Maintaining reliable supply to Broken Hill

RIT-T – Project Assessment Draft Report [REVISED]

Region: South Western New South Wales

Date of issue: 6 October 2021

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Executive summary

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to long-term options for maintaining reliable supply to Broken Hill. Publication of this Project Assessment Draft Report (PADR) represents the second step in the RIT-T process and follows the Project Specification Consultation Report (PSCR) released in November 2019.

This PADR has been updated based on new AER guidance on the treatment of non-network option costs

An initial Project Assessment Draft Report (PADR) was released for this RIT-T on 11 August 2020 (referred to throughout this document as the 'initial PADR'). TransGrid highlighted in the initial PADR that the regulatory treatment of non-network costs is a key driver of the preferred option under the RIT-T.

In late August 2020, the Australian Energy Regulator (AER) provided additional guidance regarding the treatment of non-network options in the RIT-T cost benefit assessment. TransGrid has confirmed with the AER that this guidance should be applied to this RIT-T. This revised PADR therefore updates the approach to assessing non-network options and presents the revised outcomes of the RIT-T assessment.

Consistent with the AER's guidance, where an option involves the use of the existing diesel-fired[1] turbines at Broken Hill, TransGrid considered how these assets would operate in the base case as well as in each option case, and have assessed the difference.

TransGrid has also taken the opportunity to update the RIT-T assessment to reflect the feedback received from stakeholders on the initial PADR.

Benefits from the options considered in this PADR

Broken Hill is located in the far west of New South Wales and is part of TransGrid's south-western transmission network. It is currently supplied by a single 220 kV transmission line, 'Line X2', from Buronga which spans approximately 260 km.

When Line X2 is out of service due to planned or unplanned outage, electricity supply to Broken Hill is supported by two diesel-fired turbines, which are owned by Essential Energy, to avoid involuntary load shedding. TransGrid relies on these turbines to meet the NSW Electricity Transmission Reliability and Performance Standards 2017 (the 'reliability standards') set by the NSW Energy Minister and regulated by the NSW Independent Pricing and Regulatory Tribunal (IPART).

Essential Energy has notified TransGrid of its decision to divest the turbines located at Broken Hill and is currently in the process of enacting that divestment. If no action is taken by TransGrid, this would result in the required reliability of supply to Broken Hill not being maintained, and involuntary load shedding when Line X2 is on planned or unplanned outage.

TransGrid considers this a 'reliability corrective action' under the RIT-T, as the identified need is to ensure that the externally-imposed reliability standards for Broken Hill continue to be met. All of the credible options assessed in this PADR provide back-up and reliable supply to Broken Hill for the future that is consistent with the NSW Electricity Transmission Reliability and Performance Standards.

[1] While the initial PADR referred to these turbines as 'gas turbines', they are actually operated using diesel and so we have updated their description throughout this document accordingly.

Some of the credible options assessed will also affect the wholesale electricity market. In particular:

- some options involve grid-connected storage that introduce new entities trading in the wholesale market, eg, dispatching into the National Electricity Market (NEM) outside of the allocation of storage needed to meet its Broken Hill network support commitments; and
- the impact on network capacity under some of the options facilitates greater uptake of renewables in surrounding Renewable Energy Zone (REZ) areas.

Both the benefits from the provision of reliable supply to Broken Hill and wider wholesale market benefits have been estimated as part of this PADR.

The updated PADR analysis has benefited from further stakeholder feedback

The initial PADR for this RIT-T was published on 11 August 2020.

TransGrid received nine submissions, including from proponents of non-network options (including a number of new non-network solutions since the initial PADR was released). The submissions can be summarised as:

- four from existing proponents from the Expression of Interest (EOI)/PSCR;
- three from new proponents, with various levels of solutions;
- one who endorsed another proponent's solution (Option 1D); and
- one from PIAC that raised concerns about trialling emerging technologies.

The submissions from proponents of non-network options raised a range of issues relating to the specific assumptions made in evaluating their options (including cost and technical capabilities). These submitters each requested confidentiality. However, in general, TransGrid revised the assessment of each of the options in light of the submissions, and adopted the assumptions proposed as far as possible.

In March 2021, TransGrid sent a request for clarification to those proponents who proposed a solution in response to the EOI that accompanied the initial PADR, in order to source the required inputs to enable TransGrid to assess their options in-line with the new AER guidance. This consultation allowed proponents to reconsider and revise their offers in light of the new guidance, as well as to raise any further points with TransGrid as part of the RIT-T consultative process.

Five types of credible options have been developed and assessed in this PADR

Stakeholder consultation on the PSCR and initial PADR has assisted greatly with developing and refining the credible options considered in this RIT-T. Specifically, consultation with third parties has enabled this revised PADR to assess the following five types of credible options:

- Option 1: nine different non-network opex solutions fully provided by third parties (Options 1A(1)– (5) (being five different sized options from one proponent), Option 1C, Option 1D, Option 1E and Option 1F);
- Option 2: a revised version, and cost for, acquiring the existing diesel-fired turbines from Essential Energy;
- Option 3: establishing new diesel-fired turbines at Broken Hill;
- Option 4: building a second single circuit 220 kV transmission line from Buronga to Broken Hill; and
- Option 5: nine variants of the first group of solutions involving either shared ownership or ownership by TransGrid (Option 5A(1) - (5) (being five different sized options from one proponent), Option 5B, Option 5C, Option 5E and Option 5G).

The updated AER guidance now means that options with the same scope in terms of the underlying technical solution will have the same net benefits, regardless of ownership. For example, Option 1A(1) that is a non-network solution will have the same resource costs and net benefits as Option 5A(1), where the solution is

owned by TransGrid. For clarity, ownership of the solution, whether by a non-network proponent or TransGrid, now results in the same level of net benefits for that solution under the RIT-T.

All options reduce expected unserved energy (EUE) at Broken Hill to the amount required under the IPART reliability standard. Option 4 provides an additional level of reliability due to the second transmission line and is assessed to reduce EUE to effectively zero.

TransGrid notes that the existing turbines at Broken Hill form a component of several options. However, they are only ultimately able to be offered either by the party who purchases the turbines, or by a party that contracts with the purchaser. Depending on when the divestment process concludes, there may therefore be a reassessment of credible options between the PADR and the PACR. It is also possible that Essential Energy may sell the turbines to a third party who does not wish to be part of a network support arrangement, prior to the finalisation of this RIT-T process. In this circumstance, Option 2 would no longer be a credible option for this RIT-T, and non-network options that rely on the Essential Energy turbines would also be affected.

The nine non-network opex solutions fully provided by third parties and the nine variants of these solutions involving either shared ownership or ownership by TransGrid have been assessed using information (including costs) provided by parties in response to our March 2021 requests for clarification, where available, and in subsequent engagement with TransGrid. In order to maintain confidentiality of commercial-in-confidence information in submissions, these costs, and cost structures, have not been presented in this PADR.

The RIT-T assessment has considered different future scenarios and different base cases for the outcome of the divestment process for the existing turbines at Broken Hill

Uncertainty is captured under the RIT-T framework through the use of scenarios, which reflect different assumptions that are expected to affect the key drivers of the estimated net market benefits.

The credible options have been assessed under three scenarios as part of this PADR assessment, which are characterised as follows:

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

The table below summarises the specific key variables that influence the net benefits of the options under each of the scenarios considered.

Table E-1: Summary of scenarios

Variable	Central	Low net economic benefits	High net economic benefits
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Broken Hill demand	Based on POE50 demand forecast	Based on POE90 demand forecast	Based on POE10 demand forecast
Wholesale market benefits estimated	EY estimated based on central ISP scenario (as outlined in section 6 below)	30 per cent lower than what EY has estimated	30 per cent higher than what EY has estimated

Variable	Central	Low net economic benefits	High net economic benefits
VCR	$36.43/kWh	$25.50/kWh	$47.36/kWh
Discount rate	5.90%	9.57%	2.23%

The underlying demand forecasts have been updated slightly since the original PADR to align with our 2021 Transmission Annual Planning Report.

TransGrid modelled two alternate base cases as part of the revised PADR assessment. For this RIT-T, an important feature of the base case is the assumption regarding the future of the existing turbines at Broken Hill in the absence of an option, reflecting the Essential Energy divestment process underway. All credible options were modelled against the following two base cases:

> Base case I – the existing turbines are sold to a party outside of the NEM, e.g., a mine situated outside of the NEM; and

> Base case II – the existing turbines are not sold and Essential Energy mothballs them in the future.

The different base cases affect the costs and benefits included in the RIT-T assessment.

The top-ranked options deliver positive net benefits across all scenarios and on a weighted basis, with the ranking of those options having the highest net benefit being consistent across both base cases

The results of the PADR assessment find that Option 2 delivers the greatest net benefit of all credible options considered for continuing to provide reliable supply to Broken Hill. Under Option 2, TransGrid would purchase the existing turbines and undertake required refurbishment activities.

Option 2 is the option with the highest net benefit across the low and central scenarios (with Option 1A(4)/5A(4) becoming top-ranked in the high scenario), and is also the highest ranked on a weighted basis. Option 2 is also the highest ranked option under a majority of the sensitivities investigated. These results are consistent across both base cases considered.

Figure E-1: Summary of the estimated net benefits under the weighted scenario, base case I

Figure E-2: Summary of the estimated net benefits under the weighted scenario, base case II

Notwithstanding that the continued use of the diesel-fired turbines under Option 2 exhibits the highest net benefit and therefore is identified as the 'preferred option' (according to the specific definition in the RIT-T), we have concerns that prolonging the use of fossil fuel technologies is inconsistent with the Sustainability Strategy of Broken Hill City Council[2] or the general transition of the electricity sector to low emission technologies.

The highest ranked non-fossil fuel option under this RIT-T assessment is a non-network option, Option 1A/5A(2). Option 1A/5A(2) does not have an enduring reliance on fossil fuel technologies as part of the long term solution to meet reliability standards at Broken Hill. Instead, Option 1A/5A(2) is a compressed-air energy storage solution that will create a mini-grid at Broken Hill that will normally operate connected to the grid, and can meet the identified need over the long term.

Option 1A/5A(2) is of a sufficient size to trade in the wholesale market and is expected to provide wholesale market benefits in addition to the required level of reliability at Broken Hill. When Line X2 is in service, the storage will be able to store renewable generation from southern NSW that would otherwise be spilt, and make it available at other times. When Line X2 is out of service, the storage will enable Broken Hill to run as a 'mini-grid', using the wind and solar generation at Broken Hill based on the assessment in this PADR.

Broader market benefits are also expected to accrue under Option 1A/5A(2) and are primarily derived from avoided or deferred costs associated with generation and storage elsewhere in the NEM. Option 1A/5A(2) is estimated to deliver net benefits of around $276 million to $278 million over the assessment period to 2044/45 (in present value terms).

Option 1A/5A(2) is found to be the second-ranked option under the central scenario and on a weighted basis. Specifically, the net benefit of Option 1A/5A(2) is found to be within 9 and 12 per cent of the net benefit of Option 2, on a weighted basis, across base case I and base case II, respectively.

The technology utilised by Option 1A/5A(2) also offers a degree of flexibility to be scaled into a larger solution should the need arise, including if potential mining spot loads in the Broken Hill area eventuate.

[2] Broken Hill City Council, *Sustainability Strategy 2018-2023*.

TransGrid understands that the proponent of Option 1A/5A(2) is exploring external out-of-market funding. Any such external funding would reduce the costs of Option 1A/5A(2) that are included in the RIT-T NPV assessment and could potentially close the gap between Option 2 and Option 1A/5A(2) such that this option becomes the 'preferred option' (according to the specific definition in the RIT-T).

TransGrid notes that it is intended that the analysis in the PACR will be updated to reflect any external funding, as well as any other recent relevant market developments not captured in these assumptions.

Next steps

TransGrid welcomes written submissions on this PADR. Submissions are due on 17 November 2021.

Submissions should be emailed to TransGrid's Regulation team via regulatory.consultation@transgrid.com.au.[3] In the subject field, please reference 'PADR Broken Hill reliability project.'

At the conclusion of the consultation process, all submissions received will be published on the TransGrid's website. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement.

The next formal stage of this RIT-T is the publication of a PACR. The PACR is expected to be published in March 2022.

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

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1. Introduction

TransGrid is applying the Regulatory Investment Test for Transmission (RIT-T) to long-term options for maintaining reliable supply to Broken Hill. An initial Project Assessment Draft Report (PADR) was released for this RIT-T on 11 August 2020 (referred to throughout this document as the 'initial PADR').

The initial PADR highlighted that the regulatory treatment of non-network costs is a key driver of the preferred option. In late August 2020, as part of developing the guidelines to make the Integrated System Plan (ISP) actionable, the Australian Energy Regulator (AER) provided additional guidance regarding the treatment of non-network options in the RIT-T cost benefit assessment.[4] TransGrid subsequently clarified the new guidance with the AER, and whether it should apply to this RIT-T, since the initial PADR applied a different approach, which was consistent with previous AER guidance and other RIT-T assessments. The AER has confirmed that the August 2020 guidance does apply to this RIT-T and that TransGrid is required to re-issue the PADR. The AER also highlighted implications of the updated guidance for consideration of the cost of options involving the existing diesel-fired turbines[5] at Broken Hill, currently owned by Essential Energy. This revised PADR therefore updates the approach to assessing non-network options in line with the AER's guidance (outlined further in section 3.2 below) and presents the revised outcomes of the RIT-T assessment.

TransGrid also took the opportunity in this revised PADR to update the RIT-T assessment to reflect the feedback received from stakeholders on the initial PADR. In particular, this revised PADR discusses the submissions received on the initial PADR, and how that has been taken into account in this revised analysis.

Broken Hill is located in the far west of New South Wales and is part of our south-western transmission network. It is currently supplied by a single 220 kV transmission line, 'Line X2', from Buronga which spans approximately 260 km.

When Line X2 is out of service due to planned or unplanned outage, electricity supply to Broken Hill is supported by two diesel-fired turbines (currently owned by Essential Energy) to avoid involuntary load shedding. TransGrid relies on these turbines (each with a 25 MW nameplate rating) to meet the NSW Electricity Transmission Reliability and Performance Standards 2017 (the 'reliability standards') set by the NSW Energy Minister and regulated by the NSW Independent Pricing and Regulatory Tribunal (IPART). In accordance with these standards, network support provided by Essential Energy's turbines allows TransGrid to operate the network so as not to expect more than 10 minutes of expected unserved energy (EUE) per year at average demand.[6]

Essential Energy has notified TransGrid of its decision to divest the turbines located at Broken Hill and is currently in the process of enacting that divestment. If no action is taken, this would result in the required reliability of supply to Broken Hill not being maintained, and involuntary load shedding when Line X2 is on planned or unplanned outage.

TransGrid considers this a 'reliability corrective action' under the RIT-T, as the identified need is to ensure that the externally-imposed reliability standards for Broken Hill continue to be met.

In order to efficiently avoid involuntary load shedding and meet the reliability standards TransGrid adopted a two-step approach.

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4 AER, *Final Decision, Guidelines to make the Integrated System Plan actionable*, August 2020, p. 26, p. 52.

5 While the initial PADR referred to these turbines as 'gas turbines', they are actually operated using diesel and so we have updated their description throughout this document accordingly.

6 IPART, *NSW Electricity Transmission Reliability and Performance Standard 2017*, available at: https://www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/licensing-compliance-electricity-transmission-reliability/nsw-electricity-transmission-reliability-and-performance-standard-2017.pdf

- Step 1 – Establish a short-term non-network support solution, via an Expression of Interest (EOI) process. The EOI was issued in October 2019 with responses received in November 2019.
- Step 2 – Establish a long-term solution via this RIT-T process, which is considering all credible long-term options, including traditional network, innovative, and non-network solutions.

The intention is that the short-term option will be available until the long-term solution, identified under this RIT-T process, is operational.

TransGrid is currently progressing the supply of a short-term solution. The ultimate timing and scope of the short-term solution is dependent on Essential Energy's divestment date for the turbines and when the long-term solution being assessed under this RIT-T can be in place. Once the timing of these processes is confirmed, TransGrid will contract for this short-term service to address the short-term gap in backup supply capacity at Broken Hill. Essential Energy has recently confirmed that it will cease to provide network support services under the current arrangements in the near term.

TransGrid's revenue determination for the 2018-2023 regulatory control period includes a contingent project for the reliability of supply to Broken Hill. This contingent project is to provide additional capacity to supply Broken Hill in the event that the total 220 kV and 22 kV load at Broken Hill exceeds the capacity of the back-up turbines owned by Essential Energy and EUE exceeds the reliability standard allowance.[7] Where the outcome of this RIT-T identifies a preferred option that requires capital expenditure above the contingent project threshold, TransGrid will lodge a Contingent Project Application in line with this provision in our current regulatory determination.

If the preferred option under this RIT-T is a non-network solution, TransGrid will recover the opex costs associated this this solution via the network support pass through provisions in the National Electricity Rules (NER).[8]

1.1 Purpose

The purpose of this PADR is to:

- identify and confirm the market benefits expected from the various options for maintaining the required reliability of supply at Broken Hill over the long-term;
- summarise the consultation undertaken since the initial PADR was released and highlight how this has been addressed in the RIT-T analysis;
- describe the options being assessed under this RIT-T, including how these have been shaped as part of the consultation process;
- present the results of the NPV analysis for each of the credible options assessed;
- describe the key drivers of these results, and the assessment that has been undertaken to ensure the robustness of the conclusion; and
- identify the preferred option at this stage of the RIT-T, i.e., the option that is expected to maximise net benefits.

Overall, this report provides ongoing transparency into the planning considerations for maintaining the required reliability of supply at Broken Hill over the long-term. A key purpose of this PADR, and the RIT-T more broadly, is to provide interested stakeholders the opportunity to review the analysis and assumptions, provide input to the process, and have certainty and confidence that the preferred option has been robustly identified as optimal.

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[7] TransGrid, *Revised Regulatory Proposal 2018/19-2022/23*, available at: https://www.aer.gov.au/system/files/TransGrid%20-%20Revised%20Revenue%20Proposal%20-%201%20December%202017.pdf

[8] NER, Chapter 6A.7.2.

As noted in the initial PADR, TransGrid requested additional information and modelling from third parties in order to determine the technical feasibility of the solutions put forward. This revised PADR adopts an updated understanding of option technical feasibility and as a result has removed the original PADR assumption of additional network components for the non-network options.

1.2 How to make a submission and next steps

TransGrid welcomes written submissions on this revised PADR. Submissions are due on 17 November 2021.

Submissions should be emailed to TransGrid's Regulation team via regulatory.consultation@transgrid.com.au.[9] In the subject field, please reference 'PADR Broken Hill reliability project.'

At the conclusion of the consultation process, all submissions received will be published on our website. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement.

The next formal stage of this RIT-T is the publication of a PACR. The PACR is expected to be published in March 2022.

