Maintaining reliable supply to Broken Hill

RIT-T – Project Assessment Draft Report

Region: South Western New South Wales

Date of issue: 11 August 2020

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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.

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 gas turbines, which are owned by Essential Energy, to avoid involuntary load shedding. TransGrid relies on these gas 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 gas 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.

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.

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

- some options involve grid-connected batteries and/or other equivalent technologies that introduce new entities trading in the wholesale market, eg, storage dispatching into the National Electricity Market (NEM) outside of times when it is 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 PADR analysis has benefited from extensive stakeholder consultation

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

Four of these parties have explicitly requested confidentiality as their submissions relate to the provision of solutions that form either part of, or standalone, credible options. The Public Interest Advocacy Centre was the fifth submitter and did not request confidentiality and TransGrid has responded to the points raised in this PADR.

Prior to, as well as after, receiving 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. These discussions have played a pivotal role in being able to define and include the credible options assessed in this PADR and TransGrid thanks all parties for their time and effort to-date.

TransGrid will be engaging further with parties based on the outcome of this PADR to confirm the technical feasibility of the options, which is expected to involve the provision of further information and modelling from these parties. A full assessment of technical feasibility is intended to be undertaken ahead of the PACR where parties confirm they are proponents and provide the required information.

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

Stakeholder consultation on the PSCR has assisted greatly with developing and refining the credible options put forward in the PSCR. Specifically, consultation with third parties since the PSCR has enabled this PADR to assess the following five types of credible options:

- Option 1: four different non-network opex solutions fully provided by third parties (Option 1A, Option 1B, Option 1C and Option 1D);
- Option 2: a refined version, and cost for, acquiring the existing gas turbines from Essential Energy;
- Option 3: establishing new gas turbines at Broken Hill;
- Option 4: building a second single circuit 220 kV transmission line from Buronga to Broken Hill; and
- Option 5: three variants of the first group of solutions involving either shared ownership or ownership by TransGrid (Option 5A, Option 5B and Option 5C).

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 gas 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 the PADR and the PACR, including the cost of non-network options that assume the use of these turbines.

The four non-network opex solutions fully provided by third parties (Option 1A, Option 1B, Option 1C and Option 1D) and the three variants of these solutions involving either shared ownership or ownership by TransGrid (Option 5A, Option 5B and Option 5C) have been assessed using information (including costs) provided by parties in response to the PSCR 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 preferred option delivers positive net benefits and is the top-ranked option across all reasonable future scenarios

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

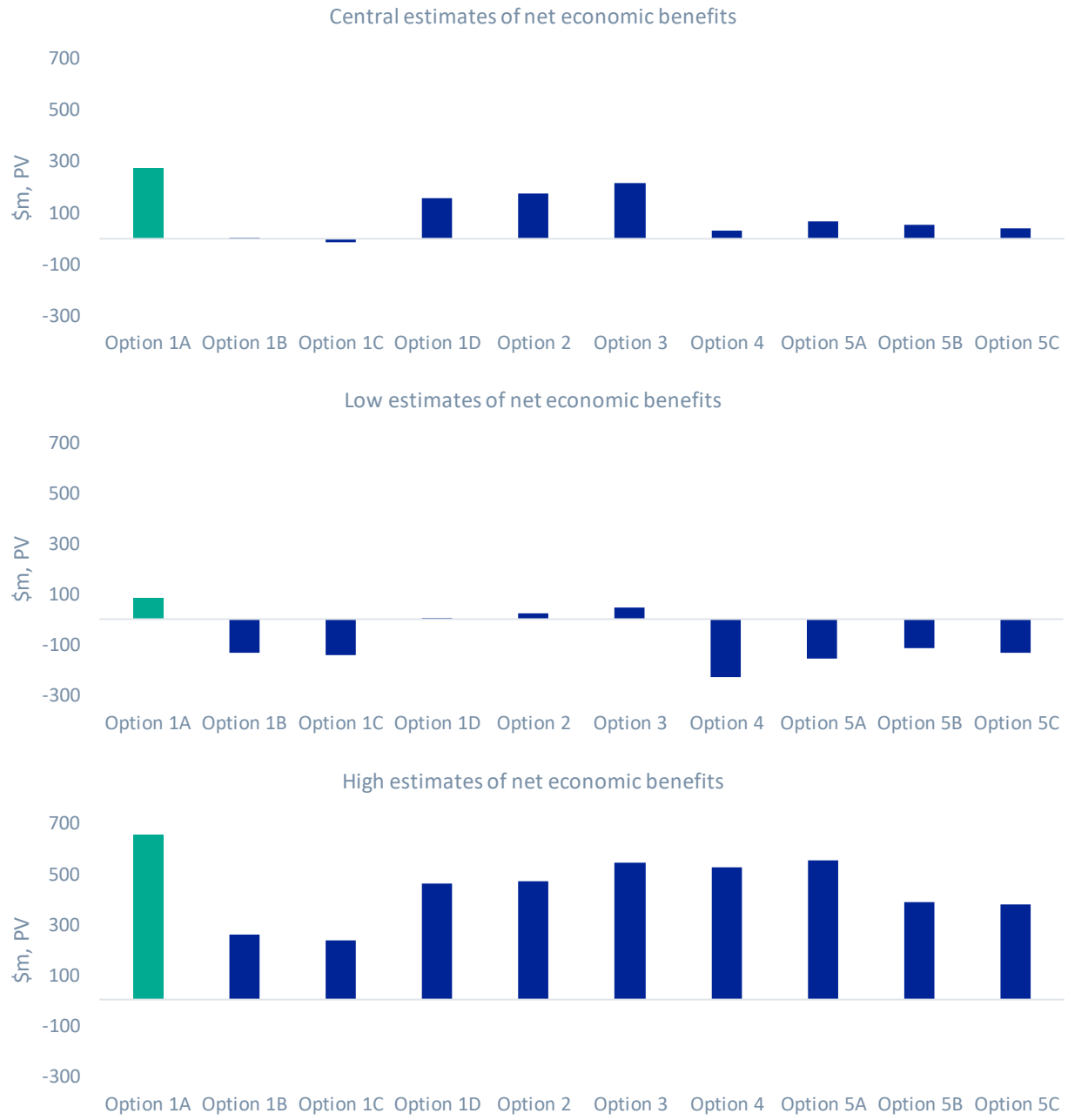
Variable	Central	Low net economic benefits	High net economic benefits
Network capital costs	Base estimate	Base estimate + 25%	Base estimate - 25%
Broken Hill demand	Based on POE50 demand forecast	Based on POE90 demand forecast	Based on POE10 demand forecast
Wholesale market benefits estimated	EY estimated 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
VCR	$36.43/kWh	$25.50/kWh	$47.36/kWh
Discount rate	5.90%	9.57%	2.23%

The results of the PADR assessment find that Option 1A (a non-network opex solution fully provided by a third party) is expected to deliver the greatest net benefits of all options, across all three scenarios considered. Estimated net benefits for this option range from approximately $85 million to $653 million depending on the scenario.

The second-ranked option is Option 3 (establishing new gas turbines at Broken Hill). On a weighted basis this option is expected to deliver around 21 per cent lower net benefits than Option 1A.

TransGrid will be engaging further with third parties based on the outcome of this PADR to confirm the technical and commercial feasibility of all options put forward. Option 3 would be the fallback option if the technical and commercial feasibility of these other options cannot be confirmed.

Figure E-1: Summary of the estimated net benefits



The market benefits of all options are primarily derived from avoided involuntary load shedding compared to the base case. The preferred option also provides significant wholesale market benefits, primarily in the form of avoided, or deferred, costs associated with generation and storage in the NEM, compared to the base case. This benefit makes up around 88 per cent of the total wholesale market benefits estimated for Option 1A and arises since the facility commissioned at Broken Hill to provide back-up supply is of sufficient size to also trade in the wholesale market (and does so at a relatively low cost). While other options also provide estimated wholesale market benefits, they are all significantly lower than those estimated for Option 1A.

TransGrid has also tested the robustness of the assessment to a range of sensitivities, in particular the capacity of the 330kV transmission system west of Wagga Wagga, removing the 150 MW REZ capacity assumed at Broken Hill for the preferred option, the assumed timing of having to replace the existing gas turbines at Broken Hill, the capital costs of the credible options and alternate commercial discount rate assumptions. All tests confirm the conclusion that Option 1A is the optimal investment at this stage of the RIT-T, with Option 3 ranked second.

