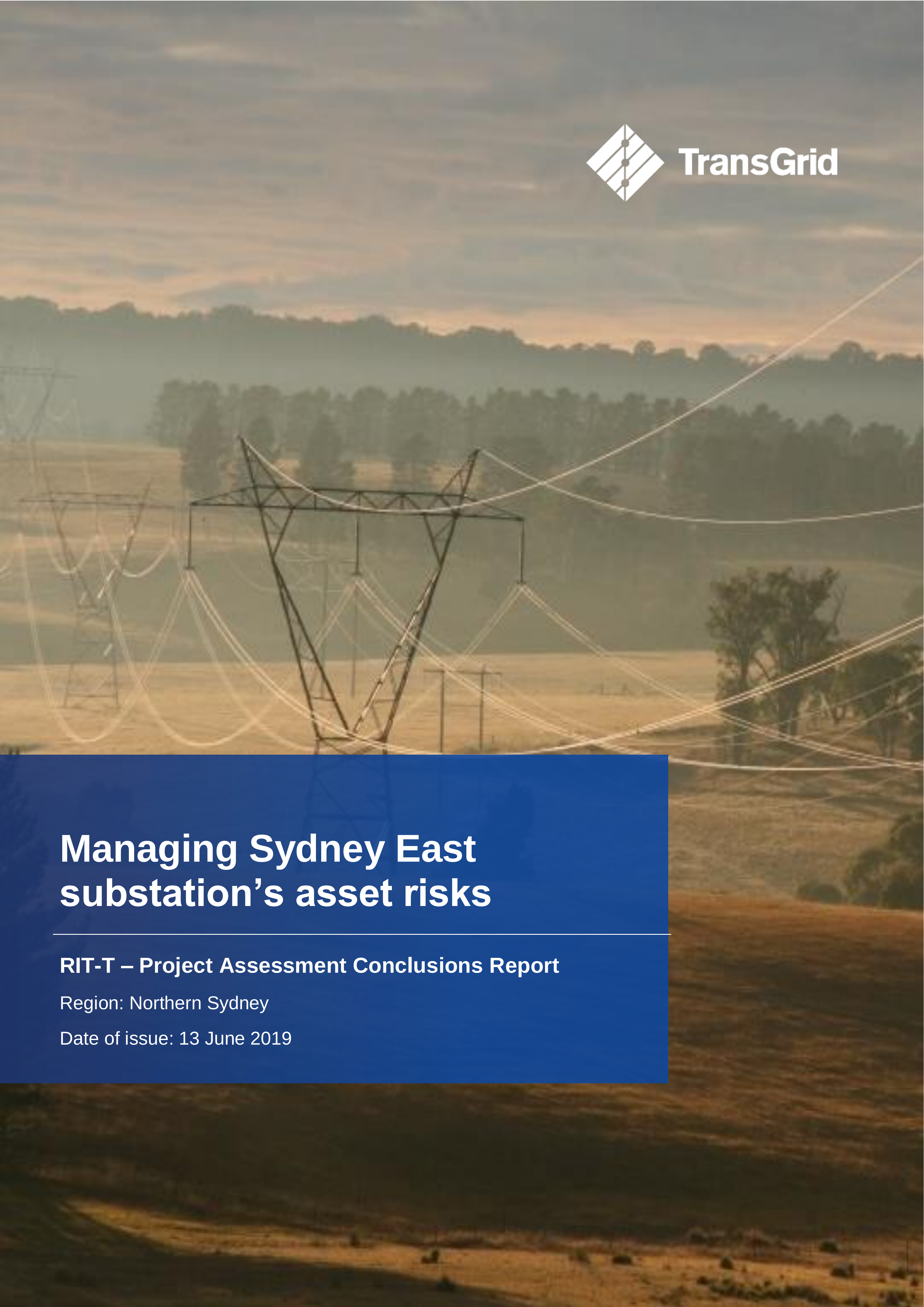


TransGrid

Managing Sydney East substation's asset risks

RIT-T – Project Assessment Conclusions Report

Region: Northern Sydney

Date of issue: 13 June 2019

Disclaimer

This suite of documents comprises TransGrid's application of the Regulatory Investment Test for Transmission (RIT-T) which has been prepared and made available solely for information purposes. It is made available on the understanding that TransGrid and/or its employees, agents and consultants are not engaged in rendering professional advice. Nothing in these documents is a recommendation in respect of any possible investment.

The information in these documents reflect the forecasts, proposals and opinions adopted by TransGrid as at 13 June 2019 other than where otherwise specifically stated. Those forecasts, proposals and opinions may change at any time without warning. Anyone considering information provided in these documents, at any date, should independently seek the latest forecasts, proposals and opinions.

These documents include information obtained from the Australian Energy Market Operator (AEMO) and other sources. That information has been adopted in good faith without further enquiry or verification. The information in these documents should be read in the context of the Electricity Statement of Opportunities, the Integrated System Plan published by AEMO and other relevant regulatory consultation documents. It does not purport to contain all of the information that AEMO, a prospective investor, Registered Participant or potential participant in the National Electricity Market (NEM), or any other person may require for making decisions. In preparing these documents it is not possible, nor is it intended, for TransGrid to have regard to the investment objectives, financial situation and particular needs of each person or organisation which reads or uses this document. In all cases, anyone proposing to rely on or use the information in this document should:

1. Independently verify and check the currency, accuracy, completeness, reliability and suitability of those information
2. Independently verify and check the currency, accuracy, completeness, reliability and suitability of reports relied on by TransGrid in preparing these documents
3. Obtain independent and specific advice from appropriate experts or other sources.

Accordingly, TransGrid makes no representations or warranty as to the currency, accuracy, reliability, completeness or suitability for particular purposes of the information in this suite of documents.

Persons reading or utilising this suite of RIT-T-related documents acknowledge and accept that TransGrid and/or its employees, agents and consultants have no liability for any direct, indirect, special, incidental or consequential damage (including liability to any person by reason of negligence or negligent misstatement) for any damage resulting from, arising out of or in connection with, reliance upon statements, opinions, information or matter (expressed or implied) arising out of, contained in or derived from, or for any omissions from the information in this document, except insofar as liability under any New South Wales and Commonwealth statute cannot be excluded.

Privacy notice

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.

Under the National Electricity Law there are circumstances where TransGrid may be compelled to provide information to the Australian Energy Regulator (AER). TransGrid will advise you should this occur.

TransGrid's Privacy Policy sets out the approach to managing your personal information. In particular, it explains how you may seek to access or correct the personal information held about you, how to make a complaint about a breach of our obligations under the Privacy Act, and how TransGrid will deal with complaints. You can access the Privacy Policy here (https://www.transgrid.com.au/Pages/Privacy.aspx).

