Western Victoria Renewable Integration

December 2018

Project Assessment Draft Report

Important notice

PURPOSE

AEMO has prepared this Project Assessment Draft Report to meet the consultation requirements of clause 5.16.4(j) – (s) of the National Electricity Rules.

DISCLAIMER

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Note that transmission line routes identified in this document are indicative only. The actual transmission line routes will be determined during the detailed design and route assessment phase, after conclusion of the RIT-T process.

VERSION CONTROL

Version	Release date	Changes
1	14/12/2018	First issue

Executive summary

The Western Victoria region[1] is an attractive location for new renewable generation, due to the quality of renewable energy resources, namely wind and solar, in the area. However, the transmission infrastructure in this region is insufficient to allow unconstrained access to all the new generation seeking to connect to it.

Around 2,000 megawatts (MW) of committed new renewable generation will be built in the Western Victoria region by 2020. AEMO projects that a further 3,000 MW of new generation will be constructed in the region by 2025, based on proposed new connections in the region and the Victorian Government's Victorian Renewable Energy Target (VRET).

- Generators connecting to the 220 kilovolt (kV) transmission system in Western Victoria are expected to be heavily constrained by emerging thermal limitations[2]. These limitations, if not addressed, may result in:
  - Inefficient development of new generation – new generation may be developed in areas with lower quality resources but higher transmission network capacity, or new generation may all be developed in the same area, leading to low generation diversity.
  - Inefficient generation dispatch – generation in Western Victoria may be constrained due to limited transmission network capacity, requiring more expensive generation to be dispatched at a higher price.
- These inefficiencies are expected to lead to higher costs to consumers.

Augmentation to address the limitation was identified as a priority Group 1 project in AEMO's 2018 Integrated System Plan[3] (ISP) for the National Electricity Market (NEM) which was endorsed by the Council of Australian Governments (COAG). While the Energy Security Board (ESB) has been asked by the COAG Energy Council to consider changes to current regulatory arrangements to make the ISP actionable, the urgency of this project requires AEMO to continue to pursue approval under the current Regulatory Investment Test - Transmission (RIT-T) process.

The RIT-T process commenced in late 2016, to assess the technical and economic benefits of increasing transmission network capacity in Western Victoria, and to identify a preferred augmentation option.

In April 2017, AEMO published a Project Specification Consultation Report[4] (PSCR) that described the need for investment in the Western Victoria area, and the potential investment options to address this need. Following this, AEMO presented on the PSCR at a number of industry forums, as well as to several other key stakeholders.

This Project Assessment Draft Report (PADR) marks step two of the consultation process for this RIT-T, as specified by clause 5.16.4(j) – (s) of the National Electricity Rules[5] (NER). The report identifies and seeks feedback on the preferred option which delivers the highest net economic benefit to all those who produce, consume or transport electricity in the market. The PADR also provides a summary of submissions received on the PSCR.

[1] "Western Victoria" in this RIT-T is defined as Central Highlands, Wimmera Southern Mallee, Mallee, Loddon Campaspe, and parts of the Great South Coast.

[2] Generators proposing to connect to the 500 kV transmission system are not expected to be impacted by thermal constraints in Western Victoria.

[3] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf.

[4] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2017/Western-Victoria-Renewable-Integration---Project-Specification-Consultation-Report_FINAL.pdf.

[5] Available at https://www.aemc.gov.au/sites/default/files/2018-07/NER%20-%20v111.pdf.

The preferred option identified in this PADR assessment, shown in Figure 1, will increase the thermal capacity of the Western Victoria transmission network by at least 1,200 megavolt amperes (MVA) and support additional generation connections in the region. The preferred option provides for staged development:

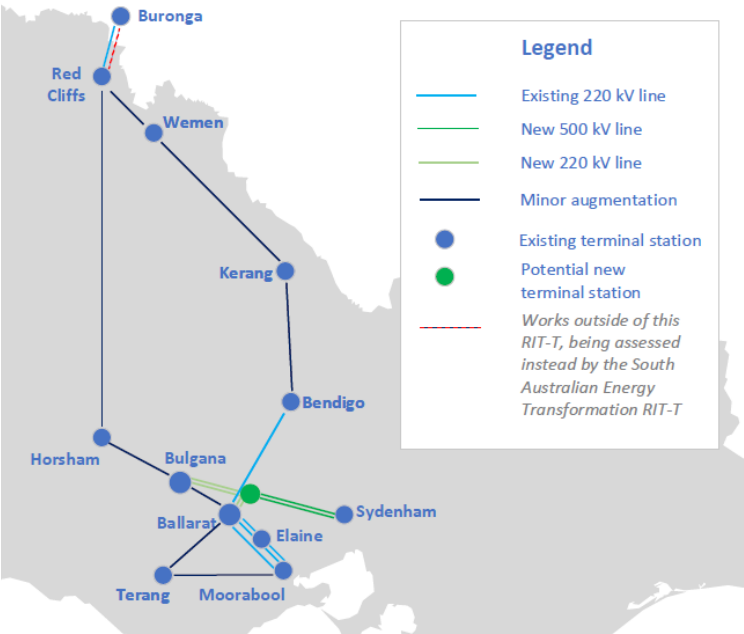
- Short term: present to 2021.
  - Minor transmission line augmentations, including wind monitoring and upgrading station limiting transmission plant, carried out for the Red Cliffs to Wemen to Kerang to Bendigo, and Moorabool to Terang to Ballarat, 220 kV transmission lines.
- Medium term: 2021 to 2025.
  - The following major transmission network augmentations (staged):
    - By 2024: New 220 kV double circuit transmission lines from Ballarat to Bulgana.
    - By 2025: New 500 kV double circuit transmission lines from Sydenham to Ballarat connecting two new 1,000 MVA 500/220 kV transformers at Ballarat[6].

The stages will be prioritised to allow for efficient delivery, with a focus on first addressing expected congestion affecting existing and committed generators, as well as network areas where augmentation is most likely to deliver the highest net market benefit.

The preferred option is consistent with the recommendations of the 2018 ISP and is estimated to deliver net market benefits of $80 million (in present value terms), through significant reductions in the capital cost and dispatch cost of generation over the longer term. The total capital cost, through the staged implementation process outlined above, is estimated at $370 million (in present value terms).

This upgrade will minimise network congestion and facilitate more efficient generation dispatch, strengthen the power system for the future and add to diversity of supply. This in turn will help to reduce the cost of electricity for consumers in the long term.

Figure 1 Preferred option



[6] Initial assessment has indicated that there may be insufficient space in Ballarat Terminal Station for the proposed 500 kV plant. AEMO has assumed that a new terminal station will be established close to Ballarat in its assessments with a 220 kV double circuit connection to the existing Ballarat Terminal Station.

Note that the transmission line route identified for each option is indicative only. The actual transmission line routes will be determined during the detailed design and route assessment phase, after conclusion of the RIT-T process. New terminal stations may be required to connect the new transmission lines, and this will also be determined during the detailed design phase.

The RIT-T analysis undertaken

This PADR has been prepared by AEMO for consultation in accordance with the requirements of the RIT-T process set out in the NER. The PADR is the second public consultation step of the RIT-T process.

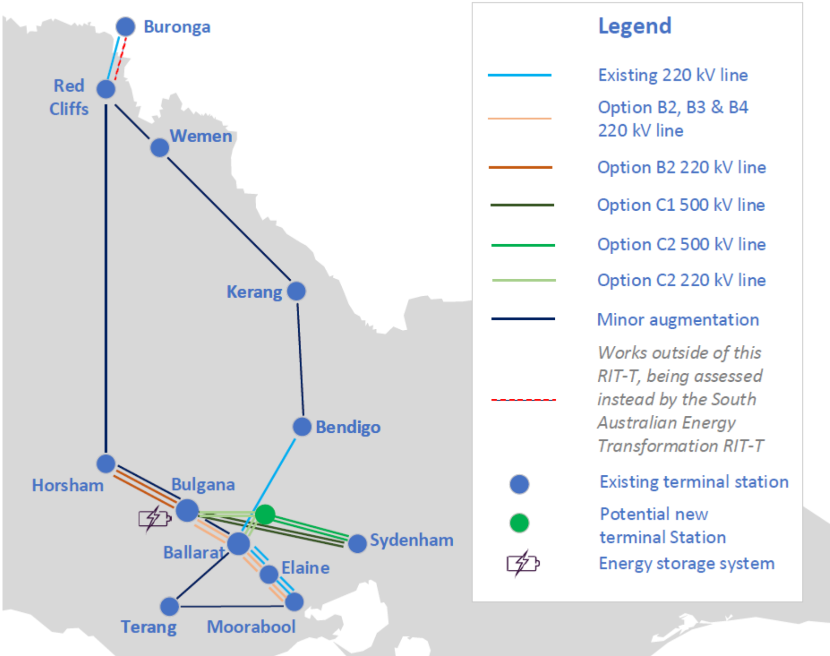
The preferred option is estimated to deliver net market benefits of $1 million in 2021, and $79 million in 2025 (both in present value terms), through significant reductions in the capital cost and dispatch cost of generation over the longer term. This option provides the highest net market benefits under all of the future scenarios assessed, and against a 'do-nothing' case incorporated in the analysis.

The total capital cost of the option is estimated at $5.2 million in 2021, and $364 million in 2025 (both in present value terms) and is expected to be delivered via a staged implementation process as outlined above.

Credible options included in the assessment

The options in Figure 2 were assessed in the RIT-T, and are described below:

Figure 2 Credible options assessed in the PADR



- Category A: Minor network augmentations.
  - Option A1 – minor transmission line upgrades for the Red Cliffs to Wemen to Kerang to Bendigo, and Moorabool to Terang to Ballarat, 220 kV transmission lines.
  - These are the short-term minor augmentations in the preferred staged augmentation described above.
- Category B: 220 kV network augmentation only.
  - Option B2 – construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana to Horsham. Retire Ballarat to Moorabool circuit 220 kV circuit No. 1, and cut in Ballarat to Moorabool circuit No. 2 at Elaine.

  - Option B3 – construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana. Retire Ballarat to Moorabool 220 kV circuit No. 1, and cut in Ballarat to Moorabool circuit No. 2 at Elaine.
  - Option B4 – rebuild existing Moorabool to Elaine to Ballarat to Bulgana 220 kV single circuit transmission line as a 220 kV double circuit transmission line. Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine.
- Category C: 500 kV and 220 kV network augmentation.
  - Option C1 – construction of a new 500 kV double circuit line from Sydenham to Ararat, with two new 1,000 MVA 500/220 kV transformers at Ararat. Cut in Ballarat to Moorabool circuit No. 2 at Elaine.
  - Option C2 – construction of a new 500 kV double circuit line from Sydenham to Ballarat. Construction of a new 220 kV double circuit line from Ballarat to Bulgana, with two new 1,000 MVA 500/220 kV transformers at Ballarat. Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine. Construction of a new terminal station close to Ballarat, with a 220 kV double circuit connection to Ballarat.
  - These are the medium-term major augmentations in the preferred staged augmentation described above.
- Category D: Red Cliffs to Buronga network augmentation.
  - Option D1 – construction of a new 220 kV double circuit line from Red Cliffs to Buronga (operated as a single circuit initially) and a 400 MVA 330/220 kV transformer at Buronga, to be considered under the South Australian Energy Transformation (SAET) RIT-T.
- Category E: Non-network options
  - Option E1 – construction of a new 100 MW/400 MWh battery storage system at Ararat Terminal Station.

Scenarios and sensitivities analysed

Four reasonable future scenarios, with the same parameters as the 2018 ISP, were considered in this PADR: Neutral scenario, Neutral with storage initiatives scenario, Fast change scenario, and Slow change scenario.

These scenarios reflect a wide range of variations in assumptions in relation to the variables that may materially affect the relative assessment of options under the RIT-T.

In addition, the following sensitivities were developed for this PADR, using the ISP's Neutral scenario as their base:

- Neutral scenario with no new interconnector developments – this scenario adopted all scenario settings of the Neutral case, but did not consider any uncommitted interconnector augmentations.
- Neutral scenario with no new generator connections – this scenario adopted all scenario settings of the Neutral case, but did not consider any uncommitted new generation in Victoria.
- Neutral scenario with early coal retirements – this scenario adopted all scenario settings of the Neutral case, but retired Victorian brown coal by 2024, while bringing forward a new interconnector between Victoria to New South Wales.

Additional sensitivity analysis was carried out for the PADR on all the results above, but varying the assumed option cost, discount rate, and scenario weightings.

Market benefits

The assessment conducted under this RIT-T has involved detailed market modelling using a market dispatch model, combined with the development of alternative generation expansion plans.

The results of the net present value (NPV) assessment highlight that the key categories of market benefit for this RIT-T are:

- Changes in generation investment costs.
- Changes in fuel consumption.

There is little change in Victorian generation development across the four scenarios, because this is primarily driven by the VRET.

Table 1 below summarises the weighted net market benefit in NPV terms for each credible option. The net market benefit for each option (the present value (PV) gross market benefits minus the PV cost) reflects the weighted net market benefit across the four reasonable scenarios considered.

Table 2 summarises the weighted net market benefit (in NPV terms) for the two options with the highest weighted net market benefits under the key sensitivities highlighted above. Sensitivity analysis considering only committed generation and committed interconnector developments still provides a positive NPV under Option C2, although Option B3 would provide the highest net market benefit in the sensitivity with no interconnector developments. Another sensitivity where coal-fired generation retires earlier than currently anticipated increases the benefits of the preferred Option C2.

The overall results show that:

- The proposed minor augmentations (Option A1) will deliver net market benefits immediately, and these have therefore been assumed to be in place for all assessments of major network augmentations.
- The major network augmentation option with the highest net market benefit is Option C2.

There are significant risks and uncertainties associated with the feasibility of obtaining planning and environmental approvals and easements to enable the implementation of the preferred major augmentations. These risks and uncertainties, and cost implications, will need to be further investigated as part of the next phase of this project.

Table 1 Weighted net market benefits (NPV terms) and costs (PV terms) for credible options across scenarios

Option	Description	Cost ($M)	Weighted net market benefit ($M)
Option A1	Minor augmentations for the Red Cliffs to Wemen to Kerang to Bendigo; and Moorabool to Terang to Ballarat 220 kV transmission lines.	5.2	1*
Option B2	• Construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana to Horsham. • Retire Ballarat to Moorabool 220 kV circuit No. 1 and cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine.	314	14
Option B3	• Construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana. • Retire Ballarat to Moorabool 220 kV circuit No. 1 and cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine.	263	67
Option B4	• Rebuild existing Moorabool to Elaine to Ballarat to Bulgana single circuit 220 kV transmission line as a 220 kV double circuit transmission line. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine.	275	57
Option C1	• Construction of a new 500 kV double circuit line from Sydenham to Ararat. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine.	323	64
Option C2	• Construction of a new 500 kV double circuit line from Sydenham to Ballarat. • Construction of a new 220 kV double circuit line from Ballarat to Bulgana. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine.	364	79
Option D1	• Construction of a new 220 kV double circuit line from Red Cliffs to Buronga (operated as a single circuit initially), and a 400 MVA 330/220 kV transformer at Buronga	SAET RIT-T	SAET RIT-T
Option E1	Battery at Ararat Terminal Station	117	-76

* Based on Neutral scenario only

Table 2 Weighted net market benefit (in NPV terms) for the top two credible options under each key sensitivity

Option	Description	Neutral ($M, base for comparison)	No interconnector augmentations ($M)	Committed generation only ($M)	Early coal retirement ($M)
Option B3	• Construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana. • Retire Ballarat to Moorabool circuit No. 1 and cut in Ballarat to Moorabool circuit No. 2 at Elaine.	67	110	117	59
Option C2	• Construction of a new 500 kV double circuit line from Sydenham to Ballarat. • Construction of a new 220 kV double circuit line from Ballarat to Bulgana. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine.	79	9	123	163

Submissions and next steps

The publication of this PADR commences the next phase of work on integrating renewable generation in Western Victoria. AEMO welcomes written submissions on this PADR, including comments on the inputs, analysis, and choice of preferred option.

Submissions are due on or before 28 February 2019 and should be emailed to WestVicRITT@aemo.com.au.

A series of forums, briefings and information sessions will also be scheduled over the coming months to provide stakeholders with an overview of the PADR and next steps. Submissions and upcoming stakeholder engagement activities will be published on the AEMO website.

AEMO will consider submissions in preparing the Project Assessment Conclusions Report (PACR) in accordance with clause 5.16.4 of the NER, targeted for publication in mid-2019.

Contents

Tables

Figures

1. Introduction

The Regulatory Investment Test for Transmission (RIT-T) is an economic cost-benefit test used to assess and rank different investment options that address an identified need. This Project Assessment Draft Report (PADR) represents step two of the consultation process in relation to the Western Victoria Renewable Integration RIT-T.

1.1 Overview

In April 2017, AEMO published a Project Specification Consultation Report[7] (PSCR) describing the need for investment in the Western Victoria region, and the potential investment options to address this need.

This PADR represents step two of the consultation process for this RIT-T, as specified by clause 5.16.4(j) – (s) of the National Electricity Rules[8] (NER). The PADR provides

- A description of the identified need for investment, in Chapter 2.
- A description of each credible option assessed, in Chapter 3.
- A summary of, and commentary on, the submissions to the PSCR, in Chapter 4.
- A detailed description of the methodologies used in quantifying each class of material market benefit and cost, in Chapter 5.
- A quantification of the costs, including a breakdown of operating and capital expenditure, and classes of material market benefit for each credible option, in Chapter 3 and Chapter 6.
- The identification of all classes of market benefits that arise both within Victoria and within other National Electricity Market (NEM) regions, in Chapter 6.
- Reasons why classes of market benefit have not been considered as material, in Chapter 6.1.
- The results of a Net Present Value (NPV) analysis of each credible option and accompanying explanatory statements regarding the results, in Chapter 6.3.
- The identification of the proposed preferred option, in Chapter 7.
- For the proposed preferred option, this PADR provides:
  - Details of its technical characteristics;
  - The estimated construction commissioning date (year);
  - If the proposed preferred option is likely to have a material inter-network impact and, if the transmission network service provider (TNSP) affected by the RIT-T project has received an augmentation technical report, that report; and
  - A statement and accompanying detailed analysis that the preferred option satisfies the RIT-T.

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[7] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2017/Western-Victoria-Renewable-Integration---Project-Specification-Consultation-Report_FINAL.pdf.

[8] Available at https://www.aemc.gov.au/sites/default/files/2018-07/NER%20-%20v111.pdf.

1.2 Background to the RIT-T process

The purpose, principles, and procedures for conducting a RIT-T are set out in clause 5.16 of the NER.

The purpose of the RIT-T is to rank credible options for meeting an identified need and identify the option that maximises net economic benefits. As outlined in clause 5.16.4 of the NER, the RIT-T process involves the publication of three reports:

- The first report, the PSCR, which seeks feedback on the identified need and credible options to address the need.
- The second report, the PADR, which identifies and seeks feedback on the preferred option which delivers the highest net market benefit and the other issues addressed in the report.
- The third and final report, the Project Assessment Conclusions Report (PACR), which makes a conclusion on the preferred option.

As part of the PADR and the PACR, the TNSP must present the results of the RIT-T analysis. This analysis is based on quantification of various categories of costs and benefits arising to all those that produce, consume, and transport electricity in the NEM.

1.3 Declared Shared Network

The transmission network proposed to be augmented in western Victoria forms part of the Victorian declared shared network.

AEMO's functions under the National Electricity Law include planning, authorising, contracting for and directing augmentation of the declared shared network.

In deciding whether a proposed augmentation to the declared shared network should proceed, AEMO is required to undertake a cost-benefit analysis. As the preferred option involves a number of augmentations to the declared shared network, the RIT-T meets this requirement in relation to those augmentations.

1.4 Submissions

AEMO invites written submissions on this PADR from registered participants and interested parties.

Submissions are due on or before 28 February 2019.

Submissions should be emailed to WestVicRITT@aemo.com.au.

Submissions will be published on the AEMO website. AEMO would prefer submissions to be public, but if you do not want your submission to be publicly available, please clearly stipulate this at the time of lodgement.

The third step of the RIT-T process, the PACR, will include the matters outlined in this PADR and consideration of any submissions made in response to this PADR.

For further details about this project please e-mail:

WestVicRITT@aemo.com.au

2. Identified need

The identified need for investment is to increase the thermal capability of the Western Victorian power system, to reduce constraints that would otherwise apply on anticipated new and existing generation:

- Due to the scale of newly committed generation in the region, transmission network development will be in stages.
- The stages will be prioritised, with a focus on first addressing expected congestion affecting committed and existing generators, as well as network areas where augmentation is most likely to deliver the highest net market benefit.
- Transmission network augmentations for increasing system strength are not included in this RIT-T, because there is currently no declared fault level shortfall in Victoria that can be addressed by the TNSP. AEMO is currently conducting detailed studies to review and refine the minimum requirement.

2.1 Description of the identified need

The identified need for investment is described in Chapter 3 of the PSCR[9], and states that investment is required to reduce constraints[10] on anticipated new and existing generation in Western Victoria, to deliver a net market benefit (that is, an increase in consumer and producer surplus) through significant reductions in the capital cost and dispatch cost of generation over the longer term.

While the identified need for investment remains the same, new information available after the publication of the PSCR has allowed AEMO to refine some aspects of the identified need, as described in the following sections.

Details on current transmission network limitations are provided in Appendix A3.

2.2 New information since the PSCR

2.2.1 Integrated System Plan (ISP) findings

AEMO published its inaugural ISP for the NEM[11] in July 2018. The ISP sought to determine a plan for the development of the power system that would meet consumer needs at the lowest possible source cost. As part of that, the ISP identified a number of renewable energy zones (REZs) which would facilitate the efficient connection of new generation sources. Three priority REZs were identified in Victoria:

- Western Victoria REZ – this REZ has high quality wind resources, and is located in the Central Highlands.

[9] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2017/Western-Victoria-Renewable-Integration---Project-Specification-Consultation-Report_FINAL.pdf.

[10] Under both system normal or contingency conditions.

[11] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf.

- Moyne REZ – this REZ has high quality wind resources, and is located in the Great South Coast.
- Murray River REZ – this REZ has high quality solar resources, and is located in the Mallee region.

Refer to Appendix A1 for the approximate REZ locations.

The ISP confirmed the identified need of this RIT-T, and prioritised transmission network investments into three groups based on their urgency, and potential to return net market benefits. Investments in Group 1 were recommended for progression as soon as possible, because of the identified benefits they provide and the support they deliver to achieve the highest projected consumer economic, system security, and reliability benefits over a range of modelled plausible scenarios.