The regulatory treatment of non-network costs is a key driver of the preferred option

While Option 1A, a non-network opex solution fully provided by a third party, is the preferred option at this stage of the RIT-T, the corresponding option proposed by the same third party involving TransGrid ownership (Option 5A) is one of the lowest ranked options, due to the different regulatory treatment of costs under the RIT-T assessment.

While Option 1A and Option 5A are identical in terms of the technologies employed and the benefits expected, the total cost of Option 1A in the analysis is significantly lower than that for Option 5A. This is due to AER guidance requiring only the proposed contract costs for non-network options be included in the RIT-T assessment, while the entire capital and operating costs must be included for network options. The costs for Option 1A can therefore be net of any funding the third party expects to receive from using the facility to trade in the NEM, while the costs of Option 5A cannot.

TransGrid notes that Energy Networks Australia (ENA) recently raised the issue of the differential treatment of third party funding in its submission to the AER on the guidelines to make the ISP actionable.[1] TransGrid considers the outcome of the assessment presented in this PADR presents a real world example of how the current AER guidance for these two types of options tilts the playing field towards non-network provision of these services.

TransGrid intends to confirm and clarify with the AER how this issue should best be treated in the RIT-T in order to promote the objective of competitive neutrality and ensure that only the most efficient cost outcome is ultimately recovered from end customers.

Next steps

TransGrid welcomes written submissions on this PADR. Submissions are due on 22 September 2020.

Submissions should be emailed to TransGrid's Regulation team via regulatory.consultation@transgrid.com.au.[2] 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 late 2020.

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1 ENA, *Submission to the AER on the Guidelines to Make the ISP Actionable*, 26 June 2020, pp. 7-8.

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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. 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.

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 gas turbines (owned by Essential Energy) to avoid involuntary load shedding. TransGrid relies on these gas turbines (25 MW nameplate rating each) 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, Essential Energy's gas turbines allow TransGrid to operate its network so as not to expect more than 10 minutes of expected unserved energy (EUE) per year at average demand.[3]

Essential Energy has notified TransGrid of its decision to divest the gas 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.

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

> 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 the RIT-T process, which will consider 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 with a number of suppliers. The ultimate timing and scope of the short-term solution is dependent on Essential Energy's divestment date for the gas turbines (when support from the existing gas turbines will no longer be available to TransGrid), 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 back-up supply capacity at Broken Hill.

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

[3] 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

Broken Hill in the event that the total 220 kV and 22 kV load at Broken Hill exceeds the capacity of the back-up gas turbines owned by Essential Energy and EUE exceeds the reliability standard allowance.[4]

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 points raised in submissions to the PSCR and highlight how these have 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 PSCR consultation;
- 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 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.

As part of the consultation undertaken since the PSCR, TransGrid has requested additional information and modelling from third parties in order to determine the technical feasibility of the solutions put forward. Parties have either been unable to provide this information within the PADR timeframes or have expressed a preference to provide this level of detail after the results of the PADR assessment have been released and they have a better understanding of the relativities between options. This is understandable given the costs and effort involved in providing this material and submitters first needing to understand whether their proposal is likely to be in the running for identification as part of the preferred option.

This PADR consequently adopts a conservative approach to option technical feasibility whereby additional network components are assumed for the options where technical feasibility has not yet been determined. This PADR outlines what has been assumed and why it is required.

TransGrid will be engaging further with parties based on the outcome of this PADR to more comprehensively confirm the technical feasibility of the options, which is expected to involve the provision of further information from these parties and modelling. A full assessment of technical feasibility is intended to be undertaken ahead of the PACR where parties confirm they are proponents and provide the required information.

[4] 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

1.2 How to make a submission and next steps

TransGrid welcomes written submissions on this PADR. Submissions are due on 22 September 2020.

Submissions should be emailed to TransGrid's Regulation team via regulatory.consultation@transgrid.com.au.[5] 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 late 2020.

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2. Benefits from continuing to provide the required supply reliability

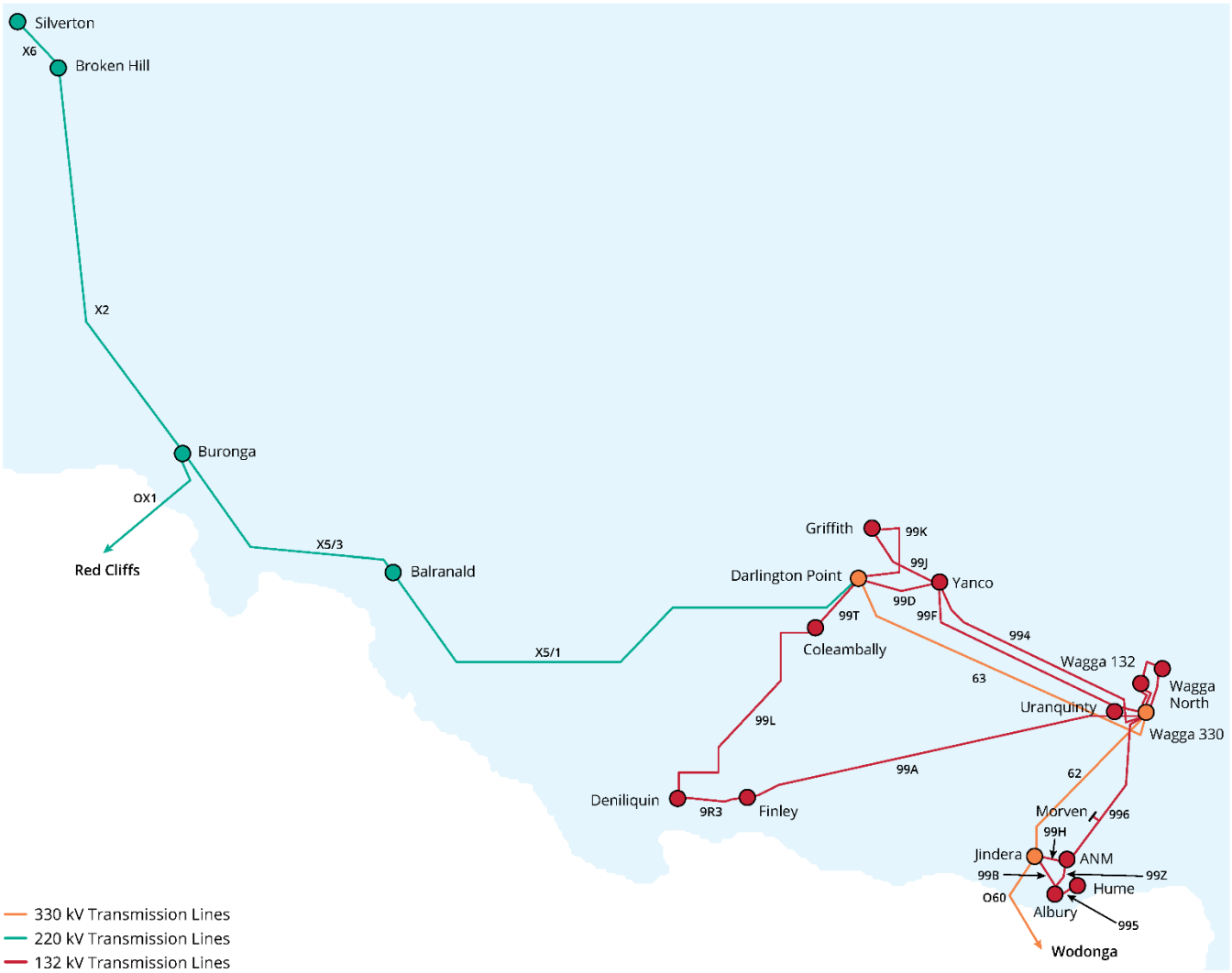
While the primary focus of this RIT-T is to maintain reliable supply at Broken Hill going forward, some of the options assessed in this PADR are also expected to provide benefits to the wider wholesale electricity market.

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 gas turbines that run on diesel fuel.[6]

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

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



[6] 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 gas 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 gas turbines to meet its 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, as currently designed and configured. This means that if Line X2 is not 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 gas turbines located at Broken Hill[7] and is currently in the process of enacting that divestment.

If no action is taken by TransGrid, 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 recently published by the AER.[8]

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.[9] However, TransGrid does 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 the AER is currently consulting on appropriate WALDO VCRs.[10]

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

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

9 The 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).

10 https://www.aer.gov.au/communication/aer-vcr-review-widespread-and-long-duration-outages-consultation-paper

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 batteries and/or other equivalent technologies that introduce new entities trading in the wholesale market, eg, storage dispatching into the National Electricity Market (NEM) outside of times when it is 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 6.3 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 on the PSCR

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

Four of these parties have 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 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. These discussions have played a pivotal role in being able to define and include the credible options assessed in this PADR and TransGrid thanks all parties for their time and effort to-date.

