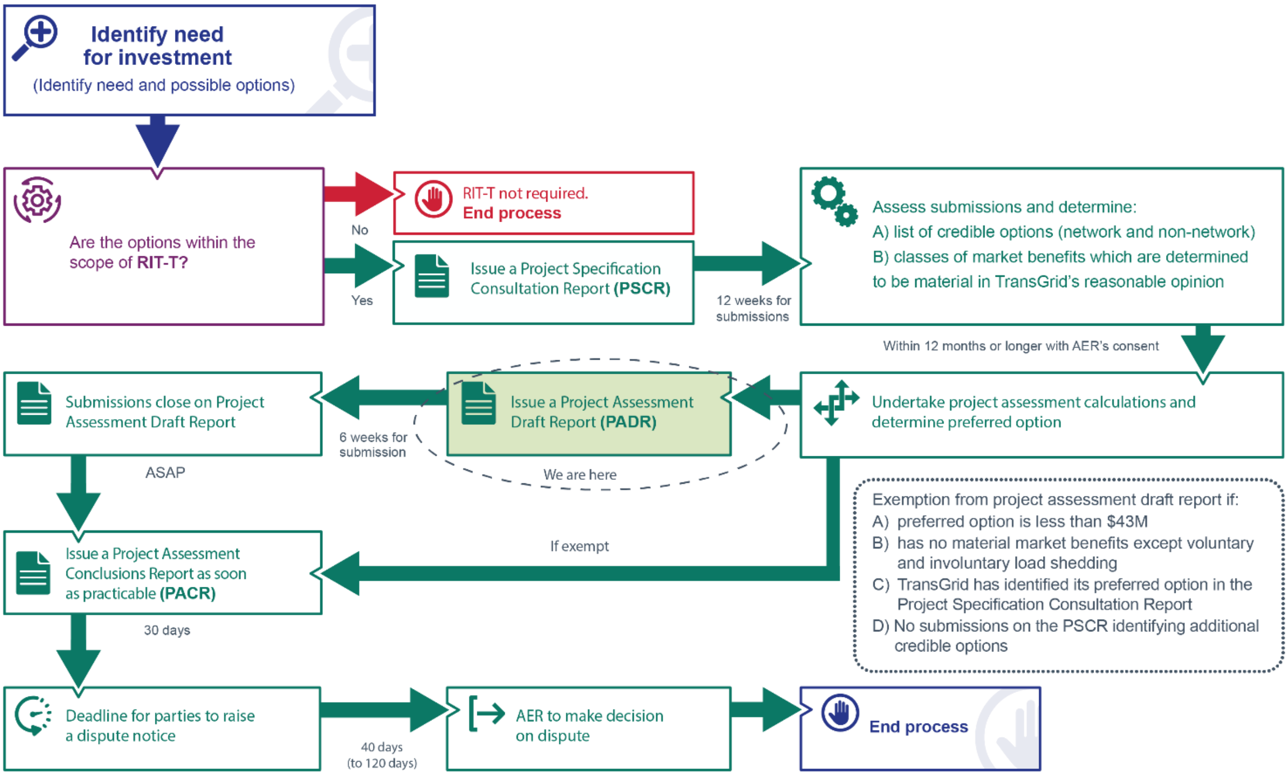
TransGrid welcomes written submissions on material contained in this PADR. Submissions are due on or before 21 January 2020.

Submissions should be emailed to TransGrid's Regulation team via RIT-TConsultations@transgrid.com.au . In the subject field, please reference 'PADR Sydney South substation steelworks project'.

Submissions will be published on the TransGrid website. If you do not want your submission to be made publicly available, please clearly specify this at the time of lodging your submission.

The next step in this RIT-T, following consideration of submissions received via the six-week consultation period and any further analysis required, will be publication of a Project Assessment Conclusion Report (PACR). TransGrid anticipates publication of a PACR by June 2020.

Figure 1-1 This PADR is the second stage of the RIT-T process[7]



7 Australian Energy Market Commission. "*Replacement expenditure planning arrangements, Rule determination*". Sydney: AEMC, 18 July 2017.65. Accessed 19 November 2019. https://www.aemc.gov.au/sites/default/files/content/89fbf559-2275-4672-b6ef-c2574eb7ce05/Final-rule-determination.pdf

2. The identified need for this RIT-T

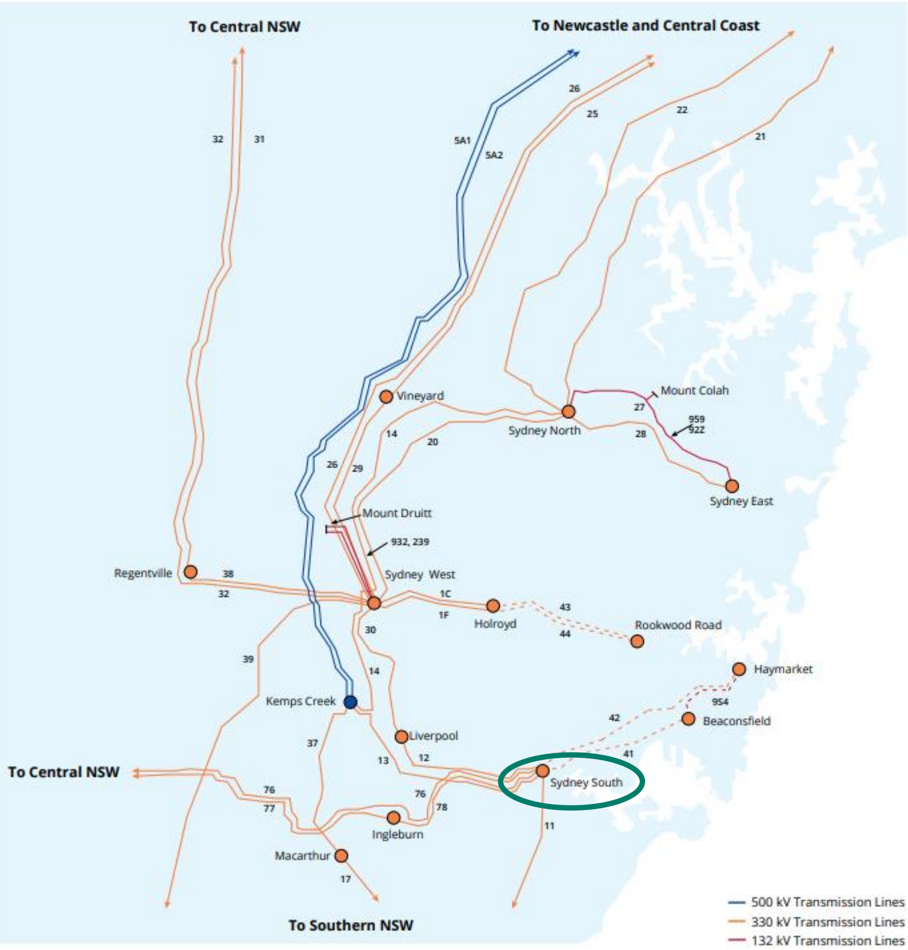
This section outlines the identified need for this RIT-T, as well as the assumptions and data underpinning it. It first sets out useful background on the Sydney South substation and the assets affected by corrosion.