Executive summary

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for mitigating the risks caused by the deteriorating condition of transformers at Sydney East substation. Publication of this Project Assessment Consultations Report (PACR) represents the final step in the RIT-T process.

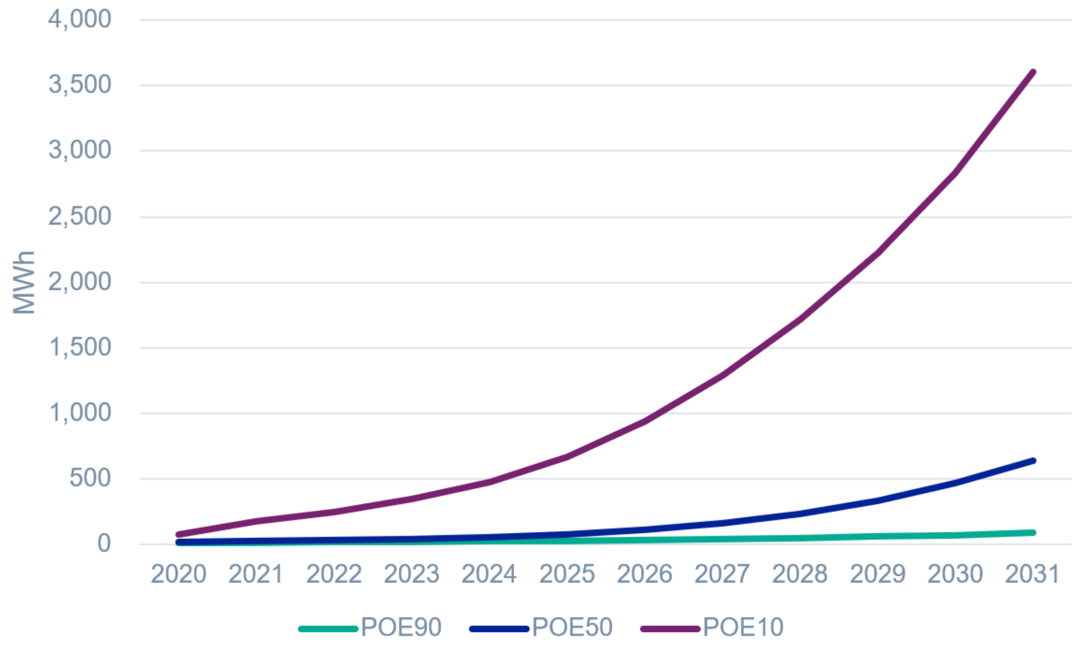
Commissioned in 1974, TransGrid's Sydney East 330/132 kV substation is located north of the Sydney Central Business District (CBD) and serves the areas north of Sydney Harbour including North Sydney, Ryde, Macquarie Park, Chatswood, and the suburbs along the Northern Beaches. It has a peak demand of about 700 MW. Sydney East substation plays a central role in providing reliable supply of electricity to the region.

The first three 400 MVA transformers (Transformer 1, Transformer 2 and Transformer 3) at Sydney East substation were installed in 1974. A fourth transformer (Transformer 4), with a capacity of 375 MVA, was installed in 2013 to accommodate growing demand in the region. The three initial transformers are showing signs of deterioration such as carbon particle contamination, paper insulation embrittlement, paper insulation moisture, dissolved gasses in main transformer tank, bushing deterioration, and large transformer losses due to mechanical failure of tapchanger switches.

As the transformers are vital to supplying the forecast high demand at Sydney East substation,[1] further deterioration of the transformers will increase the likelihood of electrical breakdown and transformer failures which will result in prolonged and frequent involuntary load shedding at a key transmission node supplying Sydney, Figure E-1.

Categorised as a 'market benefit' driven RIT-T, the proposed investment will sufficiently alleviate the risk of prolonged and frequent involuntary load shedding in Sydney. The option presented in this PACR will enable TransGrid to appropriately manage the asset risks associated with continued deterioration of Transformers 1, 2 and 3 at Sydney East substation.

Figure E-1 – Expected involuntary load shedding



[1] TransGrid. "*Transmission Annual Planning Report 2018*." Sydney: TransGrid, 2018. Accessed 28 March, 2019. https://www.transgrid.com.au/news-views/publications/Documents/Transmission%20Annual%20Planning%20Report%202018%20TransGrid.pdf

No submissions received in response to Project Specification Consultation Report

TransGrid published a Project Specification Consultation report (PSCR) on 21 December 2018 and invited written submissions on the material presented within the document. No submissions were received in response to this PSCR.

The corresponding PSCR for this RIT-T presented a range of potential network options to address the identified need. The options are summarised in the table below.

Table E-1 – Summary of the five credible options considered

Option	Capital cost ($m)	Transformer 1	Transformer 2	Transformer 3	Transformer 4
Option 1	19.3	Replace with new	Replace with new	Replace with redeployed asset	Unchanged
Option 2	12.3	Decommission	Replace with new	Replace with redeployed asset	Unchanged
Option 3	6.2	Refurbish onsite	Decommission	Replace with redeployed asset	Unchanged
Option 4	2.9	Refurbish onsite	Decommission	Refurbish onsite	Unchanged
Option 5	5.3	Do nothing	Decommission	Replace with redeployed asset	Unchanged

TransGrid's analysis identified that there should at least be three transformers to cater for unplanned transformer outages. Further reduction of the number of transformers will require large and expensive amounts of non-network support.

Conclusion: decommissioning of Transformer 1, replacement of Transformer 2 with a new asset, and replacement of Transformer 3 with a redeployed asset is optimal

The optimal commercially and technically feasible option presented in the PSCR – Option 2, decommissioning of Transformer 1, replacement of Transformer 2 with a new asset, and replacement of Transformer 3 with a redeployed three-phase 375 MVA transformer that is technically suitable for Sydney East substation and in near-new condition – remains the preferred option to meet the identified need.

Option 2 is found to have the highest net market benefits for the central and high scenarios. On a weighted basis, it is expected to deliver approximately $320 million in net market benefits. Additionally, under all sensitivity analysis to key assumptions, positive net benefits result from implementing Option 2.

The estimated capital cost of Option 2 is $12.3 million. Routine and operating maintenance costs are expected to be approximately less than 1 per cent once the replacement works have been completed.

