TransGrid

Meeting demand growth in the Greater Macarthur area

RIT-T – Project Assessment Conclusions Report

Region: Greater Sydney

Date of issue: 11 September 2020

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Executive summary

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for meeting forecast demand growth in the Greater Macarthur area in Sydney's south-west going forward. Publication of this Project Assessment Conclusions Report (PACR) represents the final step in the RIT-T process.

The Endeavour Energy 66 kV network in the Greater Macarthur area is currently supplied by:

- one 250 MVA 330/66 kV transformer at TransGrid's Macarthur substation
- two 120 MVA 132/66 kV transformers at Endeavour Energy's Nepean substation.

A single 375 MVA 330/132 kV transformer at TransGrid's Macarthur substation also provides 132 kV supply to Endeavour Energy's Nepean substation via the tail-ended high capacity 9L1 Macarthur to Nepean 132 kV circuit.

In addition, the normally open 9L4/93X and 9L5/93Y 132 kV circuits provide a limited level of backup to Nepean at 132 kV from Sydney West and Liverpool. The level of backup available from these feeders is progressively being reduced as load growth in the South West Priority Growth Area materialises.

Identified need: meeting demand growth in the Greater Macarthur area

Endeavour Energy has experienced unprecedented growth in new customer connections in the last five years driven by the growth in the greenfield housing market. Continued growth in demand within the Greater Macarthur area is forecast to result in network constraints that, if unaddressed, will result in significant involuntary load shedding to end consumers.

A summary of these constraints, and their network implications, are as follows:

- A forced outage of the Macarthur 330/66 kV transformer at times of peak demand would cause:
  - Endeavour Energy's Nepean 132/66 kV transformers to exceed their contingency rating of 127 MVA
  - Endeavour Energy's 132 kV 9L1 line to Nepean to exceed its thermal contingency rating of 358 MVA
  - TransGrid's Macarthur 330/132 kV transformer to exceed its contingency rating of 412.5 MVA
- A forced outage of the Macarthur 330/132 kV transformer at times of peak demand would cause TransGrid's Macarthur 330/66 kV transformer to exceed its short-time step rating.

For the constraints relating to a forced outage of the Macarthur 330/132 kV transformer, transfer of Campbelltown load to Ingleburn would provide some relief to this constraint in the next few years.

These constraints are forecast to result in significant Expected Unserved Energy (EUE) if nothing is done. Avoiding this EUE is the key driver for this RIT-T.

While there are several embedded generators in the area, these sources are not considered to be an effective means of reducing the EUE in light of both response capability and forecast load growth. Generation predominantly occurs using gas that is created from coal mining activity, with very limited gas storage capability that would enable the generators to adequately respond to periods of high demand and/or loss of infrastructure.

No submissions received in response to Project Specification Consultation Report

TransGrid published a Project Specification Consultation Report (PSCR) on 3 June 2020 and invited written submissions on the material presented within the document. No submissions were received in response to the PSCR.

No material developments since publication of the PSCR

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

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

- updated the discount rates used
- inflation escalation update
- updated operating costs

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

Installation of a second 330/66 kV transformer at Macarthur substation remains the most efficient way to meet forecast demand growth

In the PSCR TransGrid put forward for consideration two feasible network options from a technological and project delivery perspective:

- **Option 1** – installation of a second 330/66 kV transformer at Macarthur substation; and
- **Option 2** – permanent transfer of the Campbelltown load to the Ingleburn BSP.

Option 1 is the preferred option in accordance with NER clause 5.16.1(b) because it is the credible option that maximises the net present value of the net economic benefit to all those who produce, consume and transport electricity in the market.

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

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

Table E-1 Options considered

Option	Description	Capital cost ($m 2020/21)	Operating cost ($ per year)	Remarks
1	**Installation of a second 330/66 kV transformer at Macarthur substation**	**9**	**10,000**	**Preferred option and provides the highest net economic benefit**
2	Permanent transfer of the Campbelltown load to the Ingleburn BSP	~35	15,000	Technically and commercially feasible but provides less net economic benefits.

No credible non-network options were identified during the PSCR consultation period

In the PSCR TransGrid noted the objective of any non-network solution for this RIT-T should be to obtain a sufficient net peak demand reduction in the target area supplied by the Macarthur BSP and Nepean substation to manage the load at risk in order to defer or avoid the network option of installing a second 250 MVA 330/66 kV transformer at Macarthur BSP (preferred option). This PSCR provided detail on the technical characteristics that any non-network solutions would need to provide to help meet the identified need.

Proponents of non-network options were encouraged to make submissions on any non-network option they believe can address, or contribute to, the identified need.

No submissions were received regarding non-network options throughout the consultation period.

The proposed investment delivers positive net benefits

The table below summarises the net economic benefit in NPV terms for the options considered across the three scenarios, as well as on a weighted basis. The net economic benefit is the gross less the costs, all expressed in present value terms.

The table below demonstrates that the options considered provides an expected net economic benefit under the central and high benefits scenario, as well as on a weighted basis.

On a weighted basis, Option 1 is estimated to deliver approximately $120.3 million in net benefits and is considered the preferred option.

Table E-2 Estimated net economic benefit for each option, present value ($m 2020/21)

Option	Central scenario	Low benefit scenario	High benefit scenario	Weighted	Ranking
Option 1 – Installation of a second 330/66 kV transformer at Macarthur substation	78.3	0.7	323.8	120.3	1
Option 2 - Permanent transfer Campbelltown load to the Ingleburn BSP	57.5	-27.6	311.2	99.7	2

Sensitivity testing finds that, while the results are most sensitive to the assumed discount rate and adjustments to expected unserved energy estimates, Option 1 is still found to deliver strongly positive net benefits over a range of alternate assumptions regarding key parameters. Option 1 delivers the most benefit under all scenarios and sensitivities.

Conclusion: installation of a second 330/66 kV transformer at Macarthur substation is optimal

The optimal commercially and technically feasible option presented in the PSCR – Option 1 (installation of a second 330/66 kV transformer at the Macarthur substation) – remains the preferred option to meet the identified need.

The estimated capital cost of this option is approximately $9 million.

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

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

Option 1 is the preferred option in accordance with NER clause 5.16.1(b) because it is the credible option that maximises the net present value of the net economic benefit to all those who produce, consume and transport electricity in the market.

Next steps

This PACR represents the third and final step of the consultation process in relation to the application of the Regulatory Investment Test for Transmission (RIT-T) process undertaken by TransGrid. It follows a Project Specification Consultation Report (PSCR) released in June 2020. No submissions were received in response to the PSCR.

The second step, production of a Project Assessment Draft Report (PADR), was not required for this RIT-T as TransGrid considers its investment in relation to the preferred option to be exempt from that part of the RIT-T process under NER clause 5.16.4(z1). Production of a PADR is not required[1] due to:

- the estimated capital cost of the proposed preferred option being less than $43 million;
- the PSCR stating:
  - the proposed preferred option (including reasons for the proposed preferred option)
  - the RIT-T is exempt from producing a PADR
  - the proposed preferred option and any other credible option will not have material market benefits[2] except for voluntary load curtailment and involuntary load shedding
- the RIT-T proponent considers that there were no PSCR submissions identifying additional credible options that could deliver a material market benefit; and
- the PACR addressing any issues raised in relation to the proposed preferred option during the PSCR consultation.

Parties wishing to raise a dispute notice with the AER may do so prior to 12 October 2020 (30 days after publication of this PACR). Any dispute notices raised during this period[3] will be addressed by the AER within 40 to 120 days, after which the formal RIT-T process will conclude.

Further details on the RIT-T can be obtained from TransGrid's Regulation team via RIT-TConsultations@transgrid.com.au. In the subject field, please reference 'Greater Macarthur Area PACR'.

1 In accordance with NER clause 5.16.4(z1)(4), the exemption from producing a PADR will no longer apply if TransGrid considers that an additional credible option that could deliver a material market benefit is identified during the consultation period. No additional credible options were identified.