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

2. Benefits from continuing to provide the required supply reliability

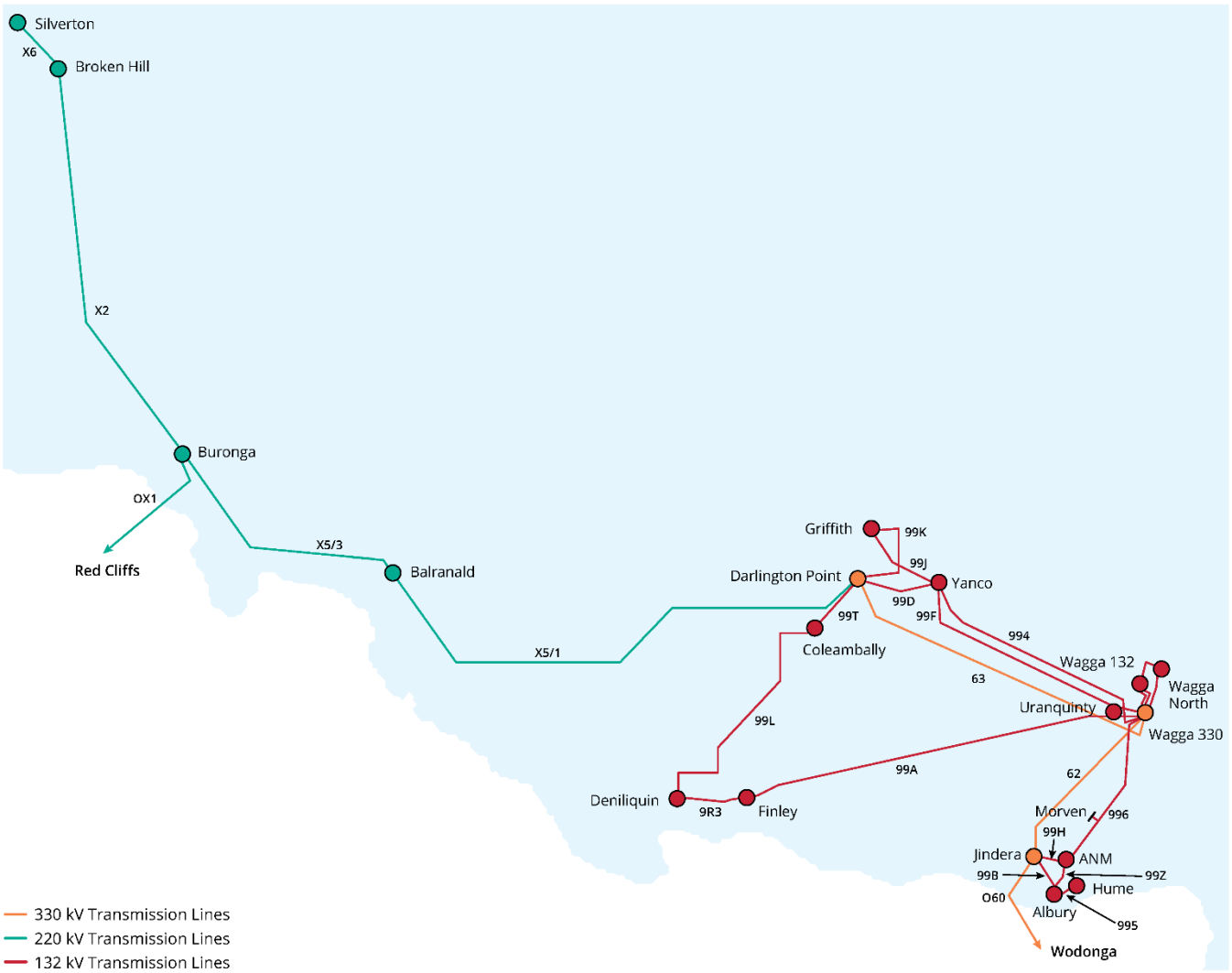
While the primary focus of this RIT-T is to maintain reliable supply at Broken Hill going forward, some of the options assessed in this PADR are also expected to provide benefits to the wider wholesale electricity market.

2.1 Avoided involuntary load shedding at Broken Hill

Broken Hill is part of the south-western transmission network and is supplied by a single 220 kV transmission line, Line X2, from Buronga that is around 260 km long. During a planned or unplanned outage of Line X2, Broken Hill has been supplied by Essential Energy's two back-up turbines that run on diesel fuel.[10]

The current electricity network supplying Broken Hill is shown in Figure 2-1 below.

Figure 2-1: The current electricity network supplying Broken Hill



[10] Broken Hill Solar Plant and Silverton Wind Farm are not presently configured to be able to generate in an event of an outage of Line X2.

The two existing back-up turbines:

- each have nominal capacity rating of 25 MW, which is reduced to 18 MW under adverse ambient temperature conditions; and
- are black-start capable and equipped for islanded operation.

TransGrid has relied on these turbines to meet our obligations under the NSW Electricity Transmission reliability standards as determined by IPART.

No other source of back-up supply is currently available.

Both Broken Hill Solar Plant (53 MW) and Silverton Wind Farm (200 MW) provide semi-scheduled, inverter-connected generation. These generators cannot currently provide firm capacity without grid forming dispatchable generation to assist, given the intermittent nature of their generation. These generators are not currently capable of operating when Broken Hill is not connected to the rest of the network and the back-up turbines are not in-service, as currently designed and configured. This means that if neither the turbines nor Line X2 are in service, these existing renewable generators are not currently able to supply Broken Hill.

Essential Energy has notified TransGrid of its decision to divest the turbines located at Broken Hill[11] and is currently in the process of enacting that divestment. Essential Energy has recently confirmed that it will cease to provide network support services under the current arrangements in the near term.

If no action is taken, this will result in the required reliability of supply to Broken Hill not being maintained, and involuntary load shedding when Line X2 is on planned or unplanned outage.

All of the credible options assessed in this PADR provide back-up and reliable supply to Broken Hill for the future that is consistent with the NSW Electricity Transmission Reliability and Performance Standards. These standards translate to approximately 7 MWh per year of EUE at Broken Hill.

The reduction in EUE that each option is expected to provide (for both planned and unplanned outages), compared to the base case, has been estimated as part of this PADR and valued using the Value of Customer Reliability (VCR) estimates published by the AER.[12]

The assumed outages under the base case for this RIT-T would be more severe than standard outages in both duration and load affected, and so should likely be valued using Widespread and Long Duration Outages (WALDO) VCRs.[13] However, we do not expect the adoption of WALDO values to be material to identifying the preferred option in this RIT-T. As set out in section 4, each of the credible options assessed avoids the same amount of EUE (with the exception of Option 4, which avoids an additional approximate 7 MWh/year) and so developing WALDO VCRs would not help determine the option that provides the greatest net market benefits.

TransGrid notes that there are a number of potential mining developments in the Broken Hill area, which may result in future spot load increases, namely:

- the Hawson's Iron project, which underwent a prefeasibility study in 2017;[14] and
- the Cobalt Blue project, which has recently opened its official pilot plant.[15]

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11 Essential Energy does not have obligations to maintain the turbines in order to comply with its licencing conditions.

12 AER, *Values of Customer Reliability*, Final report on VCR values, December 2019.

13 The March 2020 AER WALDO Consultation Paper defines these outages as being more severe than standard outages, with between 1 GWh to 15 GWh of EUE, a wider geographical region affected and longer durations than standard outages (which the AER considers may last for up to 12 hours) – see: AER, *Widespread and Long Duration Outages - Values of Customer Reliability*, Consultation Paper, March 2020 p. 6. By way of comparison, the base case outages modelled in this PADR are assumed to affect a cumulative 356 GWh per year (0.5 GWh per planned outage and 4 GWh per unplanned outage) and last up to 103 hours per year (12 hours per planned outage and 103 hours per unplanned outage).

14 https://carpentariares.com.au/hawsons-iron-project/

15 https://www.cobaltblueholdings.com/broken-hill-project/

Both of these spot loads have recently (following the initial PADR) flagged potential connection in the period between 2023/24 and 2029/30. TransGrid considered the potential impact of future spot load development on the investment options being considered in this RIT-T as a sensitivity (discussed in section 7.5.8).

2.2 Some of the credible options also provide wholesale market benefits

Some of the credible options assessed will also affect the wholesale electricity market, compared to the base case. In particular:

- some options involve grid-connected energy storage that introduce new entities trading in the wholesale market, eg, dispatching into the National Electricity Market (NEM) outside of the allocation of storage needed to meet its Broken Hill network support commitments; and
- the impact on network capacity under some of the options facilitates greater uptake of renewables in surrounding Renewable Energy Zone (REZ) areas.

TransGrid engaged EY to undertake the market modelling required to assess the wholesale market benefits expected to arise under each of the credible options. EY has applied a linear optimisation model and performed hourly, time-sequential, long-term modelling for the NEM to estimate categories of wholesale market benefits expected under each of the options that are expected to affect the wholesale market.

Section 6.4 provides further detail on how this has been undertaken, while Appendix C provides an overview of the market simulation exercise EY has undertaken and the key assumptions drawn upon.

3. Consultation undertaken

This section summarises consultation undertaken since the initial PADR was published in August 2020. It first summarises the submissions received on the initial PADR, before outlining the new guidance provided by the AER on the treatment of non-network options in RIT-T assessments as well as how TransGrid has re-engaged with proponents of these solutions in light of this guidance.

Section 3.4 summarises the consultation undertaken on the PSCR (ie, the material presented in section 3 of the initial PADR).

3.1 Consultation on the initial PADR

The initial PADR for this RIT-T was published on 11 August 2020 with submissions requested by 22 September 2020.

TransGrid received nine submissions from interested parties, many of whom are proponents of non-network options (including a number of new non-network solutions since the initial PADR was released).

The submissions can be summarised as:

- four from existing proponents from the EOI/PSCR;
- three from new proponents, with various levels of solutions;
- one who endorsed another proponent's solution (Option 1D); and
- one from PIAC that raised concerns about trialling emerging technologies.

The submissions from proponents of non-network options raised a range of issues relating to the specific assumptions made in evaluating their options (including cost and technical capabilities).

These submitters each requested confidentiality and so TransGrid has not reproduced in detail any of the points raised, or details of their proposals, in this PADR. However, as a general point, TransGrid revised the assessment of each of the options in light of the submissions made, and adopted the assumptions proposed in submissions as far as possible.

There were also two non-confidential submissions relating to non-network options. These submissions have been published on TransGrid's website.[16]

Hitachi Powergrids stated they believe Option 1D is the best option using existing, proven technology with references in the NEM.

The Public Interest Advocacy Centre (PIAC) expressed concern about the commercial feasibility of compressed air technologies and trialling emerging technologies.[17] Given that TransGrid has proponents for these options, TransGrid considers them to be commercially feasible. TransGrid also thoroughly assessed the technical and commercial feasibility of all options and consider all options assessed in this PADR to be credible at this stage, and not 'emerging'. TransGrid will be engaging further with parties based on the outcome of this PADR to confirm the technical feasibility of the options.

PIAC also questioned the assumptions regarding inverter functionality and requested TransGrid review this, particularly in light of more detailed information regarding the options from third parties.[18] The assumption of synchronous condensers in the original PADR was in lieu of having received certain models from proponents.

[16] https://www.transgrid.com.au/what-we-do/projects/current-projects/Broken%20Hill%20Supply

[17] PIAC submission, p. 1.

[18] PIAC submission, pp. 2-3.

TransGrid has now received the models and has been able to further assess the technical feasibility of these options and, while the assessment is still being finalised, has consequently removed the assumption of synchronous condensers in the revised PADR.

3.2 New AER guidance on the treatment of non-network options in the RIT-T assessment

In late August 2020, as part of developing the guidelines to make the ISP actionable, the AER provided new guidance regarding the treatment of non-network options in the RIT-T cost benefit assessment. [19]

The new guidance essentially states that the full underlying capital and operating cost of non-network options should be included in the cost benefit analysis, as opposed to only the network support cost offered by proponents, with any revenue from market participants and the network support costs between the non-network solution provider and the TNSP being treated as wealth transfers in the RIT-T assessment.

TransGrid subsequently clarified the intention of the new guidance with the AER, since the initial PADR for this RIT-T applied a different approach consistent with previous AER guidance and other RIT-T assessments. These discussions have led to a revised approach to assessing these options and have necessitated the re-issuing of the PADR for this RIT-T.

The costs of the non-network options have therefore been incorporated in the revised PADR assessment in-line with the updated guidance provided by the AER. In particular, the PADR assessment reflects new non-network investments as follows:

- the proposed network support cost is treated as the cost of the option (and this is the cost that TransGrid would recover through network charges);
- the same network support cost is treated as a benefit to the option proponent; and
- the full capital and operating costs of the option feature as part of the 'costs for parties other than the RIT-T proponent' category of market benefits.

In addition, where an option involves the use of the existing turbines at Broken Hill, TransGrid considered how these assets would operate in the base case as well as in each option case, and has assessed the difference. This is covered in more detail in section 6.1.

3.3 Consultation with non-network proponents following the new AER guidance

In light of the new guidance from the AER on the treatment of non-network options in the RIT-T assessment, TransGrid re-engaged with proponents of these solutions in order to explain the change in approach and to source the required inputs from their end to assess these options in-line with the new guidance.

In March 2021, TransGrid sent a request for clarification to those proponents who proposed a solution in response to the EOI that accompanied the initial PADR, in order to source the required inputs to enable us to assess their options in-line with the new AER guidance. This consultation allowed proponents to reconsider and revise their offers in light of the new guidance, as well as to raise any further points with us as part of the RIT-T consultative process.

All parties who responded have requested confidentiality and so their submissions have not been summarised here.

[19] AER, *Final Decision, Guidelines to make the Integrated System Plan actionable*, August 2020, p. 26, p. 52.

3.4 Summary of the consultation on the PSCR

The PSCR was released in November 2019 and TransGrid subsequently received submissions from five parties.

Four of these parties explicitly requested confidentiality as their submissions relate to the provision of solutions that form either part of, or standalone, credible options.

Prior to, as well as after, receiving these submissions, TransGrid held a number of bilateral meetings with submitters in order for them to further understand the RIT-T assessment and the reliability requirements at Broken Hill, as well as how their solutions are expected to be able to assist with meeting the identified need.

PIAC was the fifth submitting party and has not requested confidentiality. The PIAC submission has been published on our website.[20]

PIAC raised the issue of how the options involving turbines or grid-scale storage may be treated with respect to the transmission ring-fencing guidelines, particularly if all, or a portion, of these assets' values are to enter our Regulated Asset Base.[21] TransGrid notes that the AER has commenced reviewing and consulting on the transmission ring-fencing guidelines but that this was put on hold in light of the COVID-19 pandemic. TransGrid further notes that the AER is currently reviewing the timeline for this review, with an expectation that the review will recommence in the later part of 2021.[22] Where the ultimately preferred credible option provides both regulated services and contestable services, it will be treated consistently with the relevant transmission ring-fencing guidelines applying.

PIAC also noted that, since TransGrid published the PSCR in November 2019, the AER has published its final VCR estimates.[23] The assessment in this PADR, and the initial PADR, draws on the AER's updated VCR values (as outlined in section 6.3).

[20] https://www.transgrid.com.au/what-we-do/projects/current-projects/Broken%20Hill%20Supply

[21] PIAC submission to the PSCR, p. 1.

[22] While the AER has commenced reviewing and consulting on the transmission ring-fencing guidelines, this has been put on hold in light of the COVID-19 pandemic, see: https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/electricity-transmission-ring-fencing-guideline-review

[23] PIAC submission to the PSCR, p. 1.

4. Five types of options are assessed

Stakeholder consultation on the PSCR and the initial PADR has assisted greatly with developing and refining the credible options considered in this RIT-T.

Specifically, consultation with third parties has enabled this revised PADR to assess the following five types of credible options (with the specific options having been expanded since the earlier PADR):

- Option 1: nine different non-network opex solutions fully provided by third parties:[24]
  - Option 1A(1), Option 1A(2), Option 1A(3), Option 1A(4) & Option 1A(5) – five different options[25] from one proponent based on compressed-air energy storage solution that ranges from a 50MW/250MWh sized system to a 270MW/1,500MWh sized system;[26]
  - Option 1C: 73MW/292MWh battery;[27]
  - Option 1D: use of the existing 50 MW diesel-fired turbines acquired from Essential Energy (and provided to TransGrid as a service), 50MW/75MWh battery and 10 MW demand management;
  - Option 1E: 222MW/444MWh battery;[27] and
  - Option 1F: 100MW/800MWh liquid-air energy storage.[27]
- Option 2: a revised version, and cost for, acquiring the existing turbines from Essential Energy;
- Option 3: establishing new diesel-fired turbines at Broken Hill; [27]
- Option 4: building a second single circuit 220 kV transmission line from Buronga to Broken Hill; [27] and
- Option 5: nine variants of the first group of solutions involving either shared ownership or ownership by TransGrid:
  - Option 5A(1), Option 5A(2), Option 5A(3), Option 5A(4) & Option 5A(5) – five different sized options that mirror Option 1A(1) – (5) solutions, from the same proponent;[26]
  - Option 5B: 62.5MW/250MWh battery; [27]
  - Option 5C: 73MW/292MWh battery; [27]
  - Option 5E: 222MW/444MWh battery; [27] and
  - Option 5G: 50MW/275MWh thermal energy storage.[27]

Option 2, Option 1D, and Option 3 all provide backup supply services from the continued use of fossil fuels for longer duration (2 hours) outages over the long-term.

Under the new AER guidance, options with the same scope in terms of its solution will have the same net benefits regardless of ownership. For example, Option 1A(1) that is a non-network solution will have the same resource costs and net benefits as Option 5A(1) where the same technology is owned by TransGrid. For clarity, ownership of the solution, whether by a non-network proponent or TransGrid, now results in the same level of net benefits in the RIT-T.

All options reduce EUE to the amount required under the IPART reliability standard, which translates to approximately 7 MWh per year, on the assumption of no future spot load development. Option 4 provides an additional level of reliability due to the second transmission line and is assessed to reduce EUE to effectively zero (again on the assumption of no future spot load development). We consider the impact of spot load development as a sensitivity in section 7.5.8.

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[24] TransGrid notes that 'Option 1B' from the earlier PADR has been removed following clarification with the proponent that this option is being offered on the basis of ownership by TransGrid ('Option 5B'), rather than as a non-network solution.

[25] These options require continued use of diesel-fired turbines in the short-term, prior to their delivery and commissioning.

[26] The earlier PADR only considered one variant of Option 1A. The proponent of Option 1A has subsequently offered five differing capacities for this option, with the earlier 'Option 1A' now being most equivalent to the 'Option 1A/5A(4)' considered in this RIT-T.

[27] These options require arrangements for alternative back-up generation in the short term, prior to their delivery and commissioning.

Option 3 would also provide additional reliability over the IPART reliability standard, on account of the new turbines being able to start-up faster than required under the reliability standard. However, this has not been modelled at this stage as the requisite technical parameters for these turbines is not known. The PADR assessment therefore assumes that Option 3 provides the same level of reliability as the other options (with the exception of Option 4). This is not expected to be a material assumption in terms of identifying the preferred option due to the materially higher cost of this option compared with the preferred option.

TransGrid notes that the existing turbines form a component of several options. However, they are only ultimately able to be offered either by the party who purchases the turbines, or by a party that contracts with the purchaser. Depending on when the divestment process concludes, there may therefore be a reassessment of credible options between this revised PADR and the PACR. It is also possible that Essential Energy may sell the turbines to a third party who does not wish to be part of a network support arrangement, prior to the finalisation of this RIT-T process. In this circumstance, Option 2 would no longer be a credible option for this RIT-T, and non-network options that rely on the Essential Energy turbines would also be affected.

Where an option involves the use of the existing turbines at Broken Hill, TransGrid considered how these assets would operate in the base case as well as in each option case and assessed the difference. This is covered in more detail in section 6.1.