The Group 1 investments aim to facilitate generation connections to the REZs in Western Victoria, Moyne, and Murray River. The scope of this PADR is focused on the preferred Group 1 investment options within each of the REZs identified in the ISP.

2.2.2 Victorian Annual Planning Report (VAPR) findings

The 2018 Victorian Annual Planning Report (VAPR)[12] highlighted the need to maintain a resilient power system in Victoria, and to unlock the potential of Western Victoria as a key initiative required to address future trends and needs of the power system.

2.2.3 New committed generation in Victoria

AEMO published a project update in July 2018[13] that described several newly committed projects in Victoria. Committed projects are those that have advanced to the point where proponents have secured land and planning approvals, entered into contracts for supply of major components and financing arrangements, and either started construction or set a firm date. Around 2,000 megawatts (MW) of committed new renewable generation will be built in Western Victoria by 2020.

More information on anticipated and committed generation projects for development within the next 10 years can be found in Appendix A2, and in Attachment 1 – generation expansion plans.

2.2.4 Update on system strength obligations

Section 2.2 of the PSCR identified that system strength limitations are expected to develop in Western Victoria due to increased connection of asynchronous generation. System strength is critical to supporting the stable operation of new generators and maintaining the stable operation of existing generators.

In September 2017, the Australian Energy Market Commission (AEMC) published a final rule on managing power system fault levels[14]. The new rule requires connecting generators to "do no harm" to the level of system strength necessary to maintain power system stability, and to not decrease the ability of other generating systems to maintain stable operations following any credible contingency event or protected event.

Following this Rule change, AEMO also published a System Strength Requirements and Fault Level Shortfalls report[15], to determine the minimum three phase fault levels at each fault level node in each region. This report identified no fault level shortfall in Victoria that requires investment by the TNSP. AEMO is currently conducting detailed studies to review and refine the minimum requirement, and to consider how this requirement is impacted when 500 kilovolt (kV) lines are switched out of service for voltage control purposes.

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[12] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/VAPR/2018/2018-Victorian-Annual-Planning-Report.pdf.

[13] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2018/Western-Victorian-Renewable-Integration---Project-Update.pdf.

[14] Available at https://www.aemc.gov.au/rule-changes/managing-power-system-fault-levels.

[15] Available at http://aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/System_Strength_Requirements_Methodology_PUBLISHED.pdf.

As there is currently no declared fault level shortfall in Western Victoria and generators connecting in the future are obliged to 'do no harm', transmission network augmentations for increasing system strength are not included in this RIT-T.

While the preferred option has been proposed to address thermal limitations, it will likely improve system strength in Western Victoria, as described in Section 6.2.4.

2.3 Refinements to the identified need

2.3.1 Changes in priority

AEMO is assessing the need to alleviate future constraints on generation in the following three corridors, consistent with the key REZs in Western Victoria identified in AEMO's 2018 ISP:

1. Western Victoria corridor – this corridor considers augmentation from Red Cliffs, Horsham, Ballarat, Moorabool, or Sydenham.
2. Moyne corridor – this corridor considers augmentation from Ballarat to Terang and Terang to Moorabool.
3. Murray River corridor – this corridor considers augmentation from Buronga to Red Cliffs to Kerang to Bendigo and Sydenham, and the potential connection to a new South Australian interconnector between mid-north South Australia and Wagga Wagga in New South Wales, via Buronga.

The Western Victoria and Moyne corridors contain approximately 80% of the newly committed generation capacity described above, while the Murray River corridor contains the remaining 20% of newly committed generation capacity. These corridors are further described in Chapter 3.

Augmentations in these corridors will therefore be delivered via a staged implementation plan which will first focus on addressing expected congestion affecting committed and existing generators, as well as network areas where augmentation is most likely to deliver the highest net market benefit.

2.3.2 Changes in need to mitigate low system strength

As described in Section 2.2.4, there is no need for this RIT-T to further assess investments to increase system strength.

3. Credible options included in the RIT-T analysis

Analysis has considered all network and non-network options to increase the transmission network capacity in the Western Victoria, Murray, and Moyne transmission corridors that could reasonably be classified as credible. The options described aim to provide a range of potential options that could meet the specified need and warrant a full cost and benefit analysis to determine the option which maximises the net benefits.

AEMO has also considered how each of the proposed options fit in with the transmission network development plan outlined in the ISP.

3.1 Background

Chapter 7 of the PSCR[16] described five potential broad options that could address the identified need for this RIT-T.

1. Minor network augmentations – this refers to minor line upgrades to remove rating limiting station equipment, and to enable wind monitoring. This option will not fully remove constraints on the worst affected lines but can be deployed quickly. Control schemes to quickly run back or trip generation after a transmission line trip can be used to prevent pre-contingency generation curtailment and is currently being considered as part of the new generation connection agreements.
2. New 220 kV transmission capacity – 220 kV transmission capacity could be gradually added to the worst congested parts of the network, as new generation becomes committed.
3. New 275 kV or 330 kV transmission capacity – 275 kV or 330 kV transmission capacity could be added from Buronga Terminal Station to Red Cliffs Terminal Station, if the New South Wales transmission network between Buronga to Darlington Point is upgraded, and if a new South Australia to New South Wales interconnector is built.
4. New 500 kV transmission capacity – 500 kV transmission capacity may be required to increase new generation connection capacity, and to align with long-term transmission development plans identified in the ISP.
5. Non-network options – non-network options to increase transmission network capacity will need to increase local demand (for example by battery charging or demand shifting) during periods when thermal constraints are binding due to high generation.

[16] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2017/Western-Victoria-Renewable-Integration---Project-Specification-Consultation-Report_FINAL.pdf.

Each of the five broad options identified above was further divided into sub-options which were considered as credible, and are described in the following sections.

Other potential options that were eliminated from further assessment are described in Section 3.7.

3.2 Drivers for augmentations

In developing credible options, AEMO assessed the network limitations driving the need for augmentation in the three priority REZs identified in the ISP. Appendix A3 discusses these network limitations in more detail.

3.2.1 Western Victoria corridor

The main driver for Horsham to Ballarat augmentation is development of large-scale renewable (mainly wind) generation in the area.

Most of the generation is intended to flow from Horsham towards the 500 kV network at Moorabool. The transmission line flows in the Moorabool to Geelong to Keilor 220 kV path also increase due to high generation in the Horsham to Ballarat corridor.

With no major augmentations along the Horsham to Ballarat corridor, or the Murray River corridor, and with the newly committed generation specified in Table 17 (in Appendix A2), the most overloaded transmission line section will be between Waubra to Ballarat.

After a trip of the Red Cliffs to Horsham line, the Horsham to Ballarat line becomes radial, with most of the generation flowing towards Ballarat (a small percentage of generation will also be supplying load at Horsham).

3.2.2 Moyne corridor

Augmentation of the Terang to Moorabool line is primarily driven by new wind generation connecting to Terang Terminal Station (both transmission and distribution connections). Generation connecting to the Western Victoria REZ will also increase transmission line flows on the Ballarat to Terang to Moorabool transmission lines.

Most of the generation is intended to flow towards Ballarat or towards Moorabool, from Terang.

3.2.3 Murray River corridor

There are two key drivers for Murray River augmentation:

- Development of large-scale renewable (mainly solar) generation in this area.
- AEMO's 2018 ISP identified the need for a new Victoria to New South Wales interconnector by 2035 (called Snowylink in the ISP) that runs through the Murray River REZ.

Since the main generation interest is around Red Cliffs and Kerang and there is limited local demand in this area, small-scale incremental developments will have limited benefit, since the generation cannot be absorbed locally. A transmission path would be required to the Melbourne load centre, or to other states.

If no further generation connects to the Murray River REZ (aside from the 400 megawatts [MW] of committed generation), and if no further augmentations are carried out, then the most overloaded transmission line section is between Red Cliffs to Wemen to Kerang. The ISP identified that this transmission line may require augmentation after 2030.

3.3 Network augmentations under implementation

Since publishing the PSCR, AEMO has carried out further work to assess the drivers for augmentations, market benefits, and costs of the minor network augmentations, as part of the 2017 Network Capability

Incentive Parameter Action Plan (NCIPAP). Refer to Table 3 for a summary of the NCIPAP assessment findings, and refer to Appendix A4 for further information on the scope of works for the minor augmentations.

In general, all transmission line minor upgrades in Table 3 below include upgrades of station equipment that is currently limiting the thermal ratings of the overhead lines, as well as the installation of new wind monitoring.

In early 2018, the Australian Energy Regulator (AER) approved two of the minor network augmentations as priority NCIPAP projects. The remaining minor augmentations have been assessed under this RIT-T. Refer to Chapter 7 for the proposed preferred option.

The minor network augmentations identified and assessed in this RIT-T are likely to be non-contestable[17] projects, in which case they will be delivered by AusNet Services[18].

Table 3 Minor network augmentations for Western Victorian Renewable Integration RIT-T

Project description	Capital expenditure cost, $M (2018-19)	10 -year operational expenditure costs*, $M	3-year market benefits**, $M	Project status
Ballarat to Waubra to Ararat to Horsham 220 kV transmission line minor upgrade	0.85	0.21	5	Approved by AER, for completion by June 2019.
Horsham to Red Cliffs 220 kV transmission line minor upgrade	1.45	0.29	1.9	Approved by AER, for completion by June 2019.
Red Cliffs to Wemen to Kerang 220 kV transmission line minor upgrade	2.6	0.27	Refer to section 6.3.1	Assessed under this RIT-T.
Bendigo to Kerang 220 kV transmission line minor upgrade	1.7	0.21	Refer to section 6.3.1	Assessed under this RIT-T.
Moorabool to Terang 220 kV transmission line minor upgrade	0.5	0.21	Refer to section 6.3.1	Assessed under this RIT-T.
Ballarat to Terang 220 kV transmission line minor upgrade	0.7	0.21	Refer to section 6.3.1	Assessed under this RIT-T.

* Expected lifespan of asset.
** Market benefits after three years were not considered, for the high level NCIPAP assessment.

3.4 Description of the credible network options assessed

There are four broad categories of credible network options assessed:

- Category A: Minor network augmentations.
- Category B: 220 kV network augmentation only.
- Category C: 500 kV and 220 kV network augmentation.
- Category D: Red Cliffs to Buronga network augmentation, discussed further in Section 3.4.1.

Table 4 provides a high-level summary of the network options considered in this PADR, while the following sections provide additional details on each option.

[17] NER 8.11.6 sets out the criteria for determining if an augmentation is non-contestable augmentation.

[18] AusNet Services owns and operates the majority of Victoria's electricity transmission network. For more information, see https://www.ausnetservices.com.au/Misc-Pages/Links/About-Us.

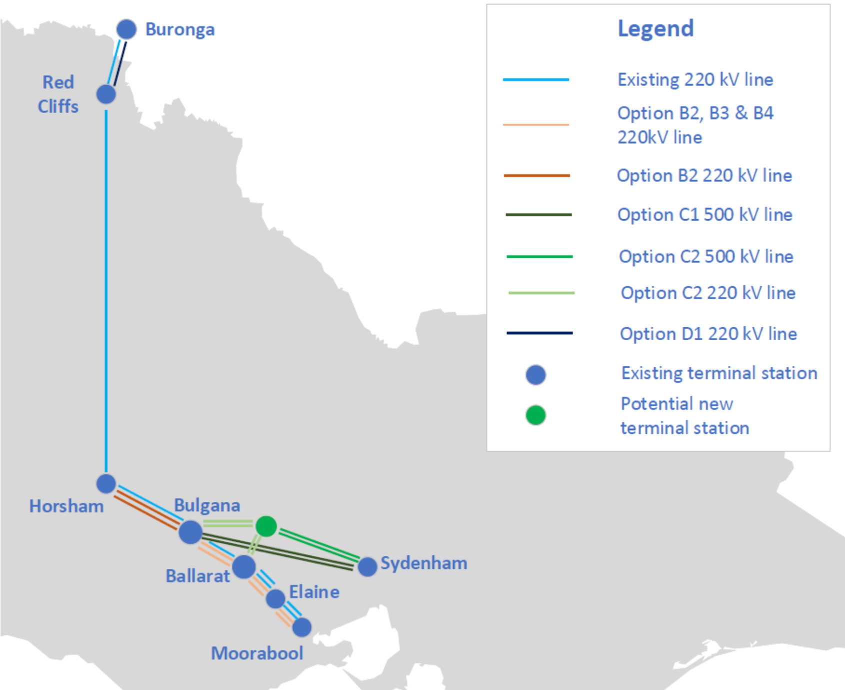
Table 4 Credible network options

Option	Description	Features	Long-term impact	Cost $M (2018-19)
A1	Implement uncommitted minor network augmentations outlined in Table 3 above.	Low cost and has a short lead time for implementation.	Not able to fully remove all projected constraints on the transmission network.	5.5
B2	• Construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana to Horsham. • Retire Ballarat to Moorabool 220 kV circuit No. 1, to allow the existing easement to be re-used for a new double circuit line, and cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine to pick up more renewable generation at Elaine Terminal Station. • Allow sufficient powerflow controllers to manage transmission line flows between Ballarat to Bulgana to Horsham.	• Most expensive category B option. • Increased opportunity for further generation connection in surrounding Western Victoria REZ • New easements required. • Reduced construction complexity compared to Option B4.	Increases transmission line loading between Moorabool to Geelong to Keilor.	406
B3	• Construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana. • Retire Ballarat to Moorabool 220 kV circuit No. 1, to allow the existing easement to be re-used for a new double circuit line, and cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine to pick up more renewable generation at Elaine Terminal Station. • Allow sufficient powerflow controllers to manage transmission line flows between Ballarat to Bulgana.	• Moderate cost. • New easements required. • Reduced construction complexity compared to Option B4.	• Increases transmission line loading between Moorabool to Geelong to Keilor. • Does not address constraints between Horsham to Bulgana.	340
B4	• Rebuild existing Moorabool to Elaine to Ballarat to Bulgana single circuit 220 kV transmission line as a 220 kV double circuit transmission line. • Retire the existing Moorabool to Ballarat to Bulgana 220 kV transmission lines, to enable the existing easement to be re-used. Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine, to pick up more renewable generation at Elaine Terminal Station. • Dynamic reactive compensation required to manage voltages.	• Moderate cost. • Requires mix of new and existing easements. • Less overall network reliability and transmission network capacity, compared to other options. • High construction complexity.	Increases transmission line loading between Moorabool to Geelong to Keilor.	367
C1	• Construction of a new 500 kV double circuit line from Sydenham to Ararat. • 2 x 1,000 megavolt amperes (MVA) 500/220 kV transformers at Ararat. • Allow for line switched reactors for the 500 kV transmission lines. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine, to pick up more renewable generation at Elaine.	• High cost. • Increased transmission network capacity around the 500 kV terminal station, compared to category B options. • Minor improvement to the existing Victoria to New South Wales transient stability limits. • New easements required.	• Provides a path for a future Victoria – New South Wales interconnector (called Snowylink) expansion and connects Western Victorian generation closer to the Melbourne load centre. • Removes transmission line overload between Moorabool to Geelong to Keilor.	443

Option	Description	Features	Long-term impact	Cost $M (2018-19)
C2	• Potentially establish a new terminal station close to Ballarat, with 2 x 1,000 MVA 500/220 kV transformers. AEMO's assessment is based on a new North Ballarat Terminal Station, located approximately 25km from Ballarat, with a 220 kV double circuit connection to Ballarat Terminal Station. This new station is referred to as Ballarat in the rest of the option description. • Construction of a new 500 kV double circuit line from Sydenham to Ballarat. • Allow for line switched reactors for the 500 kV transmission lines. • Construction of a new 220 kV double circuit line from Ballarat to Bulgana. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine to pick up more renewable generation at Elaine Terminal Station. • Allow sufficient powerflow controllers to manage transmission line flows between Ballarat to Bulgana.	• High cost. • Increased transmission network capacity around the 500 kV terminal station, compared to category B options. • Supports future ISP development including the Snowylink interconnector. • New easements required.	• Provides a path for a future Snowylink expansion and connects Western Vic generation closer to the Melbourne load centre. • Removes transmission line overload between Moorabool to Geelong to Keilor.	499
D1	• Construction of a new 220 kV double circuit line from Red Cliffs to Buronga, operated as a single circuit initially. • 1 x 400 MVA 330/220 kV transformer at Buronga • To be considered under ElectraNet's South Australian Energy Transformation RIT-T.	Enables the development of solar generation around Red Cliffs Terminal Station, in the Murray River REZ, and enables the export of solar generation to South Australia and New South Wales through the proposed South Australia to New South Wales Interconnector.	Refer to ElectraNet PACR	Refer to ElectraNet PACR

The options described in Table 4 are further illustrated in Figure 3 and described in more detail below.

Figure 3 High level overview of major network options



Note that the transmission line route identified for each option is indicative only. The actual transmission line routes will be determined during the detailed design and route assessment phase, after conclusion of the RIT-T process. New terminal stations may be required to connect the new transmission lines, and this will also be confirmed during the detailed design phase.

The cost estimates provided above have an accuracy of ±30%. Refer to Section 5.5 for the methodology applied for developing cost estimates.

The construction timetable will be determined in the procurement phase, but is assumed to enable the expected commissioning years listed in the following sections.

3.4.1 Red Cliffs to Buronga 220 kV line upgrade

AEMO[19], ElectraNet, and TransGrid have been in consultation on a proposed 220 kV transmission line upgrade between Red Cliffs (in Victoria) and Buronga (in New South Wales).

This upgrade is projected to deliver high net market benefits if the proposed South Australia to New South Wales interconnector (currently proposed under ElectraNet's South Australian Energy Transformation [SAET] RIT-T) is commissioned, because it enables the development of solar generation around Red Cliffs Terminal Station, in the Murray River REZ and also enables the export of solar generation to South Australia and New South Wales via the interconnector.

AEMO has carried out a separate market benefit assessment of this upgrade, the results of which will be published in ElectraNet's SAET RIT-T PACR[20].

3.4.2 Control schemes

Control schemes can be used to run back or trip generation following a contingency, to prevent pre-contingency generation curtailment. Control schemes are only applicable if system normal limitations are not reached (on a pre-contingent basis), and cannot fully remove all projected constraints on the transmission network.

Control schemes are currently being assessed on a case-by-case basis for all new generation applications.

For this PADR, control schemes are applied in the analysis to prevent pre-contingency generation curtailment of some generators between Ballarat to Horsham to Red Cliffs, and some generators proposing to connect around Terang Terminal Station. These control schemes are expected to be implemented as part of the generators' connection agreements, and therefore do not incur any additional cost for the purposes of this RIT-T.

The size of the largest Victorian generator contingency is currently limited to 600 MW to ensure operational validity of voltage stability limits. However, the largest NEM generator that can potentially determine Frequency Control Ancillary Services (FCAS) requirements is 750 MW. Investigations by AEMO are in progress to assess the operational and market impacts associated with increasing these upper limits.

3.4.3 Option A1 – Minor network augmentations

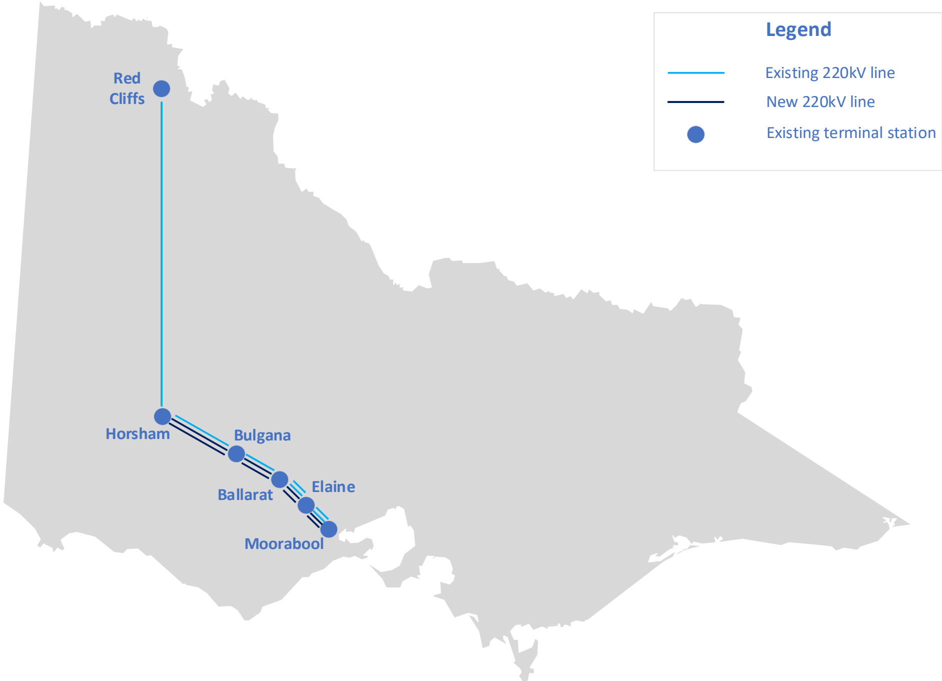
Option parameter	Details
Scope of works	Install wind monitoring, and upgrade terminal station equipment that currently limits the thermal rating of 220 kV transmission lines at: • Red Cliffs to Wemen to Kerang. • Bendigo to Kerang. • Moorabool to Terang. • Ballarat to Terang.
Construction type	Brownfield

[19] In its capacity as Victorian and National Planner

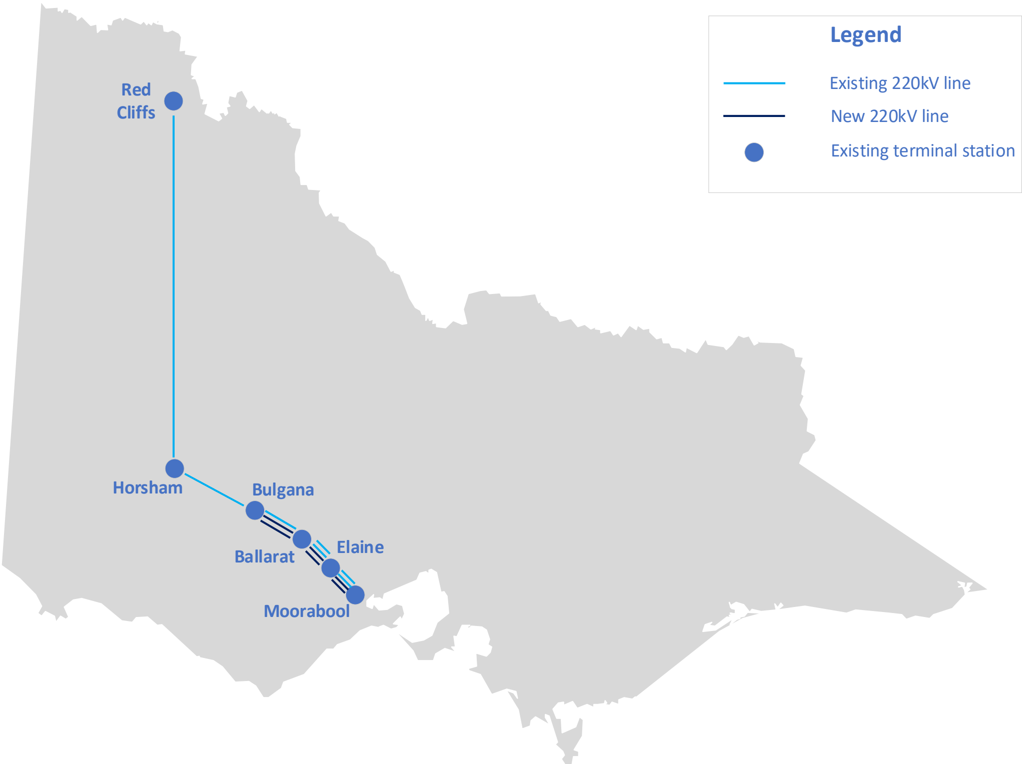
[20] See https://www.electranet.com.au/projects/south-australian-energy-transformation/.