2 As per clause 5.16.1(c)(6)

3 Additional days have been included to cover public holidays.

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1. Introduction

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to options for meeting forecast demand growth in the Macarthur-Nepean distribution network in Sydney's south-west going forward. In particular, demand growth in Endeavour Energy's distribution network is forecast to result in network constraints that, if unaddressed, will result in significant involuntary load shedding to end consumers.

Publication of this Project Assessment Conclusions Report (PACR) represents the final step in the RIT-T process to investigate options for alleviating the supply reliability concerns if action is not taken for the Nepean and Greater Macarthur supply areas posed by increasing demand.

This PACR has been prepared in conjunction with Endeavour Energy (as the relevant distribution network service provider).[4]

1.1 Purpose of this report

The purpose of this PACR[5] is to:

> describe the identified need

> describe and assess credible options to meet the identified need

> describe the assessment approach used

> provide details of the proposed preferred option to meet the identified need.

1.2 Exemption from preparing a Project Assessment Draft Report (PADR)

Publication of a Project Assessment Draft Report (PADR) was not required for this RIT-T as TransGrid considers its investment in relation to the preferred option to be exempt from that part of the process under NER clause 5.16.4(z1). Production of a PADR is not required due to:

- the estimated capital cost of the proposed preferred option being less than $43 million[6];
- the PSCR stating:
  - the proposed preferred option (including reasons for the proposed preferred option)
  - the RIT-T is exempt from producing a PADR
  - the proposed preferred option and any other credible option will not have material market benefits[7] except for voluntary load curtailment and involuntary load shedding
- the RIT-T proponent considers that there were no PSCR submissions identifying additional credible options that could deliver a material market benefit; and
- the PACR addressing any issues raised in relation to the proposed preferred option during the PSCR consultation.

4 Consistent with the joint-planning requirements in the National Electricity Rules.

5 See Appendix A for the National Electricity Rules requirements.

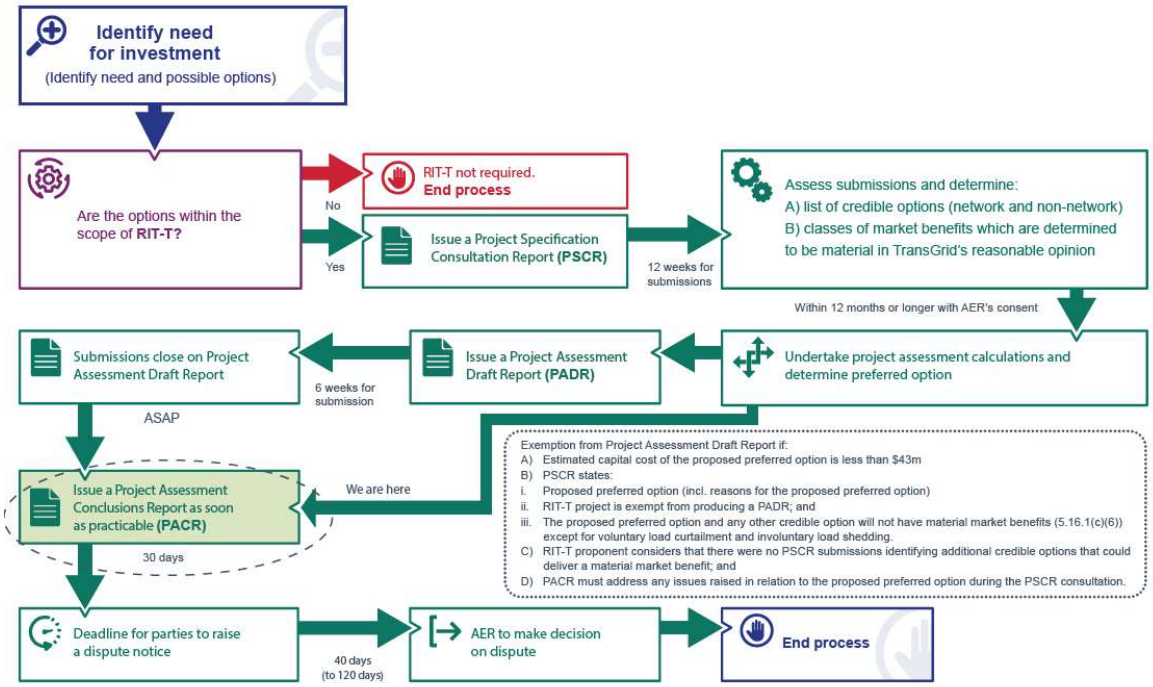
6 Varied from $35m to $43m based on the AER Final Determination: Cost threshold review November 2018.14. Accessed 20 May 2020 https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/cost-thresholds-review-for-the-regulatory-investment-tests-2018

7 As per clause 5.16.1(c)(6)

1.3 Next steps

This PACR represents the third and final step of the consultation process in relation to the application of the Regulatory Investment Test for Transmission (RIT-T) process undertaken by TransGrid. It follows a Project Specification Consultation Report (PSCR) released in June 2020. No submissions were received in response to the PSCR.

Figure 1-1 This PACR is the third stage of the RIT-T process[8]



Parties wishing to raise a dispute notice with the AER may do so prior to 12 October 2020 (30 days after publication of this PACR). Any dispute notices raised during this period[9] will be addressed by the AER within 40 to 120 days, after which the formal RIT-T process will conclude. 3

Further details on the RIT-T can be obtained from TransGrid's Regulation team via RIT-TConsultations@transgrid.com.au. In the subject field, please reference 'Greater Macarthur Area PACR'.

[8] Australian Energy Market Commission. "*Replacement expenditure planning arrangements, Rule determination*". Sydney: AEMC, 18 July 2017.65. Accessed 8 May 2020. https://www.aemc.gov.au/sites/default/files/content/89fbf559-2275-4672-b6ef-c2574eb7ce05/Final-rule-determination.pdf

[9] Additional days have been included to cover public holidays.

2. The identified need

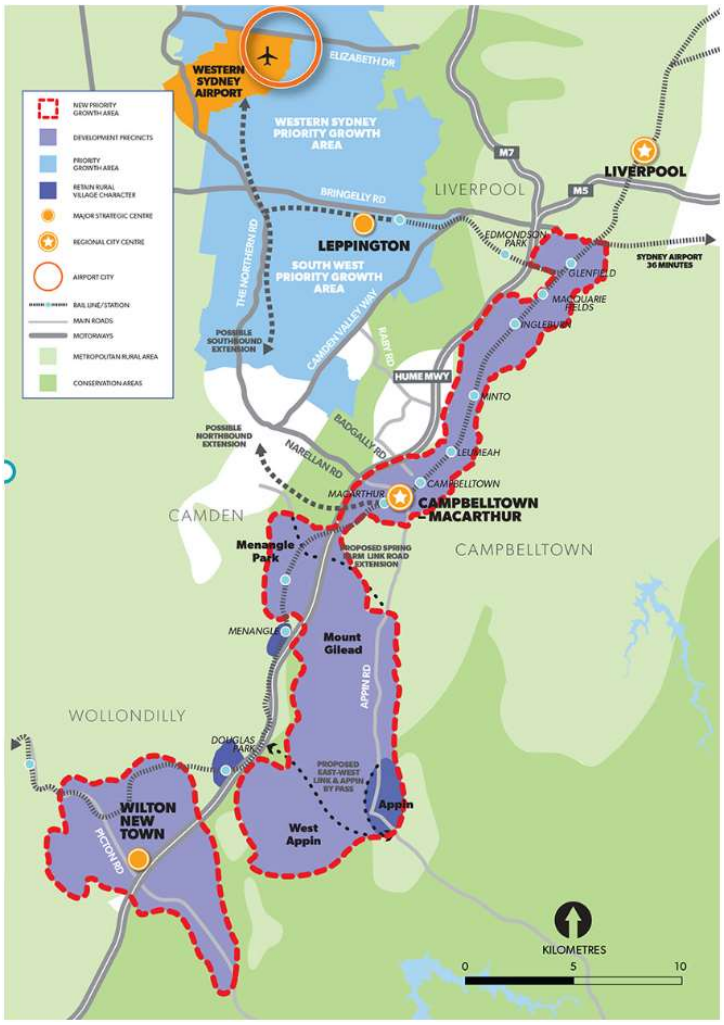
This section outlines the identified need for this RIT-T, as well as the assumptions and data underpinning it. It first sets out background information related to the Greater Macarthur area network and existing electricity supply arrangements.