As outlined in section 4.1, TransGrid will be engaging further with parties based on the outcome of this PADR to confirm the technical feasibility of the options, which is expected to involve the provision of further information and modelling from these parties. A full assessment of technical feasibility is intended to be undertaken ahead of the PACR where parties confirm they are proponents and provide the required information.

The Public Interest Advocacy Centre (PIAC) was the fifth submitting party and has not requested confidentiality. The PIAC submission has been published on TransGrid's website.[11]

PIAC raised the issue of how the options involving gas 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 TransGrid's Regulated Asset Base.[12] TransGrid notes that the AER has commenced reviewing and consulting on the transmission ring-fencing guidelines but that this has been put on hold in light of the COVID-19 pandemic.[13] 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.[14] The assessment in this PADR draws on the AER's updated VCR values (as outlined in section 6.2).

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

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

[13] 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

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

4. Five types of options are assessed

Stakeholder consultation on the PSCR has assisted greatly with developing and refining the credible options put forward in the PSCR.

Specifically, consultation with third parties since the PSCR has enabled this PADR to assess the following five types of credible options:

- Option 1: four different non-network opex solutions fully provided by third parties (Option 1A, Option 1B, Option 1C and Option 1D);
- Option 2: a refined version, and cost for, acquiring the existing gas turbines from Essential Energy;
- Option 3: establishing new gas turbines at Broken Hill;
- Option 4: building a second single circuit 220 kV transmission line from Buronga to Broken Hill; and
- Option 5: three variants of the first group of solutions involving either shared ownership or ownership by TransGrid (Option 5A, Option 5B and Option 5C).

All options reduce EUE to the amount required under the IPART reliability standard, which translates to approximately 7 MWh per year. Option 4 provides an additional level of reliability due to the second transmission line and is assessed to reduce EUE to effectively zero.

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 gas 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 the PADR and the PACR, including the cost of non-network options that assume the use of these turbines.

The four non-network opex solutions fully provided by third parties (Option 1A, Option 1B, Option 1C and Option 1D) and the three variants of these solutions involving either shared ownership or ownership by TransGrid (Option 5A, Option 5B and Option 5C) have been assessed using information (including costs) provided by parties in response to the PSCR 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.

Where an option involves continued use of the existing gas turbines, TransGrid has assumed the need for future investment in new turbines, reflecting the age and condition of the existing gas turbines at Broken Hill.[15] TransGrid assumes the cost of this future investment is the same, in real terms, as the cost of establishing new gas turbines at Broken Hill now (ie, as outlined below for Option 3) and occurs in 2040. However, in light of the uncertainty regarding the required replacement date, this PADR has also investigated a sensitivity regarding the timing of this replacement (as set out in section 7.5.3).

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.

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

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

As part of the consultation undertaken since the PSCR, TransGrid has requested additional information and modelling from third parties in order to determine the technical feasibility of the solutions put forward. Parties have either been unable to provide this information within the PADR timeframes or have expressed a preference to provide this level of detail after the results of the PADR assessment have been released and they have a better understanding of the relativities between options. This is understandable given the costs and effort involved in providing this material and submitters first needing to understand whether their proposal is likely to be in the running for identification as part of the preferred option.

TransGrid has consequently been unable to comprehensively confirm the technical feasibility of some options put forward by third parties at this stage. Without the detailed models from proponents, TransGrid has made the conservative assumption that the inverter-based solutions are grid-following inverters, which provide no system strength capability and require synchronous condensers in order to provide adequate system strength to Broken Hill. The cost of these synchronous condensers has been included in the cost of these options as part of this PADR assessment.

TransGrid will be engaging further with parties based on the outcome of this PADR in order to confirm the technical feasibility of the options, which is expected to involve the provision of further information and modelling from these parties. Detailed technical assessments will be conducted as part of the PACR analysis, where synchronous condenser requirements may be reduced, subject to grid-forming models demonstrating technical feasibility.

4.2 Non-network solutions fully provided by third parties – Option 1A, Option 1B, Option 1C and Option 1D

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 with TransGrid.

Three parties have provided these services by way of responding to the PSCR and a range of technologies have been proposed, including:

- use of the existing gas turbines;
- compressed air facilities;
- batteries;
- demand response; and
- local generation.

The options put forward also reflect a range of sized solutions, with two (Option 1A and Option 1C) enabling trade in the wholesale market. These two 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).

These options all have an energy storage component, with grid forming capability, and require modification of the Silverton Wind Farm and Broken Hill Solar Farm to operate islanded.

Most parties have requested strict confidentiality regarding their individual solutions and so this PADR, with each party's permission, only outlines the nature and size of each of the four options assessed, excluding the existing gas turbines where they form part of a party's solution.

- Option 1A – 150-200 MW/1,550 MWh compressed air energy storage facility
- Option 1B – 62.5 MW/250 MWh battery
- Option 1C – 73 MW/292 MWh battery

> Option 1D – 50 MW/75 MWh battery, 10 MW of demand response

4.3 Acquiring the existing gas turbines from Essential Energy – Option 2

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

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.

Acquiring the existing gas turbines does not enable wholesale market benefits as they are currently configured to operate only in islanded mode. The required retrofit for these turbines in order to allow them to dispatch into the NEM for arbitrage has not been proposed by any party at this stage. In effect, this option continues to provide back-up supply to Broken Hill with the same equipment and configuration (status quo) that has supplied the area for over the last thirty years.

4.4 Establishing new gas turbines at Broken Hill – Option 3

Option 3 involves the commissioning of new gas turbines at Broken Hill. This assumes that this new source of back-up supply is network owned. Potential new generators may be able to utilise the latest gas turbine technologies, which could improve fuel efficiency and response times (compared to the existing turbines).

TransGrid has engaged Aurecon to develop generic costs and technical parameters for Option 3. These new turbines are assumed to involve $67 million in capital costs upfront as well as ongoing operating costs of approximately $1.5 million per year. It is estimated that they will take one year to install and that commissioning will occur in 2021/22.

The new gas turbines commissioned under Option 3 will enable dispatch to the wholesale market. 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.

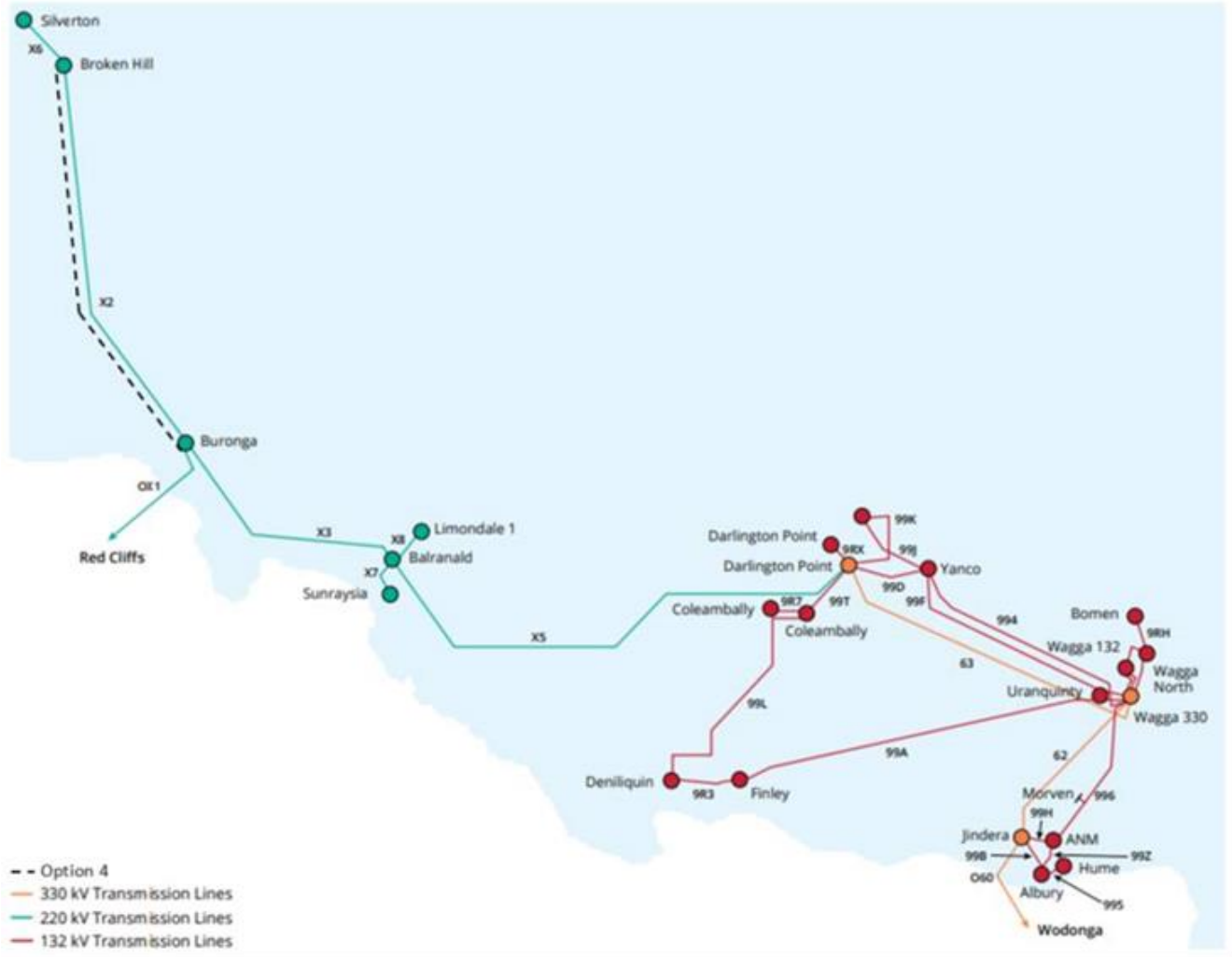
The capital expenditure estimate has been updated since the PSCR and is now expected to cost around $350 million, with project delivery in 36 months. Annual operating costs are estimated to be $175,000.