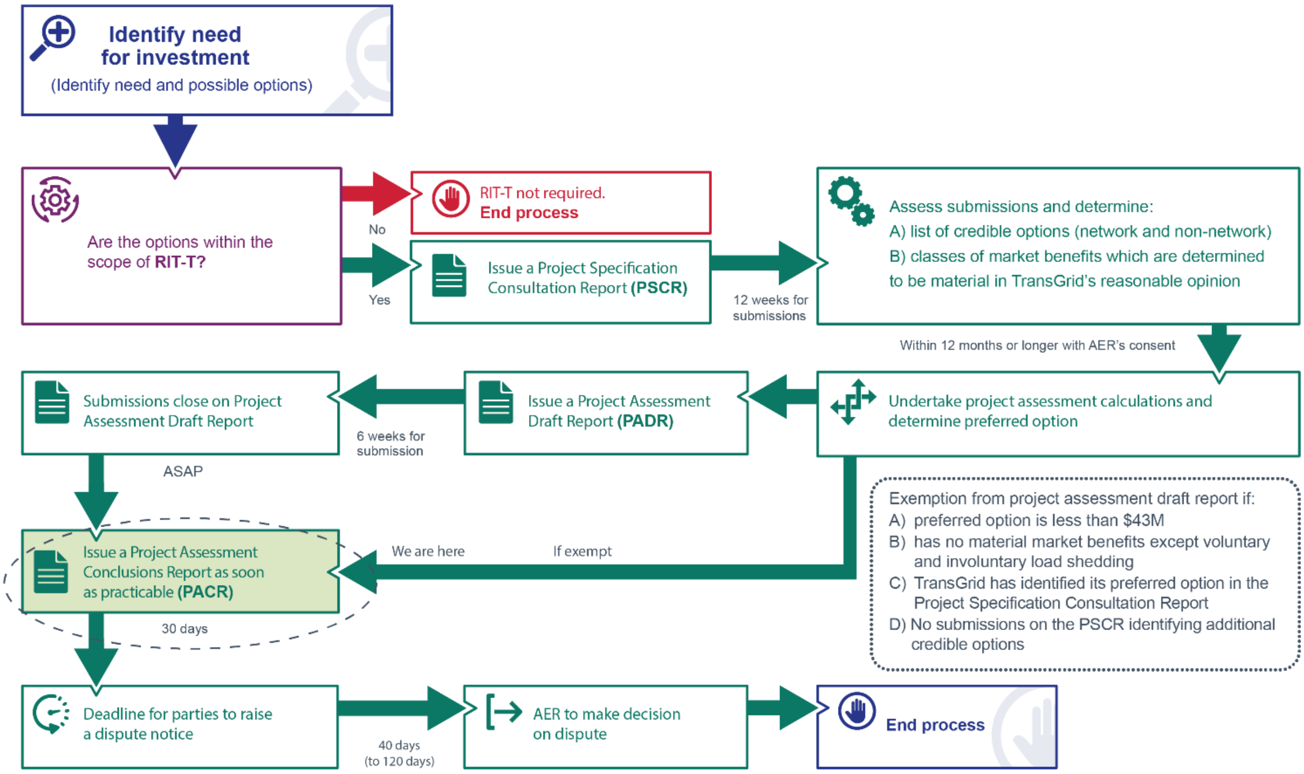
TransGrid also considered and outlined alternate timings for delivery in the PSCR, however it was concluded that the optimal works delivery date is as soon as practicable, proposed for 2021/22.

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 work will be completed by 2021/22. Necessary network asset outages will be implemented to have minimal impact on network capacity.

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 December 2018. 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



Parties wishing to raise a dispute notice with the AER may do so prior to 13 July 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 Sydney East substation transformer 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 2021/22.

Contents

List of Tables

List of Figures

1. Introduction

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for mitigating the risks caused by the deteriorating condition of transformers at Sydney East substation. Publication of this Project Assessment Consultations Report (PACR) represents the final step in the RIT-T process.

The corresponding Project Specification Consultation Report (PSCR) released in December 2018 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.