2.1 Background to the identified need

Macarthur substation provides grid exit points to Endeavour Energy at 132 kV and 66 kV. The ultimate configuration for Macarthur substation is for two 330/132 kV transformers tail-ended onto Endeavour Energy's 132 kV busbar at Nepean 132/66/33 kV substation, and two 330/66 kV transformers feeding a 66 kV busbar at TransGrid's Macarthur substation. The substation was initially commissioned with a single 330/132 kV 375 MVA transformer and a single 330/66 kV 250 MVA transformer.

Endeavour Energy has constructed two 132 kV feeders from TransGrid's Macarthur substation to Endeavour Energy's Nepean substation. However, only one feeder is operated at 132 kV (the second feeder is currently operated at 66 kV and serves as a link between the Macarthur and Nepean 66 kV busbars). The second feeder will be converted to 132 kV when the second 330/132 kV transformer at Macarthur is required.

Figure 2-1 Overview of the Greater Macarthur area



The Endeavour Energy 66 kV network in the Greater Macarthur area is currently supplied by:

- one 250 MVA 330/66 kV transformer at TransGrid's Macarthur substation
- two 120 MVA 132/66 kV transformers at Endeavour Energy's Nepean substation

A single 375 MVA 330/132 kV transformer at TransGrid's Macarthur substation also provides 132 kV supply to Endeavour Energy's Nepean substation via the tail-ended high capacity 9L1 Macarthur to Nepean 132 kV circuit.

In addition, the normally open 9L4/93X and 9L5/93Y 132 kV circuits provide a limited level of backup to Nepean at 132 kV from Sydney West and Liverpool. The level of backup available from these feeders is progressively being reduced as load growth in the South West Priority Growth Area materialises.[10]

The present configuration of this network and historical loadings allowed the Macarthur 330/132 kV and 330/66 kV transformers to provide backup capability to each other without interruptions to customers. However, due to load growth in the area and without further investment in the network, this level of backup can no longer be provided without interruptions to customers.

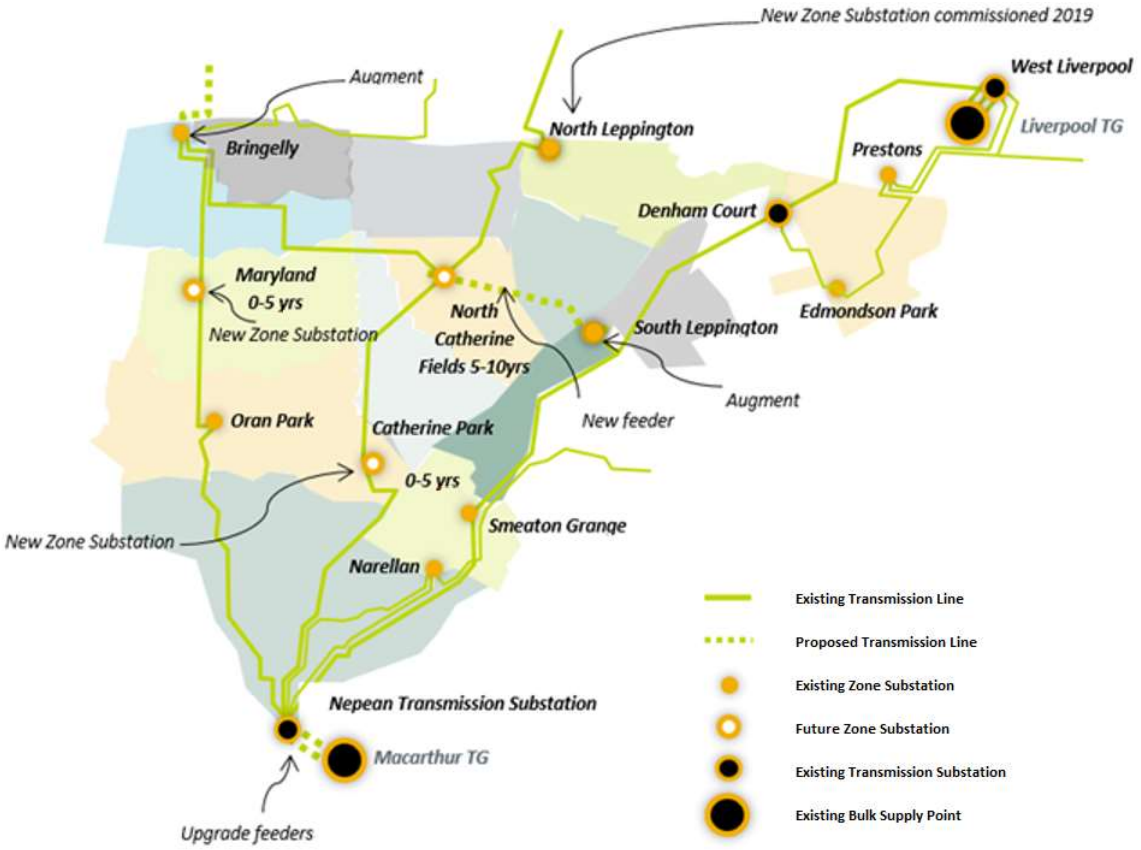
Besides other loads supplied at 132 kV, the Macarthur substation also supplies the Nepean-Macarthur 66 kV area load either directly from Macarthur substation itself or via Nepean 132/66 kV substation.

Endeavour Energy has experienced unprecedented growth in new customer connections in the last five years driven by the growth in the greenfield housing market. This uplift in demand has seen Endeavour Energy commission four new zone substations in the south-west Sydney area in the last five years and it plans to commission a further three or four in the next five years.

Figure 2-2 below depicts the number, and approximate location, of these new zone substations in Endeavour Energy's distribution network. Plans for further substations to the north of Bringelly Road including the Aerotropolis area have not been outlined in this document, although it is envisaged that initial supply into this area will be sourced from Macarthur and Sydney West substations.

[10] https://www.planning.nsw.gov.au/Plans-for-your-area/Priority-Growth-Areas-and-Precincts/South-West-Growth-Area

Figure 2-2 Actual and forecast new zone substation commissioning in the south-west Sydney area



TransGrid and Endeavour Energy have carried out a comprehensive planning study that has identified the nature and likely timing of emerging constraints if action is not taken. These are as follows:

- A forced outage of the Macarthur 330/66 kV transformer at times of peak demand would cause:
  - Endeavour Energy's Nepean 132/66 kV transformers to exceed their contingency rating of 127 MVA
  - Endeavour Energy's 132 kV 9L1 line to Nepean to exceed its thermal contingency rating of 358 MVA
  - TransGrid's Macarthur 330/132 kV transformer to exceed its contingency rating of 412.5 MVA
- A forced outage of the Macarthur 330/132 kV transformer at times of peak demand would cause TransGrid's Macarthur 330/66 kV transformer to exceed its short-time step rating.

For the constraints relating to a forced outage of the Macarthur 330/132 kV transformer, transfer of Campbelltown load to Ingleburn would provide some relief to this constraint in the next few years.

These constraints are forecast to result in significant expected unserved energy (EUE) if nothing is done. Avoiding this EUE is the key driver for this RIT-T.