The transmission costs associated with Option 4 have increased significantly since the PSCR due to 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 terrain (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 as-is 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 has 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 – Option 5A, Option 5B and Option 5C

Two 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. One of these parties provided two different ownership models for providing the same solution (ie, one involving full network ownership and another involving shared ownership between TransGrid and the third party).

These options all have an energy storage component, with grid forming capability, and require modification of the Silverton Wind Farm and Broken Hill Solar Farm to operate islanded.

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 only outlines the nature and size of each of the options assessed, excluding the existing gas turbines where they form part of a party's solution.

> Option 5A – 150-200 MW/1,550 MWh compressed air energy storage facility
> Option 5B – 62.5 MW/250 MWh battery
> Option 5C – 73 MW/292 MWh battery

As with the options outlined under section 4.2, these options reflect a range of sized solutions, with two (Option 5A and Option 5C) enabling trade in the wholesale market. These two 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 has 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.[16] 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 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.

[16] 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%
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	$36.43/kWh	$25.50/kWh	$47.36/kWh
Discount rate	5.90%	9.57%	2.23%

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.

As outlined in section 7, the assessment in this PADR finds that the top-ranked option is invariant to the scenarios investigated and so is independent of the weightings applied.

5.3 Sensitivity analysis

In addition to the scenario analysis, TransGrid has 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 330kV transmission system west of Wagga Wagga[17];
- removing the 150 MW free Broken Hill REZ transmission expansion assumed for the preferred option;
- the assumed timing of having to replace the existing gas turbines at Broken Hill, where they form part of an option;
- changes in the network capital costs of the credible options; and
- alternate commercial discount rate assumptions.

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

In addition, as part of the analysis TransGrid has 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.

[17] The sensitivity analysis tests an alternative future in which capacity of the 330kV transmission system west of Wagga Wagga is constrained to less than the capacity of three 330kV transmission lines. This may occur, for example, if a project to increase the voltage stability limit at Darlington Point does not satisfy a regulatory investment test.

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 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 three broad states of the world and a high-level description of the modelling undertaken for each.

6.1 Overview of the modelling undertaken and the base case

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 submitters to the PSCR and TransGrid's 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.

The base case modelled assumes there is a short-term non-network contract in-place until a certain date (which has been redacted to preserve the confidentiality of the separate EOI process). 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 is unrealistic, and TransGrid 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 Avoided involuntary load shedding

TransGrid has run system studies to estimate the EUE at Broken Hill under the base case 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 back-up 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 island load together with variable renewable generation. For options involving new GTs, the amount of EUE is defined by how quickly the Broken Hill load can be restored and the GTs under consideration are able to start-up faster than required under the reliability standard.

TransGrid has 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,[18] the body of this PADR presents EUE in absolute terms since it is more intuitive.[19] 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 has 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 has 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.[20]

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.

6.3 Wholesale market benefits

EY has undertaken the wholesale market modelling component of the PADR assessment. As outlined in section 6.1 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.

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[18] 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.

[19] 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*, 15 March 2019, pp. 42-43.

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

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

- a battery, or similar facility, that is in excess of 250 MWh (the minimum amount required to meet the reliability standards at Broken Hill);
- new gas turbines; or
- a new transmission line connecting Broken Hill to the NEM.

Acquiring the existing gas turbines alone does not enable wholesale market benefits as they are currently configured to operate only in islanded mode. The required retrofit for these turbines in order to allow them to dispatch into the NEM for arbitrage has not been proposed by any party at this stage.

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.

While the EY market modelling for this RIT-T focusses on the central ISP scenario, TransGrid has 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. Appendix C 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 capacity for the 330kV 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 has also investigated a sensitivity of the capacity for the 330kV transmission system west of Wagga Wagga equivalent to only two transmission lines, to assess an alternate future with less available capacity west of Wagga Wagga, and found 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, Option 1A and Option 5A, which differ only in ownership structure, are estimated to have the same market benefits). TransGrid consider 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.

6.4 General modelling parameters adopted

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

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 that all options have their costs and benefits assessed over a consistent period, irrespective of option type, technology or asset life.

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. 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 has therefore tested the sensitivity of the results to a lower bound discount rate of 2.23 per cent,[22] and an upper bound discount rate of 9.57 per cent (i.e., a symmetrical adjustment upwards).

The same commercial discount rates have been adopted for both the NPV discounting calculation in the cost benefit analysis, as well as the generator hurdle rates in the wholesale market modelling, which is consistent with the approach proposed for the 2020 ISP.[23]

6.5 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.[24]

Option value has not been estimated for any of the options since the prerequisites for there to be material option value are not considered to be met.[25]

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.

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[21] 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.

[22] 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

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

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

[25] In particular, there are four pre-requisites required for a credible 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). See Energy Networks Australia, *RIT-T Economic Assessment Handbook*, 15 March 2019, p. 49..

7. Net present value results

This section outlines the results of the assessment TransGrid has undertaken 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).

TransGrid encourages proponents to reach out to TransGrid directly in order to understand the modelling of their individual solutions further and to assist with preparing submissions to this PADR.

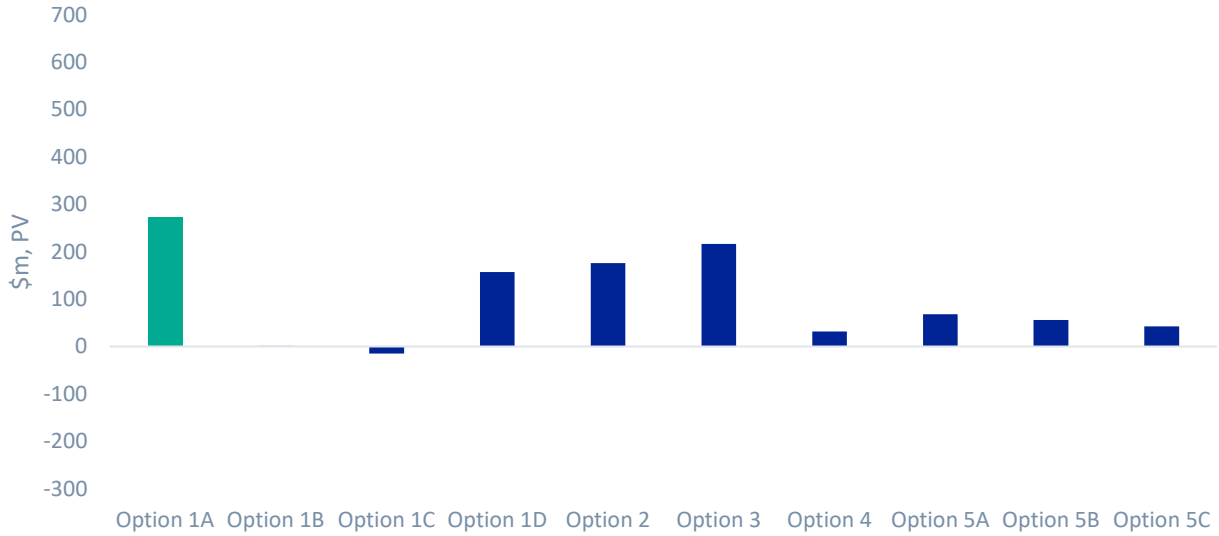
7.1 Central scenario

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 network capital 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 1A is estimated to deliver approximately $273 million in net benefits. This represents approximately 26 per cent greater net benefits than the second-ranked option (Option 3).