2.1 Background to the identified need

TransGrid's Sydney South substation was established in 1961 and connects to TransGrid's Haymarket and Beaconsfield substations via two 330 kV underground cables (Cable 42 and Cable 41, respectively). The aforementioned substations are in-turn, classified as Ausgrid's bulk supply points (BSP), necessitating the 132 kV connections to Ausgrid's sub-transmission network. Haymarket BSP provides supplies to the Inner Sydney area which includes Sydney CBD loads, whereas Beaconsfield BSP provides supplies to Eastern Suburbs area.

Therefore, the criticality and significance of TransGrid's Sydney South substation in ensuring a safe and reliable supply cannot be overstated.

Figure 2-1 TransGrid's Greater Sydney network



Given its critical role, the Sydney South substation is required to meet redundancy category 3 reliability standards with only 0.6 minutes of expected unserved energy (EUE) allowed each year across Inner Sydney. These standards are set by the Independent Pricing and Regulatory Tribunal (IPART) and were last revised in December 2016.

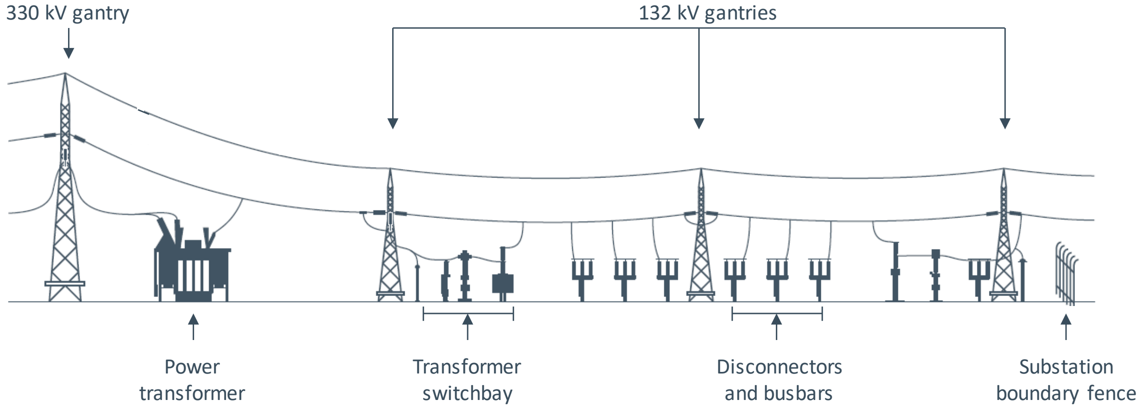
To meet these reliability standards, Sydney South substation comprises the following high voltage system assets:

> 330 kV switchbays to support:
  – five 330kV overhead transmission lines
  – two 330 kV cables
  – five 330 kV reactors
  – one 330 kV capacitor bank
  – six 330/132 kV transformers.
> 132 kV switchbays to support:
  – 12 Ausgrid 132 kV overhead transmission lines
  – six 330/132 kV transformers
  – two 132 kV capacitor banks.

The transmission assets at Sydney South substation, together with Rookwood Road substation, supply most of load in the Sydney CBD, Eastern suburbs and South Sydney. Sydney South is the largest TransGrid bulk supply point supplying Ausgrid's distribution network with summer maximum demand at estimated to be approximately 1,177 MW in 2019/20, increasing to 1,317 MW by 2028/29.[8] It follows that there is an ensuring need for Sydney South substation as a critical part of TransGrid's transmission network supplying Sydney.

At Sydney South substation, gantries support high voltage connections between switchbays and busbars. They are mainly used to support the power conductor in both directions between the transmission tower closest to the substation and the equipment within the substation. Gantries are connected to concrete footings by concrete plinths, holding down bolts and baseplates. They also support overhead earthwires that protect the substation equipment from direct lightning strikes and are essential for the safe and reliable operation of the substation. Figure 2-2 below, illustrates the role of gantries in the substation.

Figure 2-2 Simplified diagram of substation elements highlighting the role that gantries play



8 Summer maximum demand is estimated to increase to 1,317 MW by 2028/29. TransGrid. "*Transmission Annual Planning Report 2019*." Sydney: TransGrid, 2019. 81. Accessed 13 November, 2019. https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning/Documents/2019%20Transmission%20Annual%20Planning%20Report.pdf

The gantries at Sydney South substation date back to 1961 when the substation was commissioned and are now 58 years old. A large proportion of the gantry structural members at Sydney South exhibit evidence of corrosion that ranges from initial development to loss of thickness in gantry steelwork, commonly refered to as members and bolts. The loss of thickness in members and bolts reduces the structual integrity of gantry structures, which over time leads to increasing risk of structural failure, particularly during high wind events.

Examples of corrosion on gantry structural members are shown in the figures below.

Figure 2-3 View of gantry steel members showing corrosion

TransGrid's analysis indicates that the gantry members (as shown in Figure 2-3) and the holding down bolts (as shown in Figure 2-4) will reach their end of life by 2021. After this period, the probability of failure starts to increase as the capacity of members to provide support the required loads decreases due to the loss of physcial cross-sectional area.

Figure 2-4 and Figure 2-5 show examples of holding down bolts, base plates and member connection bolts displaying advanced stages of corrosion that TransGrid consider need to be addressed as a matter of urgency as some have already reached the end of their lives. It is also necessary to address the holding down bolts and base plates that have not yet displayed evidence of corrosion as it is expected that corrosion on these parts will commence in the near future.

Figure 2-4 View of corrosion to holding down bolts and baseplates

Figure 2-5 View of typical corrosion of member connection bolts

2.2 Description of the identified need

The proposed investment to address the corroded gantries has significant 'market benefits' as the proposed investment will help to avoid involuntary load shedding. Options considered under this RIT-T have been assessed relative to a base case. Under the base case, no proactive capital investment is made and the condition of Sydney South substation will continue to deteriorate. The investment will also assist TransGrid to manage and mitigate safety risks that would otherwise arise from a failure in substation gantries.[9]

The purpose of the proposed investment has similarities to those made under a reliability corrective action identified need (that is, to avoid involuntary load shedding), however the scope of the current reliability standards applicable to TransGrid do not extend to multiple failures of transmission network elements that would be expected to result from a failure of substation gantries (for example, damage to and failure of multiple busbar sections at the same substation). It follows that the proposed investment is driven by a 'market benefits' due to the lack of externally imposed obligations relating to multiple failures of transmission network elements.

The preferred investment proposed in this PADR will enable TransGrid to manage the risk associated with gantries at Sydney South substation, which is expected to realise strongly positive net market benefits. The approach to determining this, and the assessment itself, is presented in this PADR.

Appendix B outlines the assumptions underpinning the Identified Need.

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[9] TransGrid manages and mitigates safety risk to ensure they are below risk 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).[9] In particular, risks for TransGrid and its consumers 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.

3. Options that meet the identified need

TransGrid considers that there are two feasible options from a technical and project delivery perspective, which are refurbishing or replacing the gantries.

This section provides more information on the scope and cost of these options. It also outlines options considered but not progressed and how it is not expected to have a material inter-network impact.

Option 2 described below, is the preferred option at this second stage of the RIT-T. This option is considered to be both technically and commercially feasible and able to be implemented in sufficient time to meet the identified need. In addition, all works under this option are assumed to be completed in accordance with the relevant standards and components shall be replaced or refurbished with the objective of minimal modification to the wider transmission assets.

3.1 Base case

The costs and benefits of each option in this PADR were compared against those of a base case[10]. Under the base case, no proactive capital investment is made. Sydney South substation will not be remediated and will continue to operate with an increasing risk level. The substation will be maintained under the current regime and reactive replacement costs will be required. The substation failure risks will increase over time and these have been included in the base case in this RIT-T.