The nine non-network opex solutions fully provided by third parties and the nine variants of these solutions involving either shared ownership or ownership by TransGrid have been assessed using information (including costs) provided by parties in response to TransGrid's March 2021 requests for clarification, where available, following the new AER guidance, and in subsequent engagement. In order to maintain confidentiality of commercial-in-confidence information in submissions, these costs, and cost structures, have not been presented in this PADR.

Where an option involves continued use of the existing turbines, TransGrid assumed the need for future investment in turbines, reflecting the age and condition of the existing turbines at Broken Hill.[28] TransGrid has assumed that the cost of this future investment is the same, in real terms, as the cost of establishing new turbines at Broken Hill now (ie, as outlined below for Option 3) and occurs in 2040. This reflects an independent review of the asset condition and expected life of the existing turbines commissioned by TransGrid.

The next section discusses the assumed technical feasibility of the options at this stage of the RIT-T. The remainder of this section then provides further detail on each of the five types of credible options assessed in this PADR.

4.1 Technical feasibility has been assumed for all options at this stage

As noted in the initial PADR, TransGrid requested additional information and modelling from third parties in order to determine the technical feasibility of the solutions put forward. TransGrid re-engaged with all of the potential third party proponents over March and April 2021, following confirmation from the AER that the updated guidance on the assessment of non-network options would apply to this RIT-T, and provided them with the opportunity to update the information associated with their options.

The revised PADR adopts an updated understanding of option technical feasibility and as a result has removed the original PADR assumption of additional network components for the non-network options.

[28] The existing turbines at Broken Hill were commissioned in the late 1980s and were not new assets at the time.

4.2 Non-network solutions fully provided by third parties – Options 1A (1)-(5), Option 1C, Option 1D, Option 1E and Option 1F

These options involve a network support arrangement (or arrangements) to provide back-up supply for Broken Hill to meet reliability standards and satisfy the identified need. These options are considered non-network options where these services would be provided by a third-party by way of a network support contract.

Three parties have offered to provide these services and a range of technologies have been proposed:

- Option 1A(1), Option 1A(2), Option 1A(3), Option 1A(4) & Option 1A(5) – five different options from one proponent based on compressed-air energy storage solution that ranges from a 50MW/250MWh sized system to a 270MW/1,500MWh sized system;
- Option 1C: 73MW/292MWh battery;
- Option 1D: use of the existing 50 MW diesel-fired turbines acquired from Essential Energy (and provided to TransGrid as a service), 50MW/75MWh battery and 10 MW demand management;
- Option 1E: 222MW/444MWh battery; and
- Option 1F: 100MW/800MWh liquid-air energy storage.

The options put forward also reflect a range of sized solutions, with eight (Options 1A (2)-(5), Option 1C, Option 1E, and Option 1F) enabling trade in the wholesale market. These eight options are expected to provide wholesale market benefits in addition to the required level of reliability at Broken Hill and the impact they are expected to have on the wholesale market has been modelled by EY (as outlined in section 6 below).

Where these options relate to new facilities, the full cost of these new investments (and the associated operating costs) has been reflected in the cost benefit assessment (as a 'cost to other parties'), with the proposed network support payment treated as a wealth transfer between the proponent and us, in-line with the new AER guidance.

Some of the non-network solutions will require associated network investment. For example, there is a need to upgrade existing switchbays for all of the 1A options, whilst new switchbays are required for options 1C, 1D, 1E, 1F, 5B, and 5G. In addition, fault level upgrades would be required for all of the 1A options as well as 1C, 1D, 1E, 1F, 5B and 5G to address fault level limitations associated with the connection of these options. We have reflected the cost and timing of these various investments in the NPV assessment.

4.3 Acquiring the existing turbines from Essential Energy – Option 2

Option 2 involves the acquisition by TransGrid of the existing turbines at Broken Hill from Essential Energy. This option assumes that the existing turbines become directly owned by us, rather than being purchased by a third party who may then use them to offer network support services.

The relevant costs and technical specifications of this option assessed in this PADR have been kept confidential in order to not impact Essential Energy's divestment process.

The new AER guidance requires that the amount paid by TransGrid to acquire the existing turbines from Essential Energy be offset by the benefit Essential Energy receives from the sale, ie, resulting in a net direct cost of zero associated with the purchase of the turbines under Option 2. However TransGrid would then incur costs to refurbish the turbines, as well as incurring the operating costs (including fuel costs) associated with the times they are required for network support.

Estimates of the costs and timing of refurbishing the turbines were provided by Essential Energy and TransGrid also engaged Aurecon to provide an independent estimate of these costs. The total estimated costs were similar in total, but have a different profile over time. TransGrid adopted the estimates provided by Essential Energy for the purposes of the RIT-T assessment, but notes that in the event of a future contingent project application TransGrid would need to base its cost estimate on the best information available at that time.

This option also assumes that the existing turbines need to be replaced in 2040. This assumption has been based on information provided by Aurecon and is not considered material to the assessment.[29]

Option 2 would not require any associated network investment (relating to switchbays or fault level upgrades).

Acquiring the existing turbines does not enable wholesale market benefits, as they are currently configured to operate only in islanded mode. TransGrid investigated a sensitivity where the turbines are assumed able to dispatch to the NEM and find that the additional network costs to enable this are not outweighed by the additional market benefits (as outlined in section 7.5.3).

TransGrid also investigated a sensitivity on this option that assumes the installation of a battery when the turbines reach end of life, rather than new turbines, to test whether it can efficiently offset the diesel-fired turbine fuel costs.[30] This sensitivity again finds that the additional network costs to facilitate this are not outweighed by the additional market benefits expected (as outlined in section 7.5.3).

4.4 Establishing new turbines at Broken Hill – Option 3

Option 3 involves the commissioning of new turbines at Broken Hill. Potential new generators may be able to utilise the latest diesel-fired turbine technologies, which could improve fuel efficiency and response times (compared to the existing turbines).

TransGrid engaged Aurecon to develop generic costs and technical parameters for Option 3. These new turbines are assumed to involve $78 million in capital costs upfront as well as ongoing operating costs of approximately $1.6 million per year. It is estimated that they would take one year to install and that commissioning would occur in 2022/23.

There would be network costs associated with this option, to address fault level upgrades.

The new turbines commissioned under Option 3 will enable dispatch to the wholesale market during times of high wholesale market prices. The impact they are expected to have on the wholesale market has therefore been modelled by EY (as outlined in section 6 below).

4.5 Establishing a second single circuit 220 kV transmission line – Option 4

Option 4 involves a new single circuit 220 kV transmission line from Buronga to Broken Hill to improve the reliability of the supply to Broken Hill.

The scope of Option 4 involves:

> constructing a second circuit alongside Line X2 between Broken Hill and Buronga;
> constructing 220 kV line switchbays at Broken Hill and Buronga; and
> installation of line shunt reactors at Broken Hill and Buronga.

The capital expenditure estimate has been updated since the PSCR and is now expected to cost around $474 million, with project delivery in 36 months. Annual operating costs are estimated to be approximately $2.4 million.

The transmission costs associated with Option 4 have increased significantly since the PSCR on account of more accurate and up-to-date cost inputs. Specifically, the PSCR costs were based on desktop studies conducted in 2016. The PADR updated cost estimates and rates are based on nearby projects over similar

[29] Specifically, the assumed replacement of the existing turbines in 2040 is not considered material to the assessment, compared to assuming they last the entire period, since Option 2 is found to be the top-ranked option in this PADR. Removing this future cost would therefore not change this conclusion.

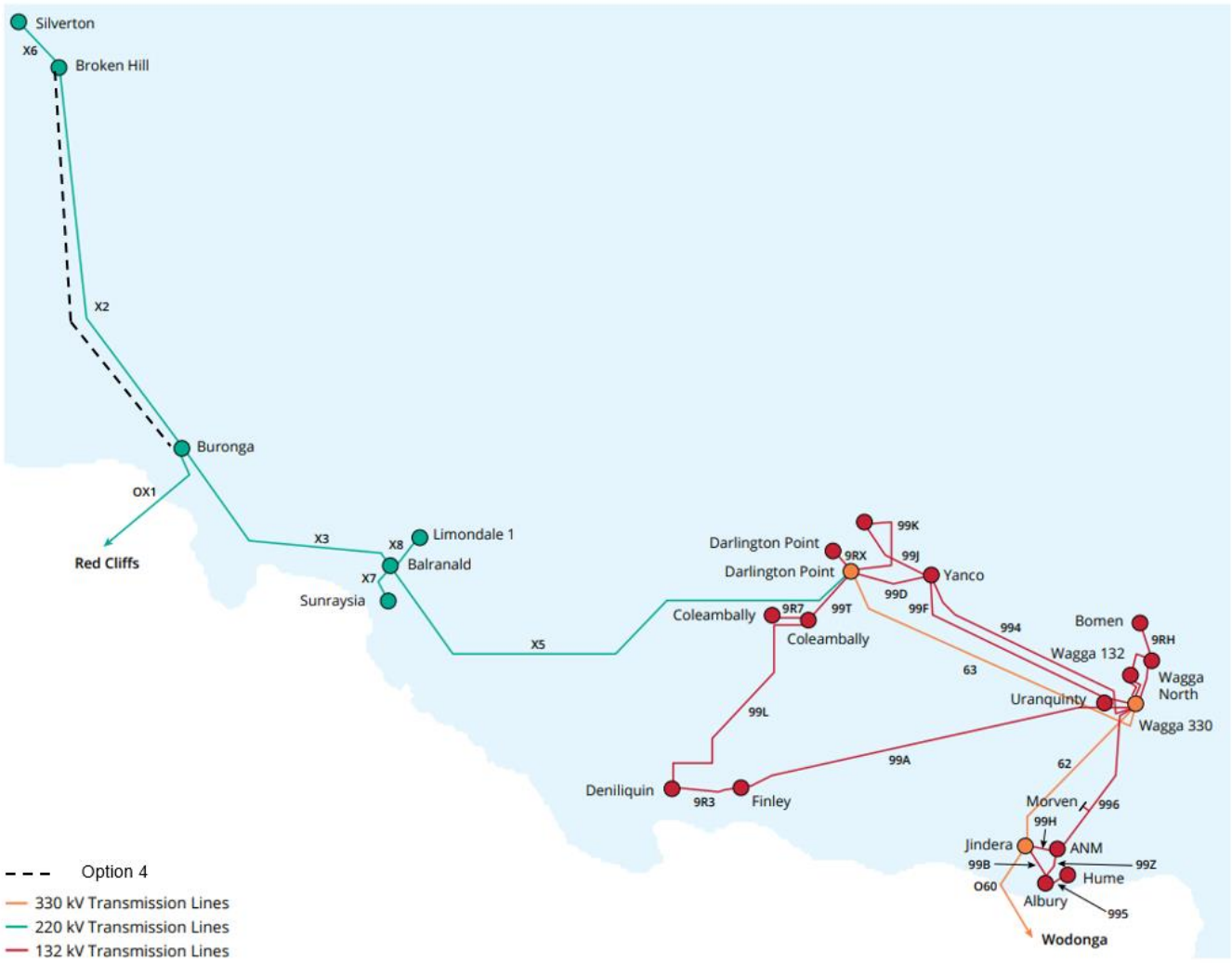
[30] Under this sensitivity the replacement of the existing turbines is still assumed to occur in 2040, as the cost of a battery of a sufficient size to avoid this replacement would cost more than the replacement turbines.

terrain for which TransGrid has recently sourced market costs (eg, EnergyConnect) and provide a more accurate cost for the new line option in the Broken Hill area under Option 4.

While Option 4 is significantly more expensive than the other options, it has been included in the PADR assessment since it is considered technically feasible and serves as a source of comparison for the other options. It also provides associated market benefits through its impact on the development of nearby REZs. TransGrid also considered whether this network option would become the preferred option in the event of future spot load development around Broken Hill (see section 7.5.8), and concluded that it would still not be preferred to other options.

TransGrid have included a network diagram below for Option 4, which shows the existing network configuration, as well as the works and new elements (with a black dashed line).

Figure 4-1: Network diagram for Option 4



4.6 Shared ownership or network ownership of network support technologies – Options 5A(1)-(5), Option 5B, Option 5C, Option 5E and Option 5G

The majority of the parties that proposed third party network support services also proposed that these solutions could be provided under a shared ownership model, or through full ownership by TransGrid as a network asset. These options are:

- Option 5A(1), Option 5A(2), Option 5A(3), Option 5A(4) & Option 5A(5) – five different options from one proponent based on compressed-air energy storage solution that ranges from a 50MW/250MWh sized system to a 270MW/1,500MWh sized system;
- Option 5B: 62.5MW/250MWh battery;
- Option 5C: 73MW/292MWh battery;
- Option 5E: 222MW/444MWh battery; and
- Option 5G: 50MW/275MWh thermal energy storage.

These options are fundamentally the same as their non-network counterparts outlined under section 4.2 above, except for how they are funded and the ultimate ownership of the assets. Each party has requested confidentiality and so this PADR does not outline in detail each of the options assessed.

Another party, that did not offer a network support solution, also proposed a network owned option (Option 5G).

Where these options relate to new facilities, the full cost of these new investments (and the associated operating costs) has been included in the cost benefit assessment, with any proposed network support payment treated as a transfer between the proponent and TransGrid in-line with the new AER guidance.

As with the options outlined under section 4.2, these options reflect a range of sized solutions, with eight enabling trade in the wholesale market (Options 5A(2)-(5), Option 5C, Option 5E, Option 1F and Option 5G). These eight options are expected to provide wholesale market benefits in addition to the required level of reliability at Broken Hill and the impact they are expected to have on the wholesale market has been modelled by EY (as outlined in section 6 below).

4.7 Options considered but not progressed

In the PSCR, TransGrid also considered whether two other network options would meet the identified need. The reasons these options were not progressed any further are summarised in Table 4-1.

Table 4-1: Options considered but not progressed at the PSCR stage

Option	Reason(s) for not progressing
Double circuit 330 kV line to Mount Piper	Costs estimated are significantly higher than Option 4 due to the distance, without any additional market benefits. Accordingly, these two options are not considered to be commercially feasible.
HVDC link to Mount Piper	

5. Ensuring the robustness of the analysis

The transmission investments considered as part of this RIT-T involve long-lived assets, and it is important that the recommended preferred option does not depend on a narrow view of future outcomes, given that the future is inherently uncertain.

Uncertainty is captured under the RIT-T framework through the use of reasonable scenarios, which reflect different assumptions about future market development, and other factors that are expected to affect the relative market benefits of the options being considered. The adoption of different scenarios tests the robustness of the RIT-T assessment to different assumptions about how the energy sector may develop in the future.

The robustness of the outcome is also investigated through the use of sensitivity analysis in relation to key input assumptions. TransGrid identified the key factors driving the outcome of this RIT-T and sought to identify the 'threshold value' for these factors, beyond which the outcome of the analysis would change.

5.1 The assessment considers three 'reasonable scenarios'

The RIT-T is focused on identifying the top ranked credible option in terms of expected net benefits. However, uncertainty exists in terms of estimating future inputs and variables (termed future 'states of the world').

To deal with this uncertainty, the NER requires that costs and market benefits for each credible option are estimated under reasonable scenarios and then weighted based on the likelihood of each scenario to determine a weighted ('expected') net benefit.[31] It is this 'expected' net benefit that is used to rank credible options and identify the preferred option.

The credible options have been assessed under three scenarios as part of this PADR assessment, which differ in terms of the key drivers of the estimated net market benefits.

The three alternative scenarios are characterised as follows:

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

The table below summarises the specific key variables that influence the net benefits of the options under each of the scenarios considered.

[31] The AER RIT-T Application Guidelines explicitly refer to the role of scenarios as the primary means of taking uncertainty into account. See: AER, *RIT-T Application Guidelines*, December 2018, p. 42.

Table 5-1: Summary of scenarios

Variable	Central	Low net economic benefits	High net economic benefits
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Non-network costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Broken Hill demand	Based on POE50 demand forecast	Based on POE90 demand forecast	Based on POE10 demand forecast
Wholesale market benefits estimated	EY estimated based on central ISP scenario (as outlined in section 6 below)	30 per cent lower than what EY has estimated	30 per cent higher than what EY has estimated
VCR[32]	$36.43/kWh	$25.50/kWh	$47.36/kWh
Discount rate	5.90%	9.57%	2.23%

The underlying demand forecasts have been updated slightly since the original PADR to align with TransGrid's 2021 Transmission Annual Planning Report. These demand forecasts exclude the impact of any future mining load development. TransGrid considered this as a sensitivity (see section 7.5.8).

5.2 Weighting the reasonable scenarios

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

While TransGrid considers this weighting is appropriate, it also considered an equal weighting across the three scenarios to ensure the weighted rankings is robust to other weightings (see section 7.4).

5.3 Sensitivity analysis

In addition to the scenario analysis, TransGrid also considered the robustness of the outcome of the cost benefit analysis through undertaking a range of sensitivity testing.

The range of factors tested as part of the sensitivity analysis in this PADR are:

- the capacity of the 330 kV transmission system west of Wagga Wagga;
- investigating a variant of Option 1D where a component of the option is assumed to proceed irrespective of the RIT-T;
- investigating two variants of Option 2, where:
  - the existing turbines in Option 2 are able to dispatch to the NEM and generate wholesale market benefits ('Option 2 (dispatch)'); and
  - the existing turbines are coupled with a battery in 2039/40 to offset fuel costs later in the period and which also enables the replacement of the existing turbines to be avoided ('Option 2 BESS');
- changes in key base case assumptions (the base cases used in this RIT-T are discussed further in section 6.1 below);
- changes in the network capital costs of the credible options;
- changes to the non-network costs of proposed options;

[32] AER, *Values of Customer Reliability*, Final report on VCR values, December 2019.

- alternate commercial discount rate assumptions; and
- new mining spot load development in the Broken Hill area, where we have investigated the impact on the RIT-T outcome of two spot load scenarios:
  - 70 MW spot load in 2024/25; and
  - 160 MW spot load over the period 2024/25 to 2028/29.

The results of the sensitivity tests are discussed in section 7.5.

In addition, as part of the analysis TransGrid also identified the key factors driving the outcome of this RIT-T and sought to identify the 'threshold value' for key variables beyond which the outcome of the analysis would change.

The above list of sensitivities focuses on the key variables that could impact the identified preferred option.

In the earlier PADR, TransGrid also considered a sensitivity on the timing of replacement for the existing turbines. TransGrid previously investigated replacement of the existing Essential Energy turbines five years earlier than 2039/40 or five years later, which was found to not be material to the outcome of the RIT-T assessment. An independent report from Aurecon has now given us confidence that the turbines could last another twenty years, assuming they are refurbished, and so we now assume they require replacement in 2039/40 (at which point they will be approximately 60 years old) and so do not consider this sensitivity is still relevant. TransGrid notes also that removing the need for replacement (i.e., assuming the turbines last the entire assessment period) is also not expected to be material to the assessment as it will simply remove a cost for Option 2, which is already the top-ranked option.

In addition, the earlier PADR investigated a sensitivity that removed the assumed 150 MW free Broken Hill REZ transmission expansion assumed for the Option 1A/5A variants, which found that removing this assumption reduced the estimated gross wholesale market benefits of variant of this option assessed in the initial PADR by approximately 5 per cent. The core market modelling for this PADR has not been updated and continues to use that presented in the initial PADR. TransGrid therefore has not updated this sensitivity but intend to, along with the core market modelling, as part of the PACR later this year (and note that it may have an important interaction with any external funding).

