Victoria to New South Wales Interconnector West (VNI West)

December 2019

Regulatory Investment Test for Transmission
Project Specification Consultation Report (PSCR)

Important notice

PURPOSE

AEMO and TransGrid have prepared this Project Specification Consultation Report in accordance with clause 5.16 of the National Electricity Rules to, among other things, provide information about certain network limitations and potential options to address these limitations.

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LOCATIONS

Equipment locations identified in this document are indicative only. Actual locations will be determined as required during the detailed design and route assessment phase, after conclusion of the RIT-T process.

VERSION CONTROL

Version	Release date	Changes
1	December 2019	First release.

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Executive summary

The National Electricity Market (NEM) is changing rapidly. The integration of renewable generation continues to shift the geography and technical characteristics of supply, while an ageing fleet of coal-fired generators will progressively withdraw from the market over the coming decades.

This energy transition is shifting the utilisation of the existing power system. Network congestion is increasing in some areas. The system's reliance on the balancing benefits of interconnection between regions is also increasing. Well-targeted and timely investment in the transmission network is therefore required to keep pace with these changes. This will provide consumers with the most cost-effective energy outcomes while maintaining reliability and security.

AEMO's 2018 Integrated System Plan[1] (ISP) set out an optimised national pathway for development of the power system that would maximise the value from new and existing resources across the NEM, while delivering reliable energy at the lowest cost to consumers. It identified that both short-term and longer-term investments were required to increase interconnection capacity between Victoria and New South Wales to enable more efficient sharing of generation between the states and deliver energy at the lowest cost to consumers.

AEMO and TransGrid are already jointly progressing a Victoria – New South Wales Interconnector (VNI) Upgrade Regulatory Investment Test for Transmission (RIT-T)[2] to address the immediate need for increased transfer capacity from Victoria to New South Wales.

In addition, the ISP also recommended that a longer-term investment would be required to strengthen bi-directional interconnection between Victoria and New South Wales to deliver fuel cost savings, facilitate efficient connection of new renewable generation, and provide greater access to hydro energy storage plant in the Snowy Mountains. This PSCR addresses this need.

AEMO's Draft 2020 ISP[3] re-confirmed this need for short-term and longer-term investment to increase in transfer capacity between the states, and designated both projects as 'Group 1' priority projects requiring urgent investment to maximise benefits.

AEMO's 2019 Victorian Annual Planning Report[4] (VAPR) identified the need for additional interconnection to maintain Victorian supply reliability following the withdrawal of further coal-fired generation plant. EnergyAustralia has officially advised that Yallourn Power Station is expected to close its four units from 2029 to 2032[5]. While participants are required to provide adequate notice before decommissioning, there are risks that a substantial plant failure, loss of significant revenue or force majeure event could cause an early or unexpected plant retirement.

AEMO's 2019 ISP Insights paper[6] identified that bringing forward an increase in the transfer capability between the Snowy area and Melbourne would mitigate supply risks associated with diminishing reliability of the existing coal fleet and provide insurance against unexpected early plant closures.

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

[2] See https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Victoria-to-New-South-Wales-Interconnector-Upgrade-Regulatory-Investment-Test-for-Transmission.

[3] AEMO, Draft 2020 ISP, December 2019, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2019-Integrated-System-Plan

[4] AEMO, 2019 VAPR, June 2019, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/VAPR/2019/Victorian-Annual-Planning-Report-2019.pdf.

[5] AEMO, Generation Information, 8 August 2019 update (under Existing Generation and New Developments tab on NEM spreadsheet), at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.

[6] AEMO, ISP Insights, Building power system resilience with pumped hydro energy storage, July 2019, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf.

Regulatory Investment Test for Transmission (RIT-T)

The RIT-T is an economic cost-benefit test used to assess and rank different options that address an identified need. Its purpose is to identify the investment option that maximises the present value of net economic benefit to all those who produce, consume and transport electricity in the market.

AEMO and TransGrid are jointly undertaking this RIT-T to assess the technical and economic viability of expanding interconnector capacity between Victoria and New South Wales, to identify the preferred option to meet the identified need, and its optimal timing. This Project Specification Consultation Report (PSCR) is the first stage of the RIT-T process, and includes:

- A description of the identified need.
- A description of the credible options being considered to meet the identified need.
- The technical characteristics and performance requirements that a non-network option would need to deliver to meet the identified need.
- A discussion of specific categories of market benefit and their applicability to this RIT-T.

Identified need for investment

The identified need is for additional transfer capacity between New South Wales and Victoria to realise net market benefits[7] by:

- Efficiently maintaining supply reliability in Victoria following the closure of further coal-fired generation and the decline in ageing generator reliability – including mitigation of the risk that existing plant closes earlier than expected.
- Facilitating efficient development and dispatch of generation in areas with high quality renewable resources in Victoria and southern New South Wales through improved network capacity and access to demand centres.
- Enabling more efficient sharing of resources between NEM regions.

The withdrawal of further coal-fired generation in the Latrobe Valley is expected to result in a supply shortfall in Victoria unless alternative sources of supply are found. Concurrently, the increasing frequency of unplanned outages of dispatchable supply resources, as reported in AEMO's 2019 Electricity Statement of Opportunities (ESOO), will also compound long term supply reliability risks[8]. Investment will be required to address this expected shortfall, including the need to increase interconnection to better utilise available supply in other states across the NEM, and the need to unlock projected new generation connections.

AEMO's 2019 VAPR and TransGrid's 2019 Transmission Annual Planning Report (TAPR) identified high volumes of interest in renewable generation connection in northern and western Victoria and southern New South Wales areas, respectively. There is currently over 8 gigawatts (GW) of renewable generation and storage operational or proposed to connect in northern and western Victoria[9], with an additional 20 GW in southern New South Wales[10]. This includes the development of Snowy 2.0, which the Federal Government is supporting as part of its broader energy plan.

The VAPR identified that, considering projected generation connections, both new and existing generators are expected to experience constrained output due to networks limitations within Victoria and southern New South Wales. Investment to increase the capability of targeted network areas will reduce generation constraints in areas with high quality renewable resources, and is expected to lower overall investment and dispatch costs across the NEM. This will enable more efficient sharing of renewable resources between states,

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[7] The present value of net economic benefit to all those who produce, consume and transport electricity in the market.

[8] AEMO, 2019 ESOO, August 2019, at https://aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEM_ESOO/2019/2019-Electricity-Statement-of-Opportunities.pdf

[9] See Victoria Generation Map on AEMO's NEM Generation Maps webpage, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Network-connections/NEM-generation-maps

[10] See Figure 26 of TransGrid's 2019 Transmission Annual Planning Report, at https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning/Documents/2019%20Transmission%20Annual%20Planning%20Report.pdf

encourage diversity of supply sources, and provide better access to hydro storage (including Snowy), providing firm energy to support growing levels of intermittent renewable generation.

Credible options

Through this RIT-T, AEMO and TransGrid are jointly considering options to address the identified need. The recommended solution will be required to address the identified need, and maximise net economic benefits to all those who produce, consume, and transport electricity in the NEM.

AEMO's Draft 2020 ISP also proposes a range of augmentation options to increase the transfer capacity between Victoria to New South Wales. Options VNI 5A to VNI 8 as set out in the Draft 2020 ISP are longer-term investments intended to deliver larger-scale increases in bi-directional interconnection between Victoria and New South Wales.

This RIT-T will assess options VNI 5A to VNI 8, along with some additional variations as described in Section 6. For ease of reference between the two reports, this RIT-T will maintain naming consistency with the VNI options presented in the Draft 2020 ISP, and the labels VNI 5A to 8 have been adopted and utilised in this PSCR.