Option parameter	Details
Expected lead time	12-18 months, from contract with AusNet Services
Estimated cost (2018-19)	$5.5 million
Ongoing operating cost	$0.09 million per annum

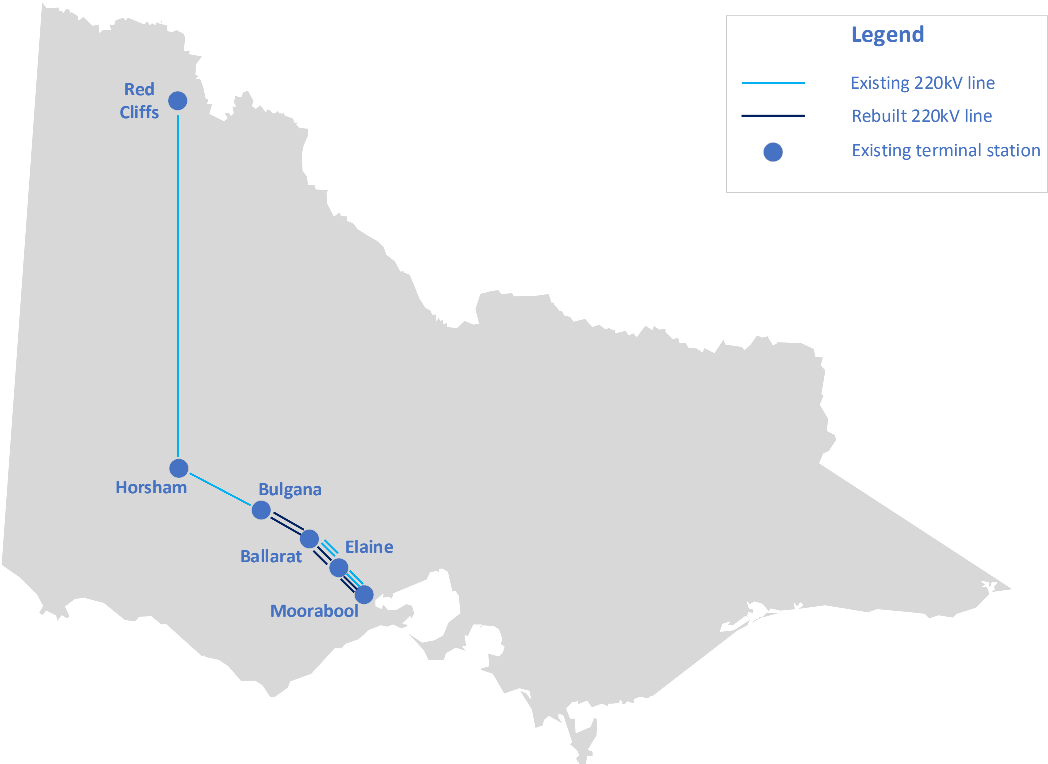
3.4.4 Option B2 – Construction of a new double circuit 220 kV line from Moorabool to Elaine to Ballarat to Bulgana to Horsham

Option parameter	Details
High-level drawing	
Scope of works	• Construct a new Moorabool to Elaine to Ballarat to Bulgana to Horsham 220 kV double circuit transmission line, with a summer rating of at least 800 megavolt amperes (MVA) per circuit. • Retire the existing Ballarat to Moorabool 220 kV circuit No. 1, to allow the existing easement to be re-used for a new double circuit line. • Cut in the existing Ballarat to Moorabool circuit No. 2 at Elaine Terminal Station, to pick up more renewable generation at Elaine Terminal Station. • Allow for power flow controllers to manage transmission line flows between Ballarat to Bulgana to Horsham.
Construction type	Greenfield
Expected commissioning year	2024
Estimated capital cost (2018-19)	$406 million
Ongoing operating cost	0.6% of capital cost

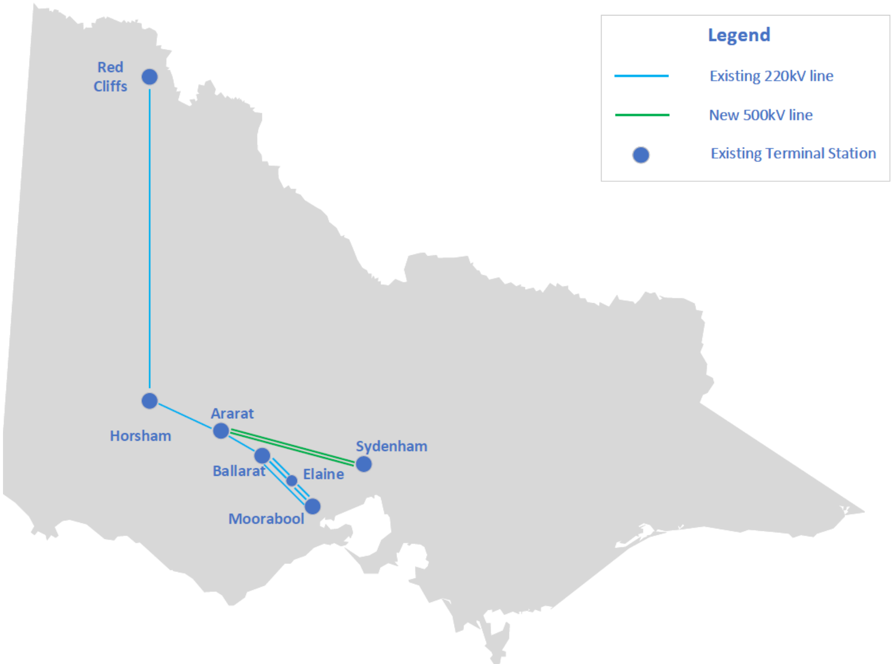
3.4.5 Option B3 – Construction of a new double circuit 220 kV line from Moorabool to Elaine to Ballarat to Bulgana

Option parameter	Details
High-level drawing	
Scope of works	• Construct a new Moorabool to Elaine to Ballarat to Bulgana 220 kV double circuit transmission line, with a summer rating of at least 800 MVA per circuit. • Retire the existing Ballarat to Moorabool 220 kV circuit No. 1, to allow the existing easement to be re-used for a new double circuit line. • Cut in the existing Ballarat to Moorabool 220 kV circuit No. 2 at Elaine Terminal Station, to pick up more renewable generation at Elaine Terminal Station. • Allow for power flow controllers to manage transmission line flows between Ballarat to Bulgana.
Construction type	Greenfield
Expected commissioning year	2024
Estimated capital cost (2018-19)	$340 million
Ongoing operating cost	0.6% of capital cost

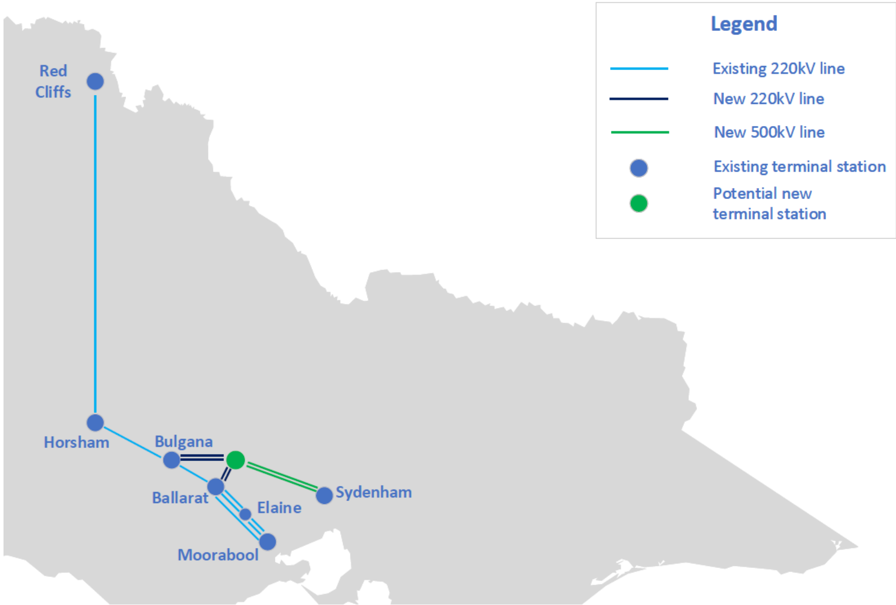
3.4.6 Option B4 – Rebuild existing 220 kV line from Moorabool to Elaine to Ballarat to Bulgana

Option parameter	Details
High-level drawing	
Scope of works	• Rebuild the existing single circuit Moorabool to Elaine to Ballarat to Bulgana 220 kV transmission line as a double circuit 220 kV transmission line, with a summer rating of at least 800 MVA per circuit. • Retire the existing Ballarat to Moorabool 220 kV circuit No. 1, to enable existing easement to be re-used for a new double circuit line. • Cut in the existing Ballarat to Moorabool 220 kV circuit No. 2 at Elaine Terminal Station, to pick up more renewable generation at Elaine Terminal Station. • Dynamic reactive compensation required, to manage voltages.
Construction type	Brownfield
Expected commissioning year	2024
Estimated capital cost (2018-19)	$367 million
Ongoing operating cost	0.6% of capital cost

3.4.7 Option C1 – Construction of new double circuit 500 kV line from Sydenham to Ararat

Option parameter	Details
High-level drawing	
Scope of works	• Construct a new Sydenham to Ararat 500 kV double circuit transmission line with a summer rating of up to 3,000 MVA per circuit. • Allow for transmission line reactors on one or both ends of the 500 kV transmission lines. • 2 x 1,000 MVA 500/220 kV transformers at Ararat. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine Terminal Station, to pick up more renewable generation at Elaine Terminal Station.
Construction type	Greenfield
Expected commissioning year	2025
Estimated capital cost (2018-19)	$443 million
Ongoing operating cost	0.7% of capital cost

3.4.8 Option C2 – Construction of new double circuit 500 kV line from Sydenham to Ballarat, and a new 220 kV double circuit line from Ballarat to Bulgana

Option parameter	Details
High-level drawing	
Scope of works	• Construct a new Sydenham to Ballarat 500 kV double circuit transmission line with a summer rating of up to 3,000 MVA per circuit. • Initial assessment has indicated that there may be insufficient space in Ballarat Terminal Station for the proposed 500 kV plant. AEMO has assumed that a new terminal station will be established close to Ballarat, called North Ballarat Terminal Station, with a 220 kV double circuit connection to Ballarat Terminal Station. The exact terminal station location will be determined during the planning phase and is still referred to as Ballarat in the rest of this option description. • 2 x 1,000 MVA 500/220 kV transformers at Ballarat. • Allow for transmission line reactors on one or both ends of the 500 kV transmission lines. • Construct a new Ballarat to Bulgana 220 kV double circuit transmission line, with a summer rating of at least 800 MVA per circuit. • Allow for power flow controllers to manage transmission line flows between Ballarat to Bulgana. This option is slightly different from what was proposed in the ISP and VAPR. Refer to Appendix A6 for further details on the differences. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine Terminal Station, to pick up more renewable generation at Elaine Terminal Station.
Construction type	Greenfield
Expected commissioning year	2025
Estimated capital cost (2018-19)	$499 million
Ongoing operating cost	0.9% of capital cost

3.5 Description of the credible non-network options assessed

To increase the thermal capacity of the transmission network, a non-network option would need to increase local demand (such as by battery charging or demand shifting) during periods when thermal constraints are binding.

AEMO has assessed the impact of a 100 MW/400 megawatt hour (MWh) energy storage system on the transmission network. This non-network capacity could also come from multiple aggregated units.

An energy storage system can provide additional power system services such as frequency control ancillary services (FCAS), or voltage control ancillary services (VCAS), and these benefits should be considered as additional revenue streams by the non-network service provider, but such revenue streams are considered as wealth transfers (not a net market benefit) in this PADR.

Option parameter	Details
High-level drawing	
Scope of works	100 MW/400 MWh energy storage system at the following locations: • Ararat Terminal Station (Option E1, this option had the highest market benefits, which are further discussed in this PADR). • Horsham Terminal Station (Option E2, this option had lower market benefits than Option E1, and was not assessed further in the PADR). • Red Cliffs Terminal Station (Option E3, this option had lower market benefits than Option E1, and was not assessed further in the PADR).
Expected commissioning year	2020
Estimated capital cost (2018-19)	$117 million

3.6 Material inter-network impact

The options assessed in this RIT-T predominantly address local issues within the Victorian transmission network, and are unlikely to have material inter-network impact, since it does not materially impact interconnector limits.

3.7 Other options considered

AEMO also gave due consideration to the following potential options, but for the reasons summarised below they were considered not to address the identified need or to not be technically or commercially feasible and were therefore not included in market modelling as 'credible options':

- Re-stringing the existing single circuit transmission lines – this option will have a high cost due to outage requirements and construction complexity, while delivering limited additional capacity. The trip of a single transmission line may result in a very large contingency, and the loss of a large amount of generation. This option is assumed not to deliver net market benefits.
- Building a double circuit line and stringing one circuit initially – this option is not considered viable, for similar reasons to the option above. The option is not expected to deliver net market benefits.
- Building a new transmission cable entirely underground – this option is expected to cost up to 10 times more per kilometre than overhead lines, and is not expected to deliver net market benefits.
- Build a 275 kV transmission line from Horsham – this interconnector is not the preferred option in the PADR for the SAET RIT-T[21], and has not been identified as an option in the ISP. Building additional 275 kV transmission lines in Victoria will result in additional costs for transformation and is unlikely to return net market benefits.
- Augmentation to Haunted Gully Terminal Station – a connection from the 220 kV Western Victoria transmission network around Bulgana Terminal Station to Haunted Gully Terminal Station was considered, and was not included in the modelling for the following reasons:
  - This option was primarily driven by the desire to reduce the loading on the Terang to Moorabool to Ballarat transmission lines, although a control scheme can also manage the transmission line overloads, at a lower cost.
  - This option would allow for more generation connection capacity to the Moyne REZ. However, the generation expansion modelling shows market benefits for allowing balanced generation development in both the Moyne and Western Victoria REZs.
  - Load flow studies showed that this option would not reduce the projected transmission line overload of the Ballarat to Waubra transmission line (the primary constraint causing renewable generation curtailment) to the same extent as the other options being considered.
  - This option would result in a higher future risk in operating and maintaining the transmission lines, since any outage of the 500 kV transmission line between Moorabool and Haunted Gully Terminal Station will increase the transmission line flow of the path between Ararat to Waubra to Ballarat to Moorabool, and may require pre-contingency generation runback.
  - Since this option was not expected to deliver additional benefits over the other options being considered, and has higher future maintenance risks as described above, it was eliminated from this assessment.
- Augmentation to Donnybrook Terminal Station – Donnybrook Terminal Station is a new station that can be established if the other network options proposed in this PADR are not feasible. Donnybrook Terminal Station was not considered in this step of the PADR, because the additional cost of building a new terminal station, and the additional cost for longer transmission lines, is likely to result in reduced net market benefits.
- Transmission augmentation from Horsham Terminal Station to Red Cliffs Terminal Station – a transmission line augmentation from Horsham Terminal Station to Red Cliffs Terminal Station was eliminated in this assessment, for the following reasons:

[21] See https://www.electranet.com.au/wp-content/uploads/projects/2016/11/2018-07-06-SAET-PADR-Final.pdf.

  - This option is relatively expensive and there is currently a lack of committed generation between Horsham to Red Cliffs, relative to other transmission corridors assessed.
  - Preliminary market modelling showed that the Victorian Government's Victorian Renewable Energy Target (VRET) can be efficiently met without the need for additional generation connection along this path.
  - The ISP identified a long-term plan to develop the transmission lines between Red Cliffs to Kerang to Bendigo, to connect more solar generation, and as part of a new interconnector between Victoria and New South Wales.
  - Therefore, any major augmentation between Horsham to Red Cliffs is unlikely to return net market benefits.
- High voltage direct current (HVDC) option – the primary reason for eliminating HVDC was the lack of flexibility for facilitating future generation connections (that is, generators will require costly transition stations for future connections). HVDC was assumed to be far costlier than an alternating current (AC) solution while delivering similar benefits.

4. Submissions to the Project Specification Consultation Report

Nine submissions were received on the Western Victorian RIT-T PSCR, from:

- Clean Energy Council (CEC).
- Monash Energy Materials and Systems Institute (MEMSI).
- Meridian.
- Mildura, Swan Hill, and Gannawarra Councils.
- TransGrid.
- Wimmera Council.
- Three confidential submissions.

This chapter discusses the key issues raised in the non-confidential submissions, and AEMO's responses.

4.1 Support for a long-term transmission network development plan in Victoria

In general, stakeholders have requested a long-term, strategic, transmission network development plan for Western Victoria, to accommodate potential developments in:

- Future renewable generation connections in Western Victoria.
- A potential interconnector from South Australia, or interconnection between South Australia, New South Wales, and Victoria.
- A potential Snowy Hydro 2.0 development.

4.1.1 Clean Energy Council submission

The CEC:

- Supported the need for more transmission to support a high penetration of future renewables, noting that it is critical for investment in transmission to be undertaken in a way that identifies the best economic cost-benefit outcomes.
- Supported the RIT-T process as a means of providing a long-term planning strategy for guiding investment in new transmission that is required.
- Recommended AEMO consider a combination of options that will not stall the deployment of current projects in the pipeline and will provide an environment of long-term planning.

- Suggested a possible combination of minor network augmentations and development of new 220 kV or 500 kV transmission capacity.

4.1.2 Monash Energy Materials and Systems Institute submission

MEMSI:

- Recognised that the purpose of augmenting the Western Victorian network is to provide for connection of additional renewable energy generation (wind and solar power) as well as to increase system strength.
- Feels, however, that there is a third purpose which was not explicit in the PSCR, being that the network also needs to provide for, or be compatible with, enhanced interconnections between Victoria, South Australia, and south-western New South Wales.

With this in mind, MEMSI's submission recommended that the scope of the study be extended to:

1. Commence with a Scale Efficient Network Extension (SENE) analysis of the region between southern New South Wales and south-eastern South Australia, to examine the full potential for production of renewable energy in this region and determine a strategy for subsidiary networks to connect the prospective generation projects, and to design an ultimate network concept for the region with ultimate developments of 500 kV or above.
2. Consider interactions with interconnection developments between South Australia, Victoria, and New South Wales.
3. Consider the impact that the proposed 2,000 MW upgrade of Snowy would have in optimising the Western Victorian grid.

Broadly, MEMSI's submission requested a long-term network investment strategy spanning to 2050. MEMSI asked that AEMO consider 500 kV interconnectors from South Australia to Victoria and on to New South Wales, through the Western Victoria area. MEMSI believes a new 500 kV ring is required in Western Victoria, together with significant 220 kV network augmentations.

4.1.3 Meridian submission

Meridian:

- Highlighted the need for a stable investment environment to deliver the lowest cost of energy to consumers while maintaining a secure and stable network.
- Acknowledged that investment in the Western Victoria transmission system will bring the potential for significant market benefits, including relieving constraints on existing Victorian generators and allowing for investment in additional low-cost generation capacity in an area renowned for its renewable resources.
- Noted that it supports options that lead to the existing and future constraints on the network being alleviated as soon as possible, because this will provide the maximum investment certainty for both new and existing generation, leading to lower costs for consumers.

4.1.4 AEMO response

AEMO acknowledges the interest from various stakeholders across the NEM in developing new renewable generation in the Western Victoria area, and is currently exploring a staged approach to making network investment decisions, with control schemes, minor augmentations, and non-network solutions deployed initially, and staged major transmission network augmentations within the Western Victoria area to follow.

The preferred option outlined in this PADR aligns with AEMO's long-term strategic view on network development, which has been outlined in the 2018 ISP. The ISP has an outlook period of 20 years, and AEMO considers a long-term strategy of up to 2050 to be beyond the scope of its current assessments. The ISP considered the need to connect new renewable generation through its analysis of REZs.

In determining the preferred option, this PADR considers all interconnector developments identified in the ISP, and a sensitivity without any interconnectors. This PADR has also included a scenario with the proposed Snowy 2.0 development, together with the development of large-scale storage in Tasmania.

The ISP did not identify a need for additional 500 kV interconnectors from South Australia to Victoria through the Western Victoria network, but has identified the need for an additional interconnector from Victoria to New South Wales. The long-term plans outlined by the ISP are considered in the RIT-T assumptions.

AEMO has not received a request for a SENE Design and Costing Study in accordance with clause 5.19 of the NER, and therefore will not conduct a SENE analysis as part of this RIT-T.

4.2 Support for non-network options

MEMSI noted that non-network options (such as storage) will be a key technology to maximise utilisation of the existing network, however agreed that it is unlikely non-network services could completely remove the expected or potential network limitations.

Meridian suggested that AEMO consider the use of very fast runback schemes in place of binding network constraints to maintain grid stability.

4.2.1 AEMO response

Battery storage has been considered as an option to address the identified need in this RIT-T. Further details on this option are provided in Section 3.5.

Control schemes are being considered as part of new generation connection agreements.

4.3 Cost of outages

Meridian highlighted the cost of outages, which it strongly believes should be included within the RIT-T assessment.