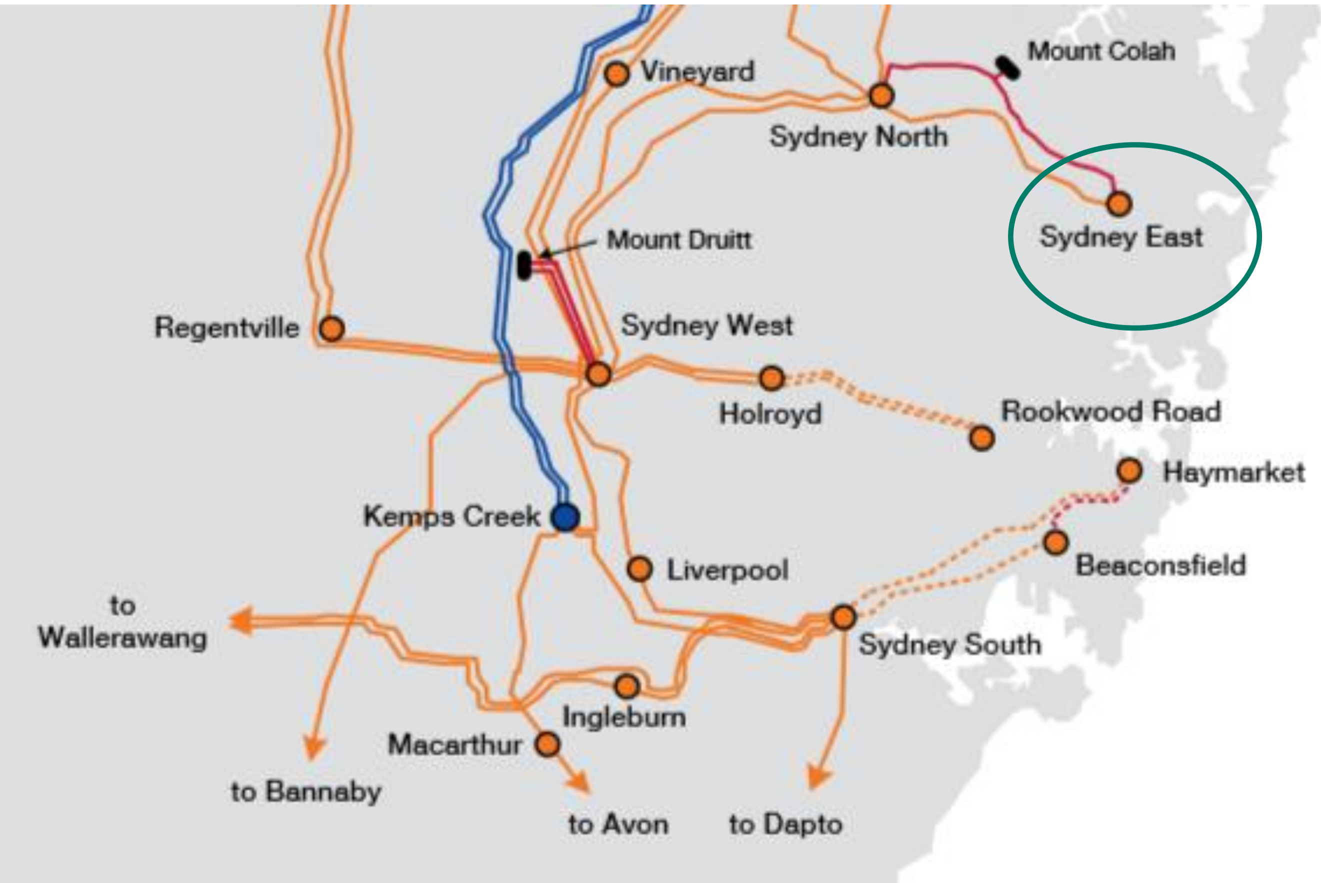
2. The identified need

2.1 Background

TransGrid's Sydney East 330/132 kV substation was commissioned in 1974 and is located north of the Sydney CBD. It plays a critical role in stepping down voltage level to supply the areas north of Sydney Harbour including North Sydney, Ryde, Macquarie Park, Chatswood, and the suburbs along the Northern Beaches. Sydney East substation plays a central role in providing reliable supply of electricity to the region.

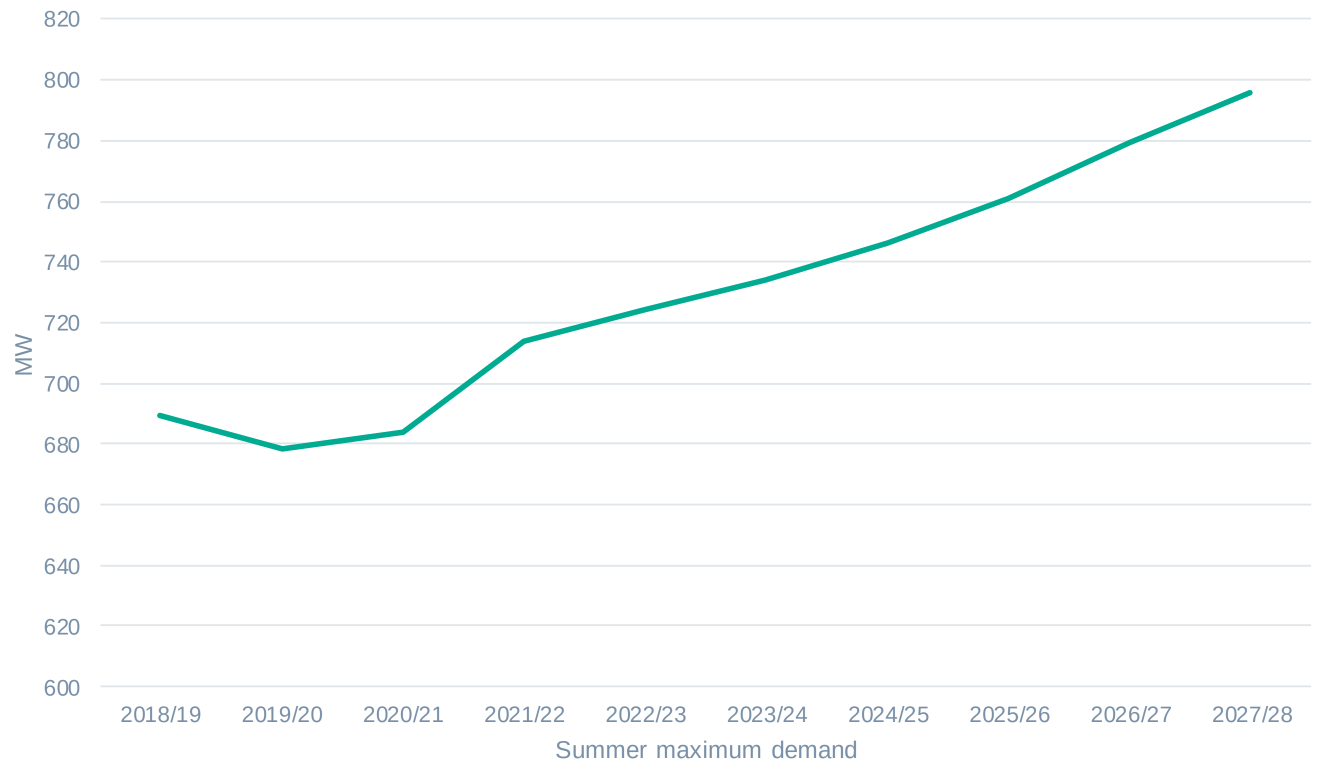
Figure 2-1 depicts the location of Sydney East substation in TransGrid's greater Sydney network.

Figure 2-1 – TransGrid's greater Sydney network



When Sydney East substation was first commissioned, it comprised three 400 MVA transformers (Transformer 1, Transformer 2 and Transformer 3) which still remain in operation. A fourth transformer (Transformer 4), with a capacity of 375 MVA, was installed in 2013 to accommodate growing demand in the region. Further growth in demand is anticipated in the region over the next ten years, as shown in Figure 2-2.

Figure 2-2 – Sydney East – summer peak demand[2]



2.2 Description of the identified need

The transformers at Sydney East substation play a central role in supplying electricity to a key transmission node in TransGrid's greater Sydney network. However, the condition of the original three transformers is leading to carbon particle contamination, paper insulation embrittlement, paper insulation moisture, dissolved gasses in main transformer tank, bushing deterioration, and large transformer losses due to mechanical failure of tapchanger switches. Consequently, this is increasing the risk of performance issues and failures.

Further deterioration of the transformers will increase the likelihood of electrical breakdown and transformer failures which will result in prolonged and frequent involuntary load shedding at a key transmission node supplying Sydney and damage to TransGrid's transmission assets.

The figures below are photos taken for Sydney East transformers.

2 TransGrid. "*Transmission Annual Planning Report 2018*." Sydney: TransGrid, 2018. Accessed 28 March, 2019. https://www.transgrid.com.au/news-views/publications/Documents/Transmission%20Annual%20Planning%20Report%202018%20TransGrid.pdf

Figure 2-3 – Examples of the condition of Sydney East transformers

Without remedial action, the condition and performance of the transformers will continue to deteriorate, hence increasing the likelihood of prolonged and frequent failure. As the Sydney East transformers are crucial to supplying the high demand in northern Sydney,[3] failure of the transformers creates a significant risk of prolonged and frequent involuntary load shedding if a technically and commercially feasible credible option is not implemented in sufficient time to meet the identified need.

TransGrid considers that the preferred option presented in this PACR will sufficiently alleviate the risk of prolonged and frequent involuntary load shedding. Accordingly, TransGrid views the investment to rectify the condition of the transformers as a 'market benefit' driven RIT-T.