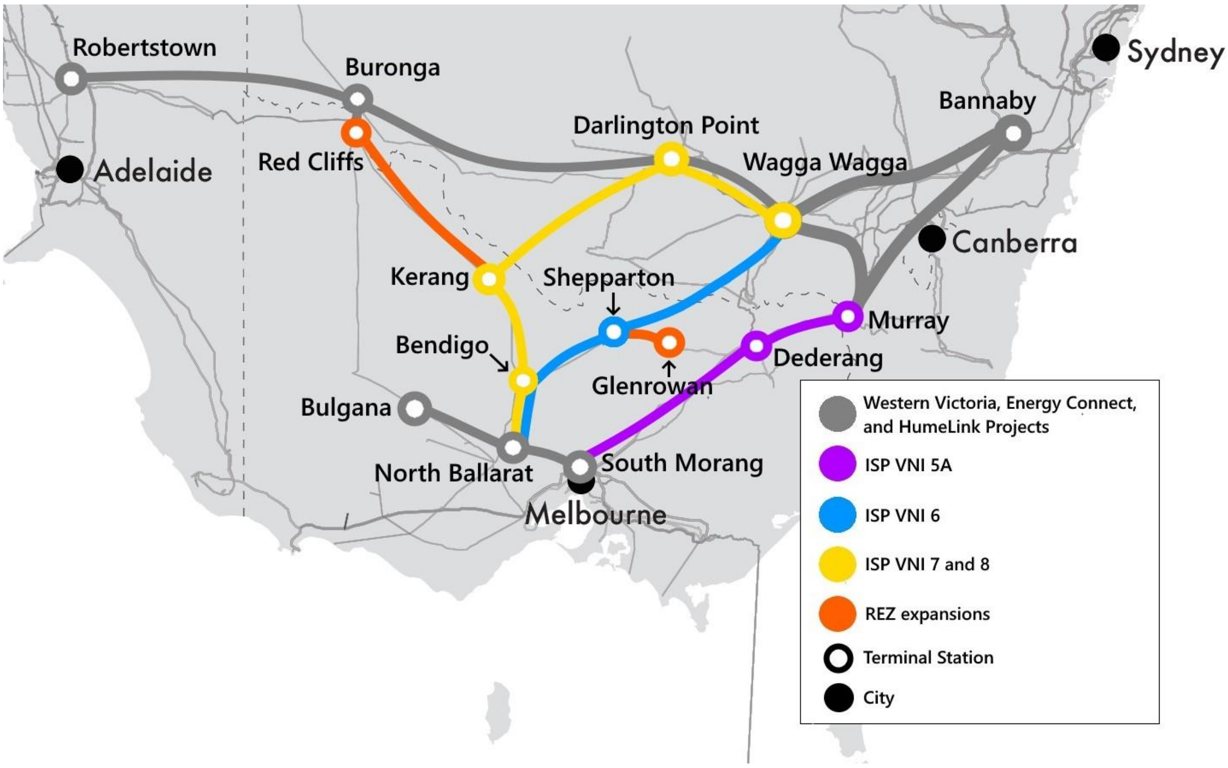
The following options are currently proposed to meet the identified need.

Table 1 Credible options

Augmentation to existing VNI corridor	
VIC-NSW Option 5A ('VNI 5A')	New 330 kV transmission lines from South Morang – Dederang – Murray
Augmentation on new corridors (Via Bendigo or Shepparton)	
VNI 6	New 500 kV transmission lines from North Ballarat – Bendigo* – Shepparton – Wagga
Augmentation on new corridors (Via Kerang)	
VNI 7	New 500 kV transmission lines from North Ballarat – Bendigo – Kerang – Darlington Point – Wagga
VNI 8	New 330 kV transmission lines from North Ballarat – Kerang – Darlington Point - Wagga
Potential expansions to accommodate renewable energy zones (REZs)	
Expansion A	New transmission lines to unlock generation capacity from Kerang – Red Cliffs
Expansion B	New transmission lines to unlock generation capacity from Shepparton – Glenrowan

*VNI 6 also includes option variations which bypass Bendigo and/or Shepparton (see Section 6).

Figure 1 Map of credible options



Potential benefits

To satisfy the RIT-T, there must be net market benefits associated with implementing the preferred option. The classes of market benefits considered for this project are:

- Changes in fuel consumption arising through different patterns of generation dispatch.
- Changes in voluntary load curtailment and involuntary load shedding.
- Changes in costs to other parties due to differences in the timing of new plant, differences in capital costs and differences in operational and maintenance costs.
- Differences in the timing of transmission investment.
- Changes in network losses.
- Option value benefit.

In addition, these credible options may provide market benefits beyond the identified need, such as increased system strength, voltage support, or the ability to optimise fuel costs over time with storage devices, which will be considered in this RIT-T.

Credible options that result in increased interconnection may also improve the power system's resilience to non-credible contingencies, changing operating patterns, and other possible market changes (such as early withdrawal of existing generating units). Such high-impact, low probability events can carry significant cost implications, and related market benefits will also be considered.

Next steps

The second stage of the RIT-T process is a full options analysis, followed by publication of a Project Assessment Draft Report (PADR) in accordance with clause 5.16.4 of the National Electricity Rules (NER).
The recommended preferred option may be a combination of network and non-network options, since minor network augmentations and non-network solutions are unlikely to fully address the identified need, while

network augmentation can address the identified need but may not be implemented in time, or have sufficient market benefits.

The third and final stage of the RIT-T process, the Project Assessment Conclusions Report (PACR), will make a conclusion on the preferred option.

AEMO and TransGrid welcome written submissions on this PSCR. All feedback will be considered and will help to refine the proposed preferred option to be published in the PADR. In particular, AEMO and TransGrid are seeking feedback on the following questions:

- Have AEMO and TransGrid properly described the identified need for this project? If not, how can the description of the need be improved?
- Have AEMO and TransGrid considered the most appropriate development options in this PSCR? If not, what other credible options should be considered for the PADR?
- Are there any non-network options that AEMO and TransGrid should consider to meet or partially meet the identified need, for example non-network options with the capability to alleviate constraints and unlock REZ capacity?
- What, if any, additional factors should AEMO and TransGrid consider to determine the preferred option for VNI West?

Submissions are not limited to these specific consultation questions, and not all questions are expected to be answered in each submission.

Submissions should be emailed to VNIWestRITT@aemo.com.au and are due on or before 13 March 2020.

Note that consultation on the Draft 2020 ISP is occurring concurrently with this PSCR consultation process. The next stage of the RIT-T process will have regard for submissions to this PSCR and new information which may impact the RIT-T, including submissions to the Draft 2020 ISP, where appropriate.

Submissions will be published on the AEMO and TransGrid websites. If you do not want your submission to be publicly available, please clearly stipulate this at the time of lodgement.

Contents

1. Introduction

This Project Specification Consultation Report (PSCR) has been prepared in accordance with the requirements of clause 5.16.4 of the National Electricity Rules (NER) as part of a Regulatory Investment Test for Transmission (RIT-T).

In line with these requirements, this PSCR describes:

1. The identified need that is being addressed, and the assumptions used in identifying the need.
2. The technical characteristics that a non-network option would be required to deliver to meet the identified need.
3. All credible options that AEMO and TransGrid consider can reasonably address the identified need.
4. The classes of market benefit that are likely not to be material.

The next stage of the RIT-T process is a full option analysis, followed by publication of a Project Assessment Draft Report (PADR), in accordance with the requirements of clause 5.16.4 of the NER.

The PADR will include information on which credible option returns the highest net market benefit, details on its technical characteristics, estimated commissioning date, and analysis showing that the preferred option satisfies the RIT-T.

The third and final stage of the RIT-T process, the Project Assessment Conclusions Report (PACR), will make a conclusion on the preferred option following consultation on the proposed preferred option presented in the PADR.

In deciding whether a proposed augmentation to the Victorian Declared Shared Network should proceed, AEMO is required to undertake a cost benefit analysis. As the preferred option arising out of this RIT-T may involve a number of augmentations to the Victorian Declared Shared Network, the RIT-T meets this requirement in relation to those augmentations.