4.3.1 AEMO response

The cost of outages has mainly been considered in Option B4, which will require significantly more outages than the other proposed options. The cost of outages has not been considered for all other network options, because they are assumed to be similar, and will likely have minimal impact on option ranking. Refer to Section 3.4.6 for additional details on Option B4.

4.4 Murray River REZ development

4.4.1 Murray Valley council submission

Mildura, Swan Hill, and Gannawarra Councils (the Murray Valley) are supportive of the RIT-T. The Murray Valley has requested that additional options to expand the capacity of the network be considered to exceed the identified 1,500 MW upper limit with 220 kV system augmentation that would allow additional proponents to access the national transmission lines. As a minimum, the Murray Valley recommends that the 220 kV options outlined in the PSCR are completed.

4.4.2 Wimmera council submission

Wimmera Council supported the need for more transmission to sustain the various future renewable developments proposed for the region. Wimmera Council noted that without significant investment, further opportunities for Western Victoria and the Wimmera Southern Mallee Region will be extremely limited. Wimmera Council also noted that while batteries will assist with power storage and efficient movement in several locations, these will also only be possible where the network has existing capacity.

Finally, Wimmera Council highlighted the significance of a third interconnector to increase the supply and stability of the Victorian and South Australian power supply.

4.4.3 AEMO response

AEMO is considering transmission network investments to facilitate more renewable generation connections in the Murray River corridor.

An additional interconnector between Victoria and South Australia with an upgrade of the Red Cliffs to Buronga 220 kV transmission line is currently being considered by ElectraNet under its SAET RIT-T. This augmentation is expected to reduce congestion on anticipated new solar generation in the Murray River REZ.

4.5 Interconnector with New South Wales

TransGrid's submission highlighted the potential market benefits of an additional interconnector between Kerang Terminal Station in Victoria and Darlington Point Terminal Station in New South Wales. TransGrid noted that it is exploring opportunities for connecting renewable generation by extending the New South Wales transmission network. TransGrid carried out independent technical and economic analysis in response to AEMO's PSCR and identified the gross market benefits of this augmentation.

4.5.1 AEMO response

A new interconnector between Victoria and New South Wates was considered in AEMO's 2018 ISP. This interconnector is projected to be required after 2030, due to projected large-scale coal retirements in the NEM. This interconnector development has been included within the ISP's Group 3 priority investments. This RIT-T considers the benefit of bringing forward a portion of what would otherwise form part of this new interconnector.

5. Description of methodology and assumptions

The modelling carried out in this RIT-T is based on least-cost development of the Victorian electricity network to meet the identified need. The methodologies in this RIT-T are based on relevant regulatory requirements and the assumptions are consistent with the 2018 ISP.

5.1 Overview

The assessments in this PADR are based on the AER's RIT-T application guidelines, published in 2017[22]. Many of the assumptions used were also used in AEMO's 2018 ISP, and further details are available on AEMO's website[23]. This chapter describes the key assumptions and methodologies applied in this RIT-T.

5.2 Assumptions

5.2.1 Analysis period

The RIT-T analysis has been undertaken over the period from 2020-21 to 2031-32[24].

The modelling period selected extends seven years past the VRET final target in 2025, a key driver of increased renewable generation in Western Victoria.

To capture the overall market benefits of a credible option with asset life, or assumed network support arrangements, extending past 2031-32, the market dispatch benefits calculated for the final three years of the modelling period have been averaged, and this average value has been assumed to be indicative of the annual market dispatch benefit that would continue to arise under that credible option in the future.

Terminal values[25] have been used to capture the remaining asset life[26] of the credible options and other investments in the market (generation plant).

5.2.2 Discount rate

A base discount rate of 6% (real, pre-tax) has been used in the NPV analysis, for all credible options. This discount rate represents the typical regulated weighted average cost of capital (WACC) for TNSPs in the NEM.

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22 Available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/rit-t-and-rit-d-application-guidelines-minor-amendments-2017.

23 See https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/ISP-database.

24 Note the generation expansion plan modelling was undertaken from 2018-19 to 2032-33 to align with the ISP model.

25 The value of an asset at the end of the modelled horizon.

26 Based on ISP assumptions for various asset types.

Sensitivity testing has been conducted on the base discount rate, with a lower bound discount rate of 3.5%, and an upper bound discount rate of 8.5%[27].

5.2.3 Reasonable scenarios

Clause 5.16.1(c)(1) of the NER requires that the RIT-T is based on a cost-benefit analysis that includes an assessment of reasonable scenarios of future supply and demand if each credible option were implemented, compared to the situation where no option is implemented. A reasonable scenario represents a set of variables or parameters that are not expected to change across each of the credible options or the base case.

This RIT-T analysis has included four reasonable scenarios from the 2018 ISP:

1. Neutral – central projections of economic growth, future demand growth, fuel costs, technology cost reductions, and distributed energy resources (DER) aggregation growth.
2. Neutral with storage initiatives – all the scenario settings of the Neutral scenario, combined with the proposed Snowy 2.0 and Battery of the Nation pumped hydro storage projects, and associated augmentations of the transmission network.
3. Slow change – compared with the Neutral scenario, assumed weaker economic and demand consumption growth, lower levels of investments in energy efficiency, slower uptake of electric vehicles, slower cost reductions in renewable generation technologies, and greater aggregation of DER.
4. Fast change – compared with the Neutral scenario, assumed stronger economic and demand growth, higher levels of investments in energy efficiency, faster uptake of electric vehicles, faster cost reductions in renewable generation technologies, and less aggregation of DER.

All scenarios assumed existing market and policy settings including:

- Emissions trajectories: reduce emissions to 28% on 2005 levels by 2030.
- VRET: 25% renewables by 2020 and 40% by 2025.
- Queensland Renewable Energy Target (QRET): 50% renewables by 2030[28].

5.2.4 Weightings applied to each scenario

Four separate weightings have been applied to the reasonable scenarios, to test if different weightings have an impact on the preferred option. The different scenario weightings did not change the ordering of credible options.

Table 5 Scenario weightings

Scenario weightings	Neutral	Neutral with storage initiatives	Slow change	Fast change
Set A - all equal	25%	25%	25%	25%
Set B – Neutral	40%	40%	10%	10%
Set C – Fast change	20%	20%	20%	40%
Set D – Slow change	20%	20%	40%	20%

5.2.5 Generation expansion

Generation expansion, including the development of new generation and the closure of existing generation, was obtained from the capacity outlook model described in Section 5.3.1, for each reasonable scenario.

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[27] Grattan Institute report on unfreezing discount rates. Available at https://grattan.edu.au/wp-content/uploads/2018/02/900-unfreezing-discount-rates.pdf.

[28] A QRET of 50% renewable energy by 2030 and an overall emissions reduction trajectory of 52% by 2030 were modelled as soft targets. Both targets were not met in the time sequential model for the Fast change scenario. This is unlikely to impact generation development in Victoria.

Committed generation projects are as listed in Appendix A2, and were modelled in each reasonable scenario.

Attachment 1 - generation expansion plans shows modelled new renewable generation in Victoria by its MW capacity, REZ it connects to, and year of connection, with and without transmission network investments.

5.2.6 Demand

This RIT-T applied the same regional electricity and gas demand projections as the 2018 ISP.

The 50% Probability of Exceedance (PoE) projections were used, to reflect an expectation of typical maximum demand conditions. The 10% POE projections reflect an expectation of more extreme maximum demand conditions driven by variations in weather conditions. Initial market modelling using both 50% PoE and 10% PoE demand traces showed there was an immaterial impact on net market benefits. Therefore, all additional market modelling was carried out using 50% PoE demand traces only.

5.2.7 Interconnector development

Interconnector development, including augmenting existing interconnectors and building new interconnectors, was consistent with modelled outcome identified in the 2018 ISP. A sensitivity study was carried out with no interconnector augmentations, and the preferred option still provided a positive net market benefit.

Table 6 Interconnector developments assumed in this PADR

Interconnector	Year	Capacity, MW, forward direction	Capacity, MW, reverse direction
NSW–QLD	2020	770 (increase of 460)	1,215 (increase of 190)
NSW–QLD	2023	770 (increase of 460)	1,593 (increase of 568)
VIC–NSW	2020	870 (increase of 170)	400 (no increase)
VIC–NSW	2035	2,800 (increase of 2,100)	2,200 (increase of 1,800)
SA–NSW	2025	750	750

5.3 Market modelling methodology

AEMO used market dispatch modelling to estimate the market benefits associated with the credible options. This estimation was done by comparing the 'state of the world' in the base case (or 'do nothing' case) with the 'state of the world' with each of the credible options in place. 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, storage, and transmission investment, as well as the market dispatch outcomes over the modelling period.

AEMO maintains four mutually-interacting planning models, shown in Figure 4. These models incorporate the assumptions about future development described by the scenarios and simulate the operation of energy networks to determine a reasonable view as to how those networks may develop under different demand, technology, policy, and environmental conditions.

This PADR primarily uses two of these market models to deliver its key outputs:

- Capacity outlook model – determines the most cost-efficient long-term trajectory of generator and transmission investments and retirements to maintain power system reliability. Two variants exist and were used in the analysis:
  - Long Term Integrated model (IM) – co-optimised model which considers interdependencies between gas and electricity markets to determine optimal thermal generation investments, retirements, transmission and pipeline investment plans, over the longest time horizon (25 years or beyond).

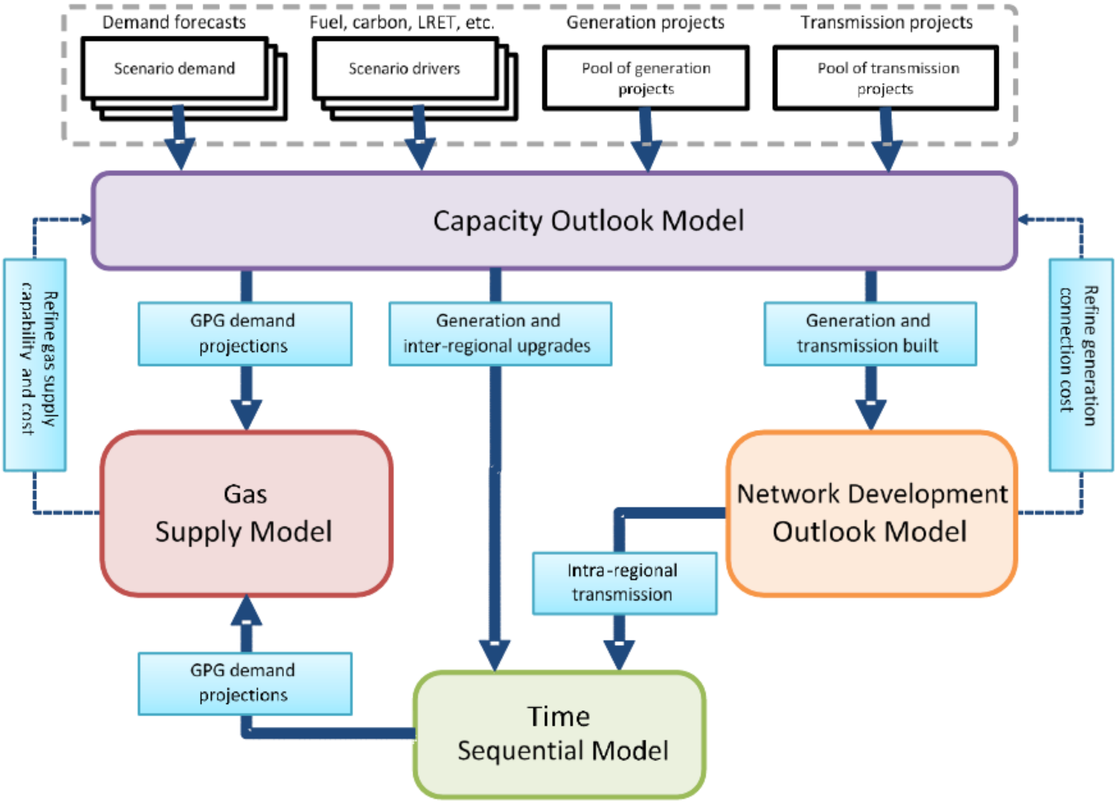
- Detailed Long Term (DLT) model – co-optimised model of the electricity system in isolation to the gas market, optimising new generation investments and sub-regional transmission developments, using inter-regional transmission and other long-lived thermal generation development decisions produced by the IM capacity outlook model. The DLT model is a more granular capacity outlook approach that provides chronological, detailed representations of the long term via a multi-step solve, thus with reduced foresight relative to the IM.

- Time-sequential model – carries out an hourly simulation of generation dispatch and regional demand while considering various power system limitations, generator forced outages, variable generation availability, and bidding models. This model validates insights on power system reliability, available generation reserves, emerging network limitations, and other operational concerns. Depending on the study this model is used for, the generation and transmission outlook from the capacity outlook model may be incorporated.

The Network development outlook model in the figure is a PSS/e[29] model used to examine the engineering parameters of the identified need and the credible options.

The Gas supply model in the figure is used primarily in the Gas Statement of Opportunities (GSOO), and was not used in PADR studies.

Figure 4 Market modelling process



5.3.1 Capacity outlook model

A 'least-cost'[30] market development modelling was undertaken, according to the RIT-T and the application guidelines. The least-cost market development model used was the PLEXOS® long-term optimisation model.

[29] Description of software available at https://www.siemens.com/global/en/home/products/energy/services/transmission-distribution-smart-grid/consulting-and-planning/pss-software/pss-e.html.

[30] This means that the modelling is orientated towards minimising the cost of serving load (or allowing load to remain unserved if that is least-cost) while meeting minimum reserve levels.

Do Nothing capacity outlook model

A capacity outlook model was developed assuming no future transmission network investments in Western Victoria, to represent the 'state of the world' in the base case (or 'do nothing' case). New generation connections are limited in the Western Victoria REZ and the Murray River REZ, due to existing thermal limitations in the transmission network. Generation expansion in other parts of Victoria and the rest of the NEM can proceed based on least-cost modelling.

The outcome of this model is different from the ISP, which considered transmission augmentations in the Western Victoria and Murray River REZs, if economic.

Credible option capacity outlook model

Two capacity outlook models were developed:

1. Upgrade Western Victoria model – compared to the Do Nothing model above, this model identified an economic level of transmission augmentation and generation expansion in the Western Victoria REZ, by paying a "penalty price" for augmentation (that is, cost for generation expansion in Western Victoria = capital cost for new generation + penalty price for developing new transmission infrastructure). The model identified an efficient level of generation expansion in the Western Victoria REZ only, but still limited generation expansion in the Murray River REZ, assuming that transmission investment is limited to the Western Victoria REZ. Generation expansion in other parts of Victoria and the rest of the NEM can proceed based on least-cost modelling. The generation expansion identified from this model was applied to all credible investment options for Western Victoria (all Options B and C[31]).
2. Upgrade both Western Victoria and Murray River model – this model identified an economic level of generation and transmission expansion in both the Western Victoria and Murray River REZs, to represent the 'state of the world' with network investments in Western Victoria and in Murray River (that is, cost for generation expansion in Western Victoria and Murray River = capital cost for new generation + penalty price for developing new transmission infrastructure). Generation expansion in other parts of Victoria and the rest of the NEM can proceed based on least-cost modelling. This model is applicable to a Red Cliffs to Buronga upgrade.

Following this, time sequential modelling (described in the next section) was applied to assess the differences in market benefits for each option.

5.3.2 Time sequential model

The time sequential modelling aims to dispatch the least-cost generation to meet customer demand, mandatory service standards, and the various carbon abatement targets that have been assumed, while remaining within the technical parameters of the electricity transmission network.

Detailed market modelling was undertaken with the PLEXOS® short-term dispatch model.

Model parameters

- Generation and interconnector expansion plans were obtained from the Capacity outlook model described in Section 5.3.1.
- Generator reliability, technical and financial settings were obtained from the 2018 ISP assumptions workbook[32].
- Generation and demand side resources are dispatched to meet load in order from lowest to highest short-run marginal cost.
- Transmission network parameters included in the modelling are described in Section 5.4.

[31] Refer to Table 4 for a description of the credible options.

[32] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/2018-Integrated-System-Plan--Modelling-Assumptions.xlsx.

Model outputs

This model produced an hourly pricing and dispatch solution for generation, which was used to calculate operational benefits (reduction in fuel and operation and maintenance costs). These benefits primarily stem from reduced curtailment of renewable generation output, from network locations that are either currently congested, or are expected to become congested based on committed and modelled new generation.

5.4 Transmission network parameters

Constraint equations and dynamic rating traces are two key inputs to the time sequential model.

5.4.1 Constraint equations

Constraint equations are a mathematical representation of transmission network parameters that AEMO uses to manage power system limitations, generation dispatch, and FCAS requirements.

Thermal constraint equations were built for each augmentation option described in Section 3.4 under system normal and contingency [(N-0)[33] and (N-1)[34]] conditions for all transmission lines in the study area with a voltage level of 220 kV and above. Constraint equations were validated against different demand, interconnector, and generation dispatch scenarios.

Constraint equations for network limitations outside of the study area were obtained from the ISP[35]. In general, the following types of constraints were considered:

- Thermal – for managing the power flow on a transmission element so that it does not exceed a rating (either continuous or short term) under normal conditions or following a credible contingency[36].
- Voltage stability – for managing transmission voltages and reactive power margin so that they remain at acceptable levels after a credible contingency.
- Transient stability – for managing network flows to ensure the continued synchronism of all generators on the power system following a credible contingency.
- Oscillatory stability – for managing network flows to ensure the damping of power system oscillations is adequate under system normal and following a credible contingency.

Refer to AEMO's Constraint Formulation Guidelines[37] for more information on constraint equations. FCAS constraints were not modelled in this RIT-T, since they are not expected to materially impact market benefits (refer to Section 6.1 for further details).

5.4.2 Dynamic ratings traces

Dynamic transmission line ratings were modelled for critical transmission lines in Victoria, using thermal rating traces, which were developed using a 2014-15 reference year ambient temperature trace. Some transmission lines are limited by substation equipment, or their protection settings. AEMO used 15-minute short-term ratings for contingency constraint equations.

5.4.3 Sensitivity studies

In addition to the base assumptions described above, this RIT-T involved sensitivity studies to examine key risks to market benefits. This is essential, given the need to plan and recommend investment in an industry in

[33] Steady state operating condition with the power system in a secure operating state.

[34] The unexpected disconnection of one operating generating unit, or the unexpected disconnection of one major item of transmission plant (such as transmission line, transformer or reactive plant).

[35] 2018 ISP modelling database, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/ISP-database.

[36] Refer to footnote 34.

[37] See http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2016/Constraint_Formulation_Guidelines_v10_1.pdf.

transition where there is a level of inherent uncertainty. The description and purpose of each sensitivity study is described below:

1. No interconnector augmentations – this sensitivity was modelled together with the Neutral scenario, to assess the impact on net market benefits if none of the projected interconnector augmentations proceed.
2. Committed generation only – this sensitivity was modelled together with the Neutral scenario, to assess the impact on net market benefits with only committed generators in Victoria. Modelled generators in other states as well as interconnectors were left in the model to prevent excessive unserved energy.
3. Early coal retirement – this sensitivity was modelled together with the Neutral scenario, to assess the impact on net market benefits, if brown coal generation in Victoria retired earlier than assumed in the ISP.
4. Change in cost – change cost by ±30% and assess impact on net market benefits and the preferred option.
5. Change in discount rate – change discount rate by ±2.5% and assess impact on net market benefits and the preferred option.
6. Change in scenario weightings – change scenario weightings as described in Table 5 (in Section 5.2.4) and assess impact on net market benefits and the preferred option.

5.5 Cost estimate methodology

Cost estimates for the different types of credible options were estimated in different ways:

1. Minor network augmentations – costs were obtained from AusNet Services.
2. Network options – the cost of each option was estimated by requesting quotes from three different vendors, and AusNet Services, for transmission line works, which are the main cost component.
3. Non-network options – the cost estimates were derived from the ISP's modelling assumptions[38].

Costs for each option were varied by ±30% to test the robustness of the market benefits.

5.5.1 Cost estimate of network options

The cost of each option was estimated by obtaining quotes from three different vendors, and AusNet Services, for transmission line works, which are the main cost component. In addition, AusNet Services provided the following costs:

- Contracts (sub-contracting).
- Administration and overheads.
- Project management.
- All station upgrade works, including:
  - Plant and equipment.
  - Civils.
  - Internal labour.
- Division of costs between capital expenditure and operating expenditure.

The construction costs above have an accuracy of ±30%.

The cost of easements was estimated on the basis of estimated land values.

Table 7 shows the cost estimates for all credible options received from different parties. The average cost has been applied for cost benefit assessments.

[38] Refer to the tab "Build cost" at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/2018-Integrated-System-Plan--Modelling-Assumptions.xlsx.

Table 7 Cost estimates of each option from different parties

Option Name	Average capital cost, $M (used in NPV calculations)	Capital cost - AusNet Services estimate, $M	Capital cost - Vendor A estimate, $M	Capital cost - Vendor B estimate, $M	Capital cost - Vendor C estimate, $M	Operating costs (as a percentage of capital costs)
Option B2	406	432	393	364	436	0.6%
Option B3	340	359	330	308	361	0.6%
Option B4*	303	311	300	291	311	0.6%
Option C1	287	330	284	245	289	0.7%
Option C1 Snowylink component	156	184	154	128	157	
Option C2	203	215	197	183	217	0.9%
Option C2 Snowylink component	296	332	293	260	297	

* Cost estimates do not include outage costs. Outage costs were considered in the overall net market benefit assessment for this option (see below).

Should any of the augmentations comprising the preferred option be contestable, the final costs will be determined through a procurement process under the NER, after the publication of the PACR.

5.5.2 Cost estimate of outages

Option B4 involves decommissioning the single circuit 220 kV transmission lines between Ballarat to Bulgana and rebuilding them as new double circuit lines. This option will require significant additional transmission network outages in comparison with the other assessed options.

The cost of outages (refer to Table 8) were assessed assuming:

- A total of 222 days of outages will be required over a four-year period, which is 15% of a year (based on construction staging and timing information provided by AusNet Services that accounts for rebuilding a portion of the towers in-situ and accounts for time required to reconstruct towers and install new conductor and fittings).
- All the generation between Ballarat to Bulgana would be switched out of service during construction.
- The cost of outages is the difference between the modelled generation cost and the generation cost in the Do Nothing base case.
- 15% of the total outage cost is applied to the option cost.

This outage cost is assumed to represent the cost to the market from losing access to cheaper generation sources, that is replaced with more expensive generation.

Table 8 Outage cost for implementing Option B4

Year	Outage cost, $M
2020	-
2021	13.26
2022	16.02
2023	19.64
2024 (commissioning year)	14.49

6. Detailed option assessment

The primary sources of net market benefits are in capital investment savings and fuel cost savings.