In addition to the market benefit of avoided prolonged and frequent involuntary load shedding, TransGrid notes that rectifying the deteriorating condition of the transformers will also reduce safety risks, as well as lower planned and unplanned corrective maintenance costs. However, these costs are of small magnitude compared to the cost of prolonged and frequent involuntary load shedding and do not affect the preference for Option 2. As such, TransGrid has not quantified these avoided safety risk costs as part of this assessment.

[3] TransGrid. "*Transmission Annual Planning Report 2018*." Sydney: TransGrid, 2018. Accessed 28 March, 2019. https://www.transgrid.com.au/news-views/publications/Documents/Transmission%20Annual%20Planning%20Report%202018%20TransGrid.pdf

3. Options that meet the identified need

In identifying credible options, TransGrid took the following factors into account: energy source; technology; ownership; the extent to which the option would enable intra-regional or intra-regional trading of electricity; whether it was a network option or a non-network option; whether the credible option was intended to be regulated; whether the credible option had a proponent; and any other factor which TransGrid reasonably considered should have been taken into account.[4]

Among the five credible options considered[5] and summarised in Table 3-1, TransGrid considers that the optimal timing for the most efficient option (Option 2: decommissioning of Transformer 1, replacement of Transformer 2 with a new asset, and replacement of Transformer 3 with a redeployed asset) that meets the identified need to mitigate the asset risks is as soon as possible, that is 2021/22.

TransGrid did not receive any responses regarding options presented in the PSCR.

Table 3-1 – Summary of the credible options

Option	Capital cost ($m)	Transformer 1	Transformer 2	Transformer 3	Transformer 4
Option 1	19.3	Replace with new	Replace with new	Replace with redeployed asset	Unchanged
Option 2	12.3	Decommission	Replace with new	Replace with redeployed asset	Unchanged
Option 3	6.2	Refurbish onsite	Decommission	Replace with redeployed asset	Unchanged
Option 4	2.9	Refurbish onsite	Decommission	Refurbish onsite	Unchanged
Option 5	5.3	Maintain current regime	Decommission	Replace with redeployed asset	Unchanged

TransGrid's analysis revealed that there should at least be three transformers to cater for unplanned transformer outages. Further reduction of the number of transformers would require large amounts of non-network support as outlined in sections 3.1 to 3.7 of this PACR.

All options considered to address the identified need are commercially and technically feasible and can be implemented in sufficient time to meet the identified need.[6] 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 2021/22.

In addition, all works under each option are assumed to be completed in accordance with the relevant standards and components shall be replaced with the objective of minimal modification to the wider transmission assets.

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

---

4 As per clause 5.15.2(b) of the NER.

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

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

3.1 Description of the 'base case'

The costs and benefits of each option in this PACR were compared against those of a base case.

Under this base case, no proactive capital investment is made to remediate the deterioration of Sydney East transformers, and the asset will continue to operate and be maintained under the current regime. The base case considers no investment in the transformer assets other than the continuation of the maintenance regime. In this case, the risk of prolonged and frequent involuntary load shedding and risks on safety will continue to increase.

The regular maintenance regime will not be able to address the identified need to undertake action, and as a consequence, will not address the increasing probability of transformer failure. It is expected that this will expose end-customers to prolonged and frequent involuntary load shedding.

3.2 Option 1 – Replacement of Transformer 1 and 2 with new assets, and replacement of Transformer 3 with redeployed asset

Option 1 involves:

> replacing Transformer 1 and 2 with new assets
> replacing Transformer 3 with a redeployed three phase 375 MVA transformer that is technically-suitable for Sydney East substation and in near-new condition.

The estimated capital cost of Option 1 is $19.3 million. In this option, risks posed by all three ageing transformers are greatly reduced with the installation of new and redeployed transformers. Planned operating costs for Option 1 are expected to be approximately $3,500 per year.

3.3 Option 2 – Decommissioning of Transformer 1, replacement of Transformer 2 with new asset, and replacement of Transformer 3 with redeployed asset

Option 2 involves:

> Decommissioning of Transformer 1
> replacing Transformer 2 with a new asset
> replacing Transformer 3 with a redeployed three phase 375 MVA transformer that is technically-suitable for Sydney East substation and in near-new condition.

The estimated capital cost of Option 2 is $12.3 million. Planned operating costs for Option 2 are expected to be approximately $3,500 per year.

3.4 Option 3 – Refurbishment of Transformer 1, decommissioning of Transformer 2, and replacement of Transformer 3 with redeployed asset

Option 3 involves:

> onsite refurbishment of Transformer 1, which includes oil treatment and degassing to remove moisture and gases, replacing high voltage and low voltage bushings, fixing oil leaks, and minor painting
> decommissioning of Transformer 2
> replacing Transformer 3 with a redeployed three phase 375 MVA transformer that is technically-suitable for Sydney East substation and in near-new condition.

There is marginal improvement on the Transformer 1's failure rates after onsite refurbishment.

The estimated capital cost of Option 3 is $6.2 million. A near-new redeployed transformer will greatly reduce the risk of failure for Transformer 3. Decommissioning of Transformer 2 will not only remove its failure risk from the network but also provide asset component cover for Transformer 1. Routine operating costs for Option 3 are expected to be approximately $6,000 per year.

3.5 Option 4 – Decommissioning of Transformer 2, and refurbishment of Transformer 1 and Transformer 3

Option 4 involves:

> the following for Transformer 1 and Transformer 3:
  – onsite treatment and degassing to remove moisture and gases
  – replacing high voltage and low voltage bushings
  – oil leak repair and minor painting
> decommissioning of Transformer 2.

There are marginal improvements on Transformers 1 and 3's failure rates after refurbishment.

The estimated capital cost of Option 4 is $2.9 million. The main impact arising from refurbishment on these transformers will arise from the removal of high risk bushings. Routine operating costs for Option 4 are expected to approximately $6,600 per year.

3.6 Option 5 – Decommissioning of Transformer 2 and replacement of Transformer 3 with redeployed asset

Option 5 involves:

> leaving Transformer 1 unchanged
> decommissioning of Transformer 2
> replacing Transformer 3 with a redeployed three phase 375 MVA transformer that is technically-suitable for Sydney East substation and in near-new condition.

The estimated capital cost of Option 5 is $5.3 million. A near-new redeployed transformer will greatly reduce the risk of failure for Transformer 3. Decommissioning of Transformer 2 will not only remove its failure risk from the network but also provide asset component cover for Transformer 1. Routine operating costs for Option 3 are expected to be approximately $6,300 per year.

3.7 Non-network option

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 compared the costs and benefits of the option to a base case where the existing condition issues at Sydney East substation would not be remediated and it would continue to operate, with an increasing risk level.