For noting

As the national transmission planner, AEMO has published a Draft 2020 Integrated System Plan (ISP) which provides an actionable whole-of-system roadmap for the efficient development of the NEM over the next 20 years and beyond. The final 2020 ISP is planned to be published in June 2020. Information on the ISP timeline and opportunities for engagement is available on the AEMO website[11].

On 20 November 2019, the Energy Security Board (ESB) published draft ISP Rules for consultation[12] to make AEMO's ISP actionable. The draft ISP Rules include transitional provisions to ensure a streamlined regulatory process for existing projects identified in the ISP, including VNI West. The design of these draft transitional arrangements is based on what stage each existing actionable ISP project has reached in the RIT-T process at the date when the new ISP Rules commence. Consultation on the new ISP Rules is open until 17 January 2020.

AEMO and TransGrid are actively contributing to this process and evaluating and tracking the progress of the proposed reforms and their implications for current and planned RIT-Ts and other affected projects. AEMO and TransGrid will advise stakeholders of any updates and next steps if this RIT-T is impacted by the final revised framework.

[11] At https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2019-Integrated-System-Plan

[12] At http://www.coagenergycouncil.gov.au/publications/consultation-draft-isp-rules

2. Background and context

The energy landscape across the National Electricity Market (NEM) is undergoing a significant transition. As the ageing fleet of existing coal-fired generation progressively withdraw from the NEM, it is anticipated that these conventional generation sources will be replaced by a combination of utility-scale renewable generation, energy storage and distributed energy resources (DER) across the states.

This energy transition is:

- Having a dramatic impact on the utilisation of the existing power system.
- Placing greater reliance on the interconnection between states to enable efficient sharing of resources.
- Introducing new areas of network congestion that impact the ability of supplies to reach demand.

Targeted and timely investment is required to keep pace with these changes, and to provide consumers with the most cost-effective energy outcomes that leverage the geographic diversity of renewable resources, while adapting to the newly emerging technical characteristics of the power system.

The 2018 ISP[13] set out a national strategic pathway to maximise value of new and existing resources across the NEM. It recommends strengthening the interconnected grid to deliver energy reliability, system security, diversity and resilience at the lowest cost to consumers. The 2018 ISP identified the need for action to increase the transfer capability between Victoria and New South Wales in the near term. AEMO and TransGrid are currently undertaking a joint VNI Upgrade RIT-T to assess options that meet this need.

Beyond the near term, the 2018 ISP also identified a need for long-term investment to increase the transfer capability between Victoria and New South Wales to deliver market benefits through improved access to low-cost fuel resources, more efficient sharing of generation between regions, reduced need for firming capacity investment, and improved supply reliability as ageing thermal plant withdraws from the market.

AEMO's Draft 2020 ISP re-confirmed this need for short-term and longer-term investment to increase in transfer capacity between the states, and designated both projects as 'Group 1' priority projects requiring urgent investment to maximise benefits. The draft ISP modelling indicates optimal timing for delivery by 2026-27 but no later than 2028-29, aligned with the closure of further plant in the Latrobe Valley. This will be further assessed through the final 2020 ISP and through this RIT-T.

EnergyAustralia has advised an expected staged closure of its four units at Yallourn Power Station from 2029 to 2032[14], likely advancing the optimal timing of interconnector investment. Further interconnection is expected to improve reliability and resilience of the system by allowing resources within and across regions to meet consumer demand.

AEMO's 2019 ISP Insights paper, *Building power system resilience with pumped hydro energy storage*[15] identified that early upgrades to the transfer capability between the Snowy area and Melbourne would maximise the reliability and resilience benefits, particularly given the risks associated with an early or unexpected plant closure in the Latrobe Valley.

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

[14] AEMO, Generation Information, 8 August 2019 update (under Existing Generation and New Developments tab on NEM spreadsheet), at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.

[15] AEMO, July 2019, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf

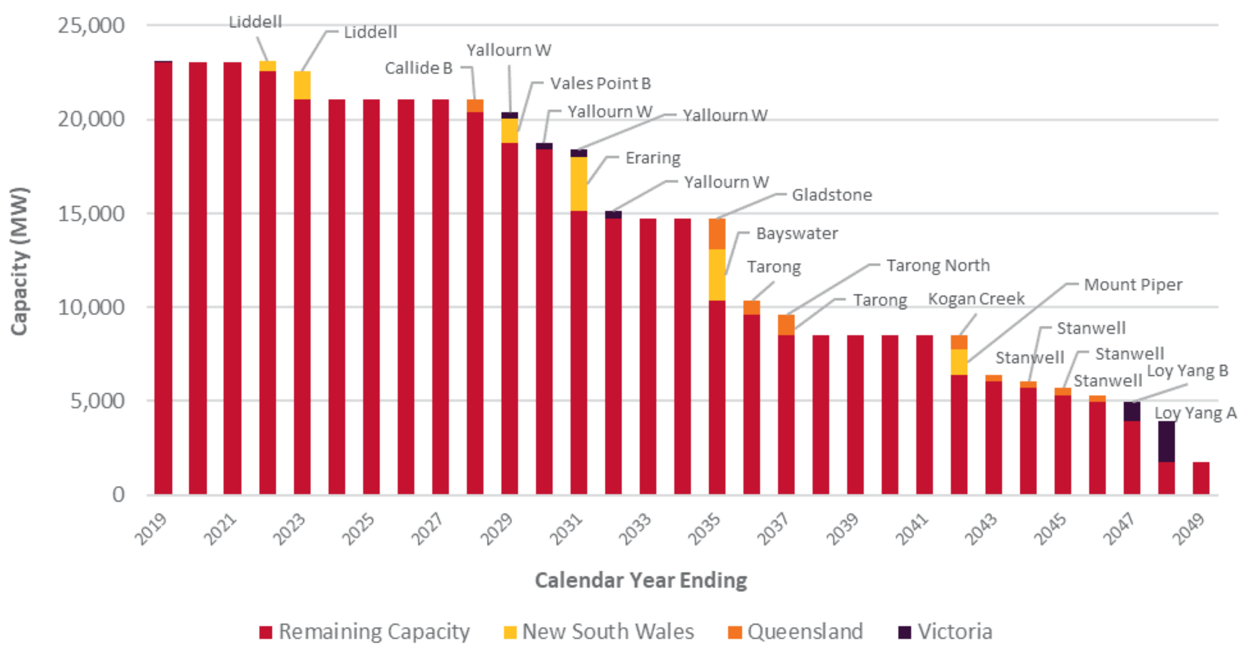
AEMO's 2019 Victorian Annual Planning Report[16] (VAPR) also highlighted a potential future need for additional interconnection between Victoria and New South Wales to maintain supply reliability during peak demand conditions and to provide resilience against uncertain future step changes in supply.

TransGrid has incorporated additional bi-directional interconnector capacity between New South Wales and Victoria in the base development pathway of the RIT-T for Reinforcing the Southern NSW Shared Network, in three of four scenarios.[17]

2.1 Conventional generation outlook

The 2018 ISP projected the withdrawal of significant amounts of existing coal-fired generation across the NEM in the coming two decades. Recent changes to the NER require an existing generator to notify AEMO of their expected closure date. Figure 2 shows the indicative timeline of coal-fired generator expected closures until 2050, as published in AEMO's Generating Unit Expected Closure Year publication (8 November 2019 update)[18].

Figure 2 NEM coal-fired generation fleet operating life to end of 2049



More than a third of the existing conventional generation capacity in the NEM is expected to withdraw by 2032. This amounts to approximately 8 GW of generation across Victoria, New South Wales, and Queensland. In June 2019, the owner of Yallourn Power Station in Victoria announced their plan for a staged closure of its four generating units between 2029 and 2032, removing almost 1.5 GW of capacity from the Victorian network. The removal of this thermal capacity will decrease the reliability of the Victorian power system, without adequate replacement from other supply resources.