6.1 Classes of market benefits not expected to be material

Chapter 8 of the PSCR[39] identified classes of market benefits that were not expected to be material to this RIT-T. A class of market benefit is considered immaterial if either:

- The class is likely not to affect materially the assessment outcome of the credible options for this RIT-T, or
- The estimated cost of undertaking the analysis to quantify market benefits of the class is likely to be disproportionate to the scale, size, and potential benefits of each credible option being considered.

The class of market benefit for "differences in the timing of transmission investment" was assumed to be immaterial in the PSCR, but is now considered material, because the outcome from this RIT-T is likely to affect the timing of other planned transmission investments in Victoria. This class of market benefit is discussed in Section 6.2.3.

AEMO did not receive any PSCR submissions on the materiality of the market benefits listed below, and therefore has continued to exclude them in this PADR assessment. The classes of market benefits that are considered immaterial are:

- Changes in ancillary services costs – there is no expected change to the costs of FCAS, Network Control Ancillary Services (NCAS), or System Restart Ancillary Services (SRAS) because of the options being considered. These costs are therefore not material to the outcome of the RIT-T assessment.
- Changes in voluntary/involuntary load curtailment – this RIT-T is driven by new generation connections and there is no expected change to voluntary or involuntary load curtailment because of the options being considered.
- Competition benefits – there are no material competition benefits expected as a result of augmentations proposed by this PADR, because Victoria currently has multiple different generation service providers and is connected to the NEM via three interconnectors. The options proposed in this RIT-T do not impact interconnector limits and are unlikely to impact competition benefits in other states either.

6.1.1 Classes of market benefit that are no longer material in the PADR

This section describes the classes of market benefits which were initially assumed to be material in the PSCR, but were subsequently found to be immaterial, after being explored in the PADR.

[39] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2017/Western-Victoria-Renewable-Integration---Project-Specification-Consultation-Report_FINAL.pdf.

Negative of any penalty for not meeting the renewable energy target

The 2030 climate change target and VRET target of at least 40% renewable generation by 2025 were met in the Do Nothing case for all credible scenarios. Therefore, this class of market benefit is not material to the PADR. Table 9 shows annual Victorian generation in the 2025 financial year for the Do Nothing case in gigawatt hours (GWh), and shows that the VRET is met for all credible scenarios.

Table 9 Annual Victorian generation (GWh), in the Do Nothing base case, 2025

Victoria generation	Neutral	Neutral with storage initiatives	Fast change	Slow change
Brown coal VIC	29,769	29,800	30,368	27,317
Natural gas VIC	71	87	214	6
Existing wind VIC	7,262	7,261	7,308	6,959
Modelled wind and solar VIC	10,757	10,752	10,782	9,683
Hydro VIC	3,207	3,198	3,114	3,103
Rooftop photovoltaics (PV)	3,932	3,932	3,932	3,932
% renewable generation	45.7%	45.7%	45.1%	46.4%

Changes in network losses

Market modelling shows that network losses increase over time, however this is largely due to renewable generation development in remote areas. The options proposed in this PADR do not have a material impact on network losses.

Any additional option value

No additional option value benefits were identified in this PADR. The estimation of option value benefit over and above that already captured via scenario analysis would require a significant modelling assessment, which would be disproportionate to any additional option value benefit that may be identified.

6.2 Quantification of classes of material market benefit for each credible option

The classes of market benefits/costs that are material in the case of this RIT-T are:

- Changes in fuel consumption arising through different patterns of generation dispatch.
- Differences in the timing of transmission investment.
- Changes in cost to parties other than the TNSP, due to:
  - Differences in the timing of the installation of new plant.
  - Differences in capital costs of different plant.
  - Differences in the operational and maintenance costs of different plant.

The next sections further describe the main market benefits of each credible option.

6.2.1 Changes in fuel consumption

AEMO calculated the difference in total generation costs between the Do Nothing base case and cases with each of the credible options in place. If cases with the credible option in place have a lower total generation cost than the Do Nothing case, then the market benefit is positive.

Generation costs include fuel consumption cost, variable operation and maintenance cost, and any emissions costs. Generation costs are calculated for the entire NEM and will therefore capture benefits to states other than Victoria.

The PLEXOS® model is optimised to always identify the least-cost generation dispatch.

6.2.2 Changes in costs for other parties

Changes in costs for other parties are the primary source of market benefit identified in this RIT-T. "Other parties" in the context of this analysis refers mainly to costs incurred by market participants[40] due to:

- Differences in the timing of the installation of new generation – where the deferral of capital investments is a positive market benefit.
- Differences in the capital cost of generation investment – where reducing costs is a positive market benefit.

AEMO modelled the least-cost generation expansion required to meet customer demand under various scenarios, using the Capacity outlook model described in Section 5.3.1. The modelling showed that transmission network augmentations in Victoria tended to result in a lower-cost generation expansion plan, due to:

- Deferral of new generation capacity built.
- Reducing the total MW capacity of new generation built.

The difference between capital costs under the Do Nothing base case and the credible option cases represents the market benefits of the proposed option. Refer to Appendix A5.1 for further information on the capital cost savings identified in this PADR.

6.2.3 Differences in the timing of transmission investment

AEMO's ISP identified that transmission augmentation from Sydenham to Ballarat to Kerang to Darlington Point in New South Wales will be required by 2035. Part of this augmentation is within the study area of this RIT-T. Therefore, the 500 kV Category C options in this RIT-T consider the benefits of reducing the future cost of Snowylink, compared to the 220 kV options, in meeting the identified need of this RIT-T.

This RIT-T does not have any impact on known transmission network replacement projects in Victoria.

6.2.4 System strength improvements

All the new transmission lines proposed in this RIT-T will increase fault levels at the terminal stations they are connecting to, and therefore increase system strength. These benefits have not been quantified in the PADR.

6.3 Net market benefit assessment

6.3.1 Net market benefits of minor network augmentations

The net market benefits of minor network augmentations are assessed, assuming a Neutral, Do Nothing scenario. Other scenarios and sensitivities were not assessed because the total cost of the minor augmentations is below the RIT-T threshold of $6 million, and the full range of market modelling would require a level of analysis that is disproportionate to the scale and likely impact of the option being considered.

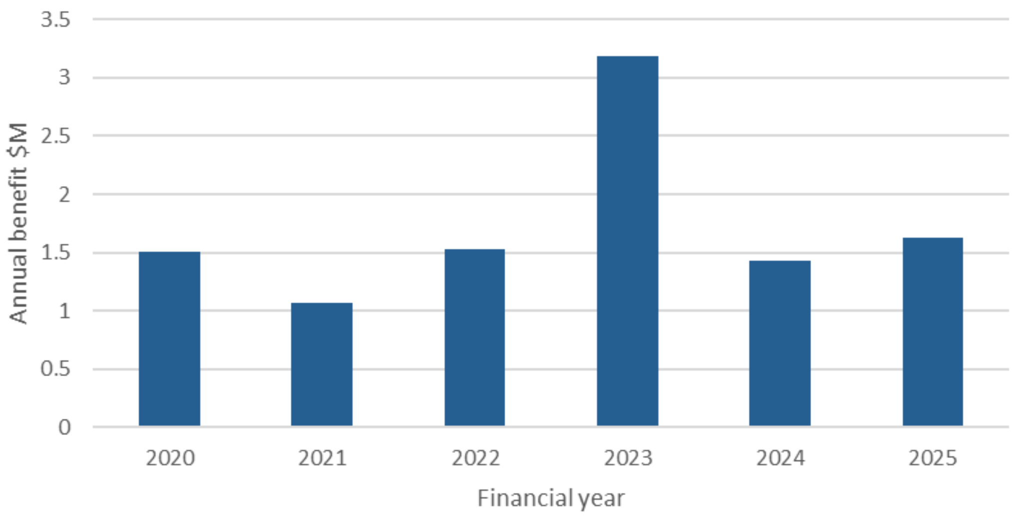
Figure 5 shows the gross market benefits of implementing the uncommitted minor network augmentations identified in Table 3. The market benefits of augmentation are projected to increase in 2023, due to the connection of new wind generation in Victoria. The minor augmentations have a total cost of approximately

[40] Parties other than AEMO in its capacity as one of the Victorian TNSPs.

$5.5 million. If these upgrades can be deployed by 2020, it will return a net market benefit of $1.7 million. If these upgrades are deployed in 2021, it will return a net market benefit of $1 million.

AEMO recommends proceeding with these upgrades as soon as practicable.

Figure 5 Gross market benefits for minor augmentations



6.3.2 Net market benefits of major network augmentations

Table 10 presents the net market benefits for each major augmentation option, under each reasonable scenario. The results presented in this chapter only show the outcomes assuming an equal scenario weighting. Refer to Attachment 2 – market benefits calculator, and Attachment 3 – market benefits sensitivities calculator for net market benefits under each assessed sensitivity.

All uncommitted minor augmentations identified in Table 3 (in Section 3.3) have already been applied to the Do Nothing base cases, to prevent double counting the market benefits.

Refer to Appendix A5 for a more detailed breakdown of fuel and capital cost savings for each year.

Table 10 Weighted net market benefits for each augmentation option and reasonable scenario

Option	Description	Cost, $M (2018-19)	Neutral, $M	Neutral with storage initiatives, $M	Slow change, $M	Fast change, $M	Weighted benefit, $M (NPV)
Scenario weighting			25%	25%	25%	25%	
A1	Minor augmentations for the 220 kV lines at Red Cliffs to Wemen to Kerang to Bendigo; and Ballarat to Moorabool to Terang.	5.5	1				1

Option	Description	Cost, $M (2018-19)	Neutral, $M	Neutral with storage initiatives, $M	Slow change, $M	Fast change, $M	Weighted benefit, $M (NPV)
B2	• Construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana to Horsham. • Retire Ballarat to Moorabool 220 kV circuit No. 1, and cut in Ballarat to Moorabool 220kV circuit No. 2 at Elaine. • Allow sufficient powerflow controllers to manage transmission line flows between Ballarat to Bulgana to Horsham.	406	13	-25	-14	81	14
B3	• Construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana. • Retire Ballarat to Moorabool 220 kV circuit No. 1, and cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine. • Allow sufficient powerflow controllers to manage transmission line flows between Ballarat to Bulgana.	340	68	22	44	134	67
B4	• Rebuild existing Moorabool to Elaine to Ballarat to Bulgana single circuit 220 kV transmission line as a 220 kV double circuit transmission line. • Retire the existing Moorabool to Ballarat to Bulgana 220 kV transmission lines to enable existing easement to be re-used for a new double circuit line. Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine. • Dynamic reactive compensation required to manage voltages.	367	57	9	30	133	57
C1	• Construction of a new 500 kV double circuit line from Sydenham to Ararat. • 2 x 1,000 MVA 500/220 kV transformers at Ararat • Allow for line switched reactors for the 500 kV transmission lines. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine.	443	65	19	38	135	64

Option	Description	Cost, $M (2018-19)	Neutral, $M	Neutral with storage initiatives, $M	Slow change, $M	Fast change, $M	Weighted benefit, $M (NPV)
C2	• Potentially establish a new terminal station close to Ballarat, with 2 x 1,000 MVA 500/220 kV transformers. AEMO's assessment is based on a new North Ballarat Terminal Station, located approximately 25km from Ballarat, with a 220 kV double circuit connection to Ballarat Terminal Station. This new station is referred to as Ballarat in the rest of the option description. • Construction of a new 500 kV double circuit line from Sydenham to Ballarat. • Allow for line switched reactors for the 500 kV transmission lines. • Construction of a new 220 kV double circuit line from Ballarat to Bulgana. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine. • Allow sufficient powerflow controllers to manage transmission line flows between Ballarat to Bulgana.	499	80	34	53	150	79
E1	Battery at Ararat Terminal Station	117	-74	-72	-98	-60	-76

Option B2, B3, and B4

Option B2 has an additional transmission network augmentation between Bulgana and Horsham, compared with Options B3 and B4. The results show that the cost associated with this additional augmentation is higher than the market benefits it provides.

Option B4 is a rebuild of the existing Moorabool to Elaine to Ballarat to Bulgana single circuit 220 kV transmission line as a 220 kV double circuit transmission line. This option has a lower net market benefit compared to Option B3 because it results in less transmission network capacity in the path between Ballarat to Bulgana. In addition, Option B4 has high outage costs over its four-year construction period, which leads to a higher total construction cost.

Overall, Option B3 has higher net market benefits than Option B2 and Option B4, due to its lower cost and higher gross benefit delivered.

Option C1 and C2

Option C1 is a 500 kV augmentation from Sydenham to Ararat, while Option C2 is a 500 kV augmentation from Sydenham to Ballarat and a 220 kV augmentation from Ballarat to Bulgana.

Option C1 has a slightly lower cost because it avoids highly built up areas around Ballarat Terminal Station. Option C2 assumes that a new terminal station will need to be established close to the existing Ballarat Terminal Station to accommodate new 500/220 kV transformers and other 500 kV switchgear.

Option C2 has a higher net market benefit because it supports a greater proportion of the new Snowylink interconnector proposed by the ISP than Option C1.

For the NPV analysis, Option C1 and C2 were assumed to be delivered one year after Option B2, B3, and B4 above, because of additional complexities associated with building 500 kV transmission lines.

Option E1

AEMO assessed the benefit of connecting a 100 MW/400 MWh battery storage system at Ararat Terminal Station, Horsham Terminal Station, and Red Cliffs Terminal Station. Of these three locations, the battery at Ararat Terminal Station had the highest net market benefits, and these results are presented in the PADR.

This option was assumed to provide no capital cost savings, and market benefits are derived from fuel cost savings only. This is because the amount of avoided spilled generation is small compared to the network options assessed. The capital cost of installing a battery is annualised over 10 years and there are no further capital costs assumed beyond this time period. The battery is assumed to have a 15-year asset life.

Preferred option

Option B3 and C2 provide the highest net market benefits for Western Victoria of all major network augmentations considered. Both options were selected for further sensitivity testing, as described in Section 6.3.3.

Option C2 has higher net market benefits than Option B3 because it does not increase the transmission line loading on the Moorabool to Geelong to Keilor lines, and because it supports the development of the future Snowylink interconnector.

Option C2 provides the highest net market benefits of all major network options considered under all reasonable scenarios assessed.

Refer to Appendix A5 for a more detailed discussion on the net market benefits for each option.

6.3.3 Sensitivity studies

Sensitivity analysis was carried out to test the robustness of the analysis resulting in the preferred option and to determine if any factors will change the order of the credible options assessed:

- Change in scenario weightings – scenario weightings were changed as described in Table 5 (in Section 5.2.4). The preferred option does not change, and weighted net market benefits remain positive. These scenario weightings are applied in Table 11, Table 12, Table 13, and Table 14.
- Change in cost – costs were changed by ±30%. The preferred option does not change, and average weighted net market benefits remain positive, although the net market benefit in the Neutral with storage scenario is marginally negative for all PADR options. These results are shown in Table 11 and Table 12.
- Change in discount rate – the discount rate was changed by ±2.5%. The preferred option changes from Option C2 to Option B3 if the discount rate increases by 1.5% or more. A decrease in discount rate does not change the preferred option. These results are shown in Table 13 and Table 14.

Table 11 Net market benefits after increasing cost by 30%

Scenario weightings	Option B3, $M	Option C2, $M
Set A - all equal	-12	6
Set B – Neutral	-25	-8
Set C – Fast Change	2	20
Set D – Slow Change	-16	0

Table 12 Net market benefits after decreasing cost by 30%

Scenario weightings	Option B3, $M	Option C2, $M
Set A - all equal	146	153
Set B – Neutral	133	140
Set C – Fast Change	159	167
Set D – Slow Change	141	148

Table 13 Net market benefits after increasing discount rate by 2.5% - preferred option changes

Scenario weightings	Option B3, $M	Option C2, $M
Set A - all equal	13	7
Set B – Neutral	6	-0
Set C – Fast Change	19	12
Set D – Slow Change	12	6

Table 14 Net market benefits after decreasing discount rate by 2.5%

Scenario weightings	Option B3, $M	Option C2, $M
Set A - all equal	172	218
Set B – Neutral	146	191
Set C – Fast Change	202	251
Set D – Slow Change	159	203

Following the initial round of sensitivity studies, only Options B3 and C2, which provide the highest net market benefits of all the major options considered, were chosen for additional sensitivity analysis.

The additional analysis tested:

- No interconnector augmentations – this sensitivity was modelled together with the Neutral scenario, to assess the impact on net market benefits if none of the projected interconnector augmentations proceed.
- Committed generation only – this sensitivity was modelled together with the Neutral scenario, to assess the impact on net market benefits with only committed generators in Victoria. Modelled generators in other states as well as interconnectors were left in the model to prevent excessive unserved energy.
- Early coal retirement – this sensitivity was modelled together with the Neutral scenario, to assess the impact on net market benefits, if brown coal generation in Victoria retired earlier than projected by the ISP.

As Table 15 shows, both options provide net market benefits under the assessed sensitivities. Option B3 provides higher net market benefits if all interconnector augmentations are removed. However, if brown coal in Victoria retires early, this may bring forward the Snowylink interconnector upgrade identified in the ISP, and Option C2 will provide higher net market benefits.

Table 15 Net market benefits of additional sensitivity studies

Option	Description	Neutral $M (base for comparison)	No interconnector augmentations	Committed generation only	Early coal retirement
Option B3	• Construction of a new 220 kV double circuit line from Moorabool to Elaine to Ballarat to Bulgana. • Retire Ballarat to Moorabool 220 kV circuit No. 1, and cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine. • Allow sufficient powerflow controllers to manage transmission line flows between Ballarat to Bulgana.	67	110	117	59
Option C2	• Potentially establish a new terminal station close to Ballarat, with 2 x 1,000 MVA 500/220 kV transformers. AEMO's assessment is based on a new North Ballarat Terminal Station, located approximately 25km from Ballarat, with a 220 kV double circuit connection to Ballarat Terminal Station. This new station is referred to as Ballarat in the rest of the option description. • Construction of a new 500 kV double circuit line from Sydenham to Ballarat. • Allow for line switched reactors for the 500 kV transmission lines. • Construction of a new 220 kV double circuit line from Ballarat to Bulgana. • Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine. • Allow sufficient powerflow controllers to manage transmission line flows between Ballarat to Bulgana.	79	9	123	163

6.3.4 Timing of preferred option

The optimal timing for Option A1 is 2020. The individual projects in Option A1 have a lead time of between 12-18 months. Therefore, some augmentations may only be commissioned in 2021. AEMO has assumed that the minor augmentations will only be delivered in 2021 in its NPV analysis, but will continue to progress these projects as soon as practicable.

Market modelling shows that the optimal timing of the preferred major network option is around 2024. Further information is available in Appendix A5.4.

However, this timing may not be practically achievable. The practical timing of the preferred major network option is assumed to be 2025 and subject to time required for relevant easement acquisition and the planning/environmental approval processes.

7. Proposed preferred option

The proposed preferred option includes the following augmentations:

- Minor upgrades for the transmission lines between Red Cliffs to Kerang to Bendigo, and between Moorabool to Terang to Ballarat.
- A new Sydenham to Ballarat[41] 500 kV double circuit transmission line.
- A new Ballarat to Bulgana 220 kV double circuit transmission line with sufficient power flow controllers to manage transmission line flows between Ballarat and Bulgana.
- Two new 1,000 MVA 500/220 kV transformers at Ballarat.

This option returns the highest net market benefits under all assessed scenarios and most sensitivities.

The preferred option also supports the future efficient development of the grid including a future new Victoria to New South Wales interconnector, consistent with the 2018 ISP.

7.1 Preferred option

The NER requires the PADR to identify the preferred option under the RIT-T, which should be the credible option with the greatest net market benefit.

The RIT-T analysis (discussed in Chapter 6) indicates that Option C2 (Construction of new double circuit 500 kV transmission line from Sydenham to Ballarat, and a new 220 kV double circuit line from Ballarat to Bulgana), together with minor transmission line upgrades in Option A1, have the highest net market benefits weighted across all reasonable scenarios and also under most sensitivities. Accordingly, together, these augmentations constitute the proposed preferred option and satisfy the *regulatory investment test for transmission*.

The proposed preferred option is consistent with the recommendations of the 2018 ISP and is estimated to deliver net market benefits of $80 million (in present value terms), through significant reductions in the capital cost and dispatch cost of generation over the longer term. The total capital cost, through the staged implementation process outlined above, is estimated at $370 million (in present value terms).

The optimal timing for Option A1 is 2020, but the practical timing of some of the identified minor augmentations may be 2021.

The practical timing of the major network augmentations is assumed to be 2025 and subject to time required for relevant easement acquisition and the planning/environmental approval processes.

[41] Initial assessment has indicated that there may be insufficient space in Ballarat Terminal Station for the proposed 500 kV plant. AEMO have assumed that a new terminal station, called North Ballarat Terminal Station, will be established close to Ballarat in its assessments.

The technical characteristics of the proposed preferred option, and the augmentations comprising it, are set out in Appendix A6.

7.2 Other issues

Other factors that may increase the benefit of the preferred option relative to other options, which have been considered but have not been quantified in this PADR, are:

- Future maintenance requirements – connection at Sydenham Terminal Station will provide Western Victorian and Moyne generation with three 500 kV transmission lines to the Melbourne load centre. This means Option C2 will significantly reduce the impact of planned transmission outages for the Sydenham to Moorabool No. 1 or No. 2 500 kV transmission line, and the Moorabool A1 or A2 500/220 kV transformer. With option B3, any one of the outages above may require curtailment of a large amount of generation connected to the Western Victoria or Moyne REZ.
- Diversity of supply – the proposed preferred option provides more diversity in the transmission path between Ballarat to Moorabool and could mitigate against High Impact Low Probability (HILP) events such as a bushfire.
- Future-proofing – the proposed preferred option involves building a new Ballarat to Bulgana 220 kV double circuit transmission line, parallel to the existing Ballarat to Bulgana 220 kV transmission line. If the number of generation connections continue to increase in future, the existing Ballarat to Bulgana 220 kV transmission line may be rebuilt as a new double circuit line or restrung with high capacity conductor to enable further transmission network capacity if it is economic to do so, while minimising construction outages, compared to Option B4.
- Increase in land value – the ISP identified a need for a new Victoria to New South Wales interconnector (Snowylink) by 2035, a portion of which includes the corridor between Ballarat and Sydenham. While the interconnector route is still subject to change, it must provide a connection to the Victorian load centre.