While there are several embedded generators in the area, sources are not considered to be an effective means of reducing the EUE in light of both response capability and forecast load growth. Generation predominantly occurs using gas that is created from coal mining activity, with very limited gas storage capability that would enable the generators to adequately respond to periods of high demand and/or loss of infrastructure.

2.2 Description of the identified need

TransGrid considers the proposed investment a 'market benefits' driven RIT-T as the proposed investment is for the purpose of maintaining network security, which is estimated to deliver significant benefits in terms of avoided involuntary load shedding.

Investments made under a 'market benefits' identified need differ from those undertaken under a 'reliability corrective action' identified need in that market benefits driven investments are not made to meet externally imposed obligations on the network business and, consequently the preferred option must have positive net economic benefits.[11]

2.3 Assumptions underpinning the identified need

This section sets out several key assumptions TransGrid and Endeavour Energy consider underpin the identified need. These relate to the quantum of forecast EUE and how it is expected if no action is taken.

2.3.1 Additional detail on the network elements causing constraints

Figure 2-3 below provides a high-level summary of the existing electricity supply arrangements. Additional detail is provided in Appendix B.

Under system normal conditions, the single Macarthur 330/132 kV transformer presently supplies Nepean transmission substation, Oran Park 132/11 kV zone substation, North Leppington 132/11 kV zone substation, South Leppington 132/11 kV zone Substation and a large customer installation at Smeaton Grange supplied at 132 kV. In the future it will supply additional proposed zone substations including initial supplies to the proposed Aerotropolis core 132/22 kV zone substation.

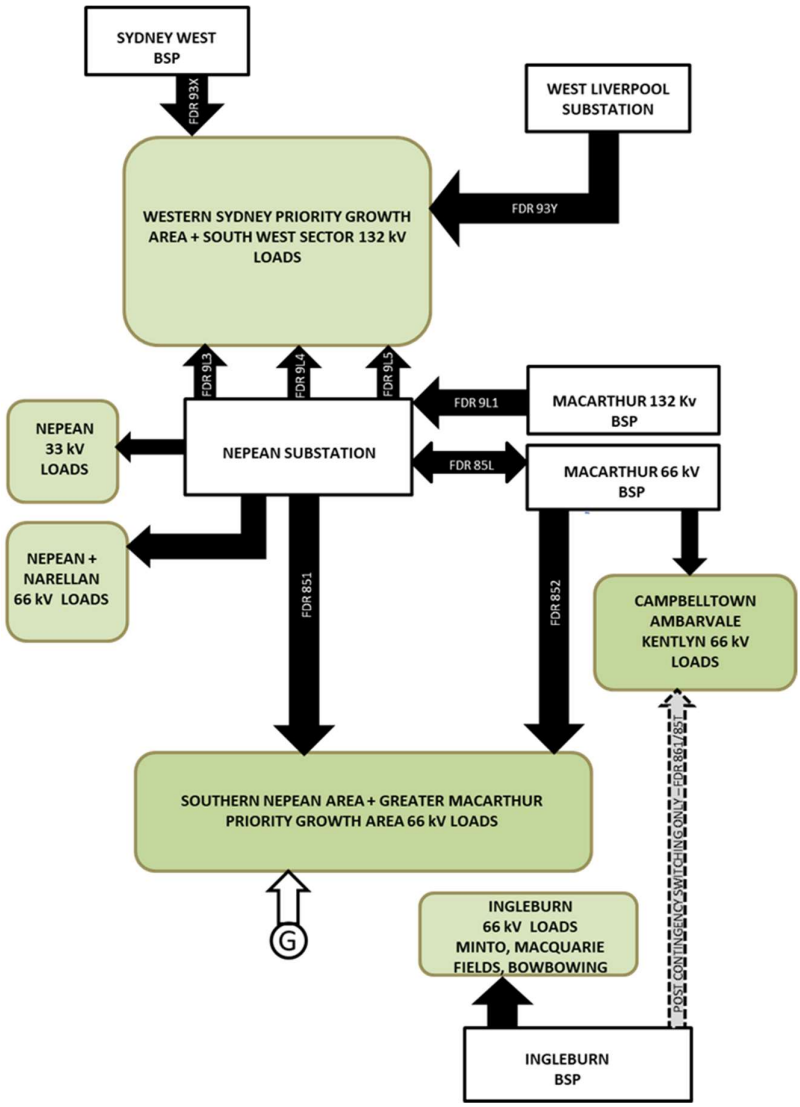
As noted above, the Macarthur 330/132 kV transformer supplies Nepean transmission substation and, in particular, the two 132/66 kV transformers that also feed the Nepean-Macarthur 66 kV network and the Nepean 33 kV network. The 66 kV loads that are fed from Nepean substation (and ultimately via the 330/132 kV Macarthur transformer) are Maldon 66/11 kV, Narellan 66/11 kV, Nepean 66/11 kV, Tahmoor 66/11 kV and Wilton 66/11 kV zone substations as well as large industrial customers.

The single Macarthur 330/66 kV transformer, under system normal conditions, presently supplies Ambarvale, Appin, Campbelltown and Kentlyn zone substations, as well as a number of significant large customer installations. In the future it will also supply Menangle Park zone substation (currently under construction) and proposed additional zone substations in the Greater Macarthur growth area (notably at Gilead, South Gilead and Wilton New Town).

From the two figures below, for an outage of the Macarthur 330/66 kV transformer, all of the Nepean-Macarthur 66 kV load will have to be supplied via the Macarthur 330/132 kV transformer and the two Nepean 132/66 kV transformers. Nameplate ratings on the 330/132 kV transformer start to be exceeded from 2020/21 onwards. The combined nameplate ratings of the two 132/66 kV Nepean transformers are already being exceeded for this contingency case.

[11] Reliability corrective action identified need RIT-Ts can have negative net economic benefits on account of having to meet an externally imposed obligation on the network business.

Figure 2-3 Existing supply arrangements to the Macarthur-Nepean area



Conversely, for an outage of the Macarthur 330/132 kV transformer, all of the load for this catchment area would need to be initially supplied from the Macarthur 330/66 kV transformer until load can be transferred away. This means that for the duration of the switching time (assuming load can be switched away), the Macarthur 330/66 kV transformer will see an additional load equivalent to the load previously on the 330/132 kV transformer. This presents a significant load jump on this smaller transformer and it is unlikely that this load will be sustained for the duration of the switching operations. In fact, it is likely to severely overload the transformer and cause significant loss of availability.

Figure 2-4 and Figure 2-5 below present load forecasts for the Macarthur and Nepean substations at the 10 per cent probability of exceedance (POE) and 50 per cent POE, respectively.

Figure 2-4 Summer POE10 Demand Forecast Load for Macarthur and Nepean Substations

Figure 2-5 Summer POE50 Demand Forecast Load for Macarthur and Nepean Substations

While the TransGrid sources of supply have their own load catchment areas (which include fast growing regions of the Aerotropolis and the South West growth area), these areas are experiencing their own supply constraints and the availability of backup supply will reduce as these areas are developed. It is not feasible to have pre-contingency switching in place due to fault level issues and for the case of Ingleburn substation, will leave substantial areas of this load catchment exposed to the risk of customer outages in the event of a single contingency event, ie, this catchment area will be left without any backup supply if pre-switching takes place to cover the risk of outages from any contingency event at Macarthur substation. If nothing were to be done, customers would therefore face outages in the event of an outage of either Macarthur transformer.

2.3.2 Forecast unserved energy if action is not taken

TransGrid and Endeavour Energy have assessed the peak load at risk based on Endeavour Energy's distribution load forecasts. It shows the expected unserved energy projections using three different 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

Figure 2-6 below illustrates these three unserved forecasts over the assessment period.

Figure 2-6 Forecast Macarthur 132 kV and 66 kV expected unserved energy

As outlined above, this load at risk is due to developments in south west Sydney and the Greater Macarthur area. These developments increase the level of unsupportable load in Endeavour Energy's network upon outage of a Macarthur transformer.