Figure 7-1 shows the overall estimated net benefit for each option under the central scenario.

Figure 7-1: Summary of the estimated net benefits under the central scenario



All options provide around $291 million in benefits from avoided unserved energy at Broken Hill, 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.

Option 1A provides the greatest level of wholesale market benefit of all the options, which is expected to accrue from 2032/33 and is primarily derived from the avoided or deferred costs associated with generation and storage elsewhere in the NEM. This benefit makes up around 88 per cent of the total wholesale market benefits estimated for Option 1A and arises since the facility commissioned at Broken Hill to provide back-up supply is of sufficient size to also trade in the wholesale market (and does so at a relatively low cost).

The wholesale market modelling finds that Option 1A:

- avoids approximately 40 MW of new OCGT build and 20 MW of wind build in NSW, but builds approximately 170 MW more solar;
- avoids approximately 20 MW of solar in Queensland but builds approximately the same capacity of wind;
- avoids approximately 80 MW of pumped hydro storage in Victoria, but builds approximately 20 MW of solar; and
- avoids 90 MW of solar, 40 MW of wind and a 40 MW of battery capacity in South Australia.

The remaining 12 per cent of the estimated wholesale market benefits for Option 1A are driven by avoided fuel costs, lower transmission capital costs to connect REZs and voluntary load curtailment.

While Option 1C, Option 2 (once the existing gas turbine is replaced with a new one), Option 3, Option 4 and Option 5C all also provide estimated wholesale market benefits, they are all significantly lower than those estimated for Option 1A (and Option 5A since it is the shared ownership version of Option 1A). For example, while Option 3 provides the second greatest level of estimated wholesale market benefits, the benefits are only around 8 per cent of those estimated for Option 1A.

The accompanying market modelling report provides additional detail in terms of the modelled wholesale market impacts for each option. Neither this PADR nor the accompanying market modelling report provide the estimated wholesale market benefits of each option in dollar terms, in order to protect the confidentiality of the options assessed.

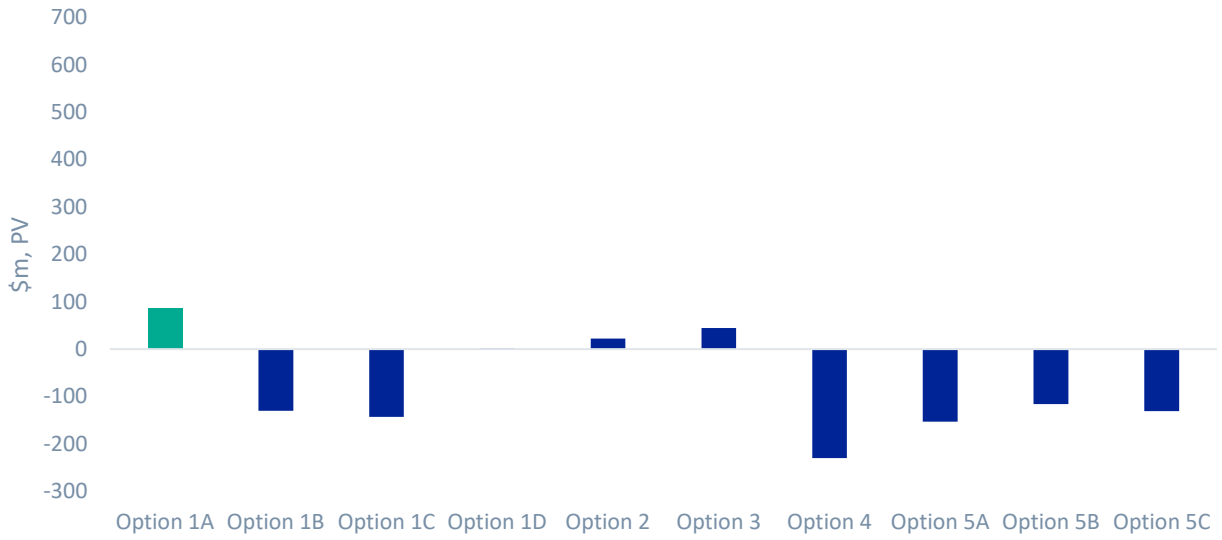
7.2 Low net economic benefits

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 network capital 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 that those estimated by EY as an additional robustness test for the option rankings.

Under these assumptions, Option 1A is estimated to deliver approximately $85 million in net benefits and continues to be the top-ranked option. This represents approximately 91 per cent greater net benefits than the second-ranked option (Option 3).

Figure 7-2 shows the overall estimated net benefit for each option under the low benefits scenario.

Figure 7-2: Summary of the estimated net benefits under the low benefits scenario



All options provide around $134 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.

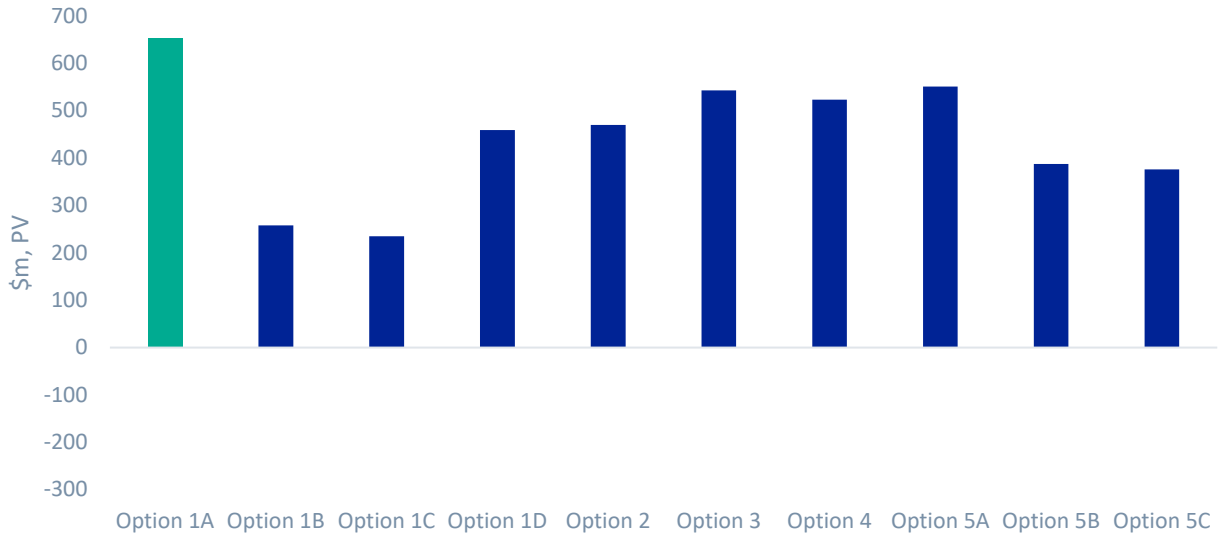
7.3 High net economic benefits

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 network capital 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 that those estimated by EY as an additional robustness test for the option rankings.

Under these assumptions, Option 1A is estimated to deliver approximately $653 million in net benefits and continues to be the top-ranked option. This represents approximately 19 per cent greater net benefits than the second-ranked options (Option 3 and Option 5A).[26]

Figure 7-3 shows the overall estimated net benefit for each option under the high benefits scenario.