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 economic benefits' scenario, involving a number of assumptions that gave a lower bound and conservative estimates of net present value of net economic benefits

> a 'central' scenario which consisted of assumptions that reflected TransGrid's central set of variable estimates that provided the most likely scenario

> a 'high net economic benefits' scenario that reflected a set of assumptions which were selected to investigate an upper bound of net economic benefits.

Table 4-1 – Summary of the three scenarios investigated

Variable / Scenario	Central	Low net economic benefits	High net economic benefits
Scenario weighting	50%	25%	25%
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
VCR	$40/kWh	$28/kWh	$52/kWh
Demand forecast	POE 50	POE 90	POE 10
Discount rate	7.04 per cent	9.48 per cent	4.60 per cent

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.

4.2 Estimated gross benefits

The table below summarises the present value of benefits estimated for each credible option, for each of the three reasonable scenarios outlined in the section above.

The only relevant class of market benefits described under the RIT-T guidelines was the avoided involuntary load shedding. The lower and upper bounds on the avoided involuntary load shedding benefits were reflected in the low net economic benefit and high net economic benefit scenarios.

As expected, higher levels of avoided involuntary load shedding benefits was estimated on the high net economic benefit scenarios which used a peakier, POE10 forecast assumption.

Table 4-2 – Present value of gross benefits relative to the base case, PV $m 2017/18

Option/scenario	Central	Low net economic benefit	High net economic benefit	Weighted value
Scenario weighting	50%	25%	25%	
Option 1	103.18	9.46	1093.10	327.23
Option 2	104.08	9.84	1,101.52	329.88
Option 3	87.9	9.77	871.66	264.31
Option 4	43.31	5.53	400.49	123.16
Option 5	79.76	10.07	748.93	229.63

4.3 Estimated costs

Table 4-3 summarises the present value of costs of the credible options for each of the three scenarios investigated.

Table 4-3 – Present value of costs of credible options relative to the base case, PV $m

Option/Scenario	Central	Low net economic benefit	High net economic benefit	Weighted value
Scenario weighting	50%	25%	25%	
Option 1	12.88	16.47	8.97	12.8
Option 2	9.01	11.72	6.18	8.98
Option 3	4.50	5.86	3.09	4.49
Option 4	2.50	3.07	1.89	2.49
Option 5	4.04	5.29	2.76	4.03

4.4 Estimated net benefits

Table 4-4 summarises the present value of the net market benefit for each credible option across the three scenarios, the weighted net market benefit, and the ranking of options. These net market benefits are the benefits (as set out in section 7.1 above) less the estimated costs (as outlined in section 7.2 above) in present value terms.

Option 2 was found to have the highest net market benefits for the central and high scenarios.

While the net market benefits were marginally negative under the low scenario, TransGrid notes that this scenario comprises an extreme combination of assumption, including low avoided involuntary load shedding and high capital costs. The low scenario, along with the other two scenarios, also applied the conservative assumption outlined in Appendix B.2 that the expected avoided involuntary load shedding would be capped at the ten-year value for the assessment period.

On a weighted basis, Option 2 is expected to deliver approximately $320 million in net market benefits.

Table 4-4 – Present value of net benefits relative to the base case, PV $m

Option	Central	Low net economic benefit	High net economic benefit	Weighted value	Rank
Option 1	90.3	-7.01	1084.13	314.43	2
Option 2	95.07	-1.88	1,095.34	320.90	1
Option 3	83.39	3.91	868.57	259.82	3
Option 4	40.81	2.46	398.60	120.67	5
Option 5	75.73	4.78	746.18	225.6	4

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 were implemented in stages.

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

> Step 2 – once a trigger year was determined, tested the sensitivity of the NPV of net benefit to different assumptions on key variables such as lower or higher involuntary load shedding risks.

4.5.1 Step 1 – Sensitivity testing of the optimal timing

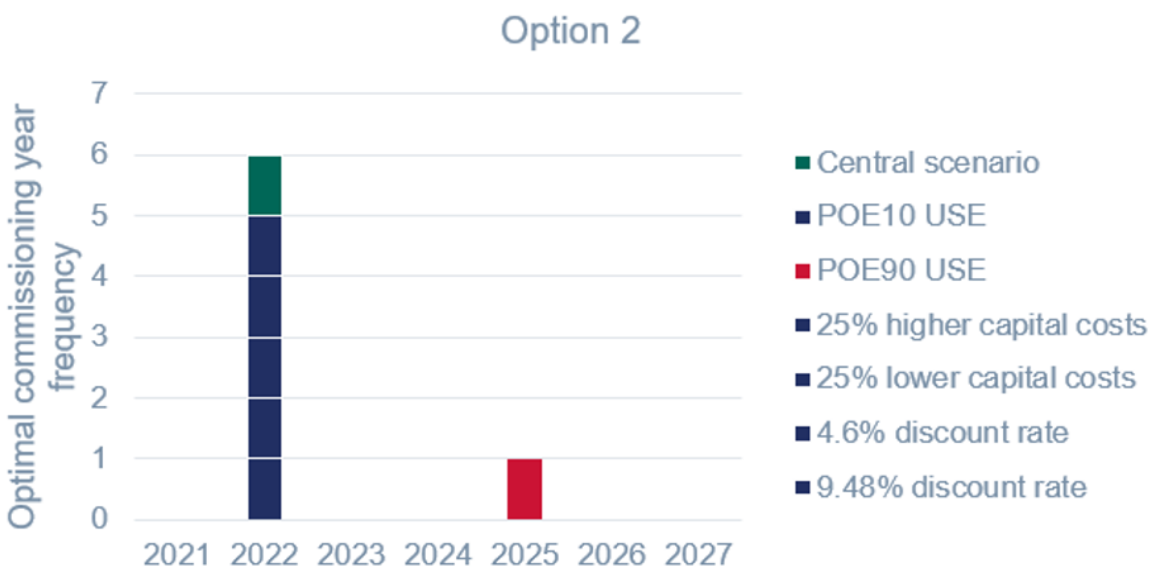
The optimal timing for Option 2 is the year in which the NPV of net benefit would be maximised. Shown on Figure 4-1, for Option 2, the optimal commissioning year is 2021/22 for most sensitivities (with the exception of the POE90 involuntary load shedding forecast) including the following range of alternative assumptions for the following key variables:

> a higher discount rate of 9.48 per cent per cent and a lower discount rate of 4.60 per cent

> 25 per cent lower and higher capital costs

> involuntary load shedding using POE90 and POE10 demand forecasts.