Annual operating costs are approximated at $400. This is the annualised cost of routine inspections.[11]

3.2 Option 1 – In-situ gantry steelwork renewal and remediation

Option 1 involves in-situ renewal of the steelwork by removing corrosion, painting and replacement of components where required. The scope of works is summarised in Table 3-1.

Table 3-1 Renewal and remediation works for Sydney South substation under Option 1

Issue	Remediation
Corrosion of gantry steel members	> Removal of rust via blasting of gantry columns, beams and earth wire peaks > Painting of blasted gantries with zinc-based paint > Replacement of connection bolts and steel members (if required)
Corrosion of gantry holding down bolts and base plates	> Removal of grout and corrosion > Painting and repair of holding down bolts and base plates > Reinstatement of grout

10 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

11 The planned operating costs presented in this PADR are comprised of routine maintenance costs. These costs typically include routine inspections but do not include costs associated with remediating defects detected during inspection. The severity of such defects is expected to continue to increase if a technically and commercially feasible option is not implemented in sufficient time to meet the identified need.

It is expected that the remediation works will be undertaken in various stages. The two broad stages to replacing all corroded elements are:

> Stage 1 (2018/19 to 2019/20) – Planning and procurement (including completion of the RIT-T)

> Stage 2 (2020/21 to 2022/23) – Project delivery and construction.

The estimated capital cost of Option 1 is $36.7 million in 2019/20 dollars depending on the extent of work required to address corrosion and the final selected remediation methods across the site. The estimate has increased from $18-24 million in the PSCR as a result of field trials which have shown that there are safety risks and difficulties in blasting in a live switchyard.

Table 3-2 Capital expenditure breakdown for Sydney South substation under Option 1 ($million 2019/20)

Item	Capital Expenditure
Gantry holding down bolt renewal	7.1
Gantry renewal	29.6
Total capital cost	**36.7**

Planned operating costs for Option 1 are not expected to materially differ from the base case once remediation of corroded members and bolts have been completed. There are expected to be significantly lower unplanned maintenance costs associated with Option 1 though as the work is designed to eliminate gantry failures due to corrosion.

Planned outages and staging will be taken as necessary to complete the construction works.

3.3 Option 2 – Replace substation gantries

At the time the PSCR was published, TransGrid's cost estimate for refurbishing the Sydney South substation gantries was primarily based on a desktop assessment of the activity required to refurbish the gantries. TransGrid has since undertaken additional investigations and onsite trials, in particular testing different blasting techniques. The field trials demonstrated:

- blasting in a live switchyard takes significantly longer than originally anticipated in primarily due to outage/system constraints
- blasting requires extensive outages of all nearby high voltage plant due to garnet overspray, these risks were not considered in PSCR
- there are safety risks and cost impacts of blasting steelwork with lead contaminated paint which were also not considered in the PSCR.

Due to the issues described above, the cost estimate of refurbishing the existing gantries in the PSCR is not adequate to cover the scope of Option 1. The risk that the cost estimates could be too low was noted in the PSCR:

> *The estimated capital cost is between $18 million and $24 million depending on the extent of work required to address corrosion and the final selected remediation methods across the site. Where corrosion is pervasive, more extensive and costly remediation works will be necessary. It is expected*

that more accurate cost estimates will be provided in the Project Assessment Conclusions Report (PACR) as detailed scoping is progressed.[12]

As the cost estimate of refurbishing the gantries outlined in the PSCR was much lower than the current estimates, more time has been spent developing better ways to address the need. In this PADR, TransGrid has updated the cost estimates and developed a new option to replace the gantries, which would result in a 45-year life extension.

This recent experience indicates the PSCR costs estimates ($18m to $24m) for refurbishing Sydney South substation presented in the PSCR was not adequate. As a consequence, Option 2 to replace the gantries is considered in this PADR. The scope of works is summarised in Table 3-3.

Table 3-3 Replacement works for Sydney South substation under Option 2

Issue	Remediation
Corrosion of gantry holding down bolts	> Removal of grout and corrosion > Painting and repair of holding down bolts > Reinstatement of grout
Gantry replacement	> Remove and replace existing corroded gantry structures with new gantries

Option 2, and also Option 1, would involve removal of gantries that are not essential to the future operation of the substation resulting in fewer gantry structures being required at the site. Fewer gantries may be viable by reconfiguring high voltage connections supported by the gantries to a more efficient layout. Some gantries which exhibit less corrosion may be subjected to treatment options rather than replacement.

It is expected that the remediation works will be undertaken in various stages. The two broad stages to replacing all corroded elements are:

> Stage 1 (2018/19 to 2020/21) – Planning and procurement (including completion of the RIT-T)

> Stage 2 (2020/21 to 2023/24) – Project delivery and construction.

The estimated capital cost of option 2 is $42.5m[13] (-/+ 25%) in 2019/20 dollars, depending on the final project methodology and outage staging.

Table 3-4 Capital expenditure breakdown for Sydney South substation under Option 2 ($million 2019/20)

Item	Capital Expenditure
Corrosion of gantry holding down bolts	7.1
Gantry replacement	35.4
Total capital cost	**42.5**

Given the extensive works that need to be planned for this new option, it is expected that more accurate cost estimates will be provided in the PACR as detailed scoping is progressed.

Planned operating costs for Option 2 are not expected to materially differ from the base case.

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[12] TransGrid. *"Managing the Sydney South Substation's Asset Risks RIT-T – Project Specification Consultation Report."* Sydney: TransGrid, 2018.4. Accessed 13 November, 2019. https://www.transgrid.com.au/what-we-do/projects/regulatory-investment-tests/Documents/TransGrid%20PSCR%20-%20Managing%20the%20Sydney%20South%20Substation%27s%20Asset%20Risks.pdf

[13] This estimate includes planning costs incurred to date, which are considered part of the total cost.

3.4 Options considered but not progressed

TransGrid has also considered whether there are other credible options that would meet the identified need. However, TransGrid considers that the identified need to address asset failure risk and safety risks associated with corroding components of substation gantries cannot be met by solutions other than those outlined above.

Table 3-5 below summarises three other options TransGrid considered as part of this RIT-T, and its earlier asset condition and replacement planning. The table also outlines the reasons why these options were not progressed further and have not been explicitly modelled alongside the options considered.

Table 3-5 Options considered but not progressed

Option	Reason(s) for not progressing
Replace Sydney South Substation	The option of replacing the entire substation is estimated to be in excess of $100m, which is significantly more than Option 1 and is not expected to provide any additional market benefits. In addition, rebuilding the substation may not be technically feasible as it is not possible to keep planned outages (necessary to deliver these options) to an acceptable level.
Stage the delivery of both operations over a longer period.	Following further development of Option 1 and Option 2, it has been determined that extensive outages and staging will be required. There are cost efficiencies associated with renewing all identified components in the shortest duration as possible, as opposed to intentionally spreading the work out over longer periods. In addition, delaying the replacement of any components comes with a greater expected risk value. The combination of greater costs and less expected benefits (in terms of avoided risk costs) has led TransGrid to consider this option commercially infeasible relative to Option 1 and 2, so on that basis it was not progressed.
Decommissioning of all substation gantries	This option is not considered technically feasible due to requirement for the substation to fulfil the required functionality for the transmission network.

In addition, as set out in section 4 below, TransGrid does not consider that non-network solutions can feasibly address, or help to address, the identified need to undertake network investment. This is driven by the fundamental role that the identified gantries play in the transmission of electricity at a substation, the enduring need for the Sydney South substation.