Producing an accurate projection of plant closures is complex, because a generator's lifecycle is dependent on a wide range of technical and commercial factors. As a large proportion of projected generator withdrawals over the coming years are driven by plant age, these generators will be operating close to the

[16] AEMO, June 2019, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/VAPR/2019/Victorian-Annual-Planning-Report-2019.pdf.

[17] TransGrid, 25 June 2019, Reinforcing the New South Wales Southern Shared Network to increase transfer capacity to the state's demand centers: Project Specification Consultation Report, at https://www.transgrid.com.au/what-we-do/projects/current-projects/Reinforcing%20the%20NSW%20Southern%20Shared%20Network.

[18] The 'Generating Unit Expected Closure Year' file on AEMO's Generation Information Page represents the most up to date collection of closure timings. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information. Note that a closure year for Queensland's Callide C Power Station is still to be confirmed. AEMO is assuming a 2050 closure at this stage, so it is not included in chart.

end of their technical life, and may therefore be at a higher risk of early closure or significant unplanned outages. As discussed in AEMO's 2019 ESOO, the reliability of the ageing brown coal generation fleet in Victoria continues to decline. This increases the risk of larger, or more rapid, withdrawals than initial projections.

A large quantity of the NEM's retiring coal-fired fleet is expected to be replaced by a combination of renewable generation and energy storage solutions. This will have significant impacts on the operation and performance of the power system, as detailed in the 2019 VAPR. Large-scale network investment is likely required to facilitate an efficient transition from conventional generation sources, to a least-cost fleet over the coming years.

Most of the announced new generation projects are variable renewable energy generators, which often do not generate at full capacity during peak demand times or may be positioned in a congested part of the network. As a result, while providing significant energy across the year, these types of generation may have a lower contribution to meeting peak demand than dispatchable generation sources.

To extract the maximum consumer benefits from these renewable investments, there is a need for network augmentation to unlock areas of high quality resources, to provide access to energy storage plant and to enable the most efficient utilisation of generation capacity across the NEM.

2.2 Renewable development

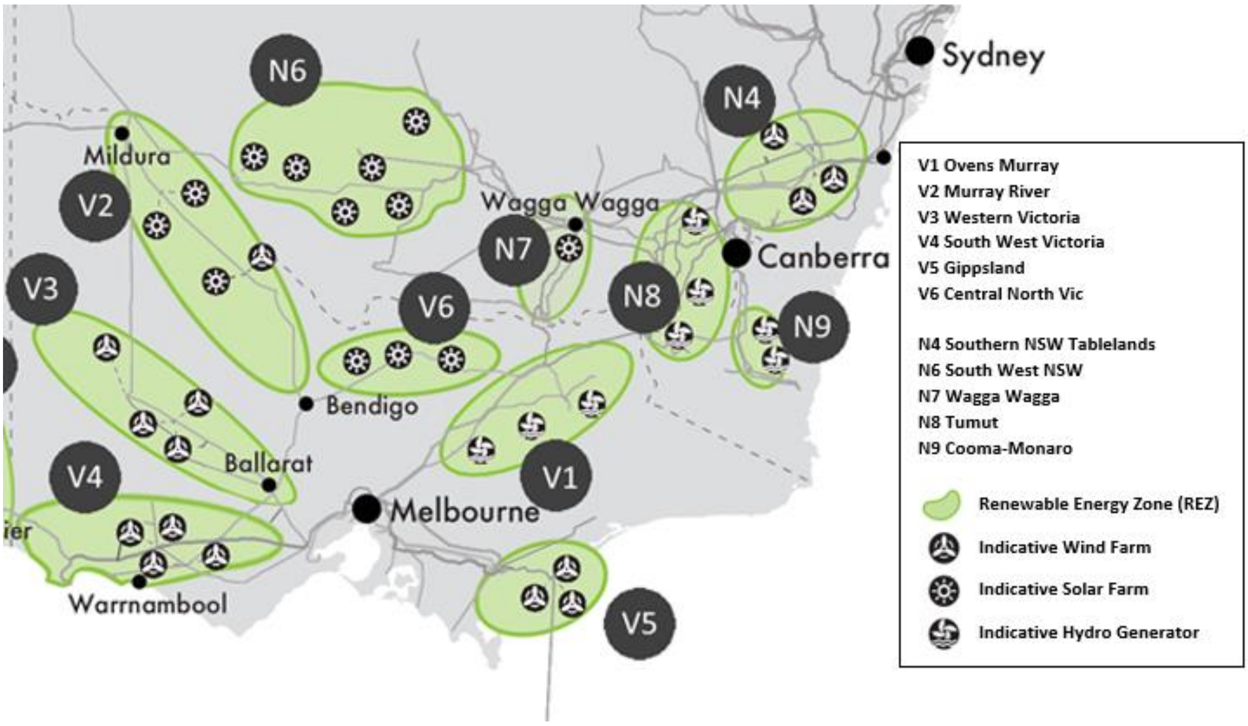
AEMO's 2019 VAPR and TransGrid's 2019 Transmission Annual Planning Report (TAPR) identified high levels of interest in renewable generation connection in western and northern Victoria and southern New South Wales areas, respectively. If the projected volume of new generation eventuates, then individual generators (both new and existing) may be significantly constrained due to thermal, stability and system strength limitations. Interconnector transfer limits between the states are also expected to constrain the output of these generators at some times. Together, these intra- and inter-regional network limitations will prevent the efficient transport of supplies to load centres in Victoria and New South Wales.

Renewable Energy Zones (REZs)

The 2018 ISP identified potential REZs throughout the NEM where high quality renewable resources exist in the vicinity of existing transmission network. These areas present a potential opportunity to reinforce the existing network and optimise transmission and generation investment. The ISP called for these areas to be prioritised for development, to drive generator investment in the most optimal locations and reduce the overall costs of renewable integration across the NEM. Following additional modelling and wide stakeholder consultation, AEMO published revised REZs, as shown below, in the 2019 Inputs and Assumptions Workbook[19].

[19] At https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2019-Integrated-System-Plan

Figure 3 Renewable Energy Zones in Victoria and southern New South Wales



Western and north-western Victoria and southern New South Wales present areas of high quality renewable energy resources near existing transmission infrastructure. There is significant interest in renewable development in these areas, with up to 8 GW of new generation currently proposed to connect in northern and western Victoria[20], and 20 GW of new generation proposed to connect in southern New South Wales[21]. The 2018 ISP identified that a large increase in bi-directional capacity between Victoria and New South Wales is expected to deliver benefits by reducing network congestion within and between the states, unlocking new low-cost renewable generation projects in key REZs, providing better access to pumped hydro storage, and providing firming supplies for growing levels of intermittent renewable generation.

Energy storage

The Snowy 2.0 project is an approximately 2 GW pumped hydro storage plant being developed in the Snowy Mountains. The Federal Government is supporting Snowy 2.0 as part of its broader energy plan.

Further interconnection between Victoria and New South Wales may provide efficiency benefits through increased access to this hydro storage development as well as offsetting the need for investment in other balancing services within Victoria to provide firm dispatchable capacity for the growing levels of intermittent renewable generation.

2.3 Network developments

A number of transmission augmentations projects are under development in Victoria, New South Wales, and South Australia are relevant to this RIT-T.

[20] See Victoria Generation Map on AEMO's NEM Generation Maps webpage, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Network-connections/NEM-generation-maps

[21] See Figure 26 of TransGrid's 2019 Transmission Annual Planning Report, at https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning/Documents/2019%20Transmission%20Annual%20Planning%20Report.pdf

RIT-Ts complete

- **Western Victoria Transmission Network Project (WVTNP)**[22] will increase the thermal capacity and voltage stability of the Western Victorian power system and reduce constraints on projected new generation in that region. The project proposal includes a combination of minor upgrades to existing infrastructure and major transmission works, including a new terminal station north of Ballarat and new high voltage transmission lines between Bulgana and Sydenham terminal stations. The project will alleviate constraints that would otherwise restrict new and existing generation in Western Victoria. A Project Assessment Conclusions Report (PACR) was published by AEMO in July 2019, and project commissioning is expected to conclude in 2025.
- **Project EnergyConnect**[23] will increase power transfer capability between South Australia, New South Wales, and Victoria by developing a new 330 kV interconnector from Robertstown in mid-north South Australia via Buronga and through to Wagga Wagga in New South Wales, and includes an augmentation between Buronga in New South Wales and Red Cliffs in Victoria. This project is expected to alleviate constraints introduced by projected generation in southern New South Wales that would otherwise restrict new and existing generation in this area and in north-west Victoria. The RIT-T is complete subject to AER final RIT-T determination. The project will then proceed into the implementation stage. The project is expected to be delivered between 2022 and 2024.