Each of the three load forecasts above has been included in the economic assessment undertaken in this PACR, as outlined in section 3. In addition, TransGrid has also undertaken a range of sensitivities on the load forecasts (along with other assumptions), which are presented in section 6.4.

3. Potential credible options

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

TransGrid considered two feasible network options from a technological and project delivery perspective in the PSCR and this PACR:

- **Option 1** – installation of a second 330/66 kV transformer at Macarthur substation; and
- **Option 2** – permanent transfer of the Campbelltown load to the Ingleburn BSP.

No submissions were received in response to the PSCR and no additional credible options have been identified.

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

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

3.1 Base Case

The costs and benefits of each option in this PACR are compared against those of a base case[12]. Under this base case, no investment is undertaken and so this presents a risk of significant amounts of involuntary load shedding.

TransGrid notes that this outcome is not expected in practice. However, this approach has been adopted since it is consistent with AER guidance on the base case for RIT-T applications.[13]

The Expected Unserved Energy (EUE) under the base case is assessed to be approximately 10 MWh[14] in 2021.

3.2 Option 1 – Installation of a second 330/66 kV transformer at Macarthur substation

This option will require the following works to be carried out by TransGrid:

- provision of a 250 MVA 330/66 kV transformer, including compound, switchgear, oil containment and all other necessary HV gear
- establishment of a 330 kV busbar to allow cut in of the second 330/66 kV transformer into the existing 330 kV mesh
- appropriate secondary systems for transformer control and protection are to be installed for the new transformer and switchbay
- integration of Automatic Voltage Regulation (AVR) for the new transformer with the existing 330/66 kV transformer control system
- upgrade of 110 V DC battery banks and chargers to meet new capacity

[12] 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 6 May 2020. 22. https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf

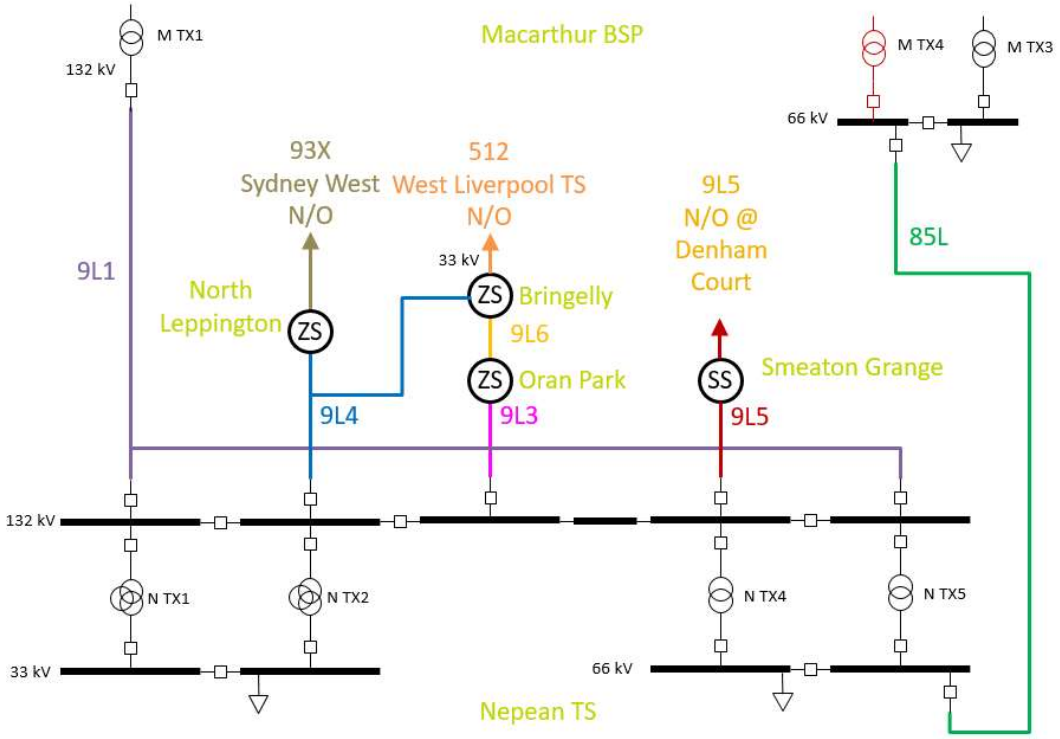
[13] TransGrid notes that the final updated December 2018 AER RIT-T Guidelines state that the base case is where the RIT–T proponent does not implement a credible option to meet the identified need, but rather continues its 'BAU activities'. The AER define 'BAU activities' as ongoing, economically prudent activities that occur in the absence of a credible option being implemented. See: AER, *Regulatory Investment Test for Transmission Application Guidelines,* December 2018. 21.

[14] Central Scenario

The risk of unserved energy under Option 1 is assessed to be effectively zero.

Figure 3-1 below provides a network diagram for Option 1.

Figure 3-1 Network diagram for Option 1



The estimated capital cost of the option is $9 million +/- 25 per cent. The table below provides a breakdown.

Table 3-1 Capital expenditure breakdown under Option 1 ($m 2020/21)

Item	Capital expenditure ($m)
Electrical Works	7
Civil and Structural Works	2
Total capital cost	**9 (+/-25%)**

The estimated operating cost for Option 1 is approximately $10,000. The table below provides a breakdown.

Table 3-2 Operating expenditure breakdown under Option 1 ($ 2020/21)

Item	Operating expenditure ($)
Annualised protection maintenance activities	10,000
Total operating cost	**10,000 (+/-25%)**

Option 1 is expected to be commissioned by June 2022, which aligns with the optimal commissioning date.

3.3 Option 2 – Permanent transfer Campbelltown load to the Ingleburn BSP

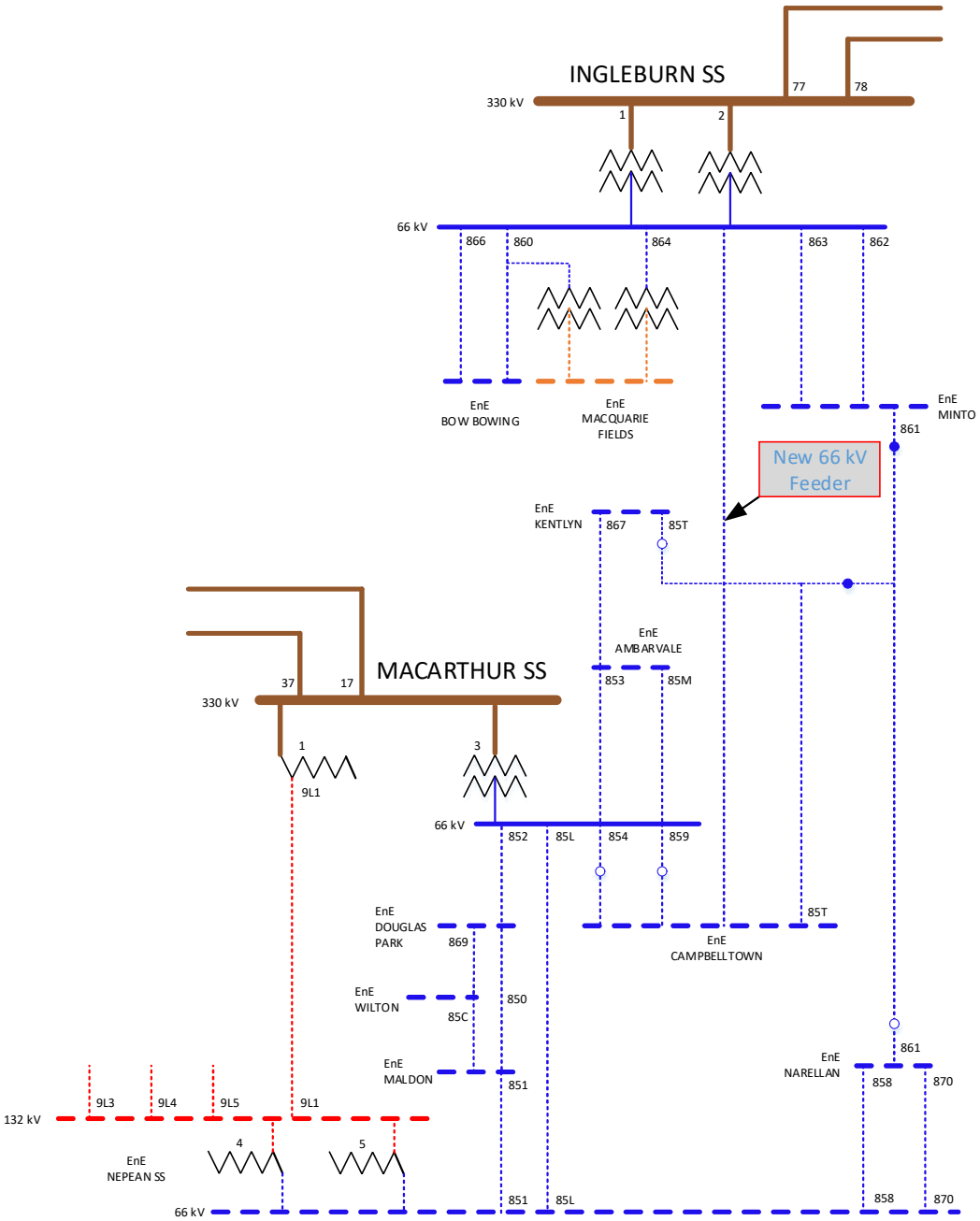
This option will require the following works to be carried out by Endeavour Energy and TransGrid:

- installation of a new feeder switchbay at Ingleburn 66 kV busbar – TransGrid
- installation of a new bus section and a new feeder bay at Campbelltown – Endeavour Energy
- a new 66 kV feeder between Ingleburn and Campbelltown – Endeavour Energy
- appropriate secondary system works for new feeder and feeder bays – Endeavour Energy

With Option 2, residual risks of unserved energy will re-emerge from 2023, based on current forecasts by Endeavour Energy. This has not been quantified in this RIT-T, as Option 2 is not the preferred option and additional risk of unserved energy will make it less favourable.

Figure 3-12 below provides a network diagram for Option 2.

Figure 3-2 Network diagram for Option 2



The estimated capital cost of the option is $35 million[15]. The table below provides a breakdown.

Table 3-3 Capital expenditure breakdown under Option 2 ($m 2020/21)

Item	Capital expenditure ($m)
Installation of a new feeder switchbay at Ingleburn 66 kV busbar – TransGrid	5
Installation of a new bus section and a new feeder bay at Campbelltown – Endeavour Energy	5
A new 66 kV feeder between Ingleburn and Campbelltown – Endeavour Energy	24
Appropriate secondary system works for new feeder and feeder bays – Endeavour Energy	1
Total capital cost	**35 (+/-25%)**

The estimated operating cost for Option 2 is approximately $15,000. The table below provides a breakdown.

Table 3-4 Operating expenditure breakdown under Option 2 ($ 2020/21)

Item	Operating expenditure ($)
Annualised protection maintenance activities	15,000
Total operating cost	**15,000 (+/-25%)**

Option 2 is expected to be commissioned by June 2022.

[15] Cost Estimate provided by Endeavour Energy,

3.4 Options considered but not progressed

TransGrid also considered whether a number of other credible options would meet the identified need. The reasons these options were not progressed further are summarised in below.

Table 3-5 Capital Options considered but not progressed

Option	Reason(s) for not progressing
Install a third 132/66 kV transformer at Nepean transmission substation	Analysis by Endeavour Energy finds that, whilst replacing the spare 33 kV bus section and 132/33 kV transformer at Nepean TS with a new 66 kV bus section and 132/66 kV transformer aligns with ultimate network configuration, the 66 kV fault level at Nepean TS will exceed the breaking capacity of some 66 kV circuit breakers at Nepean TS if all four of the 66 kV transformers are paralleled. Feeder 9L1 and Macarthur 330/132 kV transformer will still be overloaded in the pre-contingency switching stage, which is not acceptable. This option is therefore not considered technically feasible.
Seasonal transfer of Campbelltown ZS to Ingleburn BSP	Analysis by Endeavour Energy finds that this option introduces additional unserved energy risk for Campbelltown ZS. The additional EUE of this option is estimated to grow from 6.38 MWh in 2021 to 97.08 MWh by 2035[16], and so this option is not considered technically feasible. Specifically, these substations will be left on N supply security for the season if seasonal pre-contingency switching is implemented to cater for N-1 supply security on the Macarthur – Nepean system. This has the effect of shifting the outage risks onto the established Campbelltown area. These risks increase in proportion with load forecast increases and so increase with time.
Feeder 9L5 Manual changeover	Analysis by Endeavour Energy finds that this option introduces additional load at risk due to the fact that manual switching operations following a contingency are not able to be completed in time for the Nepean transformers to be safely offloaded and will result in customer outages. These risks increase as load forecast increases and so increase with time. The level of load at risk on the Nepean transformers also risks permanent damage to the transformers. This option is therefore not considered technically feasible.
Feeder 93X auto-changeover scheme	Analysis by Endeavour Energy finds that this option has the same issues as the Feeder 9L5 manual changeover option (outlined above) and so is not considered technically feasible.
Paralleling Liverpool and Macarthur BSPs	Analysis by Endeavour Energy finds that, under this option, the calculated fault level exceeds the existing fault rating in Endeavour Energy distribution network. This option is therefore not considered feasible.

[16] In accordance with Endeavour Energy EUE calculation results.

3.5 No material inter-network impact is expected

TransGrid has considered whether the credible options listed above are expected to have material inter-regional impact.[17] A 'material inter-network impact' is defined in the NER as:

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

AEMO's suggested screening test to indicate that a transmission augmentation has no material inter-network impact is that it satisfies the following:[18]

- a decrease in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3 per cent of the maximum transfer capability and 50 MW
- an increase in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3 per cent of the maximum transfer capability and 50 MW
- an increase in fault level by less than 10 MVA at any substation in another TNSP's network
- 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 they do 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.

3.6 Non-network options

As part of this consultation process, TransGrid encouraged interested parties to make submissions regarding non-network options that satisfy, or contribute to satisfying, the identified need. In the PSCR, TransGrid outlined the technical characteristics required for a non-network option to manage the load at risk in order to defer or avoid the network option of installing a second 250 MVA 330/66 kV transformer at Macarthur BSP.

No submissions were received regarding non-network options throughout the consultation period.

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

[18] 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 6 May 2020. https://www.aemo.com.au/-/media/Files/PDF/170-0035-pdf

4. Materiality of market benefits

This section outlines the classes of market benefits prescribed in the National Electricity Rules (NER) and whether they are considered material for this RIT-T[19].

4.1 Changes in involuntary load shedding are expected to be material

TransGrid considers that the only class of market benefit that is likely to be material is changes in involuntary load shedding. This is driven by Option 1 avoiding the network constraints outlined in section 2 above and the consequent risk to supply to end consumers.

4.2 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.[20]

TransGrid determines that the credible options considered in this RIT-T will not address network constraints between competing generating centres and are therefore not expected to result in any change in dispatch outcomes and wholesale market prices. Therefore, TransGrid considers that the following classes of market benefits are not material for this RIT-T assessment:

- changes in fuel consumption arising through different patterns of generation dispatch
- changes in price-responsive voluntary load curtailment (since there is no significant 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
- changes in network losses
- competition benefits
- Renewable Energy Target (RET) penalties.

4.3 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 transmission investment; option value; and changes in involuntary load shedding. TransGrid considers that none of the classes of market benefits listed are material for this RIT-T assessment for the reasons in Table 4-1.