TransGrid remains open to considering credible non-network options that address the identified need and are commercially and technically feasible. A more detailed discussion is provided in section 4.

While TransGrid has considered two credible options from a technical and project delivery perspective (replacing or refurbishing the identified corroded components in one-go), TransGrid has investigated different assumed commissioning dates for this option in order to identify the optimal commissioning date. This assessment is presented in section 7.4.1 below.

3.5 There is not expected to be a material inter-network impact

TransGrid has considered whether Options 1 and 2 are expected to have a material inter-regional impact.[14]

A 'material inter-network impact' is defined in the NER as:

> *"A material impact on another Transmission Network Service Provider's network, which 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:[15]

- 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; and
- the investment does not involve either a series capacitor or modification in the vicinity of an existing series capacitor.

TransGrid notes that Options 1 and 2 satisfies these conditions as it does not modify any aspect of electrical or transmission assets. As a consequence, by reference to AEMO's screening criteria, there are no material inter-network impacts associated with Option 2.

14 In accordance with NER clause 5.16.4(b)(6)(ii).

15 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.

4. Non-network options

TransGrid does not consider that non-network solutions can assist with meeting the identified need for this RIT-T. This is driven by the fundamental role that the identified gantries play in the transmission of electricity at a substation, the enduring need for the Sydney South substation. Notwithstanding, this section sets out the required technical characteristics for a non-network options, consistent with the requirements of the RIT-T.

4.1 Required technical characteristics of non-network options

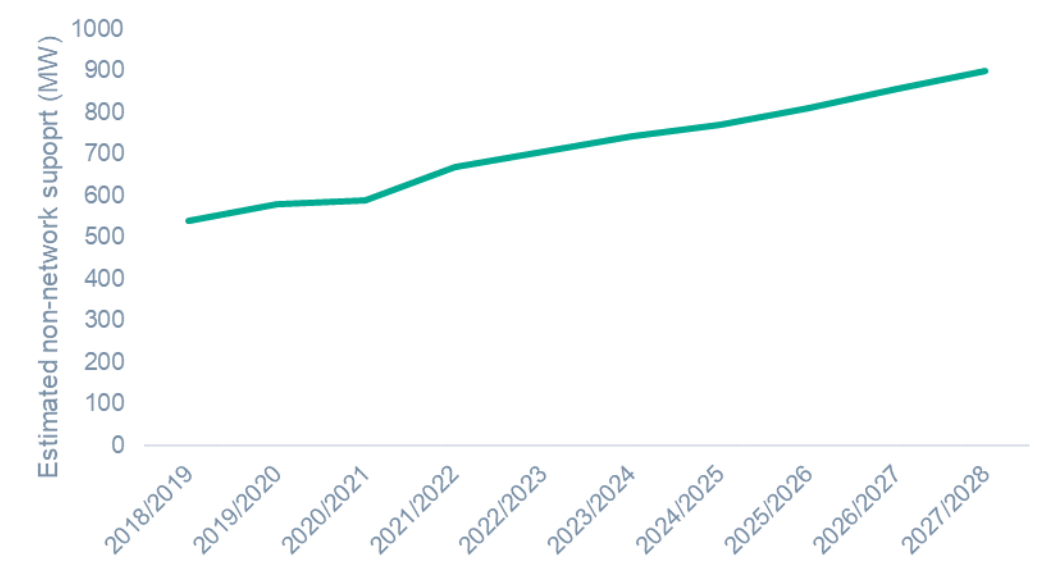
As outlined in section 2, the identified gantries are essential for the operation of the Sydney South substation.

A network support option that avoids the replacement work identified in Option 1 and Option 2 would therefore need to replicate the functionality, capacity and reliability of the substation on an enduring basis at a cost that is lower than the network options currently under consideration.

TransGrid considers that the extent of the load in question make this commercially and technically infeasible for non-network solutions.

The figure below illustrates the estimated maximum load required from a non-network option during an assumed one-week outage of the Sydney South substation (such as following a high wind event) over the next ten years. While this is a theoretical maximum, assuming the repair occurs during the peak demand period of the year, it provides an indication of the amount of support that would be required in Inner Sydney.

Figure 4-1 Indicative non-network support required during an outage



In addition, TransGrid notes that there are a number of downstream Ausgrid zone substations whose sole supply is from Sydney South.

TransGrid considers that a non-network option would be required to meet these loads on a continuous basis, potentially 24 hours a day over the period of any outage.

While non-network options may be technically possible, TransGrid considers that such solutions at the scale required is unlikely to be commercially feasible.

5. 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.[16]

5.1 Changes in involuntary load curtailment are the only material category

Changes in involuntary load curtailment is the only material category of market benefit for this RIT-T. In particular, Option 1 and Option 2 resolve the asset condition issues identified that, if unaddressed (under the base case), are forecast to result in significant amounts of unserved energy for end consumers. Option 1 will result in refurbished assets which will reduced the risk of unserved energy for 20 years and Option 2 will result in a reduction in unserved energy for 45 years as the new gantries would have a much longer asset life.

As outlined in Appendix B.3, the unserved energy under the base case arises from downstream Ausgrid distribution zone substations that rely solely on Sydney South substation. Ausgrid's Revesby and Milperra zone substations will be disconnected to the network and some of Ausgrid zone substations in south Sydney region would need to shed load to maintain voltage stability across the network if the gantries fail.

5.2 Market benefits relating to the wholesale market are not material

The AER has recognised that if the credible options considered will not have an impact on the wholesale 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.[17]

Option 1 and Option 2 outlined above do 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 for TransGrid (since there will be no deferral of generation investment)
> changes in ancillary services costs
> competition benefits
> Renewable Energy Target (RET) penalties.

5.3 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 in relation to each credible option: differences in the timing of

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16 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)(iii), 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.

17 Australian Energy Regulator. *"Application guidelines Regulatory Investment Test for Transmission - December 2018."* Melbourne: Australian Energy Regulator, 2018. 32. Accessed 19 November 2019. https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf

transmission investment; option value; and changes in network losses. TransGrid considers that none of the classes of market benefits listed are material for this RIT-T assessment for the reasons in Table 5-1.

Table 5-1 Reasons why non-wholesale market benefit classes are considered immaterial

Market benefits	Reason
Differences in the timing of expenditure	Option 1 and Option 2 are not expected to affect the timing of scope of any unrelated transmission investment.
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 in the future is likely to change 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 changes in future demand levels are not relevant for this RIT-T, since the need for and timing of the required investment is being driven by asset condition rather than future demand growth. As a result, it is not relevant to consider different future demand scenarios in undertaking the RIT-T analysis. The estimation of any option value benefit would require a significant modelling assessment, which would be disproportionate to any additional option value benefit that may be identified for this specific RIT-T assessment. Therefore, TransGrid has not estimated any additional option value market benefit for this RIT-T assessment.
Changes in network losses	As there is no change to the transmission lines or the destination of the line under any of the options considered, there will not be any material market benefits associated with changes to network losses.

[18] Australian Energy Regulator. *"Application guidelines Regulatory Investment Test for Transmission - December 2018."* Melbourne: Australian Energy Regulator, 2018. 58.59. Accessed 19 November 2019. https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf

6. Overview of the assessment approach

This section outlines the approach that TransGrid has applied in assessing the net benefits associated with remediating steelwork on substation gantries at Sydney South substation.