6. Estimating the market benefits

As outlined in section 2, the key benefit expected from the options is avoided involuntary load shedding at Broken Hill. In addition, for some of the options, there are also expected to be benefits from anticipated changes in the wholesale market outcomes going forward.

The RIT-T requires categories of market benefits to be calculated by comparing the 'state of the world' in the base case where no action is undertaken, with the 'state of the world' with each of the credible options in place, separately. The 'state of the world' is essentially a description of the National Electricity Market (NEM) outcomes expected in each case, and includes the type, quantity and timing of future generation investment as well as unrelated future transmission investment (e.g., that is required to connect REZ across the NEM).

This section outlines how each of the broad categories of market benefit have been estimated. It first outlines the base cases that have been modelled, as well as the three broad states of the world and a high-level description of the modelling undertaken for each.

6.1 Two base cases have been modelled

The RIT-T requires the assessment to compare the costs and benefits of each option to a base case 'do nothing' option. The base case is the (hypothetical) projected case if no action is taken, ie:[33]

> *"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'. 'BAU activities' are ongoing, economically prudent activities that occur in absence of a credible option being implemented"*

For this RIT-T, an important feature of the base case is the assumption regarding the future of the existing turbines at Broken Hill in the absence of an option, ie, reflecting the Essential Energy divestment process underway. Importantly, the 'do nothing' base case for this RIT-T should not assume that these turbines continue to operate in the same manner as they do currently. Essential Energy has recently confirmed that it will cease to provide network support services under the current arrangements in the near term.

TransGrid has modelled two alternate base cases as part of the revised PADR assessment, which reflect the uncertainty regarding the outcome of the Essential Energy divestment process for the existing turbines. Specifically, TransGrid has modelled all credible options against the following two base cases:

- Base case I – the existing turbines are sold to a party outside of the NEM, e.g., a mine situated outside of the NEM; and
- Base Case II – the existing turbines are not sold and Essential Energy mothballs them in the future.

TransGrid considers it important to consider these two base cases for the RIT-T assessment since the different base cases will affect the costs and benefits included in the RIT-T assessment.

Base case I reflects a view of the 'next best use' of the turbines, if they are not used to provide network support. The value of the sale to a party outside of the NEM is assumed to be less than the sale price if TransGrid, or a third party, purchases the turbines (reflecting the fact that the turbines have not yet been sold). TransGrid assumed an indicative sale price in the core analysis but also tested upper and lower bounds on this assumption (as set out in section 7.5.4).

Base case II reflects a case where TransGrid, or a third party, is the only willing buyer for the turbines to continue to provide network support at Broken Hill. Under this base case, Essential Energy incurs costs to mothball the existing turbines in the future, reflecting a case where there are no parties interested in buying the existing turbines in the absence of a network support agreement with TransGrid. TransGrid assumed an indicative

[33] AER, *Regulatory Investment Test for Transmission Application Guidelines*, August 2020, p. 21.

mothballing cost in the core analysis but also tested upper and lower bounds on this assumption (as set out in section 7.5.4).

Both base cases modelled assume there is a short-term network support contract in-place until a certain date (which has been redacted to preserve the confidentiality of the separate process to determine the short term solution). From this date, there is assumed to be no back-up supply at Broken Hill under the base case and consequent unserved energy whenever Line X2 is out-of-service.

While TransGrid notes the base case assumptions regarding unserved energy are unrealistic, and would never plan for this situation to eventuate, the RIT-T requires the credible options to be assessed against a common base case representing a state of the world where action is not taken to address the long-term need. In reality, TransGrid is planning to have the most efficient long-term solution (which will be identified through this RIT-T process) to continue to provide reliable supply to Broken Hill following the short-term solution.

6.2 Overview of the market modelling undertaken

There are three broad states of the world that have been modelled as part of this PADR. These can be summarised as:

1. Line X2 is in-service meaning electricity demand at Broken Hill can be met from supply anywhere in the NEM and any new technologies at Broken Hill able to trade in the wholesale market can do so;
2. Line X2 is out-of-service meaning Broken Hill is no longer connected to the NEM and needs to source supply from its own grid (or face unserved energy); and
3. Line X2 is out-of-service but Broken Hill remains connected to the NEM via a new line (ie, Option 4).

TransGrid engaged EY to undertake wholesale market modelling to assess the market benefits expected to arise those credible options, which are expected to have an impact on the wholesale market.

This market modelling exercise captures:

> what happens in the NEM and Broken Hill under the first and third states above; and
> what happens in the NEM, outside of Broken Hill, under the second state above.

The costs and information provided by proponents and our internal analysis are used to model what happens at Broken Hill under the second state above, ie, the cost to service Broken Hill demand when Line X2 is out of service and there is no second line connecting Broken Hill to the NEM.

6.3 Avoided involuntary load shedding

TransGrid ran system studies to estimate the EUE at Broken Hill under the base cases and each of the credible options. This involved assessing the existing load at Broken Hill, expected growth, the condition of Line X2, outage rates and outage durations.

Specifically, for options involving energy storage as the sole backup supply, additional parameters have been assessed to estimate EUE. Both the size of the energy storage facility and the output of the Broken Hill renewable generators are considered to meet the reliability standard. As an outage of Line X2 can occur at any time, the energy storage system must maintain a minimum state of charge (estimated to be 250 MWh) in anticipation of an outage to supply the Broken Hill islanded load together with variable renewable generation. For options involving new turbines, the amount of EUE is defined by how quickly the Broken Hill load can be restored and the turbines under consideration are able to start-up faster than required under the reliability standard.

TransGrid estimated the absolute level of EUE at Broken Hill under the base case and each credible option. While the RIT-T requires that reliability corrective actions only quantify the changes in EUE over and above

that required to meet the applicable reliability standard,[34] the body of this PADR presents EUE in absolute terms since it is more intuitive.[35] TransGrid notes that estimating EUE in this manner has no bearing on the identification of the preferred option and Appendix D demonstrates this by presenting the analysis in this PADR using only EUE improvements over the IPART reliability standard.

The avoided EUE for each option has been valued using the recently estimated VCRs published by the AER. Specifically, TransGrid developed a load-weighted VCR estimate for the central scenario using the AER VCR values for the four customer groups relevant to Broken Hill. TransGrid then applied VCR estimates that are 30 per cent lower and 30 per cent higher for the low and high scenarios, respectively, consistent with the AER's specified +/- 30 per cent confidence interval.[36]

The EY market modelling has also quantified the impact of changes in involuntary load shedding *outside* of Broken Hill associated with the implementation of each credible option via the time sequential modelling component of the market modelling. Specifically, the modelling estimates the MWh of EUE in each hourly trading interval over the modelling period, and then applies the AER VCRs to quantify the estimated value of avoided EUE outside of Broken Hill for each option.

6.4 Wholesale market benefits

EY has undertaken the wholesale market modelling component of the PADR assessment. As outlined in section 6.2 above, this exercise captures:

- what happens in the NEM and Broken Hill when:
  - Line X2 is in-service; and
  - Line X2 is out-of-service but Broken Hill remains connected to the NEM via a new line (ie, Option 4).
- what happens in the NEM, outside of Broken Hill, when Line X2 is out-of-service meaning Broken Hill is no longer connected to the NEM.

The credible options are able to affect the wholesale market if they involve:

- energy storage in excess of 250 MWh (the minimum amount required to meet the reliability standards at Broken Hill);
- new turbines; or
- a new transmission line connecting Broken Hill to the NEM.

Acquiring the existing turbines alone does not enable wholesale market benefits as they are currently configured to operate only in islanded mode. The inclusion of fault level upgrades required in order to allow turbines to dispatch into the NEM for arbitrage has been included as a sensitivity test (outlined in section 7.5.3).

The credible options have been assessed using a set of market modelling assumptions that are largely based on the 'central' scenario identified by AEMO to be used in the 2020 ISP. This is considered proportionate since the wholesale market benefits are not expected to have a bearing on the identification of the preferred option due to the cost differences between the options, as demonstrated in section 7 below.

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[34] Clause 9 of the RIT-T states that 'where the credible option is for reliability corrective action, the quantification of the market benefits associated with changes in voluntary load curtailment and changes in involuntary load shedding must only apply in so far as the market benefit delivered by the credible option exceeds the minimum standard required for reliability corrective action' – see: AER, *Final Regulatory Investment Test for Transmission*, June 2010, Clause 9.

[35] TransGrid notes that this is also consistent with the AER's 'service cost' framework outlined in its industry practice application note for asset replacement planning, as well as the ENA RIT-T Handbook – see: https://www.aer.gov.au/system/files/D19-2978%20-%20AER%20-Industry%20practice%20application%20note%20Asset%20replacement%20planning%20-%2025%20January%202019.pdf & Energy Networks Australia, *RIT-T Economic Assessment Handbook*, October 2020.

[36] AER, *Values of Customer Reliability – Final Report on VCR values*, December 2019, p. 84.

While the EY market modelling for this RIT-T focusses on the central ISP scenario, TransGrid also applied a broad assumption of 30 per cent lower and 30 per cent higher aggregate wholesale market benefits as part of the low and high scenario investigated, respectively. This 30 per cent does not represent any sort of confidence level for the market modelling conducted by EY but, instead, has been instigated by TransGrid as a proportionate approach to further test the robustness of the preferred option.

There are three key sets of assumptions that differ slightly from those being used by AEMO in the 2020 ISP, i.e., retirement dates of coal-fired power stations, the implications of the COP21 commitment and the assumptions made in relation to VRET/QRET. Table C-2 summarises the specific variables affected, as well as how the assumptions differ from those to be used by AEMO.

In addition, the market modelling assumes a new Darlington Point/Dinawan to Wagga 330 kV transmission line to relieve constraints in the south-western NSW power system. This line is in addition to those assumed for EnergyConnect and, while this investment is not included in the 2020 ISP, TransGrid considers it will improve stability of the power system, allowing higher dispatch of renewable energy in the area and providing increased net market benefits and we have commenced a new RIT-T[37] covering this investment.[38] TransGrid also investigated a sensitivity that excludes this investment from the market modelling and find that it has only a minor effect on the overall estimated wholesale market benefits for the preferred option and is not expected to affect the overall identified preferred option, as outlined in section 7.5.1.

The market modelling undertaken assumes that a particular solution operates the same regardless of ownership (ie, Options 1A(1)-(5) and Options 5A(1)-(5), which differ only in ownership structure, are estimated to have the same market benefits). TransGrid considers this is appropriate and consistent with an efficient least-cost modelling philosophy.

The specific categories of wholesale market benefit under the RIT-T that have been modelled as part of this PADR are:

- changes in fuel consumption in the NEM arising through different patterns of generation dispatch;
- changes in costs for parties, other than the RIT-T proponent (i.e., changes in investment in generation and storage);
- differences in unrelated transmission investment (in particular, the cost of connecting REZs to the shared network);
- changes in voluntary load curtailment;
- changes in involuntary load curtailment (outside of Broken Hill); and
- changes in network losses.

6.5 General modelling parameters adopted

The RIT-T analysis spans a 25-year assessment period from 2020/21 to 2044/45.[39]

Where the capital components of the credible options have asset lives extending beyond the end of the assessment period, the NPV modelling includes a terminal value to capture the remaining asset life. This ensures that the capital cost of long-lived options over the assessment period is appropriately captured, and

[37] https://www.transgrid.com.au/what-we-do/projects/regulatory-investment-tests/Documents/TransGrid%20PSCR_Stabilising%20SW%20NSW.pdf

[38] Refer to section 2.1.7 ('Improving stability in South-West NSW') in the TransGrid 2020 Transmission Annual Planning Report for more information, available at: https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning/Documents/2020%20Transmission%20Annual%20Planning%20Report.pdf

[39] This has been updated since the PSCR (which stated a 20 year assessment period would be used) as market modelling was not contemplated at the time of the PSCR.

that all options have their costs and benefits assessed over a consistent period, irrespective of option type, technology or asset life. The terminal values are calculated as the undepreciated value of capital costs at the end of the analysis period and can be interpreted as a conservative estimate for benefits (net of operating costs) arising after the analysis period.

A real, pre-tax discount rate of 5.90 per cent has been adopted as the central assumption for the NPV analysis presented in this PADR, consistent with the assumptions adopted in 2020 ISP. The RIT-T also requires that sensitivity testing be conducted on the discount rate and that the regulated weighted average cost of capital (WACC) be used as the lower bound. TransGrid therefore tested the sensitivity of the results to a lower bound discount rate of 2.23 per cent,[40] and an upper bound discount rate of 9.57 per cent (i.e., a symmetrical adjustment upwards).

6.6 Classes of market benefit not considered material

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.[41]

Option value has not been estimated for this RIT-T. There are four pre-requisites required for an option to have option value: (1) there is significant uncertainty about future conditions (eg, demand, spot load etc); (2) there is expected to be 'learning' about that uncertainty in the future (eg, demand continues to increase, or decreases); (3) investment in the options needs to exhibit flexibility (in particular, there are different stages for the investment); and (4) there needs to be a possibility of regret (ie, there is no 'obvious' best alternative under all future outcomes).

As discussed earlier, there is the potential for spot load development in the Broken Hill region. There is currently uncertainty in relation to this development, which is expected to lessen over time (ie, if the potential loads seek formal connection). However, with the exception of the network augmentation considered (ie, Option 4) all of the options in this RIT-T would be able to be scaled to meet future spot loads, and there would be no need for any option to incur additional costs at this stage in order to enable future stages of that option to be implemented.

As a consequence, due to the materiality of the modelling exercise that would be involved, TransGrid has not estimated option value for any of the options. However, sensitivity analysis that considers future spot load development (set out in section 7.5.8) has been undertaken, to assess whether future spot load development would change the investment decision TransGrid would make now to meet the immediate reliability need at Broken Hill.

Competition benefits have also not been estimated for any of the options since they are not considered material in the context of this RIT-T. This RIT-T is focussed on efficiently meeting the required reliability standard at Broken Hill and, while some options are expected to generate a level of wholesale market benefits, it is not considered sufficient to affect the competitiveness of generator bidding behaviour in any region of the NEM.

[40] This is equal to WACC (pre-tax, real) in the latest final decision for a transmission business in the NEM, see: https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/directlink-determination-2020-25

[41] NER clause 5.16.1(c)(6).

7. Net present value results

This section outlines the results of the assessment TransGrid undertook of the credible network options.

Due to the confidentiality requested by proponents of solutions, TransGrid is only able to present the overall *net* market benefits of each credible option (ie, the present value of the aggregate market benefits estimated less the present value of the aggregate costs).

As noted earlier, based on the AER's revised guidance for the treatment of non-network options in the RIT-T analysis, the NPV results for options involving the same underlying investments are now the same whether they are assumed to be provided as non-network solutions (ie, the 'Option 1s') or to be owned or part-owned by TransGrid (the 'Option 5s'). TransGrid therefore consolidated the reporting of option NPVs against the Option 1 and Option 5 variants, where relevant.

TransGrid will engage with individual proponents to discuss the modelling of their individual solutions further, to assist them with preparing submissions to this PADR.

7.1 Central scenario

The central scenario reflects TransGrid's central view of key underlying assumptions and is considered the most likely scenario in terms of the net market benefits for each of the options. These assumptions include central cost estimates, VCR and commercial discount rate estimates, as well as Broken Hill demand based on the central POE50 demand forecasts. This scenario also includes EY's market modelling of the wholesale market benefits, which has been assessed using a set of market modelling assumptions that are largely based on the 'central' scenario identified by AEMO to be used in the 2020 ISP.

Under these assumptions, Option 2 is estimated to deliver approximately $272 million in net benefits under base case I and approximately $286 million in net benefits under base case II. The second-ranked option, Option 1A/5A(2), has approximately 11 per cent and 15 per cent lower net benefits than Option 2 under base case I and base case II, respectively.

Figure 7-1 and figure 7-2 show the overall estimated net benefit for each option under the central scenario and across the two base cases.

Figure 7-1: Summary of the estimated net benefits under the central scenario, base case I

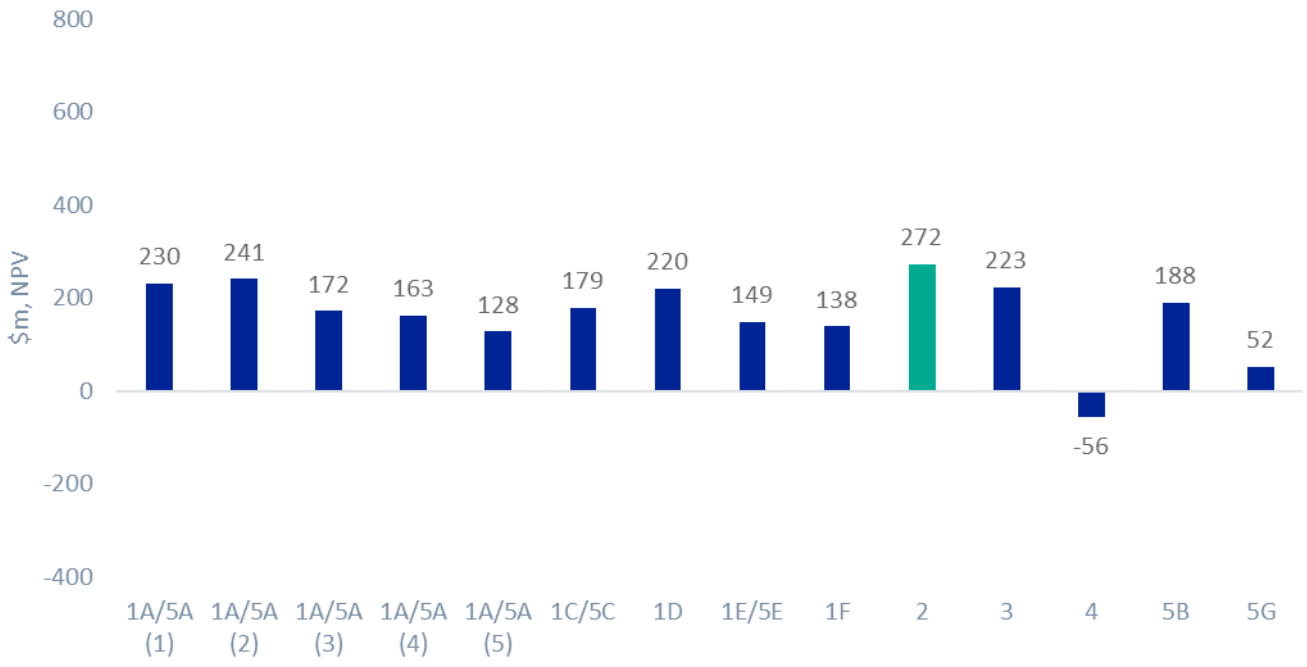
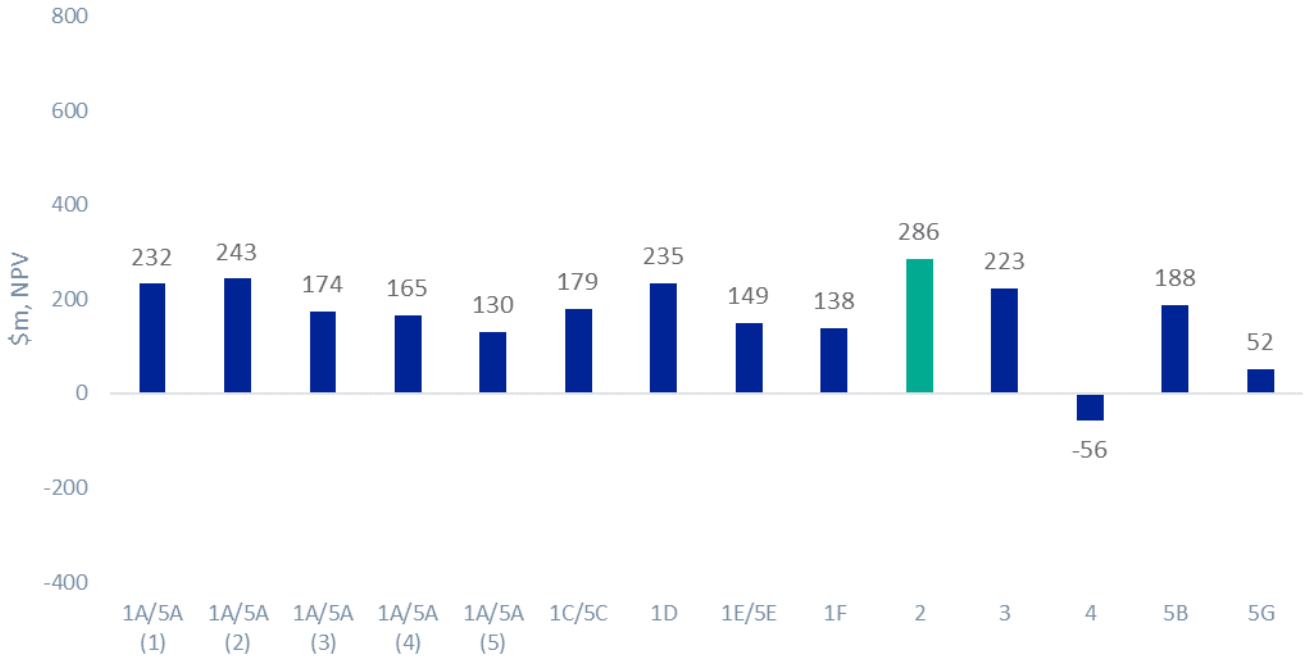


Figure 7-2: Summary of the estimated net benefits under the central scenario, base case II



All options provide around $315 million in benefits from avoided unserved energy at Broken Hill irrespective of the base case assumed, with the exception of Option 4 which provides an additional $3 million in avoided unserved energy due to the second line providing a marginally higher level of reliability. These values are calculated using POE50 demand forecasts for Broken Hill and a central load-weighted VCR estimate.