  Waiting until 2035 to obtain easements and planning/environmental approvals between Ballarat and Sydenham Terminal Stations may present challenges in future as these areas become more built up and land values increase. Bringing forward the Ballarat to Sydenham component of the Snowylink interconnector will result in higher capital costs, however this increase is likely to be less than the increase in land values in this corridor if the augmentation is progressed at a later date.

7.3 Conclusion

The overall findings in this RIT-T assessment are consistent with AEMO's conclusion in the 2018 ISP that an upgrade to the Western Victorian transmission network is an important element of the long-term strategic development of the NEM and, as one of its immediate priorities, would unlock renewable generation in the region and help to reduce the cost of electricity for consumers in the long term.

A1. Renewable energy zones in Victoria

The 2018 ISP identified the following candidate REZs in Victoria.

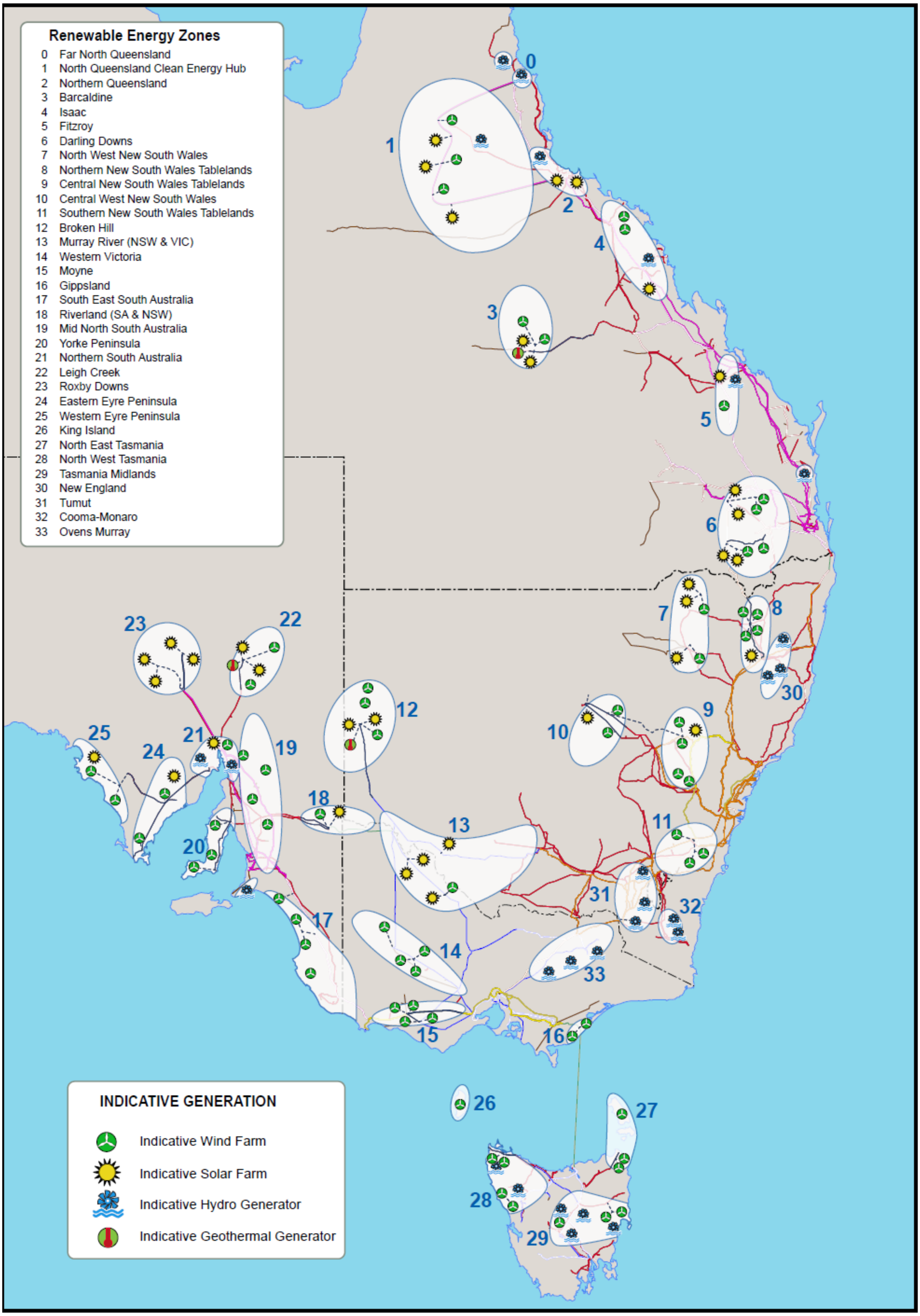
- The Murray River REZ is the only Victorian REZ with high quality solar resources.
- The Western Victoria, Moyne, and Gippsland REZs have wind resources, however, Gippsland wind resources are primarily offshore, leading to high generation development cost.
- The Ovens Murray REZ is suitable for pumped hydro generation.

Table 16 and Figure 6 (from the ISP) below show the resource availability and approximate locations of REZs in Victoria.

Table 16 Renewable energy zones in Victoria

REZ number (in Figure 6)	REZ name	NEM region	Solar resource availability	Wind resource availability	Pumped hydro resource availability
13	Murray River (Vic)	Vic	Yes	Yes	No
14	Western Victoria	Vic	No	Yes	No
15	Moyne	Vic	No	Yes	No
16	Gippsland	Vic	No	Yes	No
33	Ovens Murray	Vic	No	No	Yes

Figure 6 Candidate REZs in the NEM



A2. New committed generation

Table 17 shows newly committed generators in Western Victoria since the publication of the PSCR[42]. Modelled Victorian generation is shown in Attachment 1 - generation expansion plans. The total generation in Victoria is the sum of modelled generation and committed and existing generation.

Table 17 New committed generation

Name	Network	Generation Type	Capacity (MW)	REZ
Ballarat Energy Storage System	Transmission	Storage	30	Western Victoria
Bannerton Solar Farm	Distribution	Solar	88	Murray River
Bulgana Wind Farm	Transmission	Wind	204	Western Victoria
Bulgana Energy Storage	Transmission	Storage	21	Western Victoria
Crowlands Wind Farm	Transmission	Wind	80	Western Victoria
Gannawarra Solar Farm Stage 1	Distribution	Solar	50	Murray River
Gannawarra Energy Storage System	Distribution	Storage	25	Murray River
Karadoc Solar Farm	Distribution	Solar	90	Murray River
Kiata Wind Farm	Distribution	Wind	30	Western Victoria
Lal Lal Wind Farm Elaine	Transmission	Wind	79	Western Victoria
Moorabool Wind Farm	Transmission	Wind	320	Western Victoria
Mount Gellibrand Wind Farm	Distribution	Wind	132	Moyne
Murra Warra Wind Farm	Transmission	Wind	226	Western Victoria
Salt Creek Wind Farm	Distribution	Wind	54	Moyne
Stockyard Hill Wind Farm	Transmission	Wind	532	Moyne
Wemen Solar Farm	Distribution	Solar	88	Murray River
Yatpool Solar Farm	Distribution	Solar	81	Murray River

[42] New committed generation up to July 2018, from AEMO generation information page. Available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.

A3. Victorian transmission network limitations

A3.1 Western Victoria corridor

A3.1.1 Existing transmission lines

Horsham to Ararat to Waubra to Ballarat is a single circuit 220 kV transmission line. The contingency that results in the highest thermal overloads (also called the critical contingency) is generally a trip of the Horsham to Red Cliffs 220 kV transmission line. There is no existing wind monitoring along this line, and this line is currently limited by some station equipment[43]. The table below shows the thermal rating of the line, assuming station limiting equipment has been upgraded, with and without wind monitoring being enabled.

Table 18 Horsham to Ararat to Waubra to Ballarat 220 kV line rating (MVA)

Ambient temperature, °C	Continuous rating without wind monitoring, MVA	Continuous rating with wind monitoring, MVA	15 min rating without wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	589.97	661.40	615.64	695.17
10.0	567.74	636.47	592.44	668.97
15.0	544.59	610.53	568.29	641.70
20.0	520.42	583.43	543.06	613.21
25.0	495.07	555.00	516.61	583.34
30.0	468.34	525.05	488.72	551.85
35.0	440.00	493.27	459.14	518.46
40.0	409.70	459.30	427.53	482.76
45.0	376.98	422.62	393.38	444.19

The existing Ballarat to Moorabool path has three 220 kV circuits, including a circuit from Ballarat to Elaine to Moorabool. The Ballarat to Moorabool No. 1 220 kV circuit has a lower rating than the Ballarat to Moorabool No. 2 220 kV circuit and the Ballarat to Elaine to Moorabool circuit No. 3 220 kV circuit. This transmission line (all three circuits) has wind monitoring enabled, and periods of high wind on the transmission lines are assumed to coincide with periods of high wind generation. The transmission line ratings are shown in the following two tables.

[43] These limitations will be addressed by the augmentations described in Chapter 3.3.

Table 19 Ballarat to Moorabool 220 kV No. 1 circuit rating (MVA)

Ambient temperature, °C	Continuous rating with wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	472.32	535.27
10.0	448.62	508.41
15.0	423.59	480.05
20.0	396.99	449.90
25.0	368.48	417.59
30.0	337.56	382.55
35.0	303.51	343.96
40.0	265.12	300.45
45.0	220.14	249.48

Table 20 Ballarat to Moorabool 220 kV No. 2 and Ballarat to Elaine to Moorabool circuits rating (MVA)

Ambient temperature, °C	Continuous rating with wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	669.67	711.47
10.0	645.06	685.55
15.0	619.47	658.62
20.0	592.78	630.53
25.0	564.83	601.14
30.0	535.42	570.23
35.0	504.30	537.54
40.0	471.13	502.74
45.0	435.44	481.63

The existing Horsham to Red Cliffs line is a single circuit, 276.89 km 220 kV transmission line. There are unlikely to be any net market benefits in major upgrades of this line, due to the high cost of such an upgrade, and because there are less generator connection applications along the middle of this line, relative to the other transmission lines being assessed. The transmission line rating is provided in the table below. Increased import into Red Cliffs from Buronga will increase the flow on this line.

Table 21 Red Cliffs to Horsham 220 kV line rating (MVA)

Ambient temperature, °C	Continuous rating without wind monitoring, MVA	Continuous rating with wind monitoring, MVA	15 min rating without wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	471.39	528.46	516.39	596.85
10.0	453.75	508.69	497.07	574.52
15.0	435.40	488.12	476.97	551.29
20.0	416.25	466.64	455.99	527.04
25.0	396.16	444.13	433.99	501.61
30.0	375.01	420.41	410.81	474.82
35.0	352.59	395.28	386.25	446.43
40.0	328.64	368.43	360.01	416.11
45.0	302.80	339.46	331.71	383.40

A3.1.2 Other transmission lines affected by generation development in the Western Victoria corridor

Ballarat to Bendigo is a single circuit 220 kV transmission line. At lower temperature this transmission line is limited by its protection rating. This is not expected to cause any market impact or unserved energy, and there are no committed plans to upgrade this protection limit. The critical contingency is generally a trip of the Bendigo to Fosterville to Shepparton 220 kV transmission line. Wind monitoring is available. This line may constrain flows north under system normal conditions, when there is high wind, but low solar generation output and high demand. The transmission line rating is shown in the table below.

Table 22 Ballarat to Bendigo 220 KV line rating (MVA)

Ambient temperature, °C	Continuous rating with wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	442.11	442.11
10.0	442.11	442.11
15.0	423.59	442.11
20.0	396.99	442.11
25.0	368.48	419.15
30.0	337.56	383.98
35.0	303.51	345.24
40.0	265.12	301.58
45.0	220.14	250.41

A3.2 Moyne corridor

A3.2.1 Existing transmission line

Terang to Moorabool is a single circuit 220 kV transmission line. The critical contingency is generally a trip of the Ballarat to Terang 220 kV line. There is no existing wind monitoring along Terang to Moorabool, and the transmission line ratings in Table 23 apply.

Table 23 Terang to Moorabool line rating (MVA)

Ambient temperature, °C	Continuous rating without wind monitoring, MVA	15 min rating without wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	420.81	480.72	512.13
10.0	399.69	456.59	495.77
15.0	377.39	431.12	478.84
20.0	353.69	404.05	460.77
25.0	328.28	375.03	427.68
30.0	300.74	343.56	391.79
35.0	270.40	308.90	352.27
40.0	236.20	269.83	307.71
45.0	196.12	224.05	255.50

Ballarat to Terang is a single circuit 220 kV transmission line. The critical contingency is generally a trip of the Terang to Moorabool line. There is no existing wind monitoring along Ballarat to Terang, and the transmission line ratings in Table 24 apply.

Table 24 Ballarat to Terang line rating (MVA)

Ambient temperature, °C	Continuous rating without wind monitoring, MVA	15 min rating without wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	455.36	473.08	559.80
10.0	439.13	455.38	538.86
15.0	422.27	436.97	517.07
20.0	404.72	417.74	494.32
25.0	386.36	397.59	470.47
30.0	367.09	376.36	445.35
35.0	346.76	353.85	418.72
40.0	325.15	329.82	390.28
45.0	302.00	303.89	359.60

A3.3 Murray River corridor

A3.3.1 Existing transmission lines in the Murray River corridor

The Red Cliffs to Wemen to Kerang line is a single circuit 220 kV transmission line with a 55˚C design temperature. During periods of high ambient temperature, transmission line rating degrades severely. The critical contingency is generally a trip of the Horsham to Red Cliffs 220 kV line.

Table 25 below shows the thermal rating of the line, if station limiting equipment has been upgraded, both with and without wind monitoring.

Table 25 Red Cliffs to Wemen to Kerang overhead line rating (MVA)

Ambient temperature, °C	Continuous rating without wind monitoring, MVA	15 min rating without wind monitoring, MVA	Continuous rating with wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	494.67	528.12	555	596
10.0	464.52	495.93	521	559
15.0	432.26	461.49	485	521
20.0	397.40	424.27	446	479
25.0	359.17	383.46	403	433
30.0	316.35	337.74	355	381
35.0	266.75	284.79	299	321
40.0	205.50	219.39	230	248
45.0	115.35	123.15	129	139

Bendigo to Kerang is a single circuit 220 kV transmission line. The critical contingency is generally a trip of the Ballarat to Bendigo 220 kV line. Table 26 below shows the thermal rating of the line, if station limiting equipment has been upgraded, but with no wind monitoring.

Table 26 Kerang to Bendigo overhead line rating (MVA)

Ambient temperature, °C	Continuous rating without wind monitoring, MVA	15 min rating without wind monitoring, MVA
5.0	463.64	550.22
10.0	446.29	529.64
15.0	428.25	508.22
20.0	409.40	485.86
25.0	389.65	462.42
30.0	368.84	437.72
35.0	346.79	411.55
40.0	323.24	383.60
45.0	297.82	353.44

A3.3.2 Existing transmission lines outside Murry River corridor affected by generation development in the Murray River corridor

Bendigo to Fosterville to Shepparton is a single circuit line. High generation output from the Murray River corridor together with high export to NSW will increase the flow on this line. Subsequently, this line will be at risk of overloads during system normal conditions. The transmission line rating is provided in the table below.

Table 27 Bendigo to Fosterville to Shepparton line rating (MVA)

Ambient temperature, °C	Continuous rating without wind monitoring, MVA	15 min rating with wind monitoring, MVA
5.0	471.39	535.34
10.0	453.75	515.31
15.0	435.40	494.47
20.0	416.25	472.72
25.0	396.16	449.91
30.0	375.01	425.88
35.0	352.59	400.42
40.0	328.64	373.22
45.0	302.80	343.88

A4. Minor augmentations

A4.1 Committed minor augmentations (part of 2017 NCIPAP)

A4.1.1 Ballarat to Waubra to Ararat to Horsham 220 kV transmission line (BATS–WBTS–ARTS–HOTS)

Project name	Ballarat to Waubra to Ararat to Horsham 220 kV transmission line (BATS–WBTS–ARTS–HOTS)
Project description	AusNet Services has identified constraints/enablers to improve the line rating which is the following: • 1 x Replacement of harp string at HOTS • 1 x Replacement of line traps at HOTS • 1 x Install weather station on first tower outside ARTS • 2 x Install weather station on towers Ratings improvement for this minor augmentation are primarily from removing existing rating limiting station equipment, and enabling dynamic wind monitoring on the transmission lines.
CAPEX cost	$850,000
10-year OPEX cost	$212,897

A4.1.2 Horsham to Red Cliffs 220 kV transmission line (HOTS–RCTS)

Project name	Horsham to Red Cliffs 220 kV transmission line (HOTS–RCTS)
Project description	AusNet Services has identified constraints/enablers to improve the line rating which is the following: • 2 x Replacement of line span and harp string • 2 x Protection modification • 2 x Replacement of line traps • 1 x Install weather station at RCTS • 3 x Install weather station on towers Ratings improvement for this minor augmentation are primarily from removing existing rating limiting station equipment, and enabling dynamic wind monitoring on the transmission lines.
CAPEX cost	$1,450,000
10-year OPEX cost	$293,013

A4.2 Uncommitted minor augmentations (Option A1)

A4.2.1 Kerang to Wemen to Red Cliffs 220 kV transmission line (KGTS–WETS–RCTS)

Project name	Kerang to Wemen to Red Cliffs 220 kV transmission line (KGTS–WETS–RCTS)
Project description	AusNet Services has identified constraints/enablers to improve the line rating: • 2 x Replacement of line span and harp string • Transfer existing COMMS services off Power Line Carrier • 2 x Protection replacement • Remove line traps • 1 x Install weather station at KGTS • 2 x Install weather station on towers Ratings improvement for this minor augmentation are primarily from removing existing rating limiting station equipment.
CAPEX cost	$2,600,000
10-year OPEX cost	$265,563

A4.2.2 Bendigo to Kerang 220 kV transmission line (BETS–KGTS)

Project name	Bendigo to Kerang 220 kV transmission line (BETS–KGTS)
Project description	AusNet Services has identified constraints/enablers to improve the line rating: • 2 x Replacement of line span and harp string • Transfer existing COMMS services off Power Line Carrier • 2 x Protection replacement • Remove line traps • 1 x Install weather station at KGTS • 2 x Install weather station on towers Ratings improvement for this minor augmentation are primarily from removing existing rating limiting station equipment.
CAPEX cost	$1,700,000
10-year OPEX cost	$212,897

A4.2.3 Moorabool to Terang 220 kV transmission line (MLTS–TGTS)

Project name	Moorabool to Terang 220 kV transmission line (MLTS–TGTS)
Project description	AusNet Services has identified constraints/enablers to improve the line rating: • Replacement of a line span • 1 x Install weather station at TGTS • 2 x Install weather station on towers Ratings improvement for this minor augmentation are primarily from enabling dynamic wind monitoring on the transmission lines.
CAPEX cost	$500,000
10-year OPEX cost	$212,897

A4.2.4 Ballarat to Terang 220 kV transmission line (BATS–TGTS)

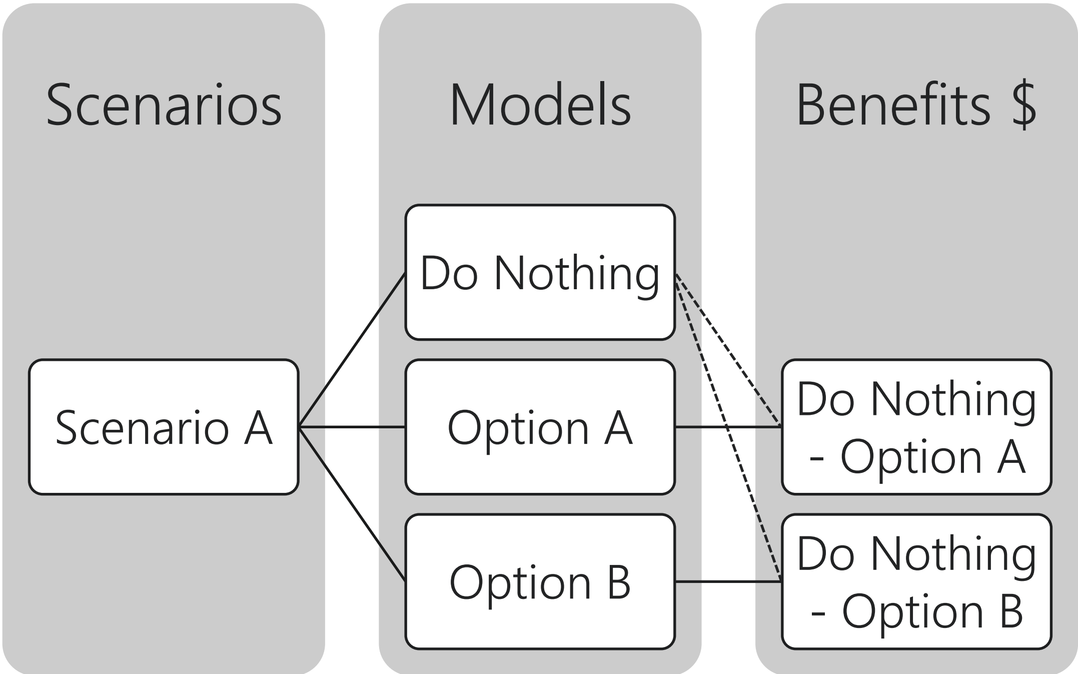
Project name	Ballarat to Terang 220 kV transmission line (BATS–TGTS)
Project description	AusNet Services has identified constraints/enablers to improve the line rating: • 1 x Replacement of line span and harp string at BATS • 2 x Protection modification • 1 x Install weather station at TGTS • 2 x Install weather station on towers Ratings improvement for this minor augmentation are primarily from enabling dynamic wind monitoring on the transmission lines.
CAPEX cost	$700,000
10-year OPEX cost	$212,897

A5. Discussion of market benefits

The general process for identifying market benefits is shown in Figure 7 below. For each scenario, modelling is carried out for a Do Nothing case and a case containing a credible investment option. The difference in costs between the Do Nothing case and credible investment option case represents the benefit of that credible option.

Capital deferral benefits have only been considered up to 2032, after which any differences in generation expansion are assumed to be independent of the augmentations described in this PADR.

Figure 7 Process for identifying market benefits



A5.1 Capital cost savings

Capital cost savings in this RIT-T have been derived from the capacity outlook model described in Section 5.3.1. Three capacity outlook models were developed for each scenario:

- Do Nothing (DN) model – a capacity outlook model was developed assuming no future transmission network investments in Western Victoria, to represent the 'state of the world' in the base case (or 'do nothing' case). New generation connections are limited in the Western Victoria and Murray River REZ, due to existing thermal limitations in the transmission network. Generation expansion in other parts of Victoria and the rest of the NEM can proceed based on least-cost modelling. This model will be referred to as DN in the rest of this Appendix.