Figure 4-1 – Distribution of optimal project commissioning year for Option 2 under each sensitivity



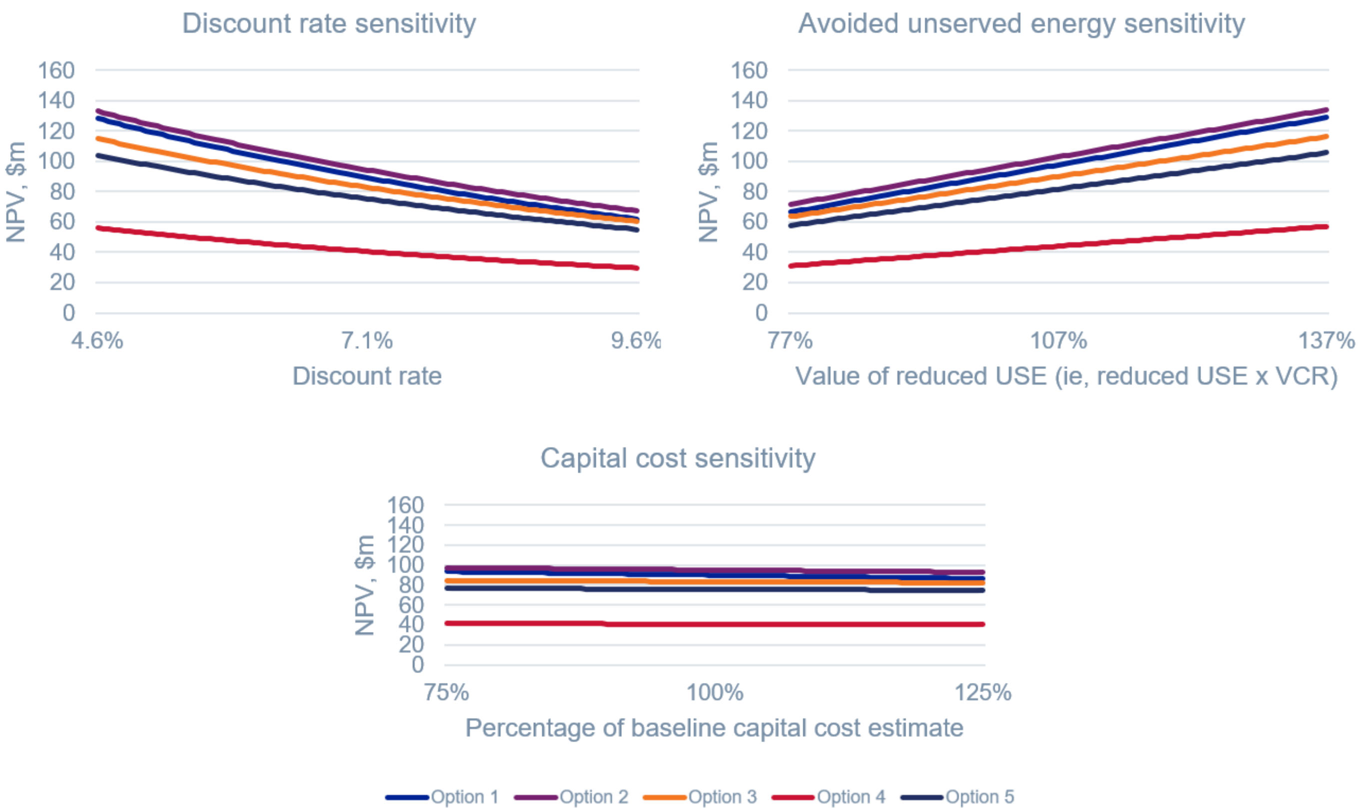
4.5.2 Step 2 – Sensitivity of the overall net benefit

TransGrid 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 investigated the same sensitivities under this second step as in the first step.

The figure below illustrates the estimated net market benefits for each option varying the discount rate, capital cost and involuntary load shedding risks. It shows that for all the sensitivity tests, and for all options, the estimated net market benefits were positive, and the ranking was consistent across sensitivities.

Figure 4-2 – Sensitivity testing of options



5. Final conclusion on the preferred option

The optimal commercially and technically feasible option presented in the PSCR – decommissioning of Transformer 1, replacement of Transformer 2 with a new asset, and replacement of Transformer 3 with a redeployed three phase 375 MVA transformer that is technically suitable for Sydney East substation and in near-new condition – remains the preferred option to meet the identified need. This preferred option, Option 2, has strong positive net benefits under most scenarios investigated and on a weighted basis will deliver approximately $320 million in net market benefits.

Moving forward with this option is the most prudent and economically efficient solution to manage risk of prolonged involuntary load shedding at Sydney East substation.

The estimated capital cost of this option is approximately $12.3 million (weighted present value of $9.0 million) – significantly lower than the weighted benefits from reduced prolonged involuntary load shedding risks which is estimated to be $320 million dollars.

Routine operating and maintenance costs relating to planned checks by TransGrid field crew are approximately $3,500 per year – similar to the cost under the base case.

TransGrid also conducted sensitivity analysis on the NPV of the net benefit to investigate the robustness of the conclusion to underlying key assumptions. TransGrid finds that under all sensitivities, highest positive net benefits results from implementing Option 2.

TransGrid intends to undertake the 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 work will be completed by 2021/22.

In addition, all works under each option are assumed to be completed in accordance with the relevant standards and components shall be replaced with the objective of minimal modification to the wider transmission assets.

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

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 111.

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 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.[7] Appendix D provides further details on the general modelling approaches applied including the commercial discounts 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 Deterioration of transformer condition increases the risk of prolonged involuntary load shedding

TransGrid's assessment of the three transformers at Sydney East revealed signs of deterioration attributable to accelerated ageing. The deterioration of the condition of the assets, summarised in Table B-1, render the transformers more challenging and more costly to service and repair.

Transformer 3 is already out of service and without action on Transformer 1 and Transformer 2, their failure rates are expected to be 2.1 per cent and 4 per cent in 2020/21, respectively. No remedial action would further mean that their failure rates will escalate in the future, and the likelihood of simultaneous transformer outage will continue to rise. Failing to correct the conditions of the transformers creates a significant risk of prolonged and frequent involuntary load shedding.

Table B-1 – Transformer condition issues at Sydney East and their consequences

Issue	Consequences if not remediated
Carbon particle contamination	Carbon is a conductor and there can be a tendency for the individual particles to accumulate in areas of strong high electric fields. This could lead to electrical breakdown and failure of the transformer.
Paper insulation system	The transformer insulation system is based on special papers impregnated with insulating oil. The papers provided insulation and also support the structure of the transformer winding. Over time and with load and the presence of moisture, the paper becomes embrittled. This may progress to the point where a mechanical shock caused by a through fault can result in electrical failure.