[19] The NER requires that all classes of market benefit identified in relation to the RIT-T are included in the RIT-T assessment, unless the TNSP can demonstrate that a specific class (or classes) is unlikely to be material in relation to the RIT-T assessment for a specific option – NER clause 5.16.1(c)(6). See Appendix A for requirements applicable to this document.

[20] Australian Energy Regulator. "Application guidelines Regulatory Investment Test for Transmission - December 2018." Melbourne: Australian Energy Regulator, 2018.39.Accessed 6 May 2020. https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf

Table 4-1 Reasons non-wholesale electricity market benefits categories are considered immaterial

Market benefits	Reason
Differences in the timing of unrelated expenditure	No unrelated planned transmission or distribution expenditure is affected by Option 1.
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.[21] 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 benefit but it would be disproportionate to potential additional benefits for this RIT-T. Therefore, TransGrid has not estimated any additional option value benefit.

[21] Australian Energy Regulator. *"Application guidelines Regulatory Investment Test for Transmission - December 2018."* Melbourne: Australian Energy Regulator, 2018.58-59. Accessed 8 May 2020. https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf

5. Overview of the assessment approach

This section outlines the approach that TransGrid has applied in assessing the net benefits associated with each of the credible options.

5.1 Description of the base case

The costs and benefits of each option in this document are compared against those of a base case. Under this base case, no investment is undertaken and so this presents a risk of significant amounts of involuntary load shedding.

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

5.2 Assessment period and discount rate

The analysis presented in this RIT-T considers a 20-year period, from 2020/21 to 2039/40. TransGrid consider that a 20-year period takes into account the size, complexity and expected life of the options and provide a reasonable indication of the costs and benefits over a long outlook period. Since the capital components have a greater asset life than 20 years, a terminal value approach has been applied to ensure that the capital costs of long-lived assets are appropriately captured in the 20-year assessment period.

TransGrid adopted a central real, pre-tax 'commercial' discount rate[23] of 5.90 per cent as the central assumption for the NPV analysis presented in this report. TransGrid consider that this is a reasonable contemporary approximation of a commercial discount rate, consistent with the commercial discount rate calculated in the RIT-T Economic Assessment Handbook published by Energy Networks Australia (ENA) in March 2019[24].

TransGrid also tested the sensitivity of the results to discount rate assumptions. A lower bound real, pre-tax discount rate of 2.23 per cent equal to the latest AER Final Decision for a TNSP's regulatory proposal at the time of preparing this document[25], and an upper bound discount rate of 9.57 per cent (a symmetrical adjustment upwards) were used.

5.3 Approach to estimating option costs

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

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

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22 TransGrid notes that the final updated December 2018 AER RIT-T Guidelines state that the base case is where the RIT–T proponent does not implement a credible option to meet the identified need, but rather continues its 'BAU activities'. The AER define 'BAU activities' as ongoing, economically prudent activities that occur in the absence of a credible option being implemented. See: AER, *Regulatory Investment Test for Transmission Application Guidelines,* December 2018. 21.

23 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.

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

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

5.4 Three different scenarios have been modelled to address uncertainty

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

A key expected driver of the net economic benefits is the Value of Customer Reliability (VCR) and the underlying demand forecast since avoided EUE is the primary market benefit. TransGrid has applied a VCR estimate of $43.03/kWh in the central scenario and +/- 30 per cent for the other two scenarios, which is consistent with the AER's VCR review released in December 2019.[26]

A summary of the key variables in each scenario is provided in 5-1.

Table 5-1 Summary of scenarios

Variable / Scenario	Central	Low benefit scenario	High benefit scenario
Scenario weighting	*50%*	*25%*	*25%*
Discount rate	5.90%	9.57%	2.23%
Costs			
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Operating and maintenance costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Benefits (negative benefits)			
Demand forecasts	Based on POE50 demand forecasts	Based on POE90 demand forecasts	Based on POE10 demand forecasts
Value of Customer Reliability (VCR)	The AER's VCR	The AER's VCR - 30%	The AER's VCR + 30%

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

[26] The central estimate of $43.03/kWh reflects an inflation adjustment to the load weighted VCR estimate for NSW and ACT ($42.12/kWh). The confidence interval selected is also drawn from the AER's VCR review. AER, *Value of Customer Reliability Review – Final report*, December 2019, pp 71 (Table 5.22) & 84. https://www.aer.gov.au/system/files/AER%20-%20Values%20of%20Customer%20Reliability%20Review%20-%20Final%20Report%20-%20December%202019.pdf.

6. Assessment of credible options

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

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

- updated the discount rates used
- inflation escalation update
- updated operating costs

There were no material changes since publication of the PSCR that affect the ranking preference for Option 1.

All costs presented in this PACR have been escalated using inflation and are in 2020/21 dollars.

6.1 Estimated gross benefits

The table below summarises the present value of the gross benefit estimates for each credible option relative to the base case under the three scenarios. The gross benefits have been calculated for the scenarios outlined in the section above and the variation in gross benefit reflects that combination of changes in VCR, demand forecast and discount rate across the scenarios.

Table 6-1 Estimated gross benefits from credible options relative to the base case, present value ($m 2020/21)

Option/scenario	Central scenario	Low benefit scenario	High benefit scenario	Weighted
Option 1 – Installation of a second 330/66 kV transformer at Macarthur substation	85.3	10.0	328.1	127.2
Option 2 - Permanent transfer Campbelltown load to the Ingleburn BSP[27]	85.3	10.0	328.1	127.2

6.2 Estimated costs

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

[27] With Option 2, residual risks of unserved energy will re-emerge from 2023, based on current forecasts by Endeavour Energy. This has not been quantified in this RIT-T, as Option 2 is not the preferred option and additional risk of unserved energy will make it less favourable.

Table 6-2 Estimated costs of credible options relative to the base case, present value ($m 2020/21)

Option	Central scenario	Low benefit scenario	High benefit scenario	Weighted
Option 1 – Installation of a second 330/66 kV transformer at Macarthur substation	7.0	9.3	4.3	6.9
Option 2 - Permanent transfer Campbelltown load to the Ingleburn BSP[28]	27.7	37.6	16.9	27.5

6.3 Estimated net economic benefits

The net economic benefit is the gross benefits (as set out in section 6.1 above) minus the costs (as outlined in section 6.2 above), all expressed in present value terms. The table below summarises the present value of the net economic benefit for each credible option across the three scenarios, as well as on a weighted basis.

The table below demonstrates that the option considered provides an expected net economic benefit under the central and high benefits scenario, as well as on a weighted basis.

Table 6-3 Estimated net economic benefits relative to the base case, present value ($m 2020/21)

Option	Central scenario	Low benefit scenario	High benefit scenario	Weighted	Ranking
Option 1 – Installation of a second 330/66 kV transformer at Macarthur substation	78.3	0.7	323.8	120.3	1
Option 2 - Permanent transfer Campbelltown load to the Ingleburn BSP	57.5	-27.6	311.2	99.7	2

[28] With Option 2, residual risks of unserved energy will re-emerge from 2023, based on current forecasts by Endeavour Energy. This has not been quantified in this RIT-T, as Option 2 is not the preferred option and additional risk of unserved energy will make it less favourable.