- Upgrade Western Victoria (WVic) model – compared to the DN model above, this model identified an economic level of transmission augmentation and generation expansion in the Western Victoria REZ, by paying a "penalty price" for augmentation (that is, cost for generation expansion in Western Victoria = capital cost for new generation + penalty price for developing new transmission infrastructure). The model identified an efficient level of generation expansion in the Western Victoria REZ only, but still limited generation expansion in the Murray River REZ, assuming that transmission investments were limited to the Western Victoria REZ only. Generation expansion in other parts of Victoria and the rest of the NEM can proceed based on least-cost modelling. This model will be referred to as WVic in the rest of this Appendix.
- Upgrade both Western Victoria and Murray River (UpgradeBoth) model – this model identified an efficient level of generation and transmission expansion in both the Western Victoria and Murray River REZs, to represent the 'state of the world' with network investments in Western Victoria and in Murray River (that is, cost for generation expansion in Western Victoria and Murray River = capital cost for new generation + penalty price for developing new transmission infrastructure). Generation expansion in other parts of Victoria and the rest of the NEM can proceed based on least-cost modelling. This model will be referred to as UpgradeBoth in the rest of this Appendix.

The three capacity outlook models above were developed for the following scenarios and sensitivities:

- Neutral.
- Neutral with storage initiatives.
- Slow change.
- Fast change.
- Early coal retirement.

The modelling showed that when comparing the DN scenarios with the scenarios with Victorian augmentations allowed, the generation expansion changes that primarily occur are:

- Changes in the timing and distribution of renewable generation in Victoria.
- Changes in the timing and capacity of new open cycle gas turbine (OCGT) generation in Victoria.
- The DN cases tend to require the highest MW capacity of new renewable generation, when compared to the WVic and UpgradeBoth cases, because when transmission augmentations are allowed, less existing and committed generation is constrained, and hence less modelled generation is required to meet the VRET targets.
- The WVic and UpgradeBoth cases result in a similar MW capacity of renewable generation built, however the UpgradeBoth cases tend to have a lower generation expansion cost, because:
  - Solar generation tends to be cheaper than wind generation based on $/MW.
  - The WVic cases tend to have more OCGT built, due to low generation diversity.
  - The UpgradeBoth cases tend to have less OCGT built, which shows the value of diverse generation sources.
- When the capacity outlook model is allowed to augment the Western Victoria REZ, it tends to shift wind generation capacity from the Moyne REZ to the Western Victoria REZ, because the connection cost in Western Victoria is cheaper, and because building generation in both REZs provides higher diversity.
- New generation expansion in Victoria occurs between 2020 and 2025 and is primarily driven by the VRET. The preferred option still provides net market benefits when considering only committed generation.

The generation expansion plan derived from capacity outlook modelling is provided in Attachment 1 – generation expansion plans.

A5.2 Fuel cost savings

The time sequential modelling described in Section 5.3.2 was carried out for the DN case and each credible option identified in Section 3.4, for each study scenario. Fuel cost savings are derived from the fuel costs in the DN case, minus the fuel cost for each augmentation option.

The DN cases have a different generation expansion plan when compared to the augmentation cases, even before any transmission augmentation is carried out. Fuel cost savings for all the credible options tend to be negative for the years before transmission network augmentation is implemented, because the capacity outlook model will plant less renewable generation capacity in the augmentation cases compared to the DN cases, and this leads to an increase in the fuel cost of generation.

Fuel cost savings are modelled up to 2032. After 2032, the average benefits from the years 2032, 2031, and 2030 are assumed for the remaining lifetime of the new assets[44].

A5.3 Options B2, B3, and B4

Options B2 and B3 have very similar gross market benefits, even though Option B2 provides higher transmission network capacity by allowing an additional transmission network augmentation between Bulgana and Horsham. The reason for this is:

- Generation expansion modelling shows that it is economic to develop generation in the Western Victoria REZ, Moyne REZ, and Murray River REZ, rather than concentrate generation development in one area.
- Subsequently, over 800 MW of new generation is modelled to connect in the Western Victoria REZ, and Option B3 provides adequate transmission network capacity for the modelled generation connections.
- Some known transmission network limitations between Bulgana Terminal Station to Horsham Terminal Station to Red Cliffs Terminal Station can be managed using control schemes, and this has been factored into the market modelling.

Option B4 is a rebuild of the existing Moorabool to Elaine to Ballarat to Bulgana single circuit 220 kV transmission line as a 220 kV double circuit transmission line. This option has a lower gross market benefit compared to Option B3 because it results in less transmission network capacity in the path between Ballarat to Bulgana. In addition, Option B4 has high outage costs over its four-year construction period, which leads to a higher total construction cost.

Overall, Option B3 has higher net market benefits than Option B2 and Option B4, due to its low cost and high gross benefit delivered.

Options B2, B3, and B4 have slightly less gross market benefits compared to Option C1 and C2 (which will be discussed next), because they increase the transmission line loading on the Moorabool to Geelong to Keilor lines. The thermal constraints on the Moorabool to Geelong to Keilor lines will bind for under 100 hours a year, after these options are implemented.

The following figures provide a breakdown of capital savings benefits, fuel savings benefits, cumulative total annual gross benefits, and cumulative annualised costs. The optimal timing for investment is around 2024.

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[44] Assumed to be 50 years for network options and 15 years for non-network options.

Figure 8 Option B3 gross benefits and investment costs in the Neutral scenario

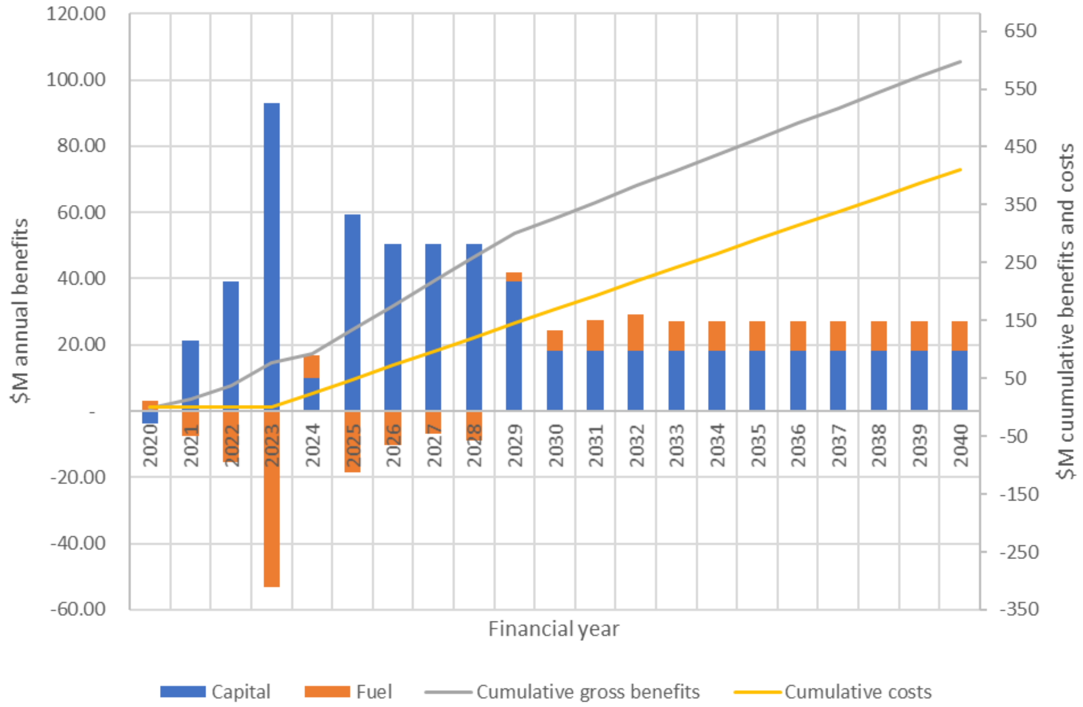
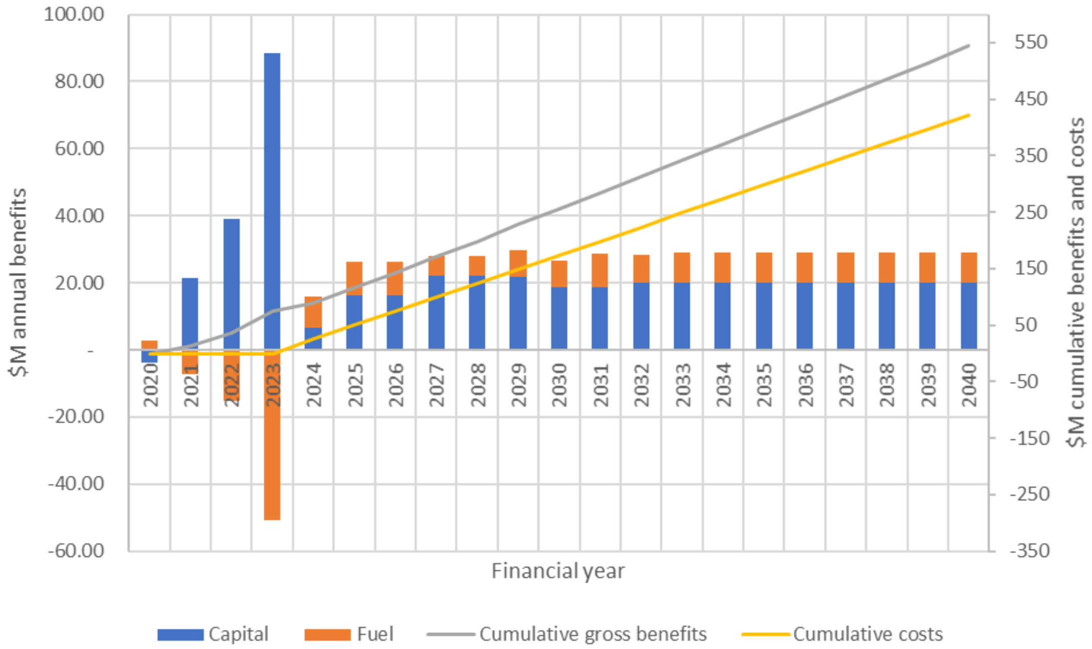


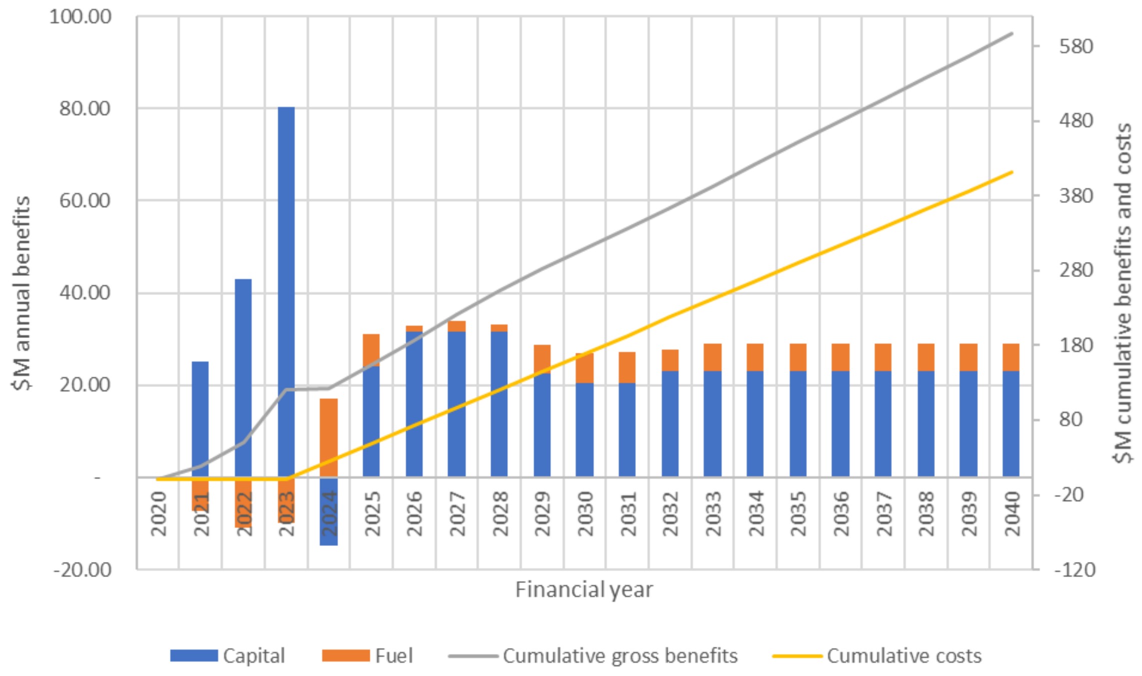
Figure 9 Option B3 gross benefits and investment costs in the Neutral with storage initiatives scenario



The proposed augmentation results in capital deferrals and less overall generation built, from 2021 until the end of the modelling period in 2032. The annualised cost of generation has been used, and the capital savings from 2033 until 2040 represent the remaining annualised cost of generation although no further changes to generation expansion are considered.

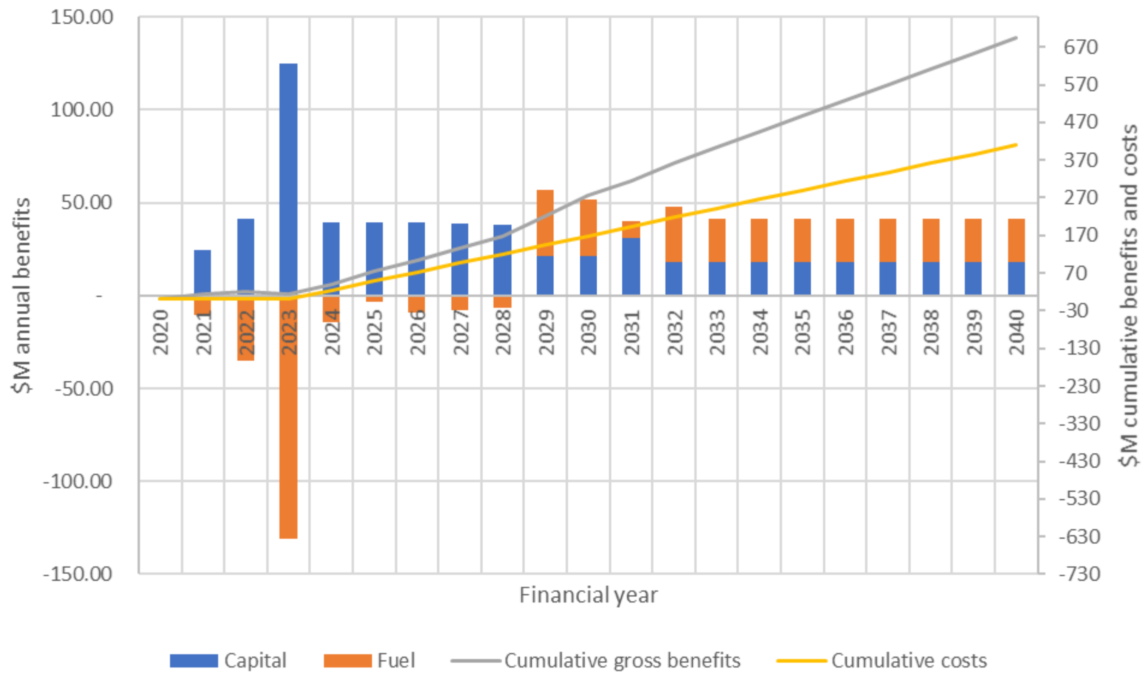
Fuel cost savings are initially negative because the DN case results in more renewable generation built overall, compared to the case with the credible option in place. The fuel cost savings from 2033 are the average fuel cost savings in 2030, 2031, and 2032.

Figure 10 Option B3 gross benefits and investment costs in the Slow change scenario



In 2024, the fuel cost savings are offset by negative capital cost savings. In this case, the credible option resulted in some renewable generation being shifted from 2023 to 2024, hence the high capital cost savings in 2023.

Figure 11 Option B3 gross benefits and investment costs in the Fast change scenario



Fuel cost savings remain negative until 2029, because the DN case results in more renewable generation built, compared to the case with the credible option in place. In general, very high capital cost deferrals may result in negative fuel cost savings because reducing the volume of renewable generation will increase overall fuel costs.

A5.4 Option C1 and Option C2

The gross market benefits of Options B2, B3, B4, and C2 are very similar, and Option C1 covers the same transmission path as Options B3, B4, and C2, therefore Option C1 was assumed to have very similar market benefits to Option C2 and was not explicitly modelled.

Option C1 is a 500 kV augmentation from Sydenham to Ararat, while Option C2 is a 500 kV augmentation from Sydenham to Ballarat and a 220 kV augmentation from Ballarat to Bulgana.

Option C1 has a slightly lower cost because it avoids highly built up areas around Ballarat Terminal Station. Option C2 assumes that a new terminal station will need to be established close to the existing Ballarat Terminal Station to accommodate new 500/220 kV transformers and other 500 kV switchgear, with a 220 kV double circuit connection to Ballarat Terminal Station.

Both options support the development of the new Snowylink interconnector proposed by the ISP, and therefore avoid some future cost associated with Snowylink. For the NPV analysis, Option C1 and C2 were assumed to be delivered one year after Options B2, B3, and B4 above, because of additional complexities associated with building 500 kV transmission lines.

The division of costs for Options C1 and C2 is provided in the table below.

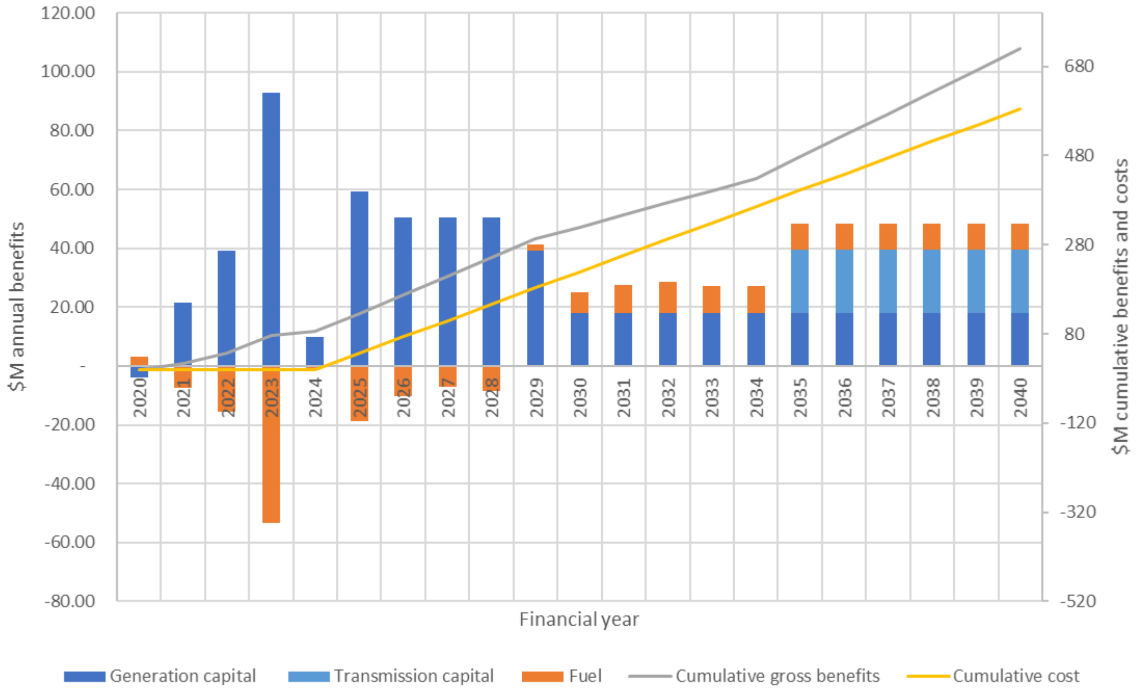
Table 28 Division of costs, Options C1 and C2

Option	Description	Construction cost ($M)
Option C1	Construction of a new 500 kV double circuit line from Ararat Terminal Station to Ballarat, without connecting at Ballarat Terminal Station.	287
	Continuation of transmission line from Ballarat to Sydenham Terminal Station. This forms part of the future Snowylink interconnector.	156
Option C2	Construction of a new 220 kV double circuit line from Bulgana Terminal Station to Ballarat Terminal Station, or establish a new terminal station close to Ballarat, with a 220 kV double circuit connection to Ballarat Terminal Station.	203
	Construction of a new 500 kV double circuit line from the new terminal station to Sydenham Terminal Station, with 2 x 500/220 kV transformers. This forms part of the future Snowylink interconnector.	296

Although Option C2 has a higher total cost compared to Option C1, more of Option C2's cost is part of the future Snowylink investment. Option C1 has a 500 kV component from Ballarat to Ararat that is not fully utilised in the modelling period, because the generation expansion modelling does not place enough new generation in the Western Victoria REZ.

The following figures provide a breakdown of generation capital savings benefits, transmission capital savings benefits, fuel savings benefits, cumulative total gross benefits and cumulative annualised costs. The optimal timing for investment is around 2024, however this timing may not be achievable. The practical timing is therefore assumed to be 2025.

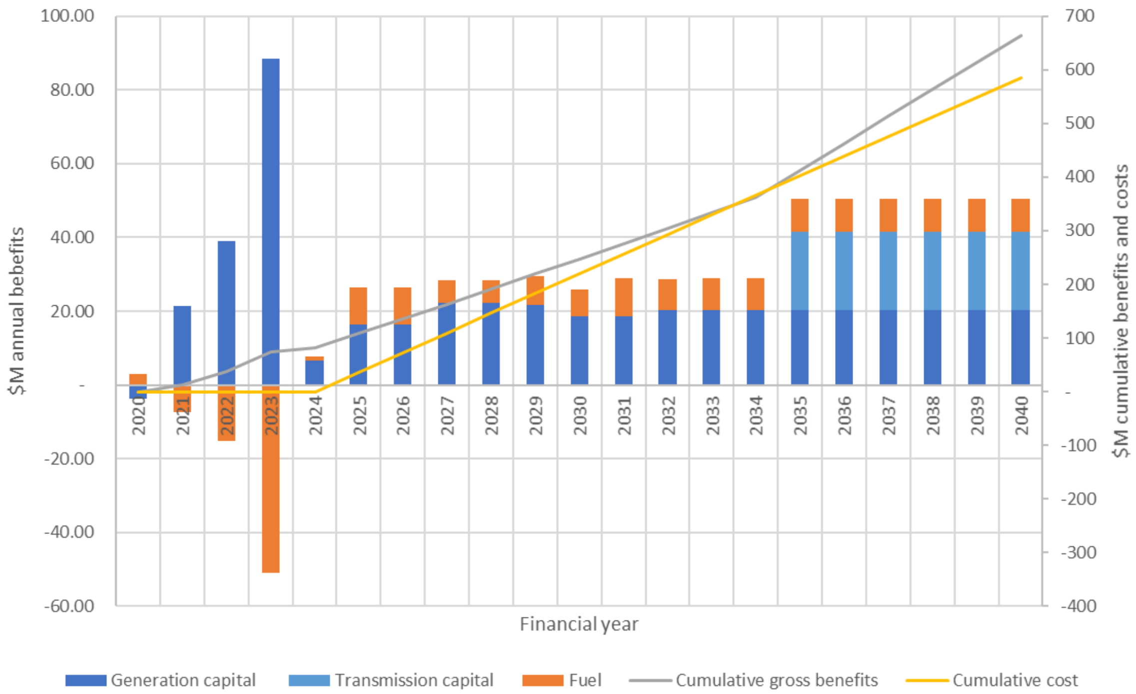
Figure 12 Option C2 gross benefits and investment costs in the Neutral scenario



Capital cost savings are primarily from deferring uncommitted new renewable generation in Victoria.