RIT-Ts underway

- **Victoria to New South Wales Interconnector Upgrade (VNI) RIT-T**[24] proposes providing an incremental increase in power transfer capability from Victoria and New South Wales, which is expected to deliver market benefits by enabling more efficient sharing of resources between states and reducing capital costs associated with new generation build in New South Wales in the short term. The proposed preferred option includes upgrades from South Morang to Dederang and modular power flow controllers on the New South Wales 330 kV network between Tumut, Canberra, and Yass. This project is related to the need of this RIT-T by alleviating existing limitations on the Victoria to New South Wales interconnector in the short term. A Project Assessment Draft Report (PADR) was jointly published by AEMO and TransGrid on 30 August 2019, and the project is expected to be delivered by 2022-23.
- **Reinforcing New South Wales Southern Shared Network (HumeLink) RIT-T**[25] proposes increasing transfer capacity between the Snowy Mountains and the major load centres of Sydney, Newcastle, and Wollongong. Options considered are expected to facilitate efficient development, dispatch, and sharing of renewable generation in high quality renewable resource areas. A PSCR was published by TransGrid in June 2019, and the project is expected to be delivered in 2024-25.
- **Project Marinus (MarinusLink) RIT-T**[26] proposes a new interconnector between Victoria and Tasmania. This project is proposed to allow additional renewable generation and storage capability (for example, Battery of the Nation) to be exported to the mainland. A PADR was published by TasNetworks on 5th Dec 2019, proposing delivery of the project in two stages - an initial 750 MW Direct Current (DC) link between Burnie in Tasmania and Hazelwood in Victoria with supporting network augmentations in Tasmania in 2028, and a further 750 MW DC link in 2032.

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[22] For information and reports, see the WVTNP webpage, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/RITT.

[23] For information and reports, see the SA Energy Transformation (SAET RIT-T webpage, at https://www.electranet.com.au/projects/south-australian-energy-transformation/, and Project EnergyConnect webpage, at http://www.projectenergyconnect.com.au/.

[24] For information and reports, see the VNI webpage, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Victoria-to-New-South-Wales-Interconnector-Upgrade-Regulatory-Investment-Test-for-Transmission.

[25] For information and reports, see the HumeLink webpage, at https://www.transgrid.com.au/what-we-do/projects/current-projects/Reinforcing%20the%20NSW%20Southern%20Shared%20Network.

[26] For information and reports, see the MarinusLink webpage, at https://projectmarinus.tasnetworks.com.au/rit-t-process/.

3. Network limitations

3.1 Victoria to New South Wales interconnector limitations

Historically, transfer between Victoria and New South Wales has been restricted by thermal, transient, and voltage stability limitations. A number of recently completed and progressing RIT-Ts include augmentations which will increase the transfer capacity between the states through their proposed preferred options.

The tables below summarise the limitations.

Table 2 Interconnector limitations – Victoria to New South Wales flow

Constraint type	Limitation	Proposed solution
Thermal capacity	500/330 kilovolt (kV) transformer at South Morang	VNI Upgrade RIT-T
Thermal capacity	330 kV transmission circuits from South Morang – Dederang	VNI Upgrade RIT-T
Thermal capacity	220 kV transmission circuits from Dederang to Mount Beauty	Nil[A]
Thermal capacity	330 kV transmission circuits from Murray to Upper Tumut and Murray to Lower Tumut	Nil[A]
Thermal capacity	330 kV transmission circuits from Canberra to Upper Tumut and Canberra to Lower Tumut	VNI Upgrade, HumeLink RIT-T
Transient stability	For the potential loss of a Hazelwood to South Morang line	EnergyConnect, WVTNP, VNI Upgrade RIT-T
Voltage stability	For the potential loss of Alcoa Portland Potline (APD) potlines[B]	Constraint update

A. The constraints not currently addressed in other ongoing RIT-Ts (categorised as 'nil') will be considered as part of this RIT-T.
B. This limitation was identified after the publication of the 2018 ISP and 2019 VAPR. This newly introduced voltage stability limitation can restrict transfers from Victoria to New South Wales only under light demand conditions

Table 3 Interconnector limitations – New South Wales to Victoria flow

Constraint type	Limitation	Proposed solution
Thermal capacity	330 kV transmission circuits from South Morang – Dederang	VNI Upgrade RIT-T
Thermal capacity	330 kV transmission circuit from Murray – Dederang	Nil[A]
Thermal capacity	220 kV transmission circuits from Dederang – Mount Beauty – Eildon – Thomastown	Nil[A]
Voltage stability	To prevent voltage collapse in southern New South Wales if a credible contingency event occurs in Victoria or Basslink	(Partially)[B]

A. The constraints not currently addressed in other ongoing RIT-Ts (categorised as 'nil') will be considered as part of this RIT-T.
B. A partial solution is proposed by TransGrid's proposed Wagga 100 MVAr 330 kV Capacitor, described in TransGrid's 2019 TAPR, at https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning/Documents/2019%20Transmission%20Annual%20Planning%20Report.pdf.

WVTNP and Project EnergyConnect, as well as the proposed preferred options in the VNI Upgrade RIT-T, are expected to increase the Victoria to New South Wales interconnector transfer capacity by relieving network limitations, as outlined above. These three projects are ISP Group 1 and 2 projects, designed to deliver near- and medium-term solutions to maximise economic use of existing resources.

As discussed in Section 2.1, more than a third of the existing conventional generation capacity in the NEM is expected to withdraw by 2032. Once these generators retire, a new generation mix based on renewables is projected to be lower-cost than new conventional generation. Projected transfer limitations in this timeframe are expected to result in limited access to low-cost generator sources across states, and prevent the efficient and reliable dispatch of supply to Victoria and New South Wales load centres.