6.1 General overview of the assessment framework

As outlined in section 3.1, all costs and benefits considered have been measured against a base case where the existing condition issues at Sydney South substation are assumed to not be remediated and the gantries will continue to operate, with an increasing risk level.

The RIT-T analysis has been undertaken over a 20-year period, from 2019/20 to 2038/39. TransGrid considers that a 20-year period takes into account the size, complexity and expected life of the refurbishment and the replacement options to provide a reasonable indication of the benefits and costs the options.

The capital components of the Option 1 and Option 2 have asset lives of 20 years and 45 years, respectively. As the capital components of Option 2 has an asset life extending beyond the end of the assessment period of 20 years. Therefore, the NPV modelling includes a terminal value to capture the remaining asset life. This ensures that the capital cost of long-lived options over the assessment period is appropriately captured, and that all options have their costs assessed over a consistent period, irrespective of option type, technology or asset life.

The choice of a 20-year period is considered to be conservative as the preferred option, Option 2, is likely to have significantly greater benefits of lower unserved energy over the 45-year period. In contrast, if a longer modelling period was chosen, then the cost of Option 1 would need to include further remediation or corrective maintenance costs when the refurbished gantries start to fail at the end of their 20-year life. In both circumstances the changes to the costs and the benefits under each option would reinforce Option 2 as the preferred option.

TransGrid has adopted a central real, pre-tax 'commercial' discount rate 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 published by Energy Networks Australia (ENA) in March 2019[19].

TransGrid has also tested the sensitivity of the results to discount rate assumptions. A lower bound real, pre-tax discount rate of 2.85% equal to the latest AER Final Decision for a TNSP's regulatory proposal at the time of preparing this PSCR[20], and an upper bound discount rate of 8.95% (a symmetrical adjustment upwards) were investigated.

6.2 Approach to estimating project costs

TransGrid has estimated the capital costs of Option 1 and Option 2 by considering the scope of works necessary together with costing experience from previous projects of a similar nature. TransGrid considers the central capital costs to be estimated to within +/- 25 per cent of the actual cost.

Routine operating and maintenance cost are not expected to be material under either Option 1, Option 2 or the base case as these costs relate to planned routine inspections by TransGrid field staff.

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[19] Available at https://www.energynetworks.com.au/rit-t-economic-assessment-handbook Note the lower bound discount rate of 2.85% is based on the most recent final decision for a TNSP revenue determination which was TasNetworks in April 2019.

[20] See 2019-24 TasNetworks' Transmission Post-tax Revenue Model (PTRM) cashflow derived pre-tax real WACC available at: https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/tasnetworks-determination-2019-24/final-decision

Reactive maintenance costs under the base cost have been estimated by considering both the:

- level of reactive maintenance required to restore assets to working order following a physical failure
- probability and expected level of network asset faults, which translates to the level of corrective maintenance costs.

Option 1 reduces the incidence of asset failures relative to the base case substantially for 20 years, and hence the expected operating and maintenance costs associated with restoring supply. Option 2 provides the same benefit but for 45 years, however Option 2 would result in completely new gantry structures being installed and would likely have slightly lower asset failure rates when compared to the refurbished assets under Option 1. This has been accounted for in the NPV modelling with Option 1 having slightly higher unserved energy than Option 2.

6.3 Three different 'scenarios' have been modelled to address uncertainty

RIT-T assessments are required to be based on cost-benefit analysis that includes an assessment of 'reasonable scenarios', which are designed to test alternate sets of key assumptions and whether they affect identification of the preferred option.

TransGrid has constructed three alternative scenarios for this PADR assessment – namely:

- a 'low benefit' scenario, involving a number of assumptions that give rise to a lower bound NPV estimate for the refurbishment option, in order to represent a conservative future state of the world with respect to potential benefits that could be realised
- a 'central' scenario, which consists of assumptions that reflect TransGrid's central set of variable estimates which, in TransGrid's opinion, provides the most likely scenario
- a 'high benefit' scenario – this scenario reflects an optimistic set of assumptions, which have been selected to investigate an upper bound on reasonably expected net benefits.

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

Table 6-1 Summary of the three scenarios investigated

Variable / Scenario	Central	Low benefit scenario	High benefit scenario
Scenario weighting	50%	25%	25%
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
VCR	$90/kWh	$40/kWh	$90/kWh
Demand forecast	POE 50	POE 90	POE 10
Discount rate	5.90%	8.95%	2.85%
Safety and Financial risk costs	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%, with the other two scenarios being weighted equally with 25% each.

A $90/kWh VCR has been applied in the central and 'high benefits' scenarios since the unserved energy the investment is intended to avoid is in the Inner Sydney region. This is consistent with both the December 2016 Independent Pricing and Regulatory Tribunal's (IPART) Electricity Transmission Reliability Standards review as well as the recent Powering Sydney's Future RIT-T. Noting that there is uncertainty in any estimate of the VCR, we have included a VCR of $40/kWh in the 'low benefits' scenario (consistent with the 2014 AEMO estimates of VCR[21]) and also tested the thresholds for what the VCR would need to be to change the outcome of the RIT-T.

21 Australian Energy Market Operator. "Value of Customer Reliability Review- Final Report." Melbourne: Australian Energy Market Operator, 2014. Accessed 14 November 2019. https://www.aemo.com.au/-/media/Files/PDF/VCR-final-report--PDF-update-27-Nov-14.pdf

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 the option to a base case. Under the base case, no proactive capital investment is made. Sydney South substation will not be remediated and will continue to operate with an increasing risk level. The substation will be maintained under the current regime and reactive replacement costs will be required. The substation failure risks will increase over time and these have been included in the base case in this RIT-T.

7.1 Benefits estimated

The table below summarises the benefit estimated for Option 1 and Option 2 relative to the base case in present value terms. The benefit has been calculated for each of the three reasonable scenarios outlined in the section above.

The only 'market benefit' under the RIT-T arises from the proposed investment avoiding involuntary load shedding, while other benefits relate to avoided costs from avoiding emergency reconstruction works[22] and avoiding safety incidents. These avoided costs are *expected* costs in that the actual cost (if an event occurs) has been multiplied by the chance of it occurring.

The 'low' and 'high' scenarios reflect lower and upper bounds on TransGrid's expectations regarding these market and avoided cost benefits.