Figure 7-3: Summary of the estimated net benefits under the high benefits scenario



All options provide around $605 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

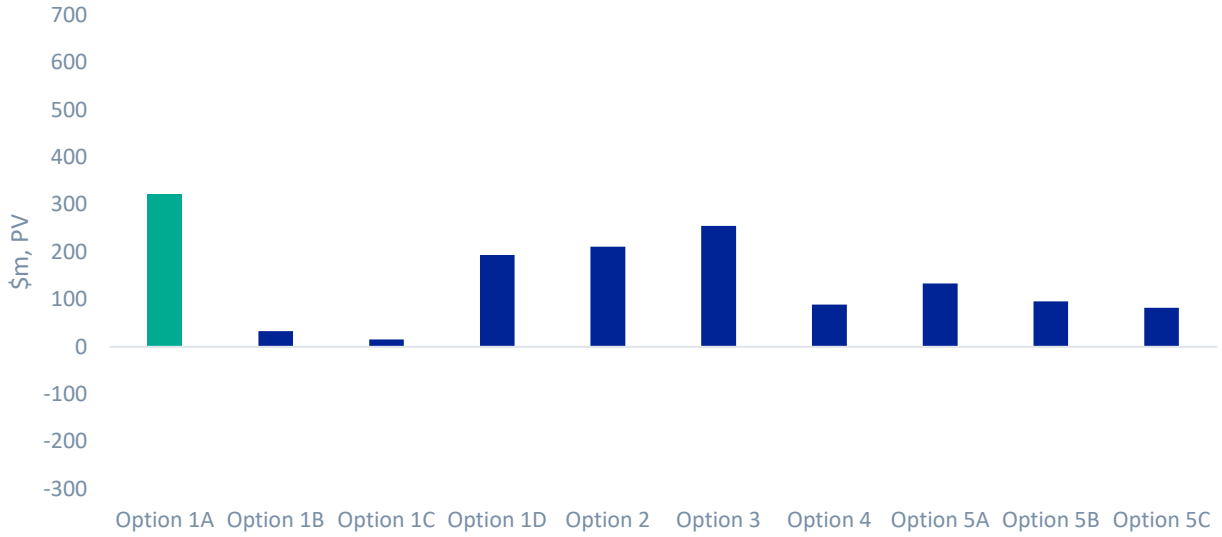
Figure 7-4 shows the estimated net benefits for each of the credible options weighted across the three scenarios investigated (and discussed above). TransGrid considers that the central scenario is most likely since it is based primarily on a set of expected assumptions. TransGrid has therefore assigned this scenario a weighting of 50 per cent, with the other two scenarios being weighted equally with 25 per cent each.

[26] Under this scenario, Option 3 and Option 5A have effectively the same estimated net market benefits at $543 million and $550 million, respectively.

Under the weighted outcome, Option 1A is expected to deliver approximately $321 million of net benefits and is the top-ranked option overall.

The second-ranked option on a weighted basis, and under each of the three individual scenarios, is Option 3, which involves procuring a new gas turbine for Broken Hill. TransGrid will be engaging further with third parties based on the outcome of this PADR to confirm the technical and commercial feasibility of all options put forward. Option 3 is currently the fallback option if the technical and feasibility of these other options cannot be confirmed.

Figure 7-4: Summary of the estimated net benefits, weighted across the three scenarios



7.5 Sensitivity analysis

In addition to the scenario analysis, TransGrid has 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 330kV transmission system west of Wagga Wagga;
> removing the 150 MW free Broken Hill REZ transmission expansion assumed for the preferred option;
> the assumed timing of having to replace the existing gas turbines at Broken Hill, where they form part of an option;
> network capital costs of the credible options; and
> alternate commercial discount rate assumptions.

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

7.5.1 Capacity of the 330kV transmission system west of Wagga Wagga

The market modelling assumes a capacity for the 330kV 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 has investigated a sensitivity of the capacity for the 330kV transmission system west of Wagga Wagga equivalent to only two transmission lines, to assess an alternate future with less available capacity west of Wagga Wagga, 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,

Specifically, assuming the capacity of only two 330kV transmission lines is found to increase the gross wholesale market benefits of Option 1A by approximately 12 per cent.

7.5.2 Assumed 150 MW REZ at Broken Hill

While the ISP assumptions have essentially no spare transmission capacity around Broken Hill for renewable generation, TransGrid has assumed that there is 150 MW of transmission capacity available for new solar connections under Option 1A. This has been determined by looking at the operating profile of Option 1A. Removing this assumption reduces Option 1A's estimated gross wholesale market benefits by approximately 5 per cent and has no impact on the overall conclusion that Option 1A is the top-ranked option.

7.5.3 Timing of replacement for the existing gas turbines

While Option 2 involves continued use of the existing gas turbines over the long-term by TransGrid, TransGrid has assumed the need for future investment in new turbines, reflecting the age and condition of the existing gas turbines at Broken Hill. TransGrid assumes the cost of this future investment is the same, in real terms, as the cost of establishing new gas turbines at Broken Hill now (ie, as outlined below for Option 3) and occurs in 2039/40.

However, in light of the uncertainty regarding the required replacement date, this PADR has also investigated a sensitivity regarding the timing of this replacement, which finds that the timing of this replacement has a minor impact on the net market benefits for Option 2. Specifically, when it is assumed that the existing gas turbines are replaced five years earlier than the current expectation of 2039/40, Option 2's net market benefits only decrease by 1 per cent. Conversely, when it is assumed that the existing gas turbines are replaced five years later than the current expectation of 2039/40, Option 2's net market benefits only increase by 12 per cent.

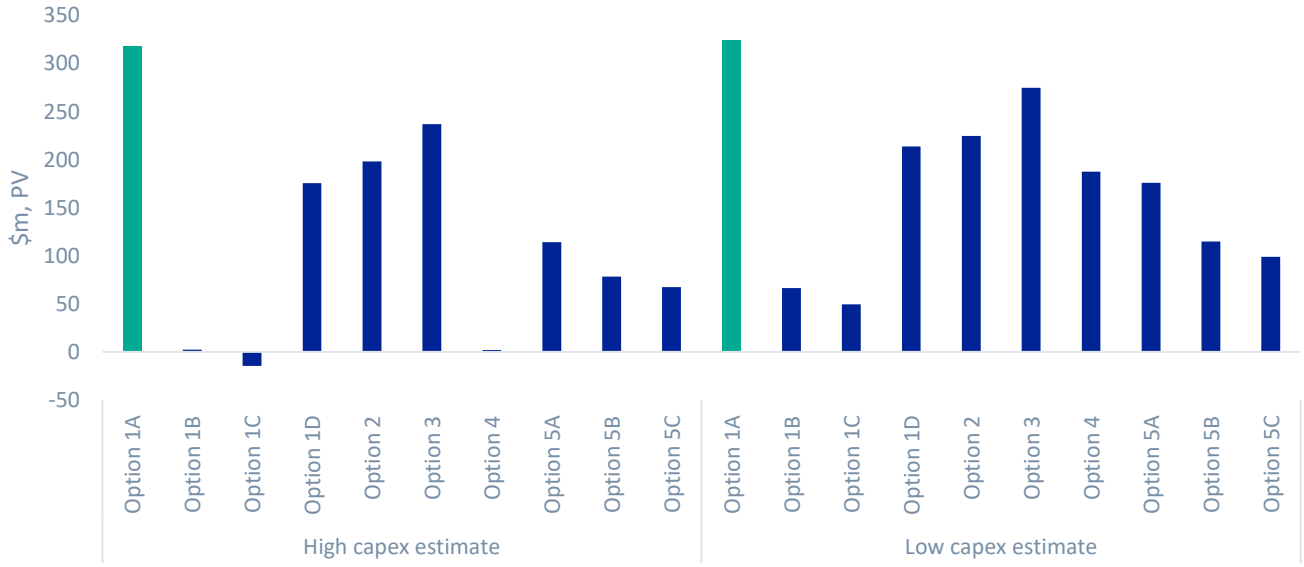
Option 1A continues to be the top-ranked option under both of these alternate assumptions and so the assumed timing for replacing these turbines is therefore not considered a material input to the overall RIT-T assessment. Moreover, Option 3 continues to be ranked ahead of Option 2 under both of these sensitivities.

7.5.4 Network capital costs of the credible options

TransGrid has tested the sensitivity of the results to the underlying network capital costs of the credible options. It is considered reasonable to expect any factors affecting the network capital costs to impact all options equally (i.e., the cost sensitivity is applied across all options).

Figure 7-5 shows that Option 1A 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 1A is limited as it only involves around $12 million of network capital costs (required fault level and switchbay upgrades).