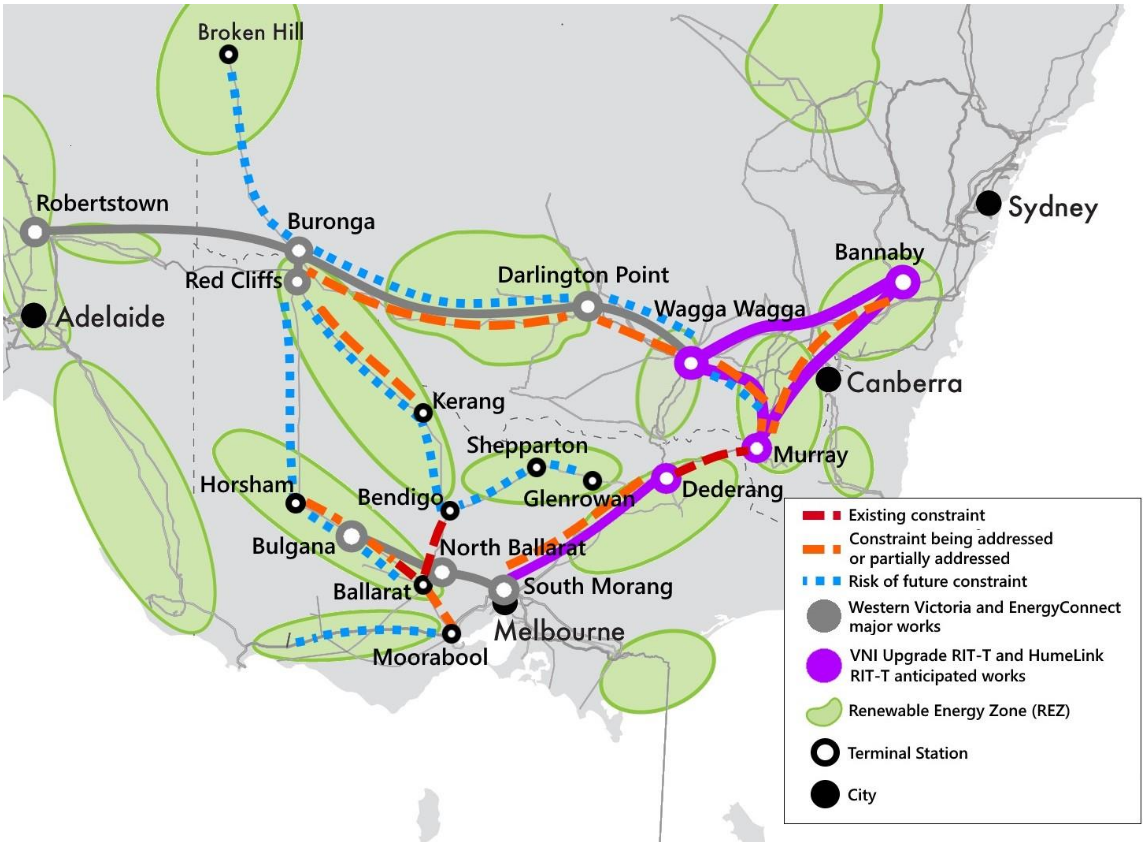
The augmentations associated with WVTNP, Project EnergyConnect, and the VNI Upgrade RIT-T are aimed at addressing existing or emerging constraints in the near to medium term. It is expected that the interconnector transfer needs will outgrow the proposed solutions in the longer term, and that further longer-term investment will be required in the second half of the 2020s to strengthen bi-directional interconnection beyond the scope of the current projects.

3.2 Intra-regional network limitations

In addition to interconnector limitations between Victoria and New South Wales, further intra-regional constraints exist in both regions that restrict the development and dispatch of remote lower-cost generation resources. These are expected to have growing market impacts as new renewable generators connect in weaker parts of the existing network.

AEMO's 2019 VAPR identified network limitations in Victoria for new generator developments, and identified key areas at risk of becoming constrained based on projections of generator connection. TransGrid's 2019 TAPR identified areas of existing congestion in New South Wales for new generator developments and emerging congestion based on projections of generator connection.[27] These limitations, in addition to existing and projected New South Wales network limitations, are illustrated in Figure 4.

Figure 4 Existing constraints in Victoria and southern New South Wales



[27] TransGrid, June 2019, New South Wales Transmission Annual Planning Report 2019, p7.

Existing constraints in western and northern Victoria

Historically, the network in western and northern Victoria was designed to support local demand, and has not previously required the infrastructure to support large volumes of supply. As significant levels of new generation connect in these areas, network limitations in Victoria are becoming more prevalent and many parts of the network are experiencing significant congestion due to thermal and stability constraints. Some of these existing limitations will be addressed by WVTNP and Project EnergyConnect. However, projected levels of new renewable generation development indicate that further investment will be required to address growing constraints in the medium and long term. The tables below outline identified existing and emerging constraints.

Table 4 Existing constraints driven by existing generator connections

Constraint type	Limitation	Solution in progress
Thermal capacity	Ballarat – Waubra 220 kV line for a credible contingency (Red Cliffs – Kiamal 220 kV line trip) or Ballarat – Waubra – Ararat 220 kV line for a credible contingency (Ballarat – Waubra –Ararat 220 kV line trip)	WVTNP *(Partially)*
Thermal capacity	Red Cliffs – Wemen – Kerang 220 kV line for a credible contingency (Ballarat – Waubra – Ararat 220 kV line trip)	WVTNP *(Partially)*
Thermal capacity	220 kV transmission circuits from Ballarat to Bendigo	Nil
Thermal capacity	220 kV transmission line No.1 from Ballarat to Moorabool	WVTNP
Voltage stability	Voltage oscillation in north-western Victoria under some system normal and credible outage conditions	Nil

Table 5 Emerging constraints based on proposed and projected generator development

Constraint type	Limitation	Solution in progress
Thermal capacity	Red Cliffs – Wemen – Kerang – Bendigo – Ballarat 220 kV lines under high generation conditions.	Nil
Thermal capacity	Bendigo – Shepparton – Glenrowan – Dederang 220 kV lines under high generation conditions.	Nil
Thermal capacity	Red Cliffs – Buronga 220 kV line	EnergyConnect *(Partially)*
Transient stability	Stability limitation on generation west of Moorabool during an outage of a 500 kV line in this area	Nil
Voltage stability	Voltage collapse in north-western Victoria for a credible contingency (Ballarat – Waubra – Ararat 220 kV line trip) which may trigger generator very fast tripping schemes	Nil

Existing constraints in southern New South Wales

Thermal capacity constraints between the Riverina, Snowy Mountains, and Sydney may also limit renewable generation in south-western and southern New South Wales, transfer capability between Victoria and New South Wales, supply to Victoria and New South Wales load centres, and access to future pumped storage (such as Snowy 2.0).

Several thermal limitations in southern New South Wales will be alleviated through TransGrid's current RIT-T to reinforce the New South Wales Southern Shared Network (HumeLink)[28], which is exploring options to increase transfer capacity between the Snowy Mountains and major New South Wales load centres. The HumeLink RIT-T will not address limitations between Victoria and southern New South Wales specifically, nor in south-western New South Wales. These limitations will be addressed through this VNI West RIT-T. The tables below outline identified existing and emerging constraints in southern New South Wales.

Table 6 Existing constraints driven by existing generator connections

Constraint type	Limitation	Solution in progress
Thermal capacity	330 kV transmission circuits from Lower Tumut / Upper Tumut to Yass / Canberra	HumeLink RIT-T
Thermal capacity	330 kV transmission circuits from Yass to Marulan	HumeLink RIT-T
Thermal capacity	330 kV transmission circuits from Yass to Bannaby (via Gullen Range and Crookwell)	HumeLink RIT-T
Thermal capacity	330 kV transmission circuit from Bannaby to Sydney West	HumeLink RIT-T
Thermal capacity	330 kV transmission circuits from Murray to Lower Tumut / Upper Tumut	Nil

Table 7 Emerging constraints based on proposed and projected generator development

Constraint type	Limitation	Solution in progress
Thermal capacity	330 kV transmission circuit from Wagga to Lower Tumut	HumeLink RIT-T
Thermal capacity	220 kV transmission circuits from Broken Hill to Darlington Point	EnergyConnect *(Partially)*
Thermal capacity	330 kV transmission circuit from Darlington Point to Wagga	EnergyConnect
Thermal capacity	132 kV transmission circuits from Darlington Point to Wagga via Finley	EnergyConnect

3.3 Other limitations

In addition to the previously listed network limitations, other locational signals guide developers to invest in areas that promote the most cost-effective outcome for consumers.

Diminishing system strength is presenting economic and technical challenges for the NEM as new inverter-based resources, including large and small scale generation, connect to weak areas of the network. There may be potential benefits in delivering a targeted and efficient investment to mitigate these challenges, deferring less efficient investment and unlocking high-value REZ capacity to deliver market benefits across the NEM.

System strength

System strength is a measure of the ability of a power system to remain stable under normal conditions and to return to a steady state condition following a system disturbance (that is, an unplanned contingency on the power system). It is therefore an important factor contributing to power system stability, and can materially impact the way a power system operates[29]. System strength is critical to supporting the stable operation of new generators and maintaining the stable operating of existing generators.

[28] For more information, see the HumeLink webpage, at https://www.transgrid.com.au/what-we-do/projects/current-projects/Reinforcing%20the%20NSW%20Southern%20Shared%20Network.