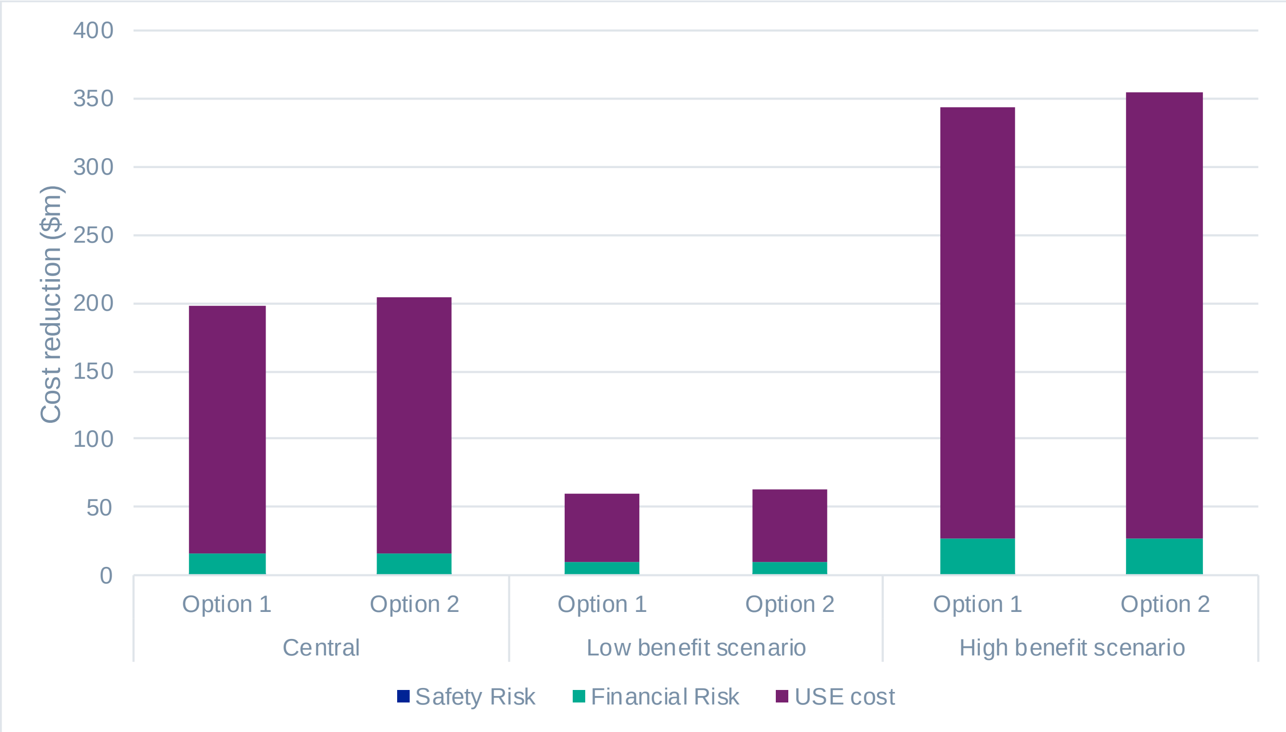
Table 7-1 Present value of gross benefits relative to the base case (2019/20 $m)

Option/scenario	Central	Low benefit scenario	High benefit scenario	Weighted
Scenario weighting	*50%*	*25%*	*25%*	
Option 1	197.9	60.5	343.8	200.0
Option 2	204.4	62.3	355.2	206.6

[22] Financial risk costs

The figure below provides a breakdown of benefits estimated for the options, showing almost all the benefits are derived from avoided involuntary load shedding, while other avoided costs contribute relatively small amounts to overall gross benefits.

Figure 7-1 Breakdown of gross benefits for credible options relative to the base case, present value (2019/20 $m)



7.2 Estimated costs

The table below summarises the costs of the options, relative to the base case, in present value terms. The cost of Option 1 and Option 2 has been calculated for each of the three reasonable scenarios outlined above.

Table 7-2 Present value of costs of credible options relative to the base case (2019/20 $m)

Option/Scenario	Central	Low economic benefit	High economic benefit	Weighted
Scenario weighting	*50%*	*25%*	*25%*	
Option 1	29.4	35.8	22.1	29.2
Option 2	26.6	35.2	16.8	26.3

7.3 Net market benefits

The table below summarises the net market benefit in NPV terms across the three scenarios, as well as on a weighted basis. The net market benefit is the benefits minus the costs, all in present value terms.

The table shows that both options have positive net market benefits for all scenarios investigated. On a weighted basis, Option 2, the preferred option is expected to deliver approximately $180.3 million in net market benefits.

Table 7-3 Present value of net benefits relative to the base case (2019/20 $m)

Option/Scenario	Central	Low benefit scenario	High benefit scenario	Weighted
Option 1	168.5	24.7	321.7	170.8
Option 2	177.8	27.2	338.4	180.3

Overall, TransGrid's analysis shows that the investment to remediate steelwork gantries at Sydney South substation is highly positive in NPV terms, even under the low benefit scenario where the preferred option is expected to generate $27.2 million in net economic benefits. The assumptions feeding into the low scenario include:

> high expected network capital costs

> a VCR of $40/kWh

> a low POE90 demand forecast

> a commercial discount rate of 8.95 per cent

> low assumed avoided emergency rebuild risks[23] under the base case.

Furthermore, underlying assumptions used to generate these results are considered conservative – namely:

> a constant probability of failure equal to 1.8 per cent is applied each year – despite escalating probabilities in reality as asset conditions deteriorate

> only the impact of 132 kV transmission equipment (that is, 132 kV busbars) has been considered in the development of the risk cost – there is an additional risk cost associated with the deterioration of the 330 kV gantries, which has not been included

> it would only take five days to recover in the event of gantry failure, limiting the amount of time involuntary load shedding would be incurred – this assumption reflects a highly optimistic view of the ability for TransGrid and its contractors to recover from gantry and transmission equipment failure.

More severe outcomes would be expected to occur in reality than reflected in the above conservatively low assumptions and this would result in a significant increase in the net economic benefits arising from the proposed investment. However, a conservative approach has been adopted for the purposes of this RIT-T given that refinement of these assumptions would involve extensive and time-consuming modelling that will not change the outcome of the RIT-T (in terms of the identified preferred option).

[23] Financial risk costs

7.4 Sensitivity testing

TransGrid has undertaken thorough sensitivity testing exercise to understand the robustness of the RIT-T assessment to underlying assumptions about key variables.

In particular, we have undertaken two sets of sensitivity tests – 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 therefore undertaken sensitivity analysis to first determine the optimal timing of the project, to conclude that a particular year represents the 'most likely' date at which the project will be needed.

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 demand forecasts are not as high as expected, for example, consideration of what the impact would be on the net market benefit associated with the project continuing to go ahead on that date.

We outline how each of these two steps have been applied to test the sensitivity of the key findings below.

7.4.1 Step 1 – Sensitivity testing of the assumed optimal timing for the credible option

TransGrid has estimated the optimal timing for the options based on the year in which the NPV is maximised. This process was undertaken for both the central set of assumptions and also a range of alternative assumptions for key variables.

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

> lower and higher capital costs of the central estimate plus 25% and minus 25%, respectively

> lower discount rate of 2.85 per cent as well as a higher rate of 8.95 per cent

> lower VCR of $40/kWh

> lower and higher demand forecasts.

The results of the sensitivity analysis determined that the optimal timing of commissioning for Option 2 under all sensitivities is found to be in 2023/24.

7.4.2 Step 2 – Sensitivity of the overall net market benefit

TransGrid has also conducted sensitivity analysis on the overall NPV of the net market benefit, based on the optimal option timing established in Step 1.

Specifically, TransGrid has investigated the same sensitivities under this second step as in the first step:

> lower and higher capital costs

> lower discount rate of 2.85 per cent as well as a higher rate of 8.95 per cent

> lower VCR of $40/kWh.

> lower and higher demand forecasts

> lower and higher safety and financial 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 market benefits for each option if we vary the separate key assumptions in the central scenario individually. Importantly, for all sensitivity tests shown below, the estimated net market benefit of Option 1 and Option 2 are found to be positive, with the benefits of Option 2 being greater.

The results are found to be most sensitive to the assumed VCR. TransGrid has extended this sensitivity exercise and found that there would need to be a VCR for Inner Sydney of less than $4.91/kWh (assuming no other variables change) to result in no expected net market benefits (NPV of zero) under the central scenario. While acknowledging there is uncertainty in any VCR estimate, TransGrid considers it unlikely that the central estimate has been overestimated to this extent.