Figure 7-5: Impact of 25 per cent higher and lower network capital costs, weighted NPVs



7.5.5 Commercial discount rate assumptions

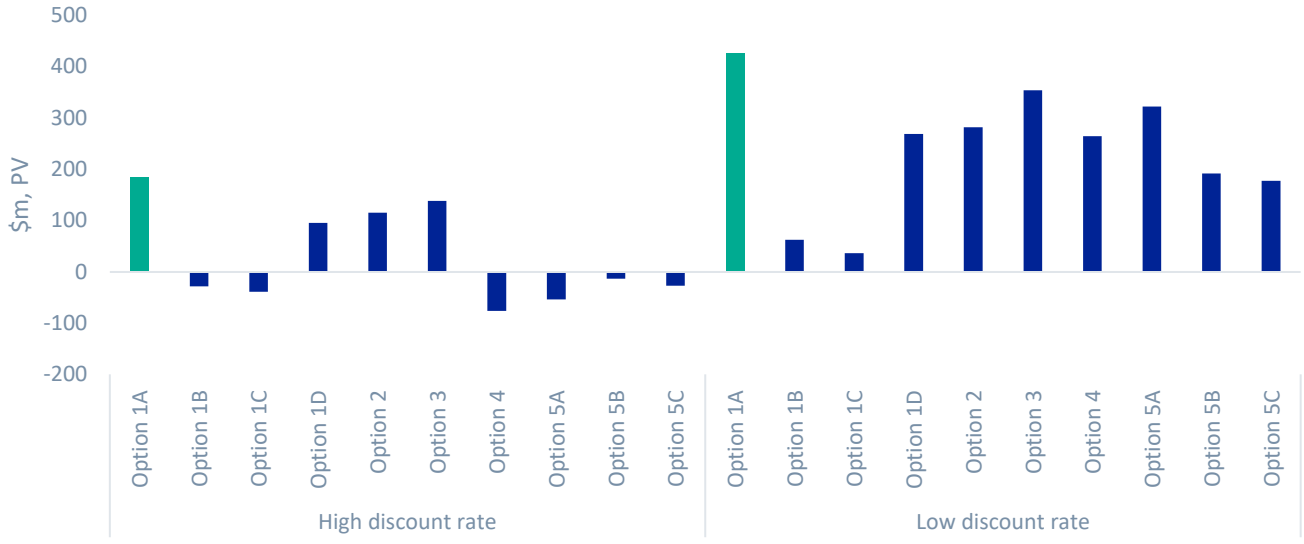
Figure 7-6 illustrates the sensitivity of the results in the central scenario to different discount rate assumptions in the NPV assessment. In particular, it illustrates two tranches of net benefits estimated for each credible option – namely:

> a high discount rate of 9.57 per cent; and

> a low discount rate of 2.23 per cent.

Option 1A continues to provide strongly positive net market benefits and be the top-ranked option under both alternate discount rate sensitivities investigated.

Figure 7-6: Impact of different assumed discount rates, weighted NPVs



TransGrid does not find a realistic discount rate that would result in Option 1A having an expected negative estimated net benefit or a commercial discount rate that would cause other options to provide more net benefits than Option 1A.

8. Conclusion

This PADR assessment shows that Option 1A – which is a network support arrangement offered by a third party to TransGrid – is expected to deliver the greatest net benefit of all credible options considered, and across all scenarios and sensitivities investigated. Option 1A is identified at this stage of the RIT-T as the most efficient way to continue to provide reliable supply to Broken Hill going forward.

Due to the strict confidentiality requested by the proponent, TransGrid is unable to specify the components of this option or the costs that have been proposed for the network support contract.

Option 1A is also 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. These market benefits are expected to accrue from 2032/33 and are primarily derived from avoided or deferred costs associated with generation and storage elsewhere in the NEM.

Option 1A is estimated to deliver net benefits of around $321 million 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.

As outlined in section 4.1, this PADR had adopted a conservative approach to option technical feasibility whereby additional network components are assumed for the options where technical feasibility has not yet been determined. TransGrid will be engaging further with parties based on the outcome of this PADR to more comprehensively confirm the technical feasibility of the options, which is expected to involve the provision of further information and modelling from these parties. A full assessment of technical feasibility is intended to be undertaken ahead of the PACR where parties confirm they are proponents and provide the required information.

TransGrid notes that the second-ranked option is Option 3 – establishing new gas turbines at Broken Hill). Option 3 would be the fallback option if the technical and feasibility of these other options cannot be confirmed.

The regulatory treatment of non-network costs is a key driver of the preferred option in this PADR

While Option 1A, a non-network opex solution fully provided by a third party, is the preferred option at this stage of the RIT-T, the corresponding option proposed by the same third party involving TransGrid ownership (Option 5A) is one of the lowest ranked options, due to how its costs are captured in the RIT-T assessment.

While Option 1A and Option 5A are identical in terms of the technologies employed and the benefits expected, the total cost of Option 1A in the analysis is significantly lower than that for Option 5A. This is due to the current AER guidance requiring only the proposed contract costs for non-network options be included in the RIT-T assessment, while the whole costs must be included for network options. The opex costs for Option 1A can therefore be net of any funding the third party expects to receive from using the facility to trade in the NEM, while the costs of Option 5A cannot.

TransGrid notes that Energy Networks Australia (ENA) recently raised this issue in its submission to the AER on the guidelines to make the ISP actionable.[27] TransGrid considers the outcome of the assessment presented in this PADR presents a real world example of how the current AER guidance for these two types of options tilts the playing field towards non-network provision of these services.

TransGrid will be seeking to confirm and clarify with the AER how this issue should best be treated in the RIT-T in order to promote the objective of competitive neutrality and ensure that the most efficient cost is ultimately recovered from end customers.

[27] ENA, *Submission to the AER on the Guidelines to Make the ISP Actionable*, 26 June 2020, pp. 7-8.

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 145.

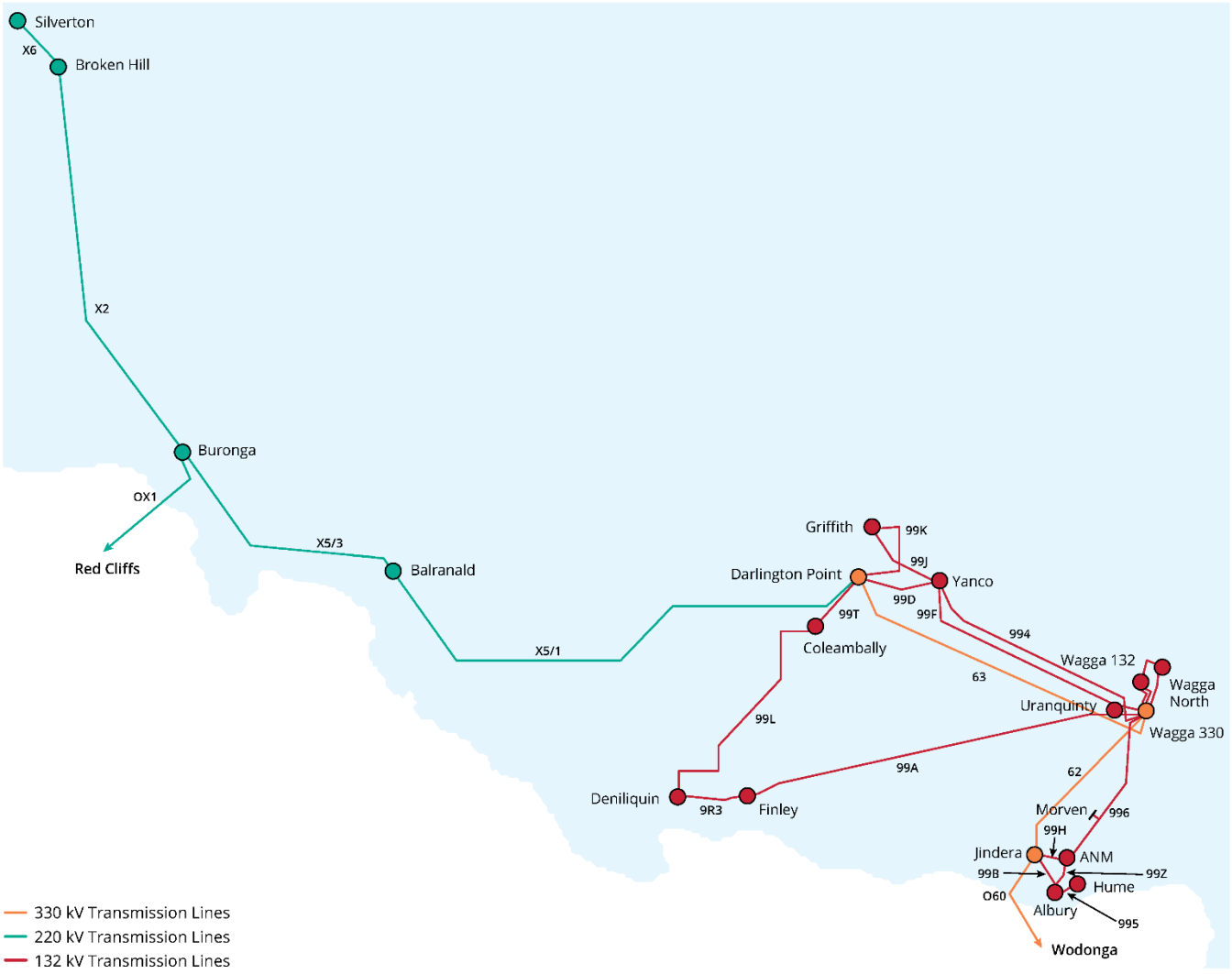
Rules clause	Summary of requirements	Relevant section(s) in the **PADR**
5.16.4(k)	A RIT-T proponent must prepare a report (the assessment draft report), which must include:	-
	(1) a description of each credible option assessed;	4
	(2) a summary of, and commentary on, the submissions to the project specification 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-1 below.