[29] See AEMO, *Power System Technical Requirements*, March 2018, at https://aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability.

A key issue associated with the integration of inverter-based renewable generation to the power system is that it can significantly reduce the system strength available to support stable operation of that generation and other inverter-based resources in the area. An area within the power system tends to have low system strength if it is remote from high voltage networks and synchronous generators.

Most projected renewable generation connections are in areas of the network that already have low system strength and, because the most common inverter technologies currently used do not inherently contribute to system strength, the available system strength in these areas is deteriorating with new connections.

In 2017, the Australian Energy Market Commission (AEMC) published a set of Rule changes which prescribed a framework for maintaining system strength on the power system[30]. There are two aspects to this framework:

- The minimum three-phase fault levels at each fault level node in each region are determined by AEMO[31] and any identified fault level shortfalls are subsequently addressed by the System Strength Service Provider (SSSP), being the TNSP.
- New generator connections, market network service facilities, and alterations to existing generating systems that give rise to an adverse system strength impact must be remediated by the relevant Connection Applicant, or by the connecting NSP at the cost of the applicant.

As new renewable generators are predominantly seeking connection to remote parts of the network, system strength requirements increasingly require developers to invest in additional remediation assets. Projects in some areas of Victoria and southern New South Wales can only progress through this system strength remediation process, and there are emerging stability issues that may impact the viability of further connections in those areas.

There are already several existing constraints which limit the output of inverter-based generation in weak parts of the network in Victoria and New South Wales. There is also a requirement to ensure a minimum level of synchronous generation is kept online to satisfy minimum system strength requirements in Victoria and South Australia[32]. As a result, low-cost inverter-based generation is being increasingly constrained in weak parts of the network.

Demand changes, network changes, and reduced online synchronous generation may also result in the deterioration of system strength in an area. If the system strength in a region falls below the base system strength requirements for these reasons, AEMO may declare a system strength shortfall. The SSSP is then required to procure system strength remediation services.

The 2018 ISP noted that a coordinated approach that allows renewable generators to contribute towards system strength for a REZ could be more economic than developing system strength solutions at individual connection points. Coordinated solutions, such as the installation of large synchronous machines or additional high voltage transmission lines, also have the potential to significantly increase system strength.

This RIT-T will consider the impacts of options on system strength, particularly in areas with low system strength, and investigate if option components provide system strength remediation.

4. Identified need

[30] See https://www.aemc.gov.au/rule-changes/managing-power-system-fault-levels.
[31] At https://www.aemc.gov.au/rule-changes/managing-power-system-fault-levels
[32] AEMO, *Transfer Limit Advice – System Strength*, October 2019, at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2019/Transfer-Limit-Advice-System-Strength.pdf.

4.1 Description of the identified need

The identified need considered by this RIT-T is for additional transfer capacity between New South Wales and Victoria to realise net market benefits[33] by:

Efficiently maintaining supply reliability in Victoria following the closure of further coal-fired generation and the decline in ageing generator reliability – including mitigation of the risk that existing plant closes earlier than expected

The 2018 ISP identified that further closure of coal-fired power stations in the Latrobe Valley would likely result in a supply shortfall in Victoria. EnergyAustralia has officially announced a staged closure of Yallourn Power Station between 2029 and 2032, which is up to three years earlier than projected in the ISP 2018. Without further investment, this is expected to bring forward projected supply shortfalls in Victoria, making it more difficult to maintain reliability.

While participants are required to provide adequate notice before decommissioning, there are risks that a substantial plant failure or force majeure event could also cause an early or unexpected plant retirement.

Additional transfer capacity between Victoria and New South Wales will also enable sharing of generation to contribute to reliability in New South Wales, given diversity in the timing of peak demand and timing of intermittent generation between states. Particularly at times of low demand and high generation in Victoria, the surplus generation can be adequately utilised to supply load centres and storage in New South Wales.

The investment may also provide route diversity[34] to increase the resilience of the grid against extreme climate conditions and improve system security.

Facilitating efficient development and dispatch of generation in areas with high quality renewable resources in Victoria and southern New South Wales through improved network capacity and access to demand centres

AEMO's 2019 VAPR and TransGrid's 2019 TAPR identified high volumes of interest in renewable generation connection in northern and western Victoria and southern New South Wales areas, respectively. These regions are attractive locations for new generation projects due to the quality and availability of renewable energy resources. As published in AEMO's Generation Information Page, approximately 8 GW of new generation is currently proposed to connect in northern and western Victoria, and 20 GW of new generation proposed to connect in southern New South Wales. This includes the development of Snowy 2.0, which the Federal Government is supporting as part of its broader energy plan.

The transmission network in these areas has not been designed to accommodate large volumes of inverter-based generation, either in terms of thermal capacity or system strength. Considering this volume of proposed generation development, there is potential for widespread thermal and stability constraints across these areas, adding to existing constraints for all (existing and new) generators in the area. Furthermore, increasing generation in these concentrated areas of high quality renewable resources may result in increased network losses between generators and load centres.

The network limitations in these regions are discussed further in Section 3.1. Addressing these limitations would facilitate the efficient development and dispatch of generation in these areas with high quality renewable resources.

Enabling more efficient resource sharing between NEM regions

The amount of renewable generation capacity and demand in any region is influenced by a number of localised conditions. This diversity may result in surplus low-cost generation in one region and high demand in another, which allows interconnection to improve sharing of diverse resources across states. Interconnector transfer limitations between Victoria, New South Wales and South Australia prevent the efficient sharing of resources between states, including from high quality REZs, as they limit the ability of surplus generation in

[33] The present value of net economic benefit to all those who produce, consume and transport electricity in the market.

[34] Having multiple physical interconnector routes between Victoria and New South Wales with no geographic points in common.

any region to supply load centres interstate. Section 3.1 discusses the existing transfer limits that may be addressed by this RIT-T.

Timely investment to increase the capacity of the western and north-western Victoria and southern New South Wales networks, and to increase the transfer capacity between the two states, is expected to enable utilisation of available supply across the NEM and encourage diversity of supply sources. This efficient resource sharing is expected to lower overall investment and dispatch costs across the NEM.

This investment is also expected to provide intermittent renewable generation with better access to pumped hydro storage (including Snowy 2.0), providing firm dispatchable energy when renewable generation is low, and storing renewable energy that may otherwise be spilled when renewable generation is high.

5. Assumptions made in identifying the need

This section provides a high-level summary of the key assumptions used in identifying the need giving rise to this RIT-T. These are consistent with the ISP 2019 Inputs And Assumptions Workbook (which contains key scenario data used as inputs in AEMO's market models for 2019 Planning and Forecasting activities and reflects the initial dataset for 2019-20 ISP modelling) and several other identified AEMO publications. The assumptions used also reflect the status of other ongoing network projects.

5.1 Scenarios and policy inputs

The 2019 Forecasting and Planning Scenarios, Inputs and Assumptions report[35] presents five scenarios which provide a suitably wide range of plausible futures. The scenarios differ with respect to the growth in grid-scale renewable generation resources, the uptake of DER, and responses to climate change. In summary, the scenarios are:

- The **Central scenario** – current transition of the energy industry.
- The **Slow Change scenario** – general slow-down of the energy transition.
- The **High DER** scenario – rapid consumer-led transformation.
- The **Fast Change** scenario – rapid technology-led transition.
- The **Step Change** scenario – strong action on climate change.

Modelling will incorporate all current policy settings in the Central scenarios, and test alternative futures in the other scenarios through the inclusion of NEM carbon budgets and policy variations[36]. Policies which are less certain may be modelled as sensitivities.

5.2 Demand forecast

Native demand for power is projected to increase, due to population and economic growth. However, much of this growth is forecast to be met by distributed energy resources (DER), such as rooftop photovoltaic (PV), and energy efficiency measures[37].

As a result, NEM operational demand for grid-supplied energy is projected to remain relatively flat over the ISP outlook period, and load growth is not the primary driver of the identified need in this RIT-T.