7.2 Low net economic benefits

The low net economic benefits scenario reflects a number of assumptions that gives a lower bound and conservative estimate of net present value of net economic benefits. These assumptions include high cost estimates, low VCR and a high commercial discount rate estimate, as well as Broken Hill demand based on POE90 demand forecasts. This scenario also includes 30 per cent lower wholesale market benefits than those estimated by EY as an additional robustness test for the option rankings.

Under these assumptions, Option 2 is estimated to deliver approximately $107 million in net benefits under base case I and approximately $121 million in net benefits under base case II. The second-ranked option, Option 1D, has approximately 56 per cent and 49 per cent lower net benefits than Option 2 under base case I and base case II, respectively. Option 1A/5A(2) is ranked fifth with net benefits that are estimated to be 66 per cent lower than Option 2 under base case I and 67 per cent lower than Option 2 under base case II.

Figure 7-3 and figure 7-4 show the overall estimated net benefit for each option under the low benefits scenario and across the two base cases.

Figure 7-3: Summary of the estimated net benefits under the low benefits scenario, base case I

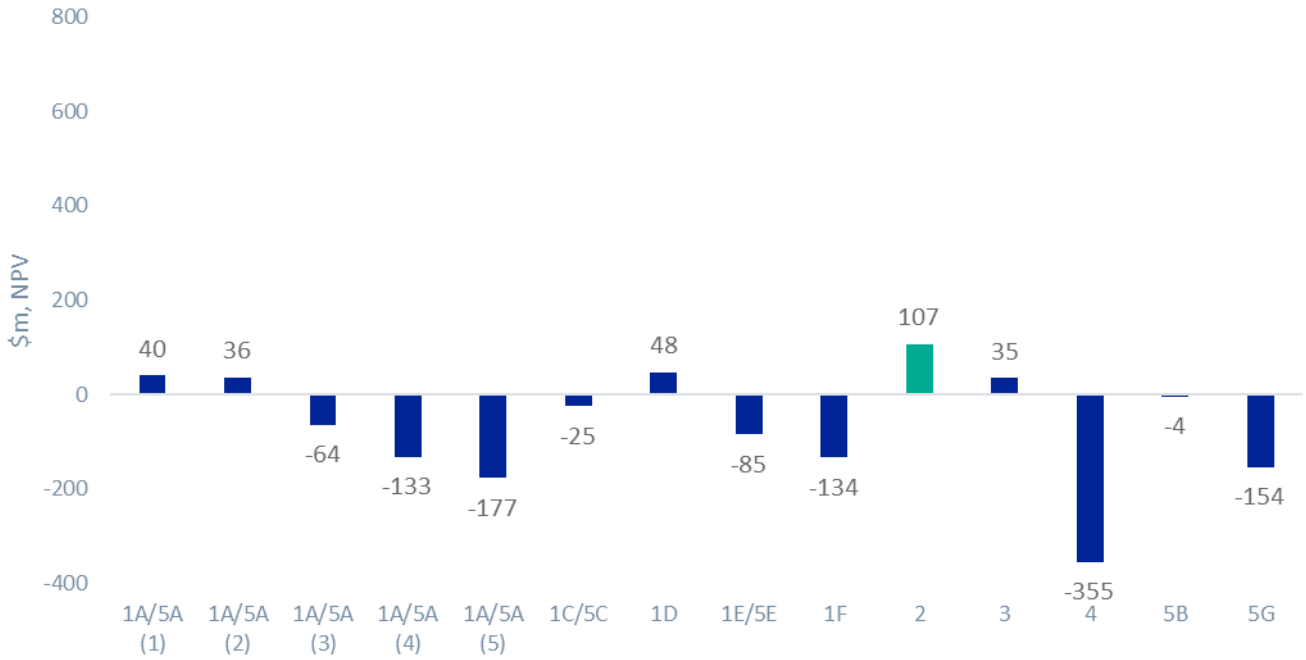
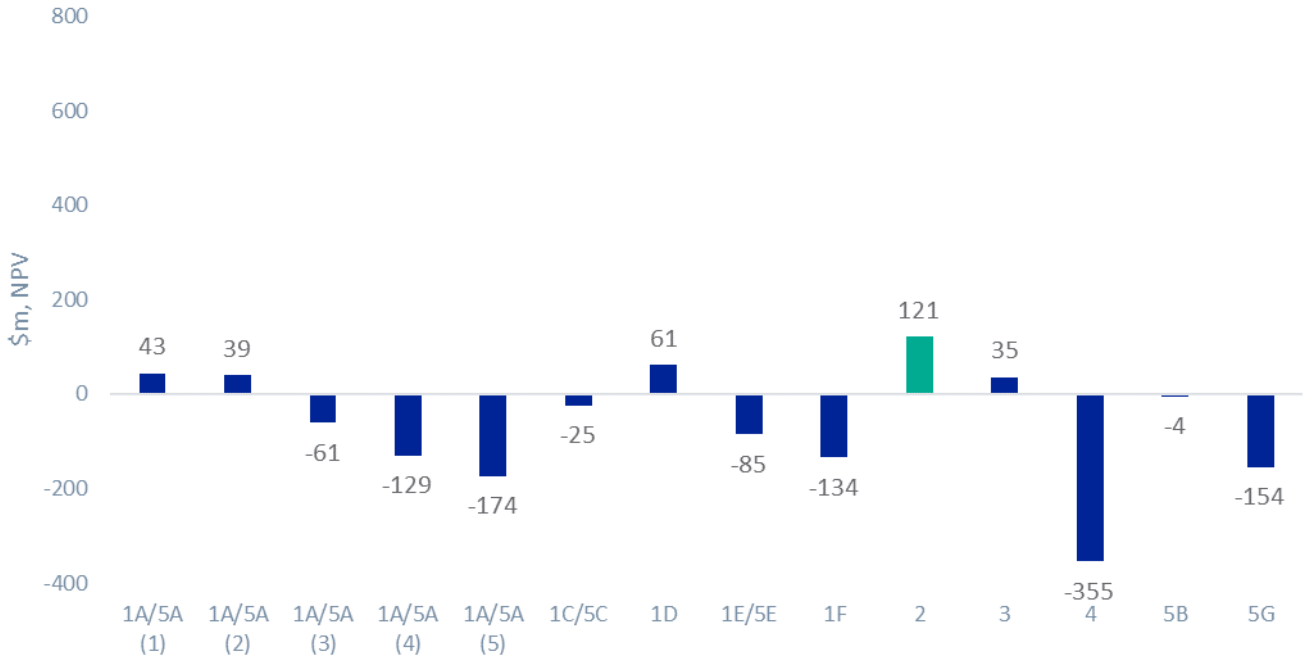


Figure 7-4: Summary of the estimated net benefits under the low benefits scenario, base case II



All options provide around $147 million in benefits from avoided unserved energy at Broken Hill under this scenario, with the exception of Option 4 which provides an additional $1 million in avoided unserved energy due to the second line providing a marginally higher level of reliability. These values are calculated using POE90 demand forecasts for Broken Hill and a low load-weighted VCR estimate.

7.3 High net economic benefits

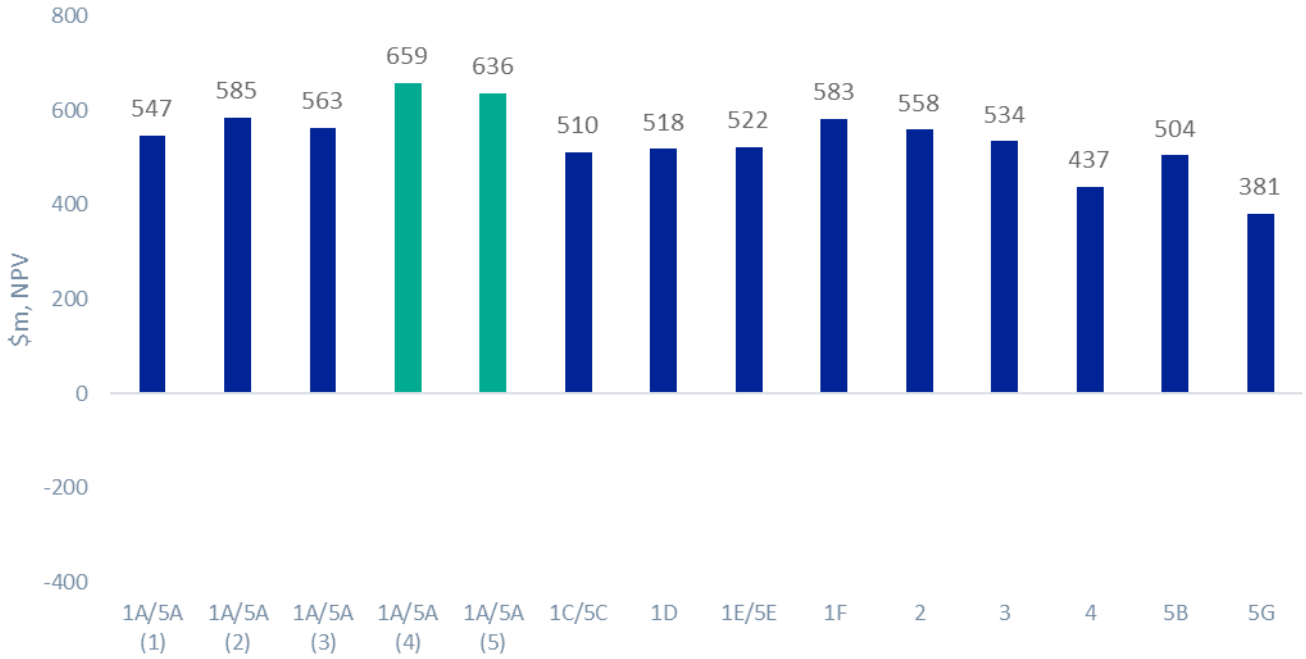
The high net economic benefits scenario reflects a number of assumptions that give an upper bound estimate of net present value of net economic benefits. These assumptions include low cost estimates, high VCR and a low commercial discount rate estimate, as well as Broken Hill demand based on POE10 demand forecasts.

This scenario also includes 30 per cent higher wholesale market benefits than those estimated by EY as an additional robustness test for the option rankings.

Under these assumptions, Option 1A/5A(4) is ranked first and is estimated to deliver approximately $659 million in net benefits under base case I and approximately $659 million in net benefits under base case II. Option 1A/5A(5) is the second-ranked option and has approximately 3 per cent lower net benefits than Option 1A/5A(4) under both base case I and base case II. Option 2 is found to have net benefits that are 15 per cent lower than Option 1A/5A(4) and 13 per cent lower than Option 1A/5A(4) under base case I and II, respectively.

Figure 7-5 and figure 7-6 show the overall estimated net benefit for each option under the high benefits scenario and across the two base cases.

Figure 7-5: Summary of the estimated net benefits under the high benefits scenario, base case I[42]



[42] The first ranked option and options that have at least 95 per cent of the net benefits of the first ranked option are colored in teal.

Figure 7-6: Summary of the estimated net benefits under the high benefits scenario, base case II

All options provide around $603 million in benefits from avoided unserved energy at Broken Hill under this scenario, with the exception of Option 4 which provides an additional $5 million in avoided unserved energy due to the second line providing a marginally higher level of reliability. These values are calculated using POE10 demand forecasts for Broken Hill and a high load-weighted VCR estimate.

7.4 Weighted net benefits

Figure 7-7 shows the estimated net benefits for each of the credible options weighted across the three scenarios investigated (and discussed above). TransGrid considers that the central scenario is most likely since it is based primarily on a set of expected assumptions. TransGrid has therefore assigned this scenario a weighting of 50 per cent, with the other two scenarios being weighted equally with 25 per cent each.

Under the weighted outcome, Option 2 is expected to deliver approximately $302 million of net benefits under base case I and approximately $316 million in net benefits under base case II. Option 2 is the top-ranked option overall.

The second-ranked option on a weighted basis, is Option 1A/5A(2), which is a storage option.

Figure 7-7: Summary of the estimated net benefits, weighted across the three scenarios, base case I

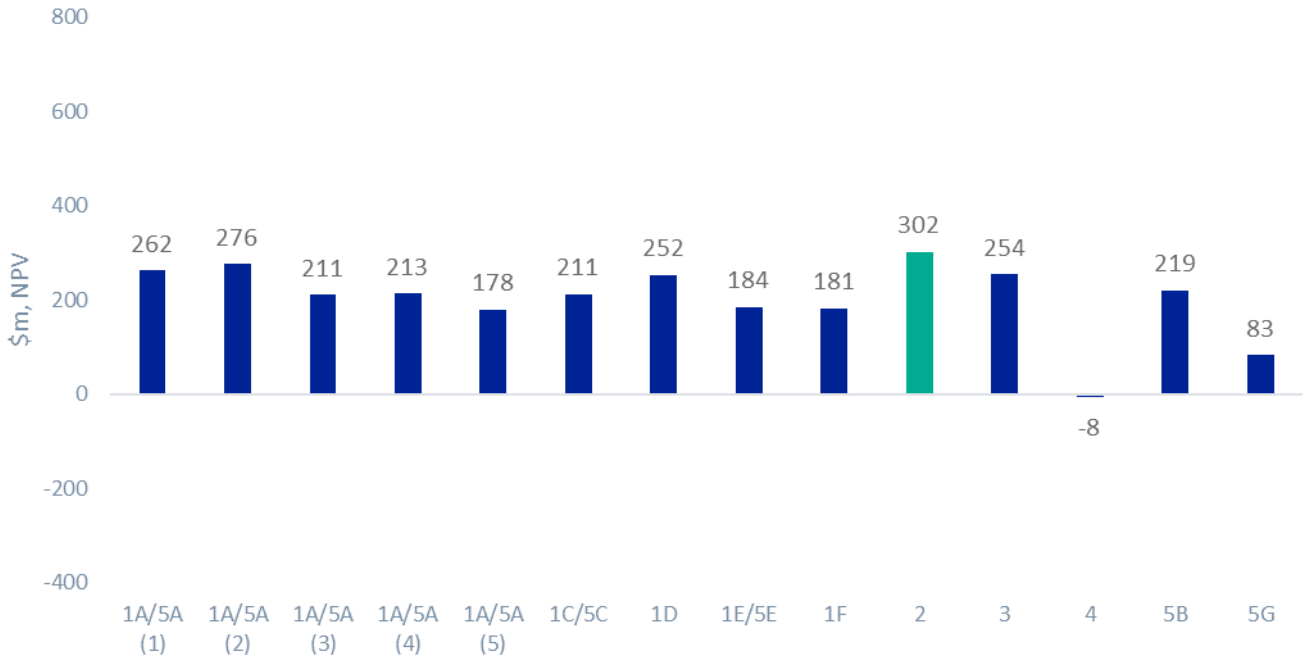
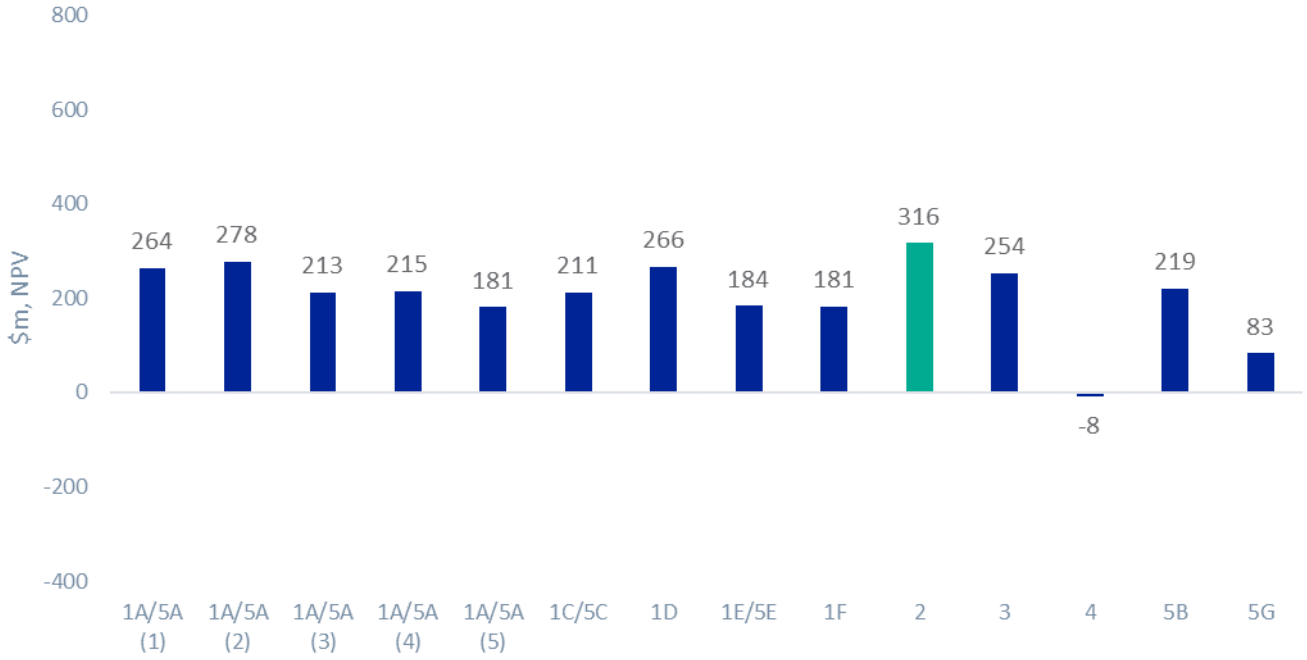


Figure 7-8: Summary of the estimated net benefits, weighted across the three scenarios, base case II



The ranking of Option 2 as the first ranked option and Option 1A/5A(2) as the second ranked option does not change when TransGrid considers an equal scenario weighting where central, low benefit and high benefit are each given one third weighting. Under equal weighting, Option 2 net benefits is expected to deliver approximately $312 million under base case I and $327 million under base case II, while Option 1A/5A(2) is the second ranked option under equal weighting is expected to deliver $287 million under base case I and $289 million under base case II.