Figure 7-2 Sensitivity testing

8. Draft Assessment

The preferred option, Option 2, involves the renewal of holding down bolts and replacing the gantries at Sydney South substation. In particular, this involves the remediation of substation gantries at Sydney South substation by, in a staged manner:

> treating corroded holding down bolts
> removing and replacing existing corroded gantry structures with new gantries

The resulting structures are expected to have a life of 45 years.

It is expected that the remediation works will be undertaken in various stages. The two broad stages to replacing all corroded elements are:

> Stage 1 (2018/19 to 2020/21) – Planning and procurement (including completion of the RIT-T)

> Stage 2 (2020/21 to 2023/24) – Project delivery and construction.

The estimated capital cost is $42.5 million (-/+ 25%) in 2019/20 dollars. It is expected that more accurate cost estimates will be provided in the Project Assessment Conclusion Report (PACR) as detailed scoping is progressed. Operating expenditure is not expected to be materially different from the base case.

The preferred option reduces the risk of substation gantry failure and this risk reduction outweighs the capital expenditure.

TransGrid welcomes written submissions on material contained in this PADR. Submissions are due on or before 21 January 2020.

Submissions should be emailed to TransGrid's Regulation team via RIT-TConsultations@transgrid.com.au[24]. In the subject field, please reference 'PADR Sydney South substation steelworks project'.

Submissions will be published on the TransGrid website. If you do not want your submission to be made publicly available, please clearly specify this at the time of lodging your submission.

The next step in this RIT-T, following consideration of submissions received via the six-week consultation period and any further analysis required, will be publication of a Project Assessment Conclusion Report (PACR). TransGrid anticipates publication of a PACR by June 2020.

[24] TransGrid is bound by the Privacy Act 1988 (Cth). In making submissions in response to this consultation process, TransGrid will collect and hold your personal information such as your name, email address, employer and phone number for the purpose of receiving and following up on your submissions. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement. See the Disclaimer section of this PADR for more details.

Appendix A – Compliance checklist

This section sets out a compliance checklist which demonstrates the compliance of this PADR with the requirements of clause 5.16.4(k) of the National Electricity Rules version 127.

Rules clause	Summary of requirements	Relevant section(s) in the PADR
5.16.4(k)	A RIT-T proponent must prepare a report (the assessment draft report), which must include:	-
	(1) a description of each credible option assessed;	Section 3
	(2) a summary of, and commentary on, the submissions to the project specification consultation report;	No submissions were received
	(3) a quantification of the costs, including a breakdown of operating and capital expenditure, and classes of material market benefit for each credible option;	Section 3
	(4) a detailed description of the methodologies used in quantifying each class of material market benefit and cost;	Sections 6,7
	(5) reasons why the RIT-T proponent has determined that a class or classes of market benefit are not material;	Section 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);	Section 5
	(7) the results of a net present value analysis of each credible option and accompanying explanatory statements regarding the results;	Section 7
	(8) the identification of the proposed preferred option;	Section 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.	Section 3, 8

Appendix B – Assumptions underpinning the identified need

Failure of holding down bolts, column members (the vertical structures of the gantry) or beam members (the horizontal structures connected to the top of the columns) of gantry structures may lead to their failure, particularly during high wind events. This, in-turn, causes loss of supply and further potential damage to other substation assets due to the contact of high voltage conductors with the ground within the substation. Such a failure would likely lead to loss of supply to Ausgrid's downstream zone substations which in turn will trigger involuntary load shedding for end customers. In addition, the failure poses significant safety hazards for TransGrid field crews in attending and rectifying the site.

The need to undertake investment is predicated on the deteriorating condition of the identified assets affected by corrosion and the characteristics of any resultant physical asset failures.

As part of preparing its Revenue Proposal for the current regulatory period, TransGrid developed a Network Asset Risk Assessment Methodology to quantify risk for replacement and refurbishment projects. In particular, 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 realistic worst-case asset failure consequence and significantly moderates this down to reflect the likely consequence in the particular circumstances
- identifies safety and compliance obligations with a linkage to key enterprise risks.

This section summarises the key assumptions and data from the risk assessment methodology modelling that underpin the identified need for this RIT-T and the assessment undertaken by TransGrid in preparing its Revenue Proposal.[25] Section 6 provides further detail on the general modelling approaches applied, including the commercial discounts rate used.

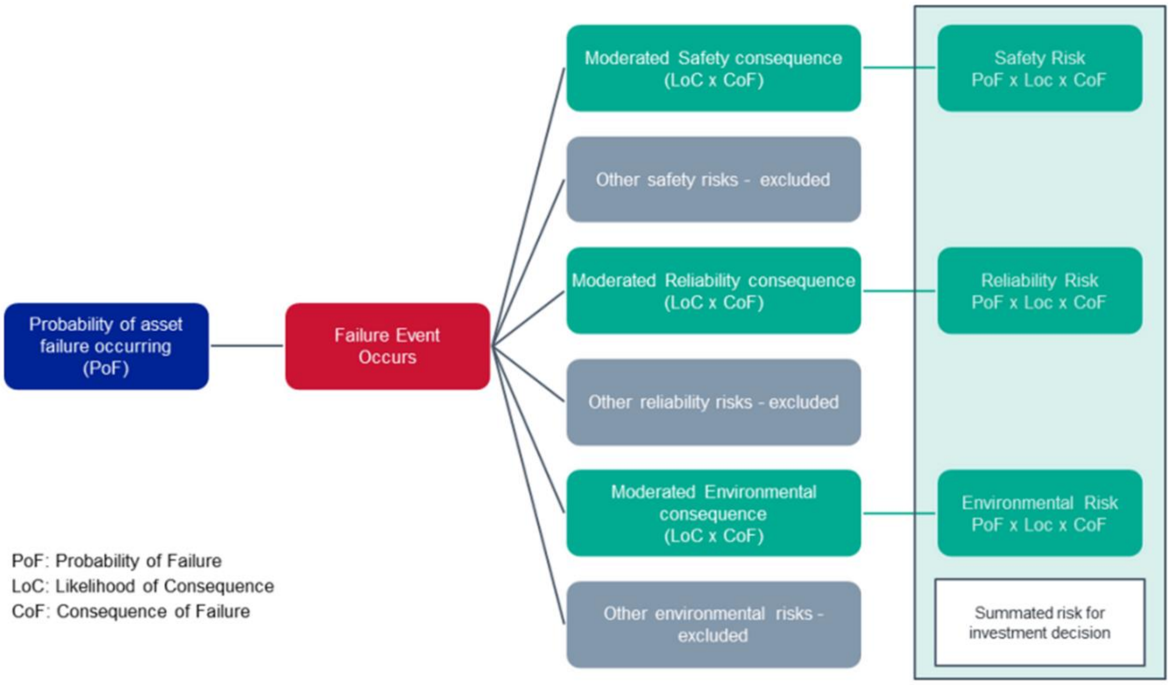
B.1 Overview of how the risks have been assessed

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

The figure below summarises the framework for calculating the 'risk cost', which has been applied across TransGrid's portfolio of assets considered to need replacing and/or refurbishing.

[25] 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

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



The ultimate 'risk costs' for a project are calculated based on the Probability of a Failure (PoF), the Consequence of Failure (CoF) and the corresponding Likelihood of consequence (LoC) in the particular situation.

In calculating the PoF, each failure mode that could result in a consequential impact is considered. For replacement planning, only 'life ending' failures are ultimately used to calculate the risk cost. PoF is calculated for each failure mode considering the asset condition and relevant wind loadings in accordance with the Australian standard.