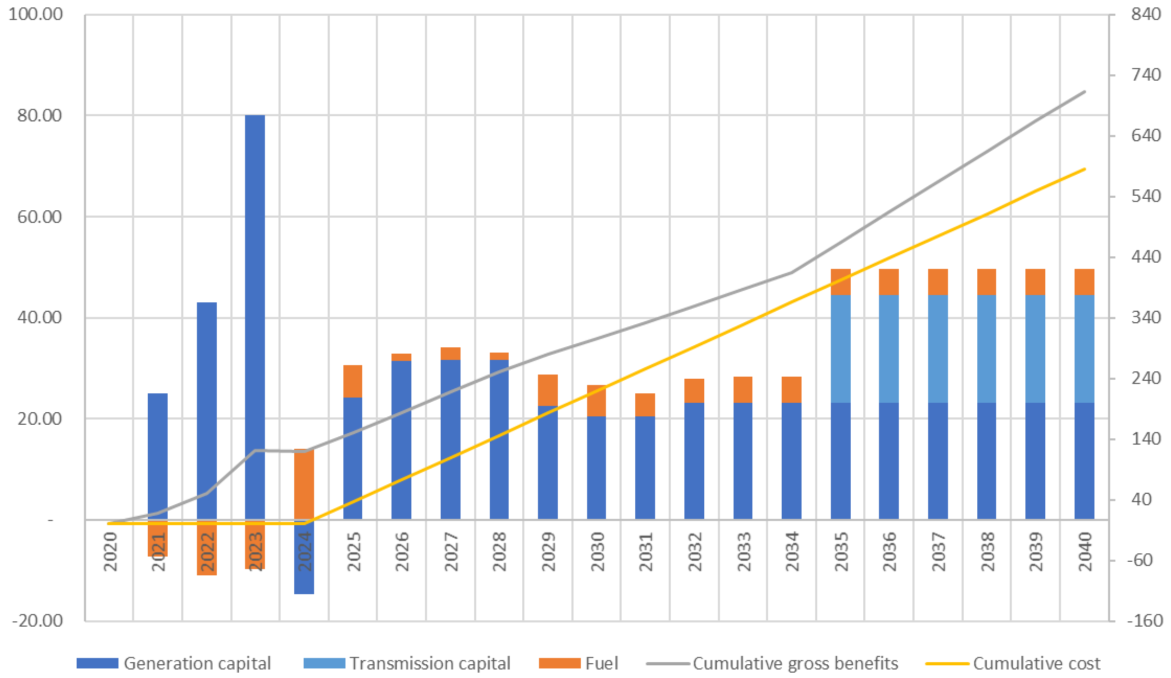
Similar to Option B3 above, fuel cost savings remain negative until 2028, because the DN case results in more renewable generation built, compared to the case with the credible option in place. High capital cost deferrals in the earlier years resulted in negative fuel cost savings because reducing the volume of renewable generation will increase overall fuel costs.

Figure 13 Option C2 gross benefits and investment costs in the Neutral with storage initiatives scenario



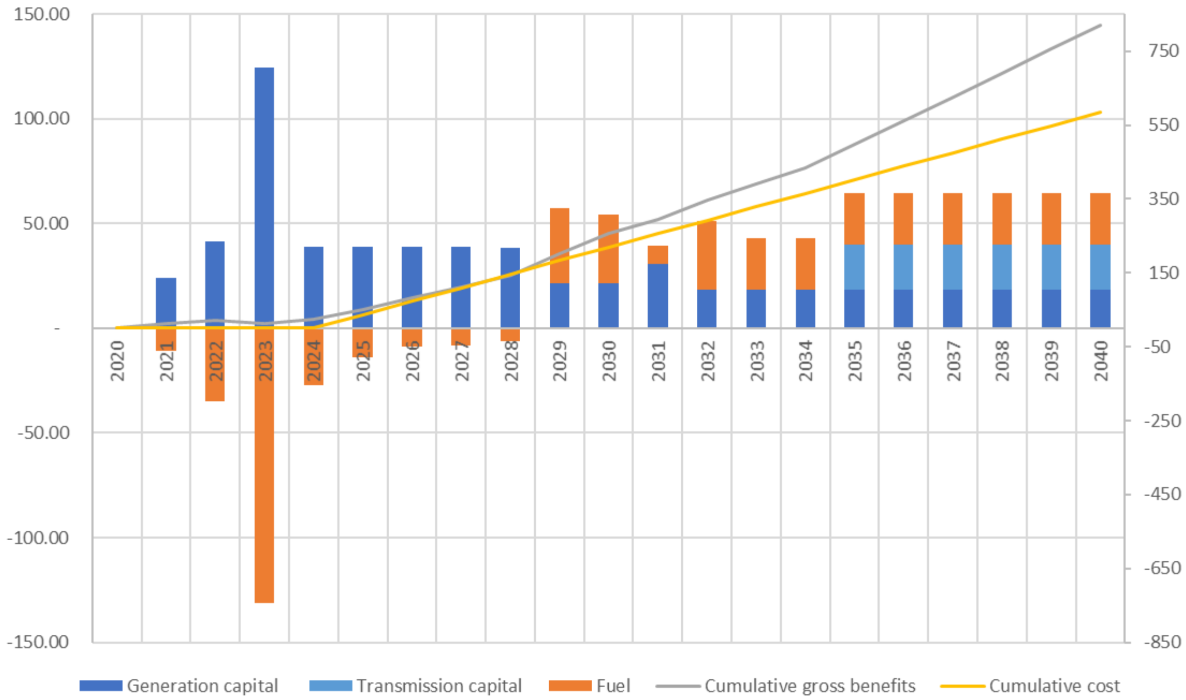
The Neutral with storage initiatives scenario results in lower capital savings benefits but higher fuel cost benefits.

Figure 14 Option C2 gross benefits and investment costs in the Slow change scenario



In 2024, the fuel cost savings are offset by negative capital cost savings. In this case, the credible option resulted in some renewable generation being shifted from 2023 to 2024, hence the high capital cost savings in 2023.

Figure 15 Option C2 gross benefits and investment costs in the Fast change scenario



The negative fuel cost savings in 2023 are caused by both the reduction in renewable generation in the augmentation case compared to DN, and the increase in customer demand, leading to more generation dispatch from generation with non-zero fuel costs. The Fast change scenario still results in a high NPV over the modelling period.

Fuel cost savings increase in 2029, due to some coal retirements in New South Wales.

A5.5 Option E1

AEMO assessed the benefit of connecting a 100 MW, four-hour battery storage system at Ararat Terminal Station, Horsham Terminal Station, and Red Cliffs Terminal Station. Of these options, the battery at Ararat Terminal Station had the highest gross market benefits, and these results are presented in the PADR.

This option is assumed to provide no capital cost savings and market benefits are derived from fuel cost savings only. This is because the amount of avoided spilled generation is small compared to the network options assessed. The capital cost of installing a battery is annualised over 10 years and there are no further capital costs after that. The battery is assumed to have a 15-year asset life.

The following figures provide a breakdown of fuel savings benefits, cumulative gross benefits, and cumulative costs with a battery at Ararat Terminal Station, which provided the highest market benefits.

Figure 16 Option E1 gross market benefits and investment costs in the Neutral scenario

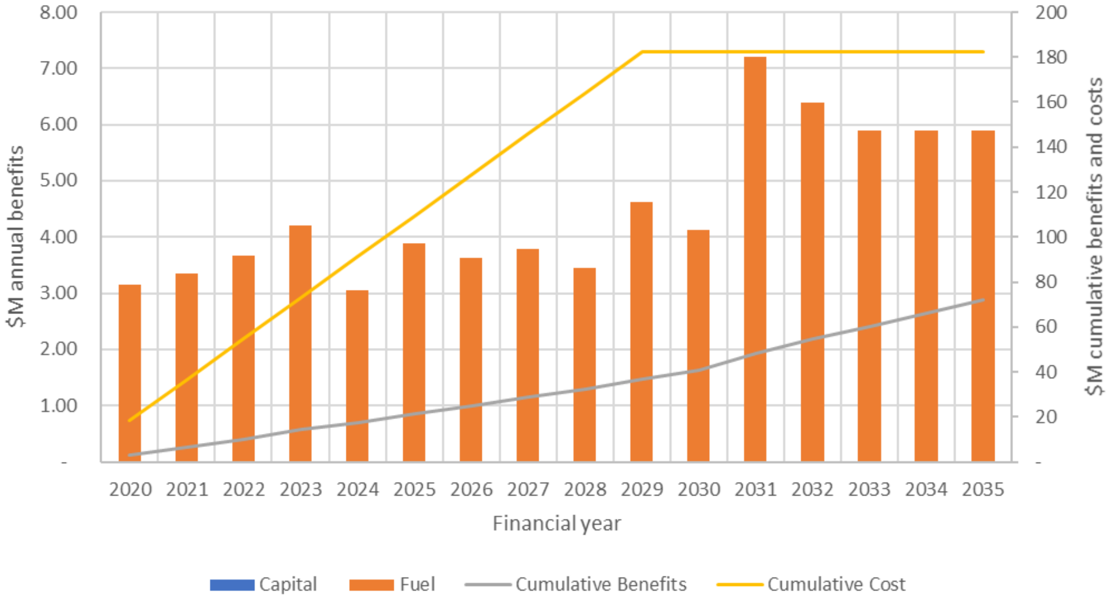


Figure 17 Option E1 gross benefits and investment costs in the Neutral with storage initiatives scenario

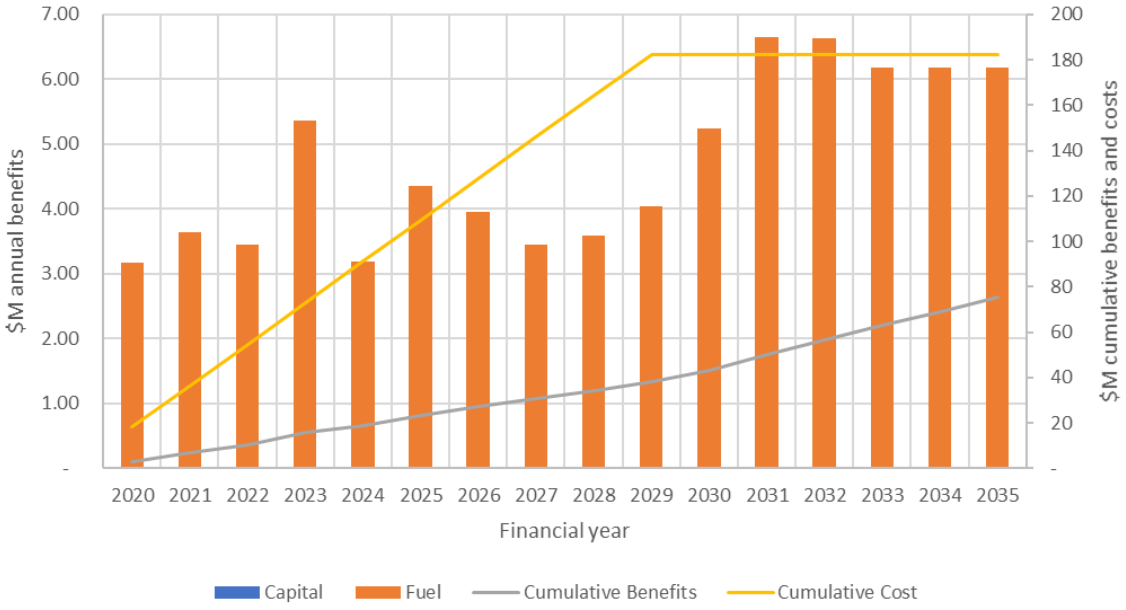


Figure 18 Option E1 gross benefits and investment costs in the Slow change scenario

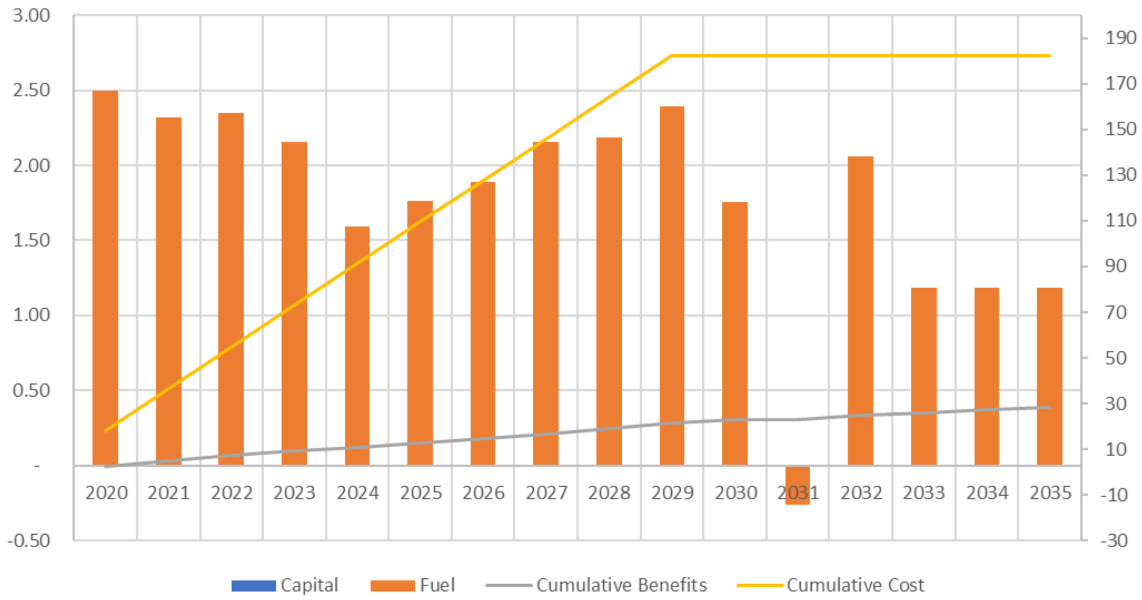
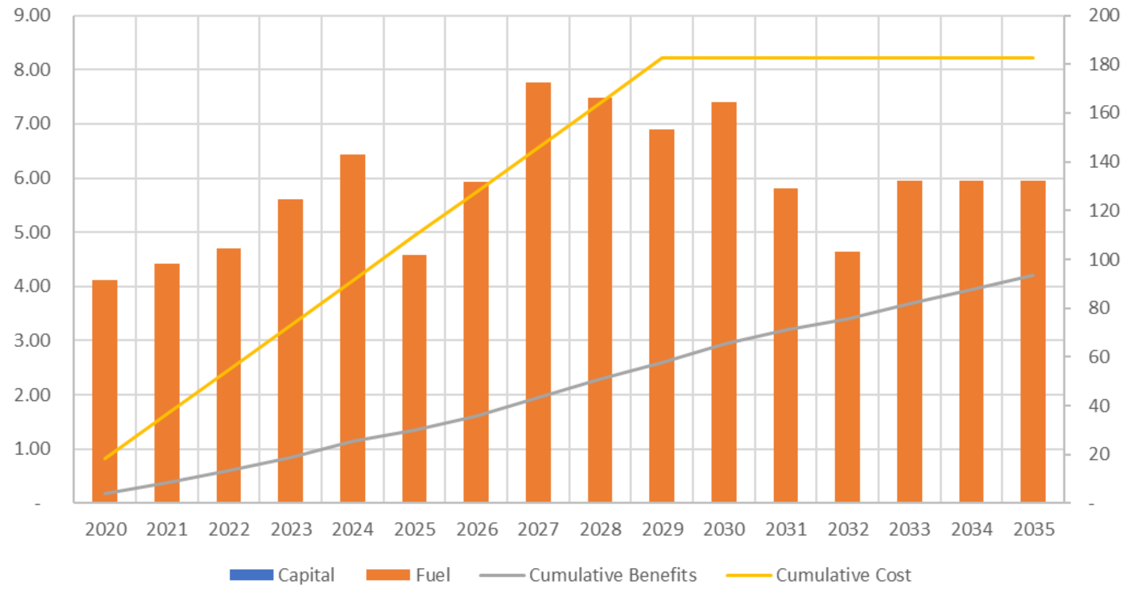


Figure 19 Option E1 gross benefits and investment costs in the Fast change scenario



In all scenarios, the total cost of Option E1 are higher than its gross market benefits, therefore this option has a negative net market benefit.

Refer to Attachment 4 – binding constraints in Western Victoria for details on constraint binding hours.

A6. Technical characteristics of proposed preferred option

A6.1 Variations

The 2018 ISP and 2018 VAPR envisaged that a new 220 kV double circuit transmission line from Ballarat Terminal Station to Ararat Terminal Station, and a new 220 kV single circuit transmission line from Ararat Terminal Station to Crowlands Terminal Station and Bulgana Terminal Station, could have net market benefits.

The preferred option differs slightly from the proposal envisaged by the ISP and VAPR, by installing a new 220 kV double circuit transmission line from Ballarat Terminal Station to Bulgana Terminal Station.

AEMO carried out a cost estimate using its internal PriceBook[45] database to determine high-level costs for both variations, as shown in Table 29 and Table 30 below.

Table 29 Variation 1 – 2018 ISP and VAPR proposal

Transmission line	km	MVA rating	CBs	Augmentations	Cost, $M
Ballarat– Ararat	75	1,600	6	Double circuit line, 800 MVA per circuit	100.89
Ararat–Crowlands–Bulgana	30	800	6	Single circuit line, 800 MVA	39.24
Total					144.55

Table 30 Variation 2 – Current RIT option

Transmission line	km	MVA rating	CBs	Augmentations	Cost, $M
Ballarat– Ararat	75	1,600	6	Double circuit line, 800 MVA per circuit	100.89
Ararat–Crowlands–Bulgana	30	2 x 800	4	Double circuit line, 800 MVA per circuit	42.35
Total					147.66

The RIT-T option will avoid additional switching requirements at Ararat Terminal Station and Crowlands Terminal Station, and delivers slightly higher capacity than the original proposal envisaged by the ISP and the VAPR, by extending the new double circuit transmission lines to Bulgana, at almost the same cost

[45] AEMO has created an internal 'PriceBook' transmission cost database, to be used for estimating the costs of transmission augmentation in the NEM.

(approximately $3 million higher). Additionally, the RIT-T option will potentially have higher cost savings by avoiding outages at Ararat Terminal Station and Crowlands Terminal Station.

A6.2 Indicative requirements for the preferred option

The new transmission line parameters are subject to further detailed assessment and detailed design. The high level functional requirements are:

- Construct a new Sydenham to Ballarat 500 kV double circuit transmission line with a summer rating of up to 3,000 MVA per circuit.
  - Initial assessment has indicated that there may be insufficient space in Ballarat Terminal Station for the proposed 500 kV plant. AEMO has assumed in its assessments that a new terminal station will be established close to Ballarat, with a 220 kV double circuit connection to Ballarat Terminal Station. The exact terminal station location will be determined during the planning phase. The new Ballarat terminal station is still referred to as Ballarat in the rest of this option description.
- Construct a new Ballarat to Bulgana 220 kV double circuit transmission line, with a summer rating of at least 800 MVA per circuit, in new easements.
- Cut in Ballarat to Moorabool 220 kV circuit No. 2 at Elaine Terminal Station, to increase generation connection capacity at Elaine Terminal Station.
- The cost estimates have allowed for powerflow controllers to manage transmission line flows on the 220 kV transmission lines between Ballarat to Bulgana. These requirements will be confirmed by further studies and presented in the PACR.
- The cost estimates have allowed for a total of 200 megavolt amperes reactive (MVAr) shunt reactors for the 500 kV transmission lines at Sydenham Terminal Station to manage voltages. The reactive compensation requirements will be confirmed by further studies and presented in PACR
- During the detailed design phase, earth grid assessments will need to be carried out for the terminal stations at: Red Cliffs, Moorabool, Horsham, Bulgana, Crowlands, Ararat, Waubra, Ballarat, and Elaine. Fault level information will be published in the PACR.
- The impact of increased fault levels on the Western Victorian distribution networks will also need to be assessed during the detailed design phase.

Glossary

This document uses many terms that have meanings defined in the National Electricity Rules (NER). The NER meanings are adopted unless otherwise specified.

Term	Definition
brownfield construction	Construction work that is carried out in a site with existing electricity infrastructure in place.
committed projects	Generation that is considered to be proceeding under the commitment criteria outlined in AEMO's generation information page. (see footnote 42).
electrical energy	Average electrical power over a time period, multiplied by the length of the time period.
electrical power	Instantaneous rate at which electrical energy is consumed, generated, or transmitted.
generating capacity	Amount of capacity (in megawatts (MW)) available for generation.
generating unit	Power stations may be broken down into separate components known as generating units, and may be considered separately in terms (for example) of dispatch, withdrawal, and maintenance.
greenfield construction	Construction work that is carried out in a site without existing electricity infrastructure in place.
installed capacity	The generating capacity (in megawatts (MW)) of the following (for example): • A single generating unit. • A number of generating units of a particular type or in a particular area. • All of the generating units in a region. Rooftop PV installed capacity is the total amount of cumulative rooftop PV capacity installed at any given time.
maximum demand (MD)	Highest amount of electrical power delivered, or forecast to be delivered, over a defined period (day, week, month, season, or year) either at a connection point, or simultaneously at a defined set of connection points.
operational electrical consumption	The electrical energy supplied by scheduled, semi-scheduled, and significant non-scheduled generating units, less the electrical energy supplied by small non-scheduled generation.