TransGrid notes that the proponent for Option 1D has submitted that a component of their solution will proceed irrespective of the RIT-T, albeit in a smaller capacity, and therefore only the incremental costs associated with sizing that component slightly larger, to meet the need of this RIT-T, should be included in the analysis. While the core analysis above assumes the full cost of this component, TransGrid has investigated a

sensitivity that includes only the incremental costs associated with sizing it larger than it is purported to be under the base case and find that, while Option 1D's net benefits increase by 8 per cent under both base case I and base case II on a weighted basis, it does not become the top-ranked option (as outlined in section 7.5.2). In addition, TransGrid notes that Option 1D involves a continuing fossil fuel element and that it has not been offered as a directly owned variant (i.e., there is no 'Option 5D').

7.5 Sensitivity analysis

In addition to the scenario analysis, TransGrid also considered the robustness of the outcome of the cost benefit analysis through undertaking a range of sensitivity testing. These tests all relate to the central scenario.

The range of factors tested as part of the sensitivity analysis in this PADR are:

- the capacity of the 330 kV transmission system west of Wagga Wagga;
- investigating a variant of Option 1D where a component of the option is assumed to proceed irrespective of the RIT-T;
- investigating two variants of Option 2, where:
  - the existing turbines in Option 2 are able to dispatch to the NEM and generate wholesale market benefits ('Option 2 (dispatch)'); and
  - the existing turbines are coupled with a battery in 2039/40 to offset fuel costs later in the period ('Option 2 BESS');
- changes in key base case assumptions;
- changes in the network capital costs of the credible options;
- changes to the non-network costs of proposed options;
- alternate commercial discount rate assumptions; and
- new mining spot load development in the Broken Hill area, where TransGrid investigated the impact on the RIT-T outcome of two spot load scenarios:
  - 70 MW spot load in 2024/25 and
  - 160 MW spot load over the period 2024/25 to 2028/29.

Each of the sensitivity tests undertaken in this PADR are discussed in the sections below.

7.5.1 The capacity of the 330 kV transmission system west of Wagga Wagga

The core market modelling assumes a capacity for the 330 kV transmission system west of Wagga Wagga equivalent to three transmission lines (the existing Darlington Point to Wagga Wagga transmission line and two new Dinawan to Wagga Wagga transmission lines proposed as part of EnergyConnect). This assumption is consistent with the 2020 ISP and a separate RIT-T TransGrid has commenced to alleviate a voltage stability limit at Darlington Point.

TransGrid investigated a sensitivity of the capacity for the 330 kV transmission system west of Wagga Wagga equivalent to only two transmission lines under the central scenario, to assess an alternate future with less available capacity west of Wagga Wagga, and find that it has no effect on Option 2 and only a minor effect on the overall estimated wholesale market benefits for Option 1A/5A(2) on a weighted basis, and therefore does not affect the overall ranking of the top five options. Specifically, removing this investment from the analysis is found to increase the gross wholesale market benefits of Option 1A/5A(2) by approximately 1 per cent.

7.5.2 Option 1D – including only the incremental costs for one component

The proponent for Option 1D has submitted that a component of their solution will proceed irrespective of the RIT-T, albeit in a smaller capacity, and therefore only the incremental costs associated with sizing that component slightly larger, to meet the need of this RIT-T, should be included in the analysis.

Under the AER's revised guidance, where all or part of a non-network solution is expected to be in the base case, this would reduce the cost impact associated with that option.

In considering how to treat this component, TransGrid has had regard to the criteria in the RIT-T for committed and anticipated projects.

The RIT-T defines a committed project as a project that meets the following criteria:

- the proponent has obtained all required planning consents, construction approvals and licenses, including completion and acceptance of any necessary environmental impact statement;
- construction has either commenced or a firm commencement date has been set;
- the proponent has purchased/settled/acquired land (or commenced legal proceedings to acquire land) for the purposes of construction;
- contracts for supply and construction of the major components of the necessary plant and equipment (such as generators, turbines, boilers, transmission towers, conductors, terminal station equipment) have been finalised and executed, including any provisions for cancellation payments; and
- the necessary financing arrangements, including any debt plans, have been finalised and contracts executed.

The RIT-T further defines an 'anticipated project' as a project which does not meet all of the criteria of a committed project, but is in the process of meeting at least three of the criteria for a committed project. The RIT–T proponent must use [..] its reasonable judgement to include anticipated projects in all relevant states of the world (clause 27).

TransGrid engaged with the proponent on this matter and considers that, in terms of the above requirements, the component can be considered 'anticipated' but not 'committed' under the RIT-T at this point in time. There is a separate question as to whether anticipated projects should be included in the base case for the RIT-T assessment and we have discussed this matter with the AER but, as at the date of this report, TransGrid has not received a formal clarification from them on this matter. TransGrid has therefore included the full cost of this component for Option 1D in the core analysis.

TransGrid has however investigated a sensitivity that assumes the component in question does meet the RIT-T requirements for it to be considered 'anticipated' and assessed only the incremental costs associated with sizing it larger than it is purported to be under the base case. Under these assumptions, TransGrid finds that Option 1D's net benefits increase by 8 per cent under both base case I and base case II on a weighted basis but that it does not become the top-ranked option.

7.5.3 Two variants of Option 2

TransGrid has investigated the following two variants of Option 2:

- where the existing turbines in Option 2 are able to dispatch to the NEM and generate wholesale market benefits ('Option 2 (dispatch)'); and
- where the existing turbines are coupled with a battery in 2039/40 to offset fuel costs later in the period ('Option 2 BESS').[43]

Additional costs would need to be incurred in relation to fault level upgrades in order to enable the existing turbines to dispatch into the market.

Both of these sensitivities find that the additional costs incurred are not outweighed by the additional benefits expected. Specifically, Option 2's estimated benefits fall by the following amounts under each sensitivity:

[43] Under this sensitivity the replacement of the existing turbines is still assumed to occur in 2040, as the cost of a battery of a sufficient size to avoid this replacement would cost more than the replacement turbines.

- approximately 0.1 per cent under both base case I and base case II, respectively, for Option 2 (dispatch); and
- approximately 3.9 per cent under base case I and 3.7 per cent under base case II, for Option 2 BESS.

7.5.4 Base case sensitivities – changes in the assumed existing turbine sale price and mothballing costs

As outlined in section 6.1, the two base cases modelled have assumed indicative costs for future transactions regarding the existing Essential Energy turbines. Specifically:

- Base case I reflects a view on the 'next best use' of the turbines and TransGrid has assumed an indicative sale price in our core analysis; and
- Base case II reflects an outcome where there are no willing buyers for the assets (unless they are used to provide network support) and Essential Energy incurs costs to mothball the existing turbines. TransGrid has assumed an indicative mothballing cost in the core analysis.

TransGrid undertook boundary tests for the assumed sale price under base case I and find that the first and second ranked options (Option 2, Option 1A/5A(2)) are insensitive to assumed turbine sale prices between $0 and the proposed purchase cost of the turbines.[44] However, the third ranked option changes between Option 1A/5A(1) under a high and medium sale price, and Option 1D under a low (ie $0) sale price.

Similarly, TransGrid undertook boundary tests for the assumed mothballing cost and find that the first and second ranked option (Option 2) are insensitive to the assumed upper and lower boundary tests for turbine mothballing costs. The second ranked option is sensitive to a high mothball cost and changes between Option 1A/5A(2) for low and medium mothball costs, and Option 1D under high mothball costs. The third ranked option mirrors that of the second ranked option where Option 1D is third ranked under low and medium mothball costs, while Option 1A/5A(2) is third ranked under high mothball costs.

7.5.5 Changes to the costs of proposed non-network options

TransGrid tested sensitivities covering low and high non-network costs relating to capital and operating resource costs for non-network proponents. Non-network costs sensitivities have been tested under both base case I and base case II, with low and high non-network costs determined as 25 per cent lower and 25 per cent higher assumed non-network cost estimates, respectively.

Figure 7-9 and figure 7-10 shows that Option 2 is ranked first across all non-network capital cost sensitivities with no other option having net benefits within 95 per cent of Option 2's net benefits except under the low non-network cost sensitivity under base case I, where Option 1A/5A(2) exhibits 98 per cent of the net benefits of Option 2. Option 1A/5A(2) continues rank in the top three options under all other non-network cost sensitivities in both base cases.

[44] In each case the values used for the lower bound of the test were zero. The values used for the high boundary tests have not been included in this PADR as they relate to the proposed purchase costs of the turbines, which are commercially sensitive.

Figure 7-9: Impact of 25 per cent higher and lower non-network capital costs, weighted NPVs, base case I

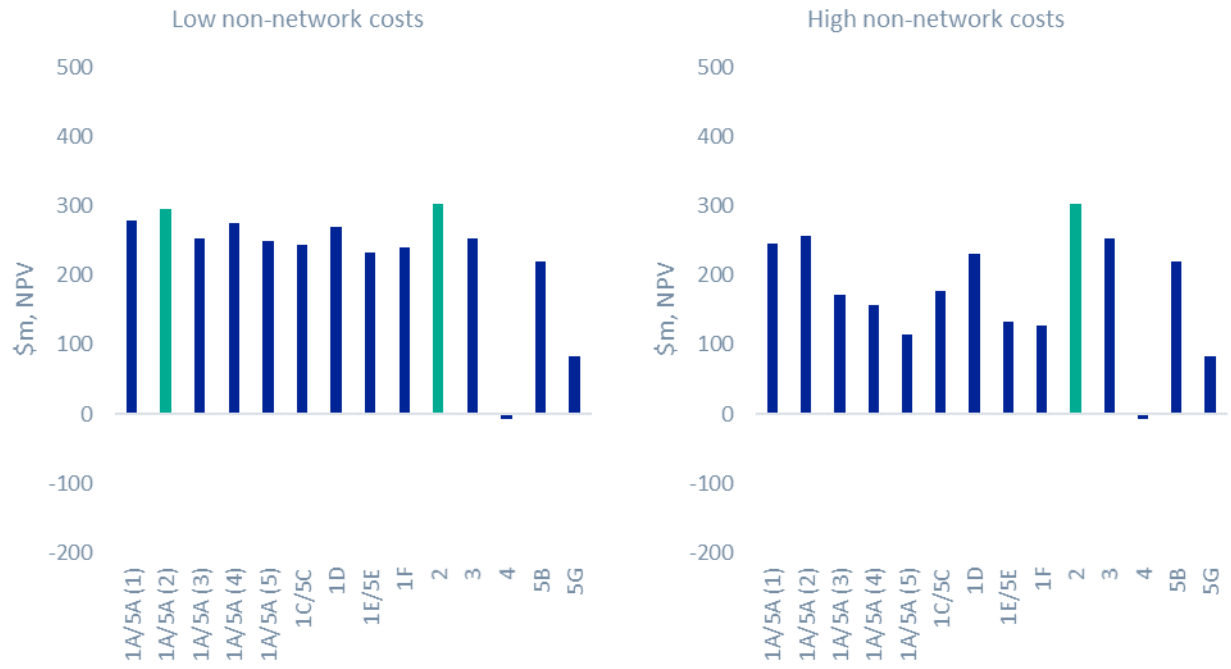
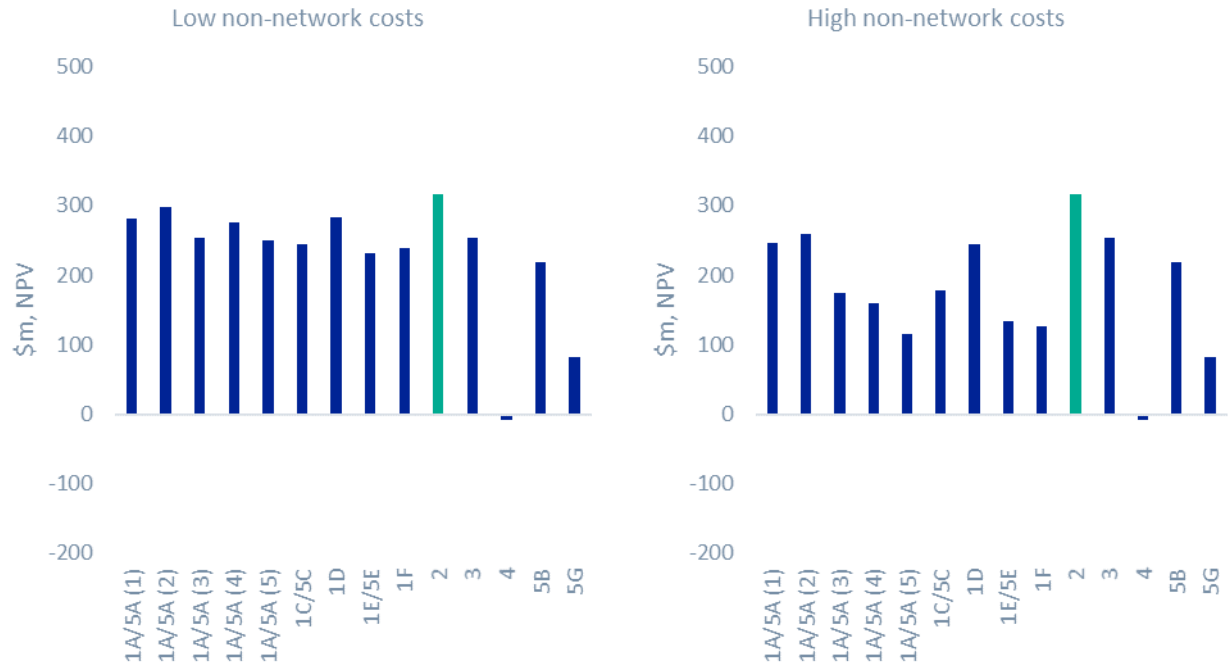


Figure 7-10: Impact of 25 per cent higher and lower non-network capital costs, weighted NPVs, base case II



7.5.6 Network capital costs of the credible options

TransGrid tested the sensitivity of the results to the underlying network capital costs of the credible options.

Figure 7-11 and figure 7-12 shows that Option 2 remains the top-ranked option under both 25 per cent higher and 25 per cent lower assumed capital costs. The effect of network capital cost sensitivities on Option 2 is limited as it only involves around $28 million of turbine refurbishment costs spread across approximately 15 years and a turbine replacement near the end of the analysis period. Option 1A/5A(2) consistently is second-ranked across network capital cost sensitivities.

Figure 7-11: Impact of 25 per cent higher and lower network capital costs, weighted NPVs, base case I

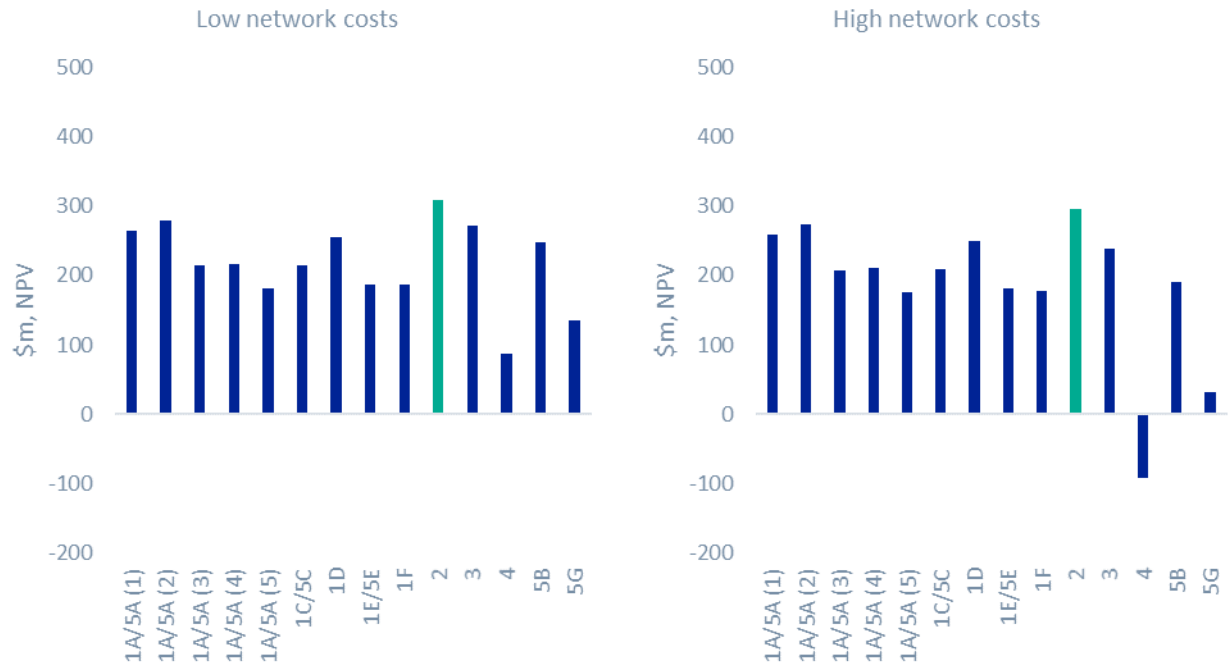
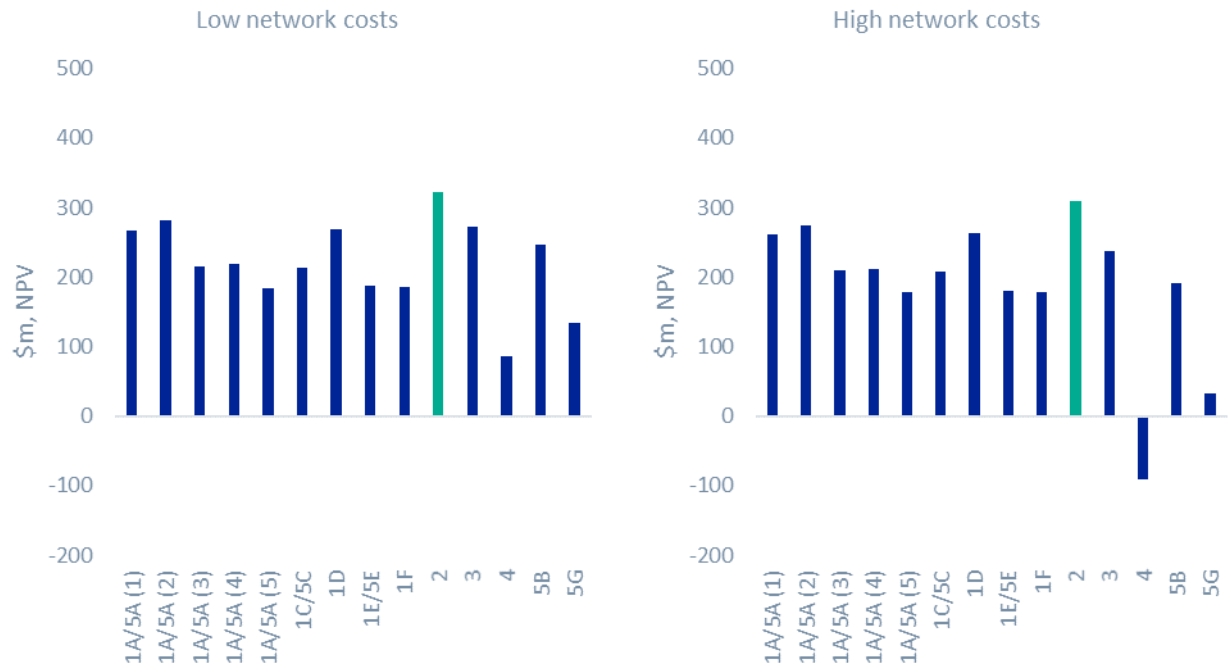