6.4 Sensitivity testing

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

In particular, TransGrid has undertaken two sets of sensitivity tests – namely:

> step 1 – testing the sensitivity of the optimal timing ('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

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

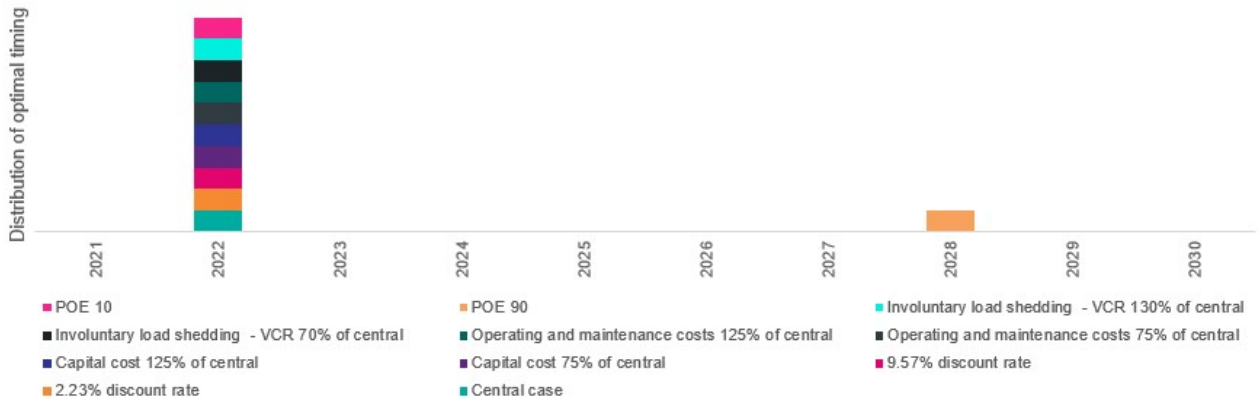
6.4.1 Step 1 – Sensitivity testing of the assumed optimal timing for each credible option

TransGrid has estimated the optimal timing for Option 1 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. Specifically, TransGrid has investigated the following scenarios:

> a 25 per cent increase/decrease in the assumed network capital costs
> lower discount rate of 2.23 per cent as well as a higher rate of 9.57 per cent
> lower (or higher) assumed operation and maintenance costs
> lower (or higher) VCR estimates
> lower (or higher) demand (POE) forecasts

The figure below outlines the impact on the optimal commissioning year, under a range of alternative assumptions. It illustrates that for Option 1, the optimal commissioning date is found to be in 2021/22 for all of the sensitivities investigated other than where demand is assumed to be low (POE90) where the optimal timing is 2027/28.

Figure 6-1 Distribution of optimal timing for Option 1 under a range of different key assumptions



6.4.2 Step 2 – Sensitivity of the overall net economic benefit

TransGrid has conducted sensitivity analysis on the present value of the net economic benefit, based on having to undertake the project by 2021/22. Specifically, TransGrid has investigated the following sensitivities:

> a 25 per cent increase/decrease in the assumed network capital costs
> lower discount rate of 2.23 per cent as well as a higher rate of 9.57 per cent
> lower (or higher) assumed operation and maintenance costs
> lower (or higher) VCR estimates

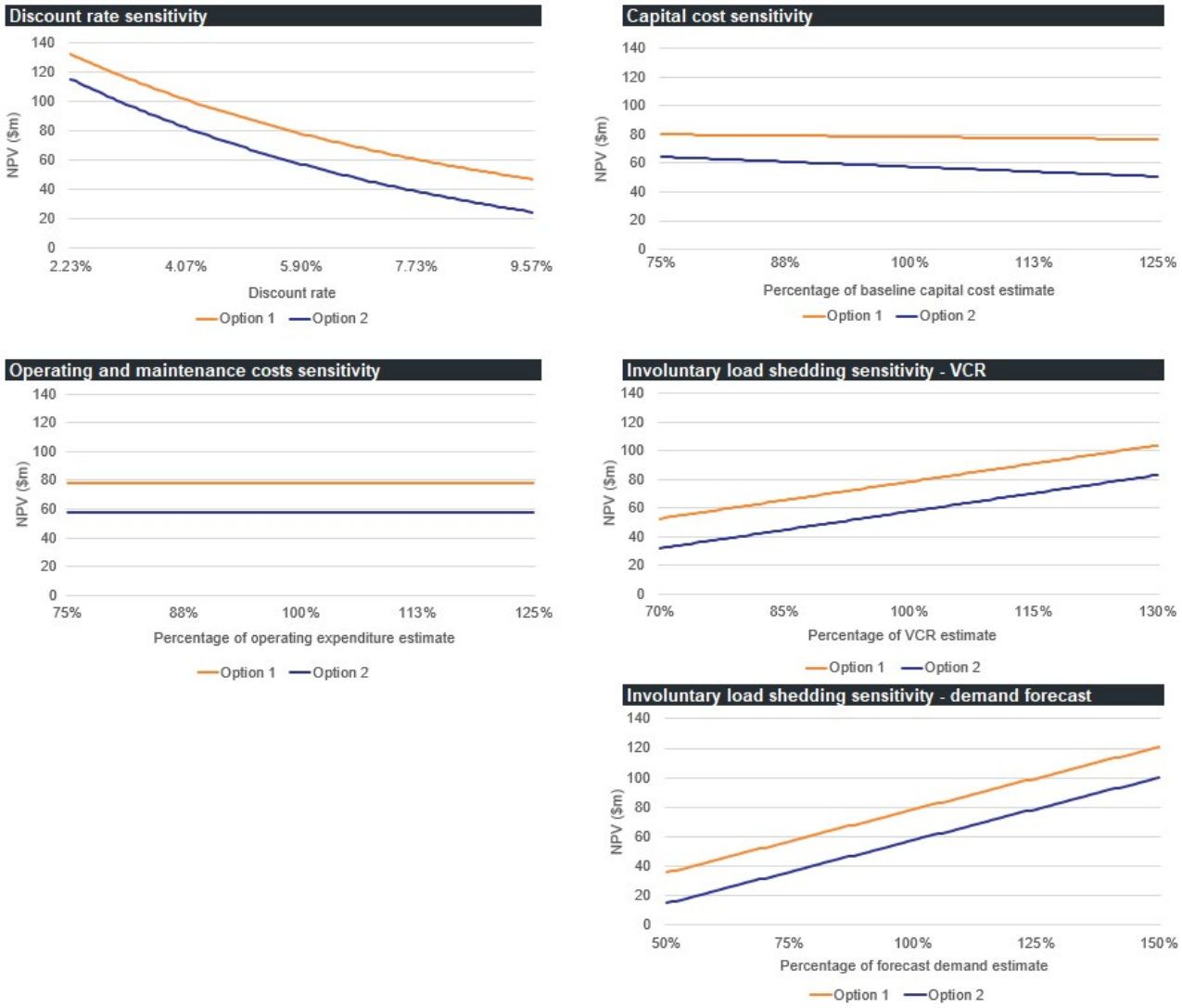
> a 50 per cent increase/decrease in the demand forecasts

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

The figures below illustrate the estimated net economic benefits for the option if TransGrid vary five separate key assumptions in the central scenario individually. Importantly, for all sensitivity tests shown below, the estimated net economic benefit of the option considered are found to be strongly positive and Option 1 delivers the most benefit under all scenarios.

The results are found to be most sensitive to the assumed VCR and demand forecast, i.e., the factors that contribute to the benefits derived from a reduction in involuntary load shedding. TransGrid extended the sensitivity exercise to better understand how net economic benefits vary with changes in either VCR or forecasted demand, and have found that either would need to decrease by approximate 92 per cent from the base scenario to result in no net economic benefits (ie, to result in an NPV of zero), holding all else constant. TransGrid considers it extremely unlikely that the central estimates for the VCR and load growth have been this overestimated.

Figure 6-2 Sensitivity testing of the NPV of net economic benefits ($m 2020/21)



7. Final conclusion on the preferred option

The optimal commercially and technically feasible option presented in the PSCR – Option 1 (installation of a second 330/66 kV transformer at the Macarthur substation) – remains the preferred option to meet the identified need.

The estimated capital cost of this option is approximately $9 million.

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

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

Option 1 is the preferred option in accordance with NER clause 5.16.1(b) because it is the credible option that maximises the net present value of the net economic benefit to all those who produce, consume and transport electricity in the market.

Appendix A - Compliance checklist

This appendix sets out a checklist which demonstrates the compliance of this PACR with the requirements of the National Electricity Rules version 149.

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

Appendix B - Existing supply in the Greater Macarthur area