In calculating the CoF and LoC, TransGrid uses a moderated 'worst case' consequence to value risk. This is an accepted approach in risk management with the benefit of ensuring that low probability but high consequence events are not dismissed or overlooked. It also excludes the risk costs of lower consequence but potentially more likely events (the resultant calculated risk is lower than it would be if these were included).

Recognising that this assessment approach has inherent uncertainty built into it, this RIT-T investigates a number of different scenarios and sensitivities that have been designed to see whether assuming alternate assumptions regarding risks and consequences (as well as other variables, such as the discount rate assumed) have an impact on the identification of the preferred option. These are outlined in more detail in sections 6.3 and 7.4 below and the results, in terms of the effects on net benefits are presented in section 7.

B.2 Substation gantry condition issues and their consequences

TransGrid's asset condition assessments in September 2016 identified a number of corrosion related issues with substation gantries, which can be grouped into:

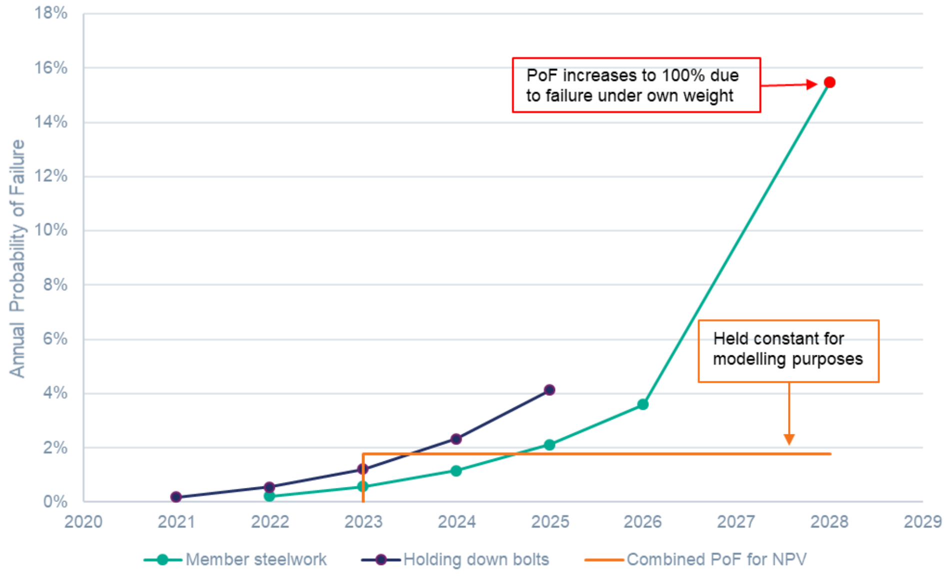
> corrosion on member sections
> corrosion on bolts, base plates and member connection bolts.

Corrosion on a member section reduces its cross-sectional area (ie, thickness) and the capacity of the member section to support the required load. Measurements already confirm up to 8 per cent of the cross-sectional area being lost in 2016. Additional measurements were taken in 2018/19 to complete the structural analysis of the gantries. Based on the expected corrosion rates, TransGrid calculates that gantry members will on average reach end of life in 2021 without remediation. When the end of life is reached, the probability of failure will start to increase markedly. The probability is determined by the governing wind events in accordance with Australian standards.

As noted above, corrosion on holding down bolts, base plates and member connection bolts displaying advanced stages of corrosion and would need to be addressed as a matter of urgency. The end of life for holding down bolts, base plates and member connection bolts is calculated to be 2020 on average.

The figure below illustrates the average probability of failure for gantry members and holding down bolts at Sydney South substation between 2020 and 2028. In particular, it outlines the modelled average probability of failure for members and holding down bolts (in green and blue, respectively), as well as how TransGrid has assumed a constant expected combined probability of failure of 1.8 per cent/annum from 2023 onwards in the economic assessment presented in this PADR. This is a conservatively low representation of the risk as the probability of failure will certainly increase due to ongoing deterioration but has been assumed to demonstrate the need to address the gantries before they reach their end of life.

Figure B-2 Probability of failure at Sydney South substation



B.3 Avoiding unserved energy to consumers is the most substantial driver of this RIT-T

Failure of substation gantry steelwork or holding down bolts will lead to conductors contacting the ground within the substation and is also likely to damage critical substation assets that are in close proximity to substation gantries, such as feeder conductors, busbars, circuit breakers, and transformers. It is also likely to result in overhead earth wires contacting high voltage conductors which would also cause outages.

Damage to these transmission assets are likely to occur concurrently given their close proximity to substation gantries, which means the failure of a single substation gantry section is likely to cause extended supply outages and reduced network reliability that would require significant time to restore.

The prospect of extended supply outages and the subsequent involuntary load shedding exists, despite a meshed transmission network around Sydney due to:

> the high likelihood of damage to multiple transmission elements that could disable multiple feeders required to ensure reliable supply
> limited capacity to provide reactive support that would be needed to reroute load to TransGrid's Beaconsfield substation (which would likely necessitate some degree of load shedding to ensure network security)
> the fact that two Ausgrid substations are exclusively supplied from Sydney South substation.

Consequently, the risk associated with involuntary load shedding arises from downstream Ausgrid distribution zone substations that either rely solely on Sydney South substation or substations that would be required to shed load to maintain voltage stability across the network in the event of a substation gantry failure at Sydney South.

TransGrid has calculated expected risk costs of not making a proactive capital investment to address the need to be over $19 million in 2022, which is predominantly from involuntary load shedding[26]. If no proactive capital investment is made, these risk costs are expected to increase over time as loads at Sydney South substation increase and as the assets deteriorate further.

TransGrid has adopted two conservative simplifying assumptions that are used to provide lower bound estimates of these risk costs – namely:

> a constant probability of failure equal to 1.8 per cent is applied each year (as shown in Figure B-2 above), despite escalating probabilities in reality as asset conditions deteriorate
> gantry failures are only considered on the 132 kV transmission network, whereas Sydney South substation has gantries supporting both 132 kV and 330 kV transmission networks.[27]

TransGrid considers these conservative assumptions appropriate for this RIT-T. In particular, refining the assumptions to be more realistic are significant exercises and will not change the outcome of the RIT-T in terms of the identified preferred option (it will just *increase* the estimated net benefits).

The economic assessment shown in this PADR demonstrates that there are strong net benefits from the preferred investment under these conservative assumptions, even under our 'low benefits' scenario (as set out in section 7). In fact, under these assumptions, the assessment in section 7 below shows that the estimated VCR would need to decrease to $5.65/kWh to result in no net benefits from the preferred investment. TransGrid therefore considers it extremely unlikely that the true underlying reliability risk costs would fall outside this sensitivity, particularly in light of the conservative assumption of a constant risk each year going forward.

Overall, the risk if nothing is done, is expected to increase beyond levels that could be considered in the long-term interests of consumers. It follows that TransGrid considers the condition of gantry steelwork and bolt corrosion must be addressed to ensure risks to consumers from falling substation gantries is reasonably minimised.

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26 This determination of per year risk cost is based on TransGrid's Network Asset Risk Assessment Methodology and incorporates variables such as likelihood of failure, various types of consequence costs and corresponding likelihood of occurrence.

27 This assumption has been made to simplify the analysis (estimating the PoF, LoC and CoC for the 330 kV gantries is a significant exercise and one that TransGrid considers is not warranted since the investment is strongly justified when considering just the 132 kV gantries).