Figure 7-12: Impact of 25 per cent higher and lower network capital costs, weighted NPVs, base case II



7.5.7 Commercial discount rate assumptions

Figure 7-13 illustrates the sensitivity of the results in the central scenario to different discount rate assumptions in the NPV assessment. In particular, it illustrates two tranches of net benefits estimated for each credible option – namely:

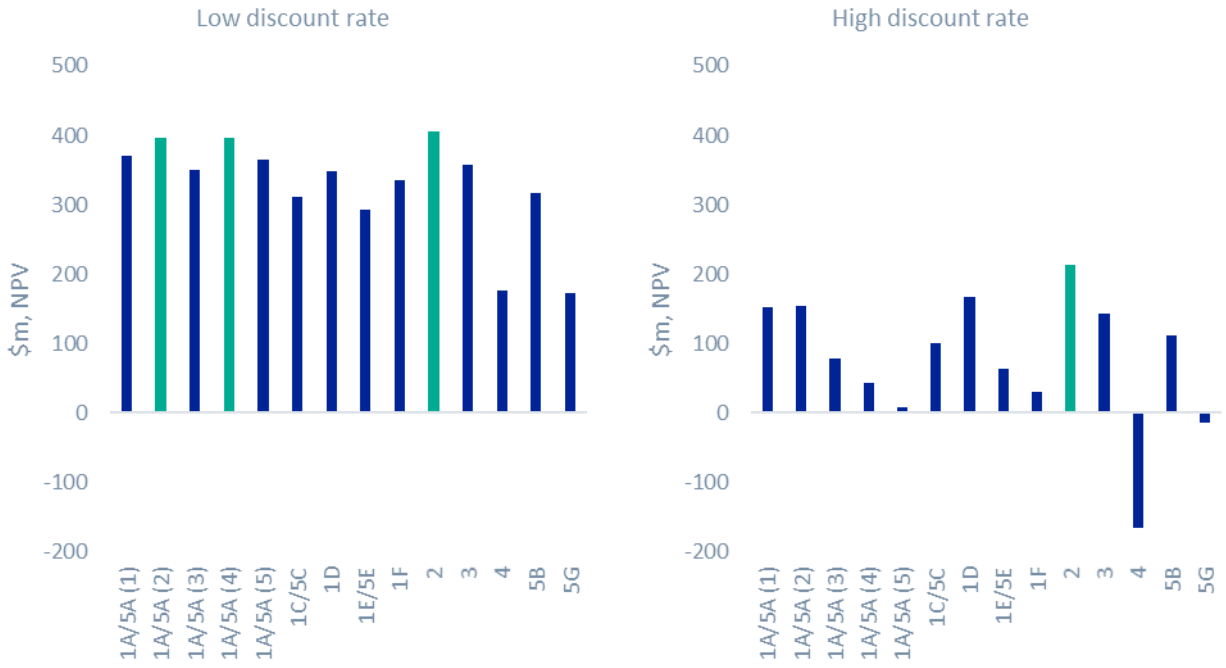
> a high discount rate of 9.57 per cent; and
> a low discount rate of 2.23 per cent.

Option 2 continues to provide strongly positive net market benefits and be the top-ranked option under both high discount rate sensitivities and the low discount rate sensitivity for both base cases. However, under the

low scenario, Option 2 is ranked equal first with Option 1A/5A(2) and Option 1A/5A(4) for both base cases. Under the high scenario, Option 1A/5A(2) is ranked within the top three options for both base case I and base case II.

Figure 7-13: Impact of different assumed discount rates, weighted NPVs, base case I

Figure 7-14: Impact of different assumed discount rates, weighted NPVs, base case II



TransGrid does not find a realistic discount rate that would result in Option 2 having an expected negative net benefit.

7.5.8 Future spot load

As noted in section 2, there are potential mining spot loads that may emerge in the Broken Hill area.

In order to test the sensitivity of the RIT-T outcome to the potential development of these spot loads TransGrid investigated two sensitivities:

- the addition of a 70 MW spot load in 2024/25; and
- the addition of 160 MW spot load between 2023/24 and 2028/29.

TransGrid considered what additional investments would be required to meet these spot loads, under a sub-set of the options being considered in this RIT-T, namely:

- Option 1A/5A (2), (3), (4) and (5);
- Option 1D; and
- Option 2.

The additional investments considered in each case are additional new technologies (batteries or compressed air storage) or additional new turbines, with both being considered in the case of Option 2.

TransGrid's assessment of the impact of spot loads is necessarily indicative. However, TransGrid finds that the need to meet additional spot load reduces the difference in net benefit between Option 2 (and additional turbines required to meet spot loads if they eventuate) and the larger capacity variants of Option 1A/5A, and that in the higher spot load case (160 MW) Option 1A/5A(4) becomes the highest ranked option. Relevantly, while Option 1A/5A(4) becomes the highest ranked option under a higher spot load case (160 MW), smaller Option 1A/5A solutions can be scaled up should the need arise, including Option 1A/5A(2), so as to allow the appropriate sizing of a solution later on to meet spot loads if they eventuate.

Extending possible variations of Option 2, TransGrid find that coupling Option 2 with different sized Option 1A/5A solutions becomes the second ranked option in the 70 MW spot load scenario.

TransGrid also finds that Option 4 (a new 220kV line) does not become the preferred option, even assuming development of these spot loads.

As a consequence, TransGrid considers that investments being considered at this stage in order to address the reliability requirement at Broken Hill are not dependent on the extent and timing of any future mining load development in the area. In the event that the spot load developments become anticipated, TransGrid will undertake a further assessment at that time in order to identify the additional efficient investments required to meet that spot load.

8. Conclusion

This PADR assessment indicates that Option 2 – which involves the purchase by TransGrid of the existing turbines at Broken Hill (currently owned by Essential Energy) and the refurbishment (and eventual replacement) of those turbines to extend their serviceable life – is the highest ranking option on a weighted basis in the NPV analysis undertaken for this RIT-T.

This option is assessed as delivering the greatest net benefit of all credible options considered to continue to provide reliable supply to Broken Hill. Option 2 is the highest ranked option in the central scenario and in the majority of the sensitivities investigated. This result is also consistent across both base cases considered.

Under Option 2, TransGrid would purchase the turbines and undertake required refurbishment activities. The cost and timing of such refurbishment has not been published in this PADR due to commercial sensitivity in light of Essential Energy's current divestment process.

Notwithstanding that the continued use of the turbines under Option 2 exhibits the highest net benefit and therefore is identified as the 'preferred option' (according to the specific definition in the RIT-T), TransGrid has concerns that prolonging the use of fossil fuel technologies is inconsistent with the Sustainability Strategy of Broken Hill City Council[45] or the general transition of the electricity sector to low emission technologies. TransGrid also notes the possibility that the existing turbines may be sold ahead of the completion of this RIT-T to a party that does not wish to continue to provide network support, at which point it would no longer be a credible option.

The highest ranked non-fossil fuel option under this RIT-T assessment is a non-network option, Option 1A/5A(2). Option 1A/5A(2) does not have an enduring reliance on fossil fuel technologies as part of the long term solution to meet reliability standards at Broken Hill. Instead, Option 1A/5A(2) is a compressed-air energy storage solution that will create a mini-grid at Broken Hill that will normally operate connected to the grid, and can meet the identified need over the long term.

Option 1A/5A(2) is of a sufficient size to trade in the wholesale market and is expected to provide wholesale market benefits in addition to the required level of reliability at Broken Hill. When Line X2 is in service, the storage will be able to store renewable generation from southern NSW that would otherwise be spilt, and make it available at other times. When Line X2 is out of service, the storage will enable Broken Hill to be run as a 'mini-grid', using the wind and solar generation at Broken Hill.

Broader market benefits are also expected to accrue under Option 1A/5A(2), primarily derived from avoided or deferred costs associated with generation and storage elsewhere in the NEM.

A larger variant of Option 1A/5A was the preferred option under the earlier PADR.[46] The change in the outcome of the RIT-T assessment in this updated PADR (noting that Option 1A/5A(2) is now the second-ranked option), is a consequence of the updated guidance from the AER on the treatment of non-network options.

Option 1A/5A(2) is estimated to deliver net benefits of around $276 million to $278 million depending on base case over the assessment period to 2044/45 (in present value terms), which includes significant wholesale market cost savings that will put downward pressure on wholesale electricity prices with flow-on benefits to customers.

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[45] Broken Hill City Council, *Sustainability Strategy 2018-2023*.

[46] The earlier PADR only considered one variant of Option 1A. The proponent of Option 1A has subsequently offered five differing capacities for this option, with the earlier 'Option 1A' now being most equivalent to the 'Option 1A/5A(4)' considered in this RIT-T.

The net benefits of Option 1A/5A(2) are found to be within 9 to 12 per cent of the net benefits of Option 2, on a weighted basis, across base case I and base case II respectively. Option 1A/5A(2) is found to be the second-ranked option under the central scenario, and most sensitivities tested.[47]

Option 1A/5A(2) also offers a degree of flexibility to be scaled into a larger solution should the need arise, for example in the case where potential mining spot loads eventuate.

TransGrid understands that the proponent of Option 1A/5A(2) is exploring external out-of-market funding. Any such external funding would reduce the costs of Option 1A/5A(2) that are included in the PACR NPV assessment and could potentially close the gap between Option 2 and Option 1A/5A(2) such that this option becomes the 'preferred option' (according to the specific definition in the RIT-T).

TransGrid notes that Option 1A/5A(2) includes technologies that would represent an innovative solution to meeting reliability requirements at Broken Hill. TransGrid will be engaging further with parties based on the outcome of this PADR (including the proponent for Option 1A/5A(2)), to confirm the technical feasibility of the options assessed.

TransGrid notes that it is intended that the analysis in the PACR will be updated to reflect any external funding, as well as any other recent relevant market developments not captured in these assumptions.

[47] Option 1A/5A(2) was ranked second in 9 out of 14 sensitivities tested. Option 1A/5A was also ranked third in 3 out of 14 sensitivities tested being: high discount rate sensitivities under base case I and base case II, and high non-network cost sensitivity under base case I, while it was ranked lower under the two spot load scenarios.

Appendix A Compliance checklist

This section sets out a compliance checklist which demonstrates the compliance of this PADR with the requirements of clause 5.16.4(b) of the National Electricity Rules version 166.

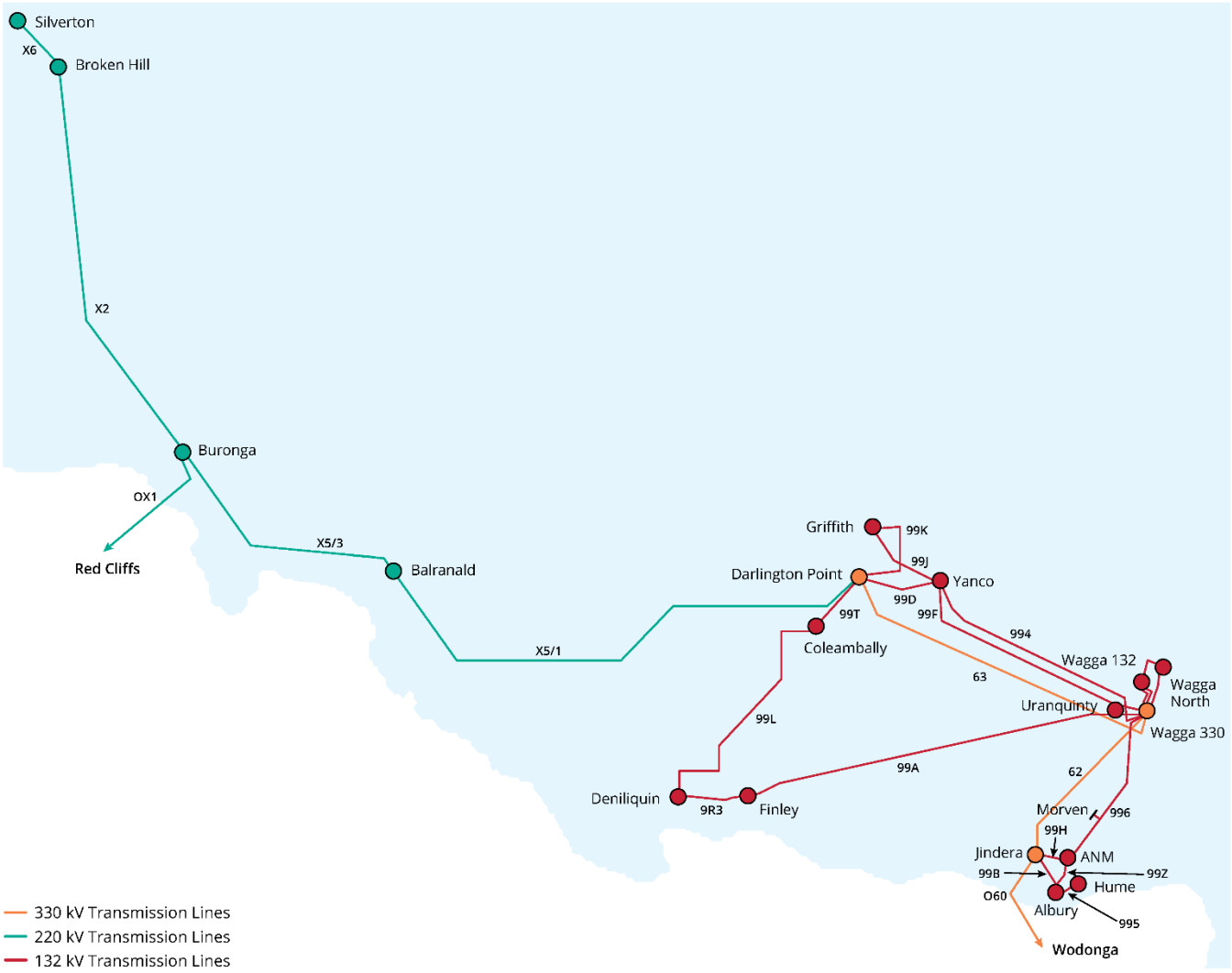
Rules clause	Summary of requirements	Relevant section(s) in the **PADR**
5.16.4(k)	A RIT-T proponent must prepare a report (the assessment draft report), which must include:	-
	(1) a description of each credible option assessed;	4
	(2) a summary of, and commentary on, the submissions to the project specification consultation report;	3
	(3) a quantification of the costs, including a breakdown of operating and capital expenditure, and classes of material market benefit for each credible option;	4 & 7
	(4) a detailed description of the methodologies used in quantifying each class of material market benefit and cost;	6
	(5) reasons why the RIT-T proponent has determined that a class or classes of market benefit are not material;	6
	(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);	7
	(7) the results of a net present value analysis of each credible option and accompanying explanatory statements regarding the results;	7
	(8) the identification of the proposed preferred option;	8
	(9) for the proposed preferred option identified under subparagraph (8), the RIT-T proponent must provide: (i) details of the technical characteristics; (ii) the estimated construction timetable and commissioning date; (iii) if the proposed preferred option is likely to have a material inter-network impact and if the Transmission Network Service Provider affected by the RIT-T project has received an augmentation technical report, that report; and (iv) a statement and the accompanying detailed analysis that the preferred option satisfies the regulatory investment test for transmission.	8

Appendix B Overview of existing electricity supply arrangements at Broken Hill

Broken Hill is part of the south-western transmission network and is supplied by a single 220 kV transmission line, Line X2, from Buronga that is around 260 km long.

The current electricity network supplying Broken Hill is shown in Figure B-8-1 below.

Figure B-8-1: South western NSW transmission network



The average electricity demand at Broken Hill substation is approximately 40 MW.[48]

In addition, Broken Hill Solar Plant (53 MW) and Silverton Wind Farm (200 MW) are both connected to Broken Hill substation.

[48] TransGrid, *Transmission Annual Planning Report 2021*, available at: https://www.transgrid.com.au/news-views/publications/Documents/Transmission%20Annual%20Planning%20Report%202018%20TransGrid.pdf

During a planned or unplanned outage of Line X2, Broken Hill has been supplied by Essential Energy's two back-up turbines that run on diesel fuel.[49]

These turbines:

> each have nominal capacity rating of 25 MW, which is reduced to 18 MW under adverse ambient temperature conditions; and

> are black-start capable and equipped for islanded operation.

TransGrid has relied on these turbines to meet its obligations under NSW Electricity Transmission reliability standards as determined by IPART.

The reliability standards applicable to Broken Hill are set out in Table B-1 below and currently require us to reliably supply the load at Broken Hill and maintain less than 10 minutes of EUE at average demand.[50]

Table B-1: IPART reliability standards applicable to Broken Hill from 2018/19 onward

Broken Hill	Redundancy category [51]	Average demand (MW)	Unserved energy allowance (minutes)	Estimated unserved energy allowance (MWh)
Broken Hill 220 kV	1	19 MW	10 minutes (grouped)	3.2 MWh
Broken Hill 22 kV	1	21 MW		3.5 MWh
Total	1	40 MW	10 minutes	7 MWh

[49] Broken Hill Solar Plant and Silverton Wind Farm are not presently configured to be able to generate in an event of an outage of Line X2.

[50] IPART, *NSW Electricity Transmission Reliability and Performance Standard 2017*, available at: https://www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/licensing-compliance-electricity-transmission-reliability/nsw-electricity-transmission-reliability-and-performance-standard-2017.pdf

[51] Redundancy category level 1 means a supply interruption may occur following the outage of a single system element.

Appendix C Overview of the wholesale market modelling undertaken

As outlined in the body of this PADR, TransGrid engaged EY to undertake the wholesale market modelling as part of this PADR.