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

Moisture in paper	Moisture acts to increase the rate of degradation of the paper insulating system. At high levels, it may compromise the insulation.
Dissolved gas	Measurement of hydrocarbon gasses in oil is used as a diagnostic tool to identify fault conditions in a transformer. In the case of the Sydney East transformers, there are leakages from the tapchanger switch compartments into the main tank of the transformers. High levels of hydrocarbon gasses are generated during tapchanger operation and the gasses pass into the main transformer tank and render the diagnostic tool ineffective.
Bushings	Bushings are used to bring the high voltage connections through the steel transformer tank into the transformer. They are oil paper insulated and are specially designed to manage the high levels of electrical stress. However, in the case of an electrical fault, total loss of the transformer with loss of all oil and a major fire is almost certain. The bushings fitted to the Sydney East transformers are the original units and electrical tests show that they are deteriorating.
Tapchanger and diverter switches	The tapchanger switches the voltage ratio on the transformer while it is under load. It is a mechanical device and in the case of failure, large amounts of energy are expected to be released and transformer loss is likely.

B.2 Increase in prolonged involuntary load shedding from absence of remedial action

Due to the increase in failure rates as a result of the deteriorating asset condition, the forecasts for involuntary load shedding for different levels of transformer outages will increase in the absence of any remedial action. These involuntary load shedding forecasts under different unplanned transformer outage configuration are weighted by the probabilities of those outages to estimate an expected involuntary load shedding figure.

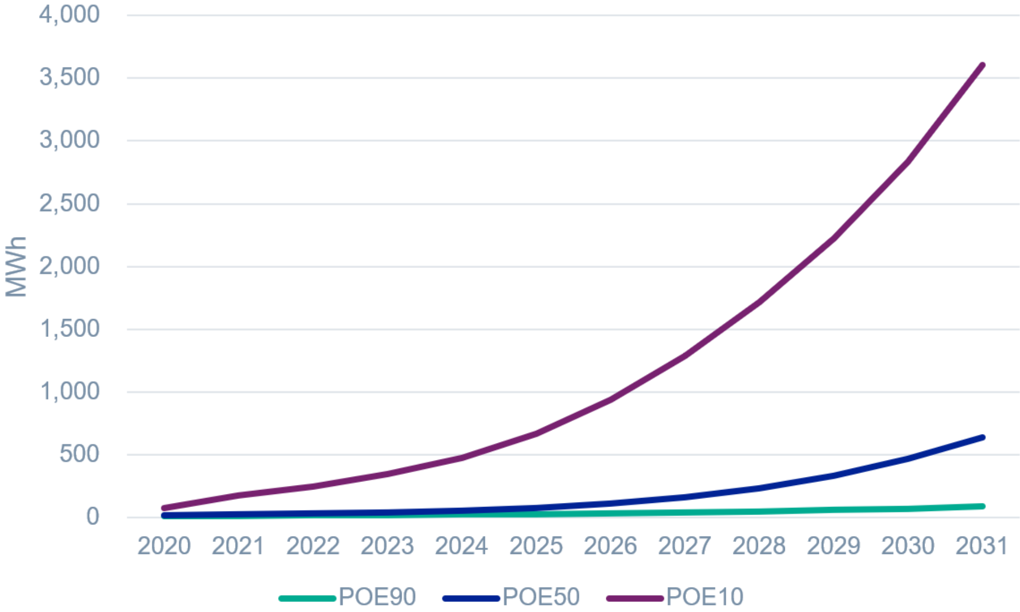
Figure B-1 shows the expected involuntary load shedding projections using three different Sydney East load forecasts, namely;

> a central forecast of 50 per cent probability of exceedance (POE50)
> a low forecast using POE90
> a high forecast using the POE10 forecasts.

In all forecast assumptions, TransGrid found that involuntary load shedding will occur if there are only two operational transformers. Therefore, to cater for unplanned transformer outages, there should at least be three transformers.

As expected, higher levels of avoided involuntary load shedding benefits is estimated based on the lower-weighted high scenario that uses a peakier, POE10 forecast assumption.

Figure B-1 – Expected involuntary load shedding



While TransGrid has forecast involuntary load shedding for a 25-year period, the estimates have been capped after the tenth year to negate large volumes in the future distorting the economic assessment.

B.3 Value of customer reliability

TransGrid values the involuntary load shedding forecasts under each option at the Value of Consumer Reliability (VCR).

The Value of Customer Reliability (VCR), in dollars per MWh, is used to evaluate the wider economic impact of involuntary load shedding on customers under the RIT-T.

TransGrid has applied AEMO's VCR estimate of $40/kWh[8] for the central scenario, see section 6.3.

Consistent with the 30% level of confidence on the AEMO estimates, a lower value of $28/kWh and a higher estimate of $52/kWh are also assumed for two sensitivities.

---

[8] Australian Energy Market Operator. "*Value of Customer Reliability Review- Final Report*." Melbourne: Australian Energy Market Operator, 2014. Accessed 15 March 2019. https://www.aemo.com.au/-/media/Files/PDF/VCR-final-report--PDF-update-27-Nov-14.pdf

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.[9]

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 so do not need to be estimated.[10]

TransGrid determined that the credible options considered in this RIT-T will not address network constraints between competing generating centres, not have an impact on the dispatch outcomes, nor have an impact on the wholesale electricity market. 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.

Additionally, as part of the RIT-T process, TransGrid considered whether the credible options listed above were expected to have material inter-regional impact.[11] 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:[12]

> a decrease in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3% of the maximum transfer capability and 50 MW
> an increase in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3% 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

---

9 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.

10 Australian Energy Market Operator. *"Power System Security Guidelines, 31 December 2018."* Melbourne: Australian Energy Market Operator, 2018. Accessed 20 March 2019. https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3715---Power-System-Security-Guidelines.pdf

11 As per clause 5.16.4(b)(6)(ii) of the NER.

12 Inter-Regional Planning Committee. *"Final Determination: Criteria for Assessing Material Inter-Network Impact of Transmission Augmentations."* Melbourne: Australian Energy Market Operator, 2004. Appendix 2 and 3. Accessed 15 March 2019. https://www.aemo.com.au/-/media/Files/PDF/170-0035-pdf.pdf

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

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

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 market benefit categories are considered immaterial

Market benefits	Reason
Differences in the timing of expenditure	Options considered would provide an alternative to meeting reliability requirements and would be unlikely to affect decisions to undertake unrelated expenditure in the network. Consequently, material market benefits would 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.[13] 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.
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 would not be any material market benefits associated with changed to network losses.

[13] 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 applied in assessing the net benefits associated with implementing Option 2.

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 2018/19 to 2038/39. 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 are appropriately captured in the 20-year assessment period.

TransGrid adopted a central real, pre-tax 'commercial'[14] discount rate of 7.04% 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 this PACR,[15] and an upper bound discount rate of 9.48% (a symmetrical adjustment upwards) are 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.

14 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.

15 See TransGrid's Post-tax Revenue Model (PTRM) for the 2018-23 period, available at: https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/transgrid-determination-2018-23