Figure B-1: South western NSW transmission network



The average electricity demand at Broken Hill substation is approximately 40 MW.[28]

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

[28] TransGrid, *Transmission Annual Planning Report 2018*, 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 gas turbines that run on diesel fuel.[29]

These gas 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 gas 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 TransGrid to reliably supply the load at Broken Hill and maintain less than 10 minutes of EUE at average demand.[30]

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

Broken Hill	Redundancy category [31]	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

[29] 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.

[30] 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

[31] 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.

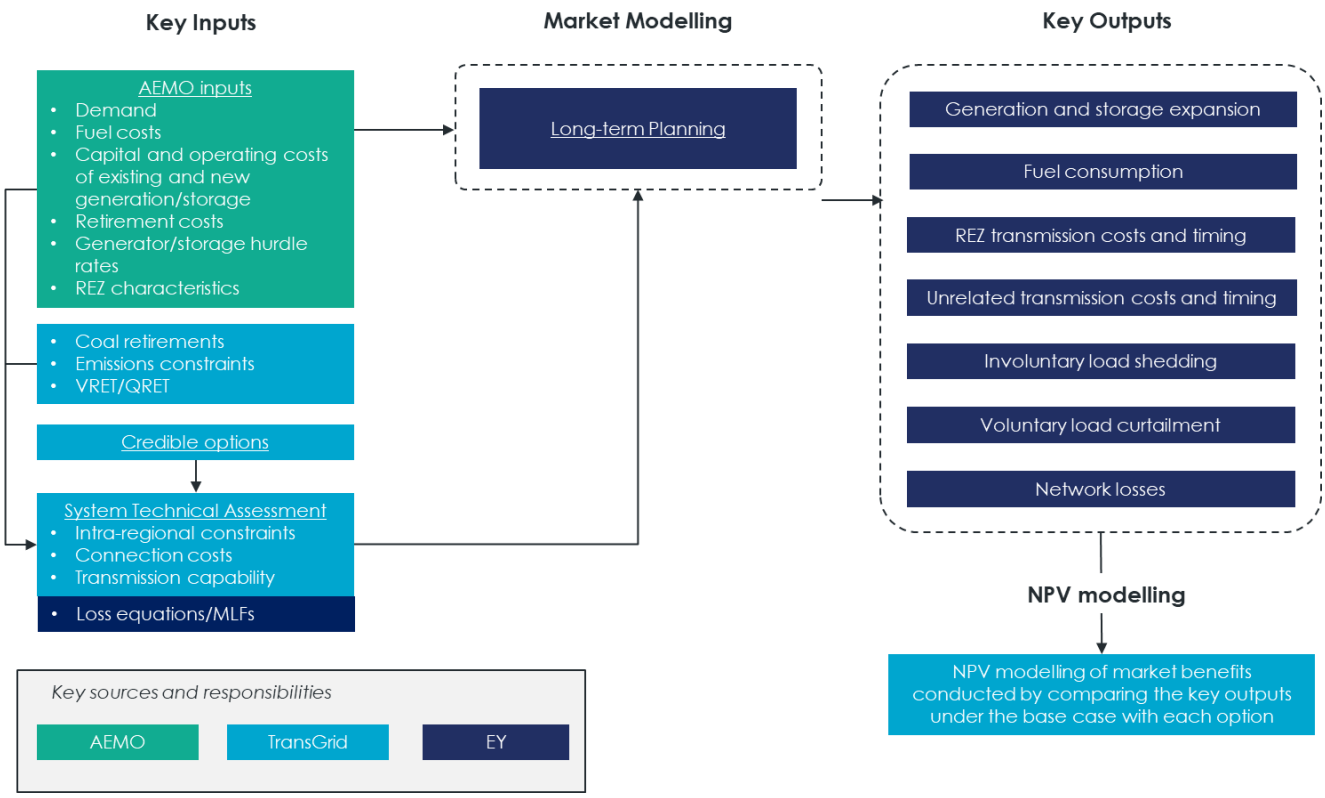
EY has applied a linear optimisation model and performed hourly, time-sequential, long-term modelling for the NEM to estimate categories of wholesale market benefits expected under the options that affect the wholesale market. Specifically, EY has undertaken market simulation exercise involving long-term 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.1 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.1: 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).[32]

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 gas 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.

[32] 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[33] 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 (EnergyConnect) is assumed commissioned by July 2023[34] with the scope in the 2020 Transmission Annual Planning Report and 2020 ISP.
Western Victoria Renewable Integration RIT-T	The preferred option in the Western Victoria Renewable Integration PACR[35] by July 2025 (220 kV upgrade in 2024 and 500 kV to Sydenham in 2025).
Marinus Link and Battery of the Nation	Excluded

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

[34] 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.

[35] 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[36] preferred option and NSW to QLD Interconnector upgrade approved option by AER[37] 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[38]
VNI West	The VNI West ISP 2018 preferred option is assumed commissioned by July 2026
Marinus Link and Battery of the Nation	Excluded

[36] 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.

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

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

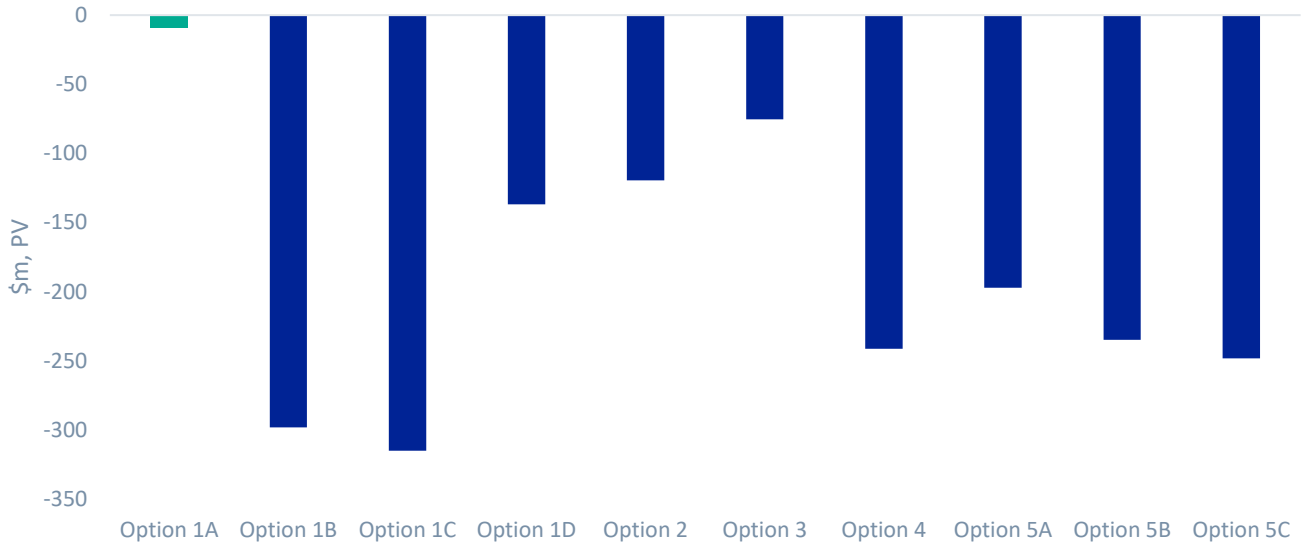
Appendix D Analysis using EUE improvements over the reliability standard

As outlined in section 6.2, 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,[39] the body of this PADR presents EUE in absolute terms since it is more intuitive.[40] 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 numbers for each of the credible options and shows that Option 1A is still the top-ranked option.

Figure D-1: Analysis using EUE improvements over the reliability standard, weighted NPVs



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.

[39] 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.

[40] 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*, 15 March 2019, pp. 42-43.