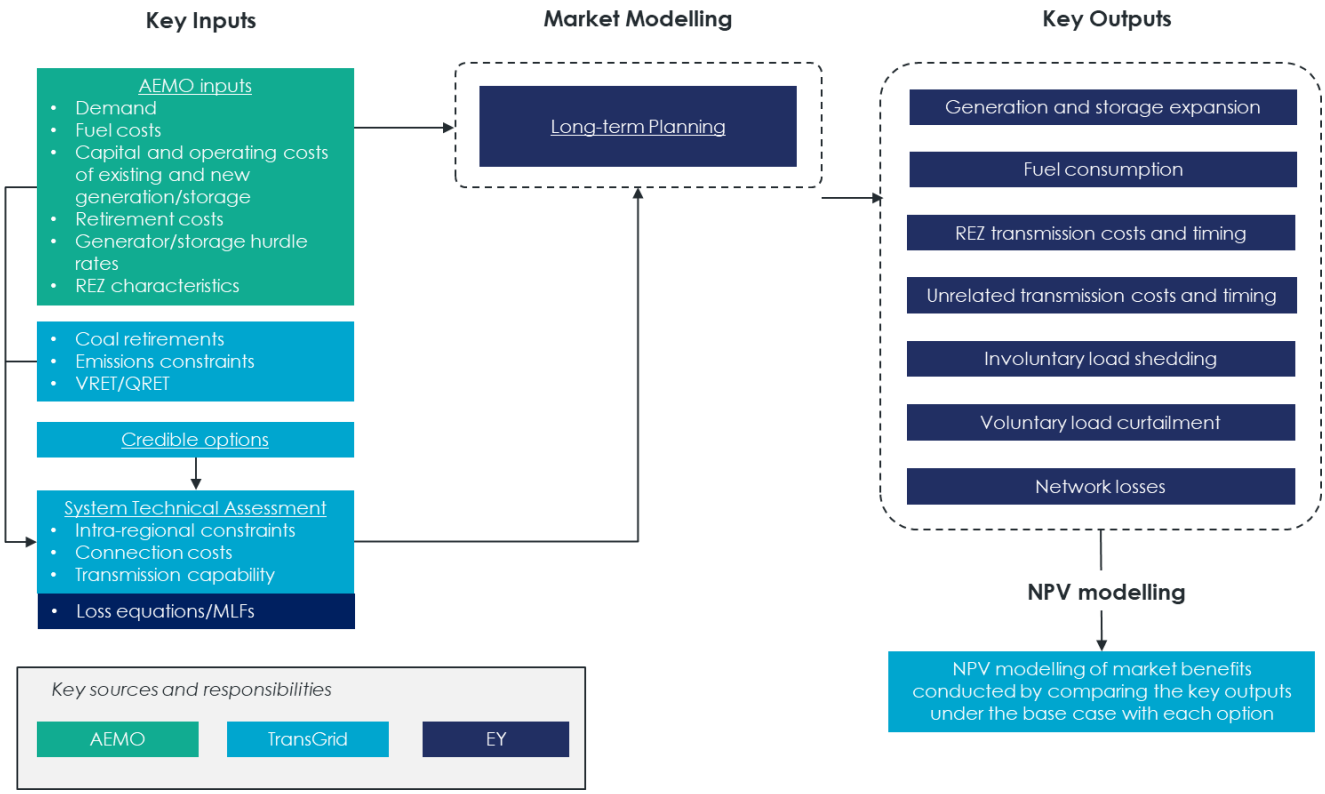
EY has applied a linear optimisation model and performed hourly, time-sequential, long-term modelling for the NEM to estimate categories of wholesale market benefits expected under the options that affect the wholesale market. Specifically, EY has undertaken market simulation exercise involving long-term investment planning, which identifies the optimum generation (including storage) and unrelated transmission infrastructure development schedule, while meeting reliability requirements, policy objectives, and technical generator and network performance limitations. This solves for the least-cost generation and transmission infrastructure development across the assessment period while meeting energy policies.

TransGrid has undertaken a detailed System Technical Assessment, which evaluates the power system behaviour and performance under each credible option and ensures market modelling outcomes are physically plausible, follow the operation of the NEM, and that the benefits of credible options align with the changes to the power system under each credible option. This assessment serves as an input to the wholesale market modelling exercises EY has undertaken (as outlined above).

These exercises are consistent with an industry-accepted methodology, including within AEMO's ISP.

Figure C.8-2 illustrates the interactions between the key modelling exercises, as well as the primary party responsible for each exercise and/or where the key assumptions have been sourced.

Figure C.8-2: Overview of the market modelling process and methodologies



As these modelling exercises investigate different aspects of the market simulation process, they necessarily interact and are executed iteratively using inputs and outputs.

The sub-sections below provide additional detail on the key wholesale market modelling exercises EY have undertaken as part of this PADR assessment.

Long-term Investment Planning

The Long-term Investment Planning's function is to develop generation (including storage) and unrelated transmission infrastructure forecasts over the assessment period for each of the credible options and base cases.

This exercise determines the least-cost development schedule for each credible option drawing on assumptions regarding demand, reservoir inflows, generator outages, wind and solar generation profiles, and maintenance over the assessment period.

The generation and transmission infrastructure development schedule resulting from the Long-term Investment Planning is determined such that:

- it economically meets hourly regional and system-wide demand while accounting for network losses;
- it builds sufficient generation capacity to meet demand when economic while considering potential generator forced outages;
- the cost of unserved energy is balanced with the cost of new generation investment to supply any potential shortfall;
- generator's technical specifications such as minimum stable loading, and maximum capacity are observed;
- notional interconnector flows do not breach technical limits and interconnector losses are accounted for;
- hydro storage levels and battery storage state of charge do not breach maximum and minimum values and cyclic losses are accounted for;
- new generation capacity is connected to locations in the network where it is most economical from a whole of system cost;
- NEM-wide emissions constraints are adhered to;
- NEM-wide and state-wide renewable energy targets are met, or else penalties are applied;
- refurbishment costs are captured;
- generator maintenance outages are scheduled to represent planned generator outages;
- regional and mainland reserve requirements are met;
- energy-limited generators such as Tasmanian hydro-electric generators and Snowy Hydro-scheme are scheduled to minimise system costs; and
- the overall system cost spanning the whole outlook period is optimised whilst adhering to constraints.

The Long-term Investment Planning adopts the same commercial discount rate as used in the NPV discounting calculation in the cost benefit analysis. This is consistent with the approach being taken in the 2020 ISP (and was applied in the inaugural 2018 ISP).[52]

Coal-fired and gas-fired generation is treated as dispatchable between its minimum load and its maximum load in the modelling. Coal-fired 'must run' generation is dispatched whenever available at least at its minimum load, while gas-fired CCGT 'must run' plant is dispatched at or above its minimum load. Open cycle turbines are typically bid at their short run marginal cost with a zero minimum load level, and started and operated whenever the price is above that level. The accompanying market modelling report provides additional detail on how cycling constraints have been reflected in the analysis.

The Long-term Investment Planning model ensures there is sufficient dispatchable capacity in each region to meet peak demand in the region, plus a reserve level sufficient to allow for generation or transmission contingences which can occur at any time, regardless of the present dispatch conditions.

[52] AEMO, *Planning and Forecasting 2019 Consultation Process Briefing Webinar*, Wednesday 3 April 2019, slide 21.

Due to load diversity and sharing of reserve across the NEM, the reserve to be carried is minimised at times of peak, and provided from the lowest cost providers of reserve including allowing for each region to contribute to its neighbours reserve requirements through interconnectors.

Modelling of diversity in peak demand

The market modelling accounts for peak period diversification across regions by basing the overall shape of hourly demand on nine historical years ranging from 2010/11 to 2018/19.

Specifically, the key steps to accounting for this diversification are as follows:

- the historical underlying demand has been calculated as the sum of historical metered demand and the estimated rooftop PV generation based on historical rooftop PV capacity and solar insolation;
- the nine-year hourly pattern has been projected forward to meet future forecast annual peak demand and energy in each region;
- the nine reference years are repeated sequentially throughout the modelling horizon; and
- the future hourly rooftop PV generation has been estimated based on insolation in the corresponding reference year and the projection of future rooftop PV capacity, which is subtracted from the forecast underlying demand along with other behind-the-meter components (e.g., electric vehicles and domestic storage) to get a projection of hourly operational demand.

This method ensures the timing of peak demand across regions reflects historical patterns, while accounting for projected changes in rooftop PV generation and other behind-the-meter loads and generators that may alter the diversity of timing.

Modelling of intra-regional constraints

The wholesale market simulations include models for intra-regional constraints in addition to the inter-regional transfer limits.

Key intra-regional transmission constraints in New South Wales have been captured by splitting NSW into zones (NNS, NCEN, CAN and SWNSW), and explicitly modelling intra-regional connectors across boundaries or cut-sets between these zones. Bi-directional flow limits and dynamic loss equations were formulated for each intra-regional connector.

In addition, loss factors for each generator were applied. These were computed from an AC power flow programme interfaced with the Long-term Investment Planning model. The loss factors for each generation investment plan were computed on a five-year basis up to 2030-31 and fed back into the Long-term Investment Planning model to capture both the impact on bids and intra-zonal losses.

Beyond 2030/31, the loss factors have been maintained at the same values as 2030-31, since network changes beyond that stage and additional renewable generation are becoming much less certain. However, this does not preclude generation investment if economic at any location.

Summary of the key assumptions feeding into the wholesale market exercise

The table below summarises the key assumptions that the market modelling exercise draws upon.

Table C-2: PADR modelled scenario's key drivers input parameters

Key drivers input parameter	Central scenario
Underlying consumption	AEMO 2020 ISP Central

New entrant capital cost for wind, solar SAT, OCGT, CCGT, PSH, and large-scale batteries	AEMO 2020 ISP Central scenario
Retirements of coal-fired power stations	AEMO Generation Information[53] announced retirement date or end-of-technical-lives.
Gas fuel cost	AEMO 2020 ISP
Coal fuel cost	AEMO 2020 ISP
Federal Large-scale Renewable Energy Target (LRET)	33 TWh by 2020 to 2030 (including GreenPower and ACT scheme)
COP21 commitment (Paris agreement)	28% reduction from 2005 by 2030, then a linear extrapolation beyond 2030 to 70% reduction of 2016 emissions by 2050
Victoria Renewable Energy Target (VRET)	40% renewable energy by 2025 and 50% renewable energy by 2030
Queensland Renewable Energy Target (QRET)	50% by 2030
Tasmanian Renewable Energy Target (TRET)	100% Tasmanian renewable energy generation by 2021-22 and 200% by 2039-40
South Australia Energy Transformation RIT-T	NSW to SA interconnector (Energy Connect) is assumed commissioned by July 2023[54]. An additional 330 kV circuit from Wagga to Darlington Point is also assumed.
Western Victoria Renewable Integration RIT-T	The preferred option in the Western Victoria Renewable Integration PACR[55] by July 2025 (220 kV upgrade in 2024 and 500 kV to Sydenham in 2025).
Marinus Link and Battery of the Nation	Excluded

[53] AEMO, 30 April 2020, *Generating Unit Expected Closure Year - April 2020.*

[54] ElectraNet, 13 February 2019. *SA Energy Transformation RIT-T: Project Assessment Conclusions Report.* Available at: https://www.electranet.com.au/wp-content/uploads/projects/2016/11/SA-Energy-Transformation-PACR.pdf. There are options for commissioning between 2022 and 2024. Limits also from this document.

[55] AEMO, July 2019, *Western Victoria Renewable Integration PACR*. Available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2019/PACR/Western-Victoria-RIT-T-PACR.pdf.

Victoria to NSW, and NSW to QLD Interconnectors Upgrades	The Victoria to NSW Interconnector upgrade PADR[56] preferred option and NSW to QLD Interconnector upgrade approved option by AER[57] are assumed commissioned by July 2022.
Snowy 2.0	Snowy 2.0 is included from July 2025
HumeLink	HumeLink PADR preferred option (Option 3C) is assumed commissioned by July 2024[58]
VNI West	The VNI West ISP 2018 preferred option is assumed commissioned by July 2026
Marinus Link and Battery of the Nation	Excluded

[56] AEMO and TransGrid, August 2019, *Victoria to New South Wales Interconnector Upgrade – PADR.* Available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2019/VNI-RIT-T/Victoria-to-New-South-Wales-Interconnector-Upgrade-RIT-T-PADR.pdf.

[57] TransGrid, *Expanding NSW-QLD transmission transfer capacity*, Available at: https://www.transgrid.com.au/gni

[58] TransGrid, *Reinforcing the NSW Southern Shared Network to increase transfer capacity to demand centres (HumeLink)*, Available at: https://www.transgrid.com.au/humelink

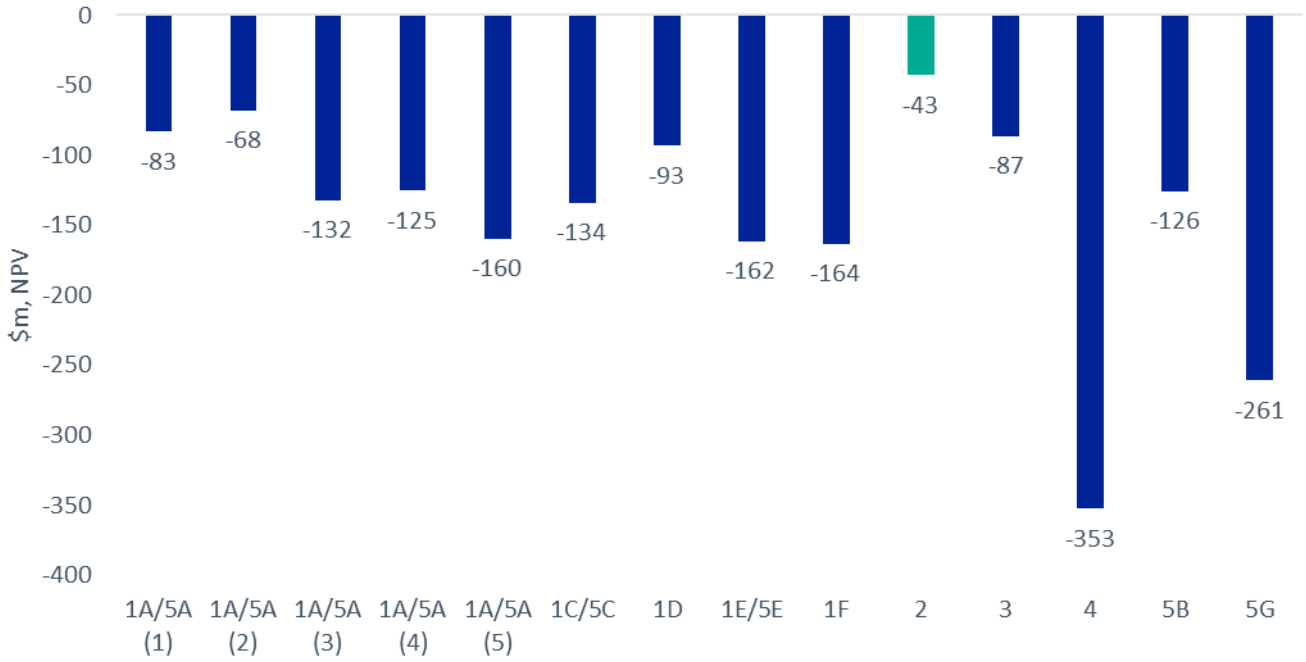
Appendix D Analysis using EUE improvements over the reliability standard

As outlined in section 6.3, TransGrid has estimated the absolute level of EUE at Broken Hill under the base case and each credible option for the analysis presented in the body of this report.

While the RIT-T requires that reliability corrective actions only quantify the changes in EUE over and above that required to meet the applicable reliability standard,[59] the body of this PADR presents EUE in absolute terms since it is more intuitive.[60] Estimating EUE in this manner has no bearing on the identification of the preferred option and this appendix demonstrates this by presenting the analysis in this PADR using only EUE improvements over the IPART reliability standard.

The figure below presents the weighted net market benefit results for each of the credible options and shows that Option 2 is still the top-ranked option.

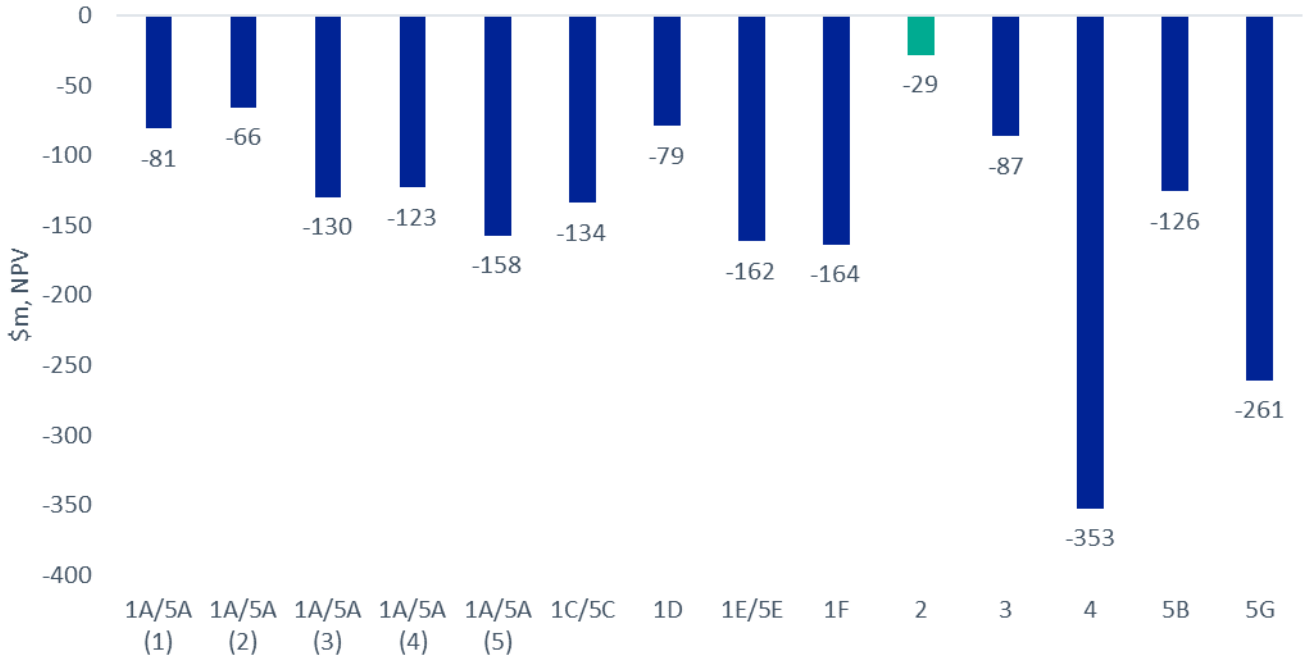
Figure D-8-3: Analysis using EUE improvements over the reliability standard, weighted NPVs, base case I



[59] Clause 9 of the RIT-T states that 'where the credible option is for reliability corrective action, the quantification of the market benefits associated with changes in voluntary load curtailment and changes in involuntary load shedding must only apply in so far as the market benefit delivered by the credible option exceeds the minimum standard required for reliability corrective action' – see: AER, *Final Regulatory Investment Test for Transmission*, June 2010, Clause 9.

[60] TransGrid notes that this is also consistent with the AER's 'service cost' framework outlined in its industry practice application note for asset replacement planning, as well as the ENA RIT-T Handbook – see: https://www.aer.gov.au/system/files/D19-2978%20-%20AER%20-Industry%20practice%20application%20note%20Asset%20replacement%20planning%20-%2025%20January%202019.pdf & Energy Networks Australia, *RIT-T Economic Assessment Handbook*, October 2020.

Figure D-8-4: Analysis using EUE improvements over the reliability standard, weighted NPVs, base case II



The key difference compared to the analysis in the body of the report is that all options now have negative estimated net market benefits on account of the analysis excluding all avoided EUE except that which exceeds the reliability standard. However, under a reliability corrective action RIT-T, the preferred option is permitted to have negative net market benefits but must still be the top-ranked option, ie, be the lowest net cost way of meeting the required reliability standard.