5.3 Projected generation and transmission development

The 2019 Inputs And Assumptions Workbook considered a wide range of potential upgrades to the national transmission grid, including intra-regional developments to connect REZs, and inter-regional developments to facilitate resource sharing and reliability.

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[35] AEMO, 2019 *Forecasting and Planning Scenarios, Inputs and Assumptions*, August 2019, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/2019-20-Forecasting-and-Planning-Scenarios-Inputs-and-Assumptions-Report.pdf.

[36] See sections 2.3 and 3.2 in *2019 Forecasting and Planning Scenarios, Inputs and Assumptions* for more information on the policy inputs used in the modelling, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies.

[37] Latest (2019 ESOO) maximum demand forecasts are at AEMO's forecasting portal, at http://forecasting.aemo.com.au/. For demand definitions, see AEMO, Demand Terms in EMMS Date Model, January 2019, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/Demand-terms-in-EMMS-Data-Model.pdf.

Refer to the New Entrant Data Summary, and Renewable Energy Zones sections of the workbook[38] for details of the future energy resource mix and projected REZs, and the Augmentation Options section for the full set of recommended transmission development options and their indicative timings.

This PSCR analysis considered all committed generation projects in Victoria and New South Wales, as listed on AEMO's Generation Information webpage at 8 August 2019[39]. Approximately 1,200 MW of generation is committed to connect to the transmission network in northern and western Victoria by mid-2020, and 3,000 MW of generation is committed to connect in southern New South Wales by 2025. This includes the development of Snowy 2.0 (2 GW).

WVTNP and Project EnergyConnect[40] have completed the RIT-T process and have been included in the preliminary analysis completed for this PSCR.

Although their RIT-Ts are not yet complete, when identifying the need for this RIT-T, the modelling performed included the proposed preferred option in the VNI Upgrade RIT-T and options being explored in the HumeLink RIT-T.

The MarinusLink RIT-T PADR, published on 5 December 2019, proposed a preferred option to construct an interconnector between Tasmania and Victoria to enable additional renewable generation and storage to be exported from Tasmania to the mainland. While this option has the potential to provide reliability benefits, it does not provide benefits in enabling greater resource sharing or efficient generation development and dispatch within and between Victoria and New South Wales. The MarinusLink proposed preferred option has not been considered in determining and assessing options presented in this PSCR. However, the RIT-T will be closely monitored throughout this VNI West RIT-T, and PADR modelling will consider the potential impacts of the MarinusLink proposed preferred option and its timing.

[38] At https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2019-Integrated-System-Plan

[39] See https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information. Commitment criteria are defined under the Background Information tab, and relate to site, components, planning, finance, and date.

[40] Project EnergyConnect RIT-T complete subject to AER final RIT-T determination.

6. Credible options to address the need

6.1 Overview of credible options

AEMO and TransGrid are jointly undertaking this RIT-T to assess options that are considered technically and economically feasible to increase bi-directional transfer capacity between Victoria and New South Wales in the long term. This RIT-T will assess options in addition to the expected preferred options identified in other RIT-Ts and discussed in Chapter 5.

Several large and long-term options will be tested as required by the current RIT-T process. Options that can be implemented quickly and economically when co-optimised with other network augmentations will also be considered.

From the credible options, the RIT-T will identify the preferred option and the optimal timing for its implementation.

AEMO and TransGrid are currently considering a number of options to increase the bi-directional transfer capacity between Victoria and New South Wales, which reflect upgrades on four alternative interconnector routes, and are considered to reasonably reflect the different permutations of network upgrades able to meet the identified need. These options build on those set out in the ISP 2019 Inputs and Assumptions Workbook[41].

In conjunction with these options, AEMO and TransGrid are considering additional network capacity upgrade expansions to accommodate areas of high quality renewable resources, which have significant potential for future generation growth. The four options and additional expansions considered are summarised in Table 8, and further illustrated in Figure 5.

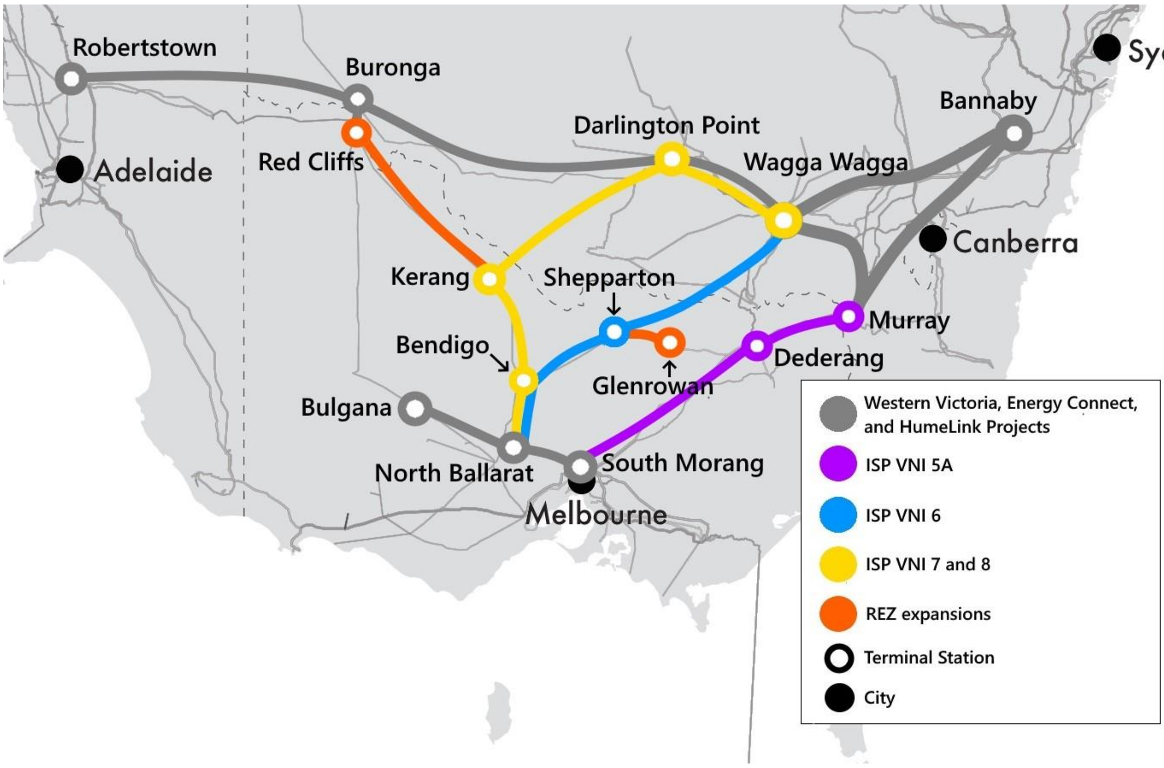
Table 8 Credible options – high level summary

Augmentation to existing VNI corridor	
VNI 5A	New 330 kV transmission lines from South Morang – Dederang – Murray
Augmentation on new corridors (Via Bendigo or Shepparton)	
VNI 6	New 500 kV transmission lines from North Ballarat – Bendigo* – Shepparton – Wagga
Augmentation on new corridors (Via Kerang)	
VNI 7	New 500 kV transmission lines from North Ballarat – Bendigo – Kerang – Darlington Point – Wagga
VNI 8	New 330 kV transmission lines from North Ballarat – Kerang – Darlington Point - Wagga
Potential expansions to accommodate REZs	
Expansion A	New transmission lines to unlock generation capacity from Kerang – Red Cliffs
Expansion B	New transmission lines to unlock generation capacity from Shepparton – Glenrowan

*VNI 6 also includes option variations which bypass Bendigo and/or Shepparton (see further detail in Table 9 and Section 6.2).

[41] AEMO, 2019 Inputs and Assumptions Workbook, September 2019, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan.

Figure 5 Map of credible options



Considerations made in identifying credible options of this RIT-T are discussed in Section 6.1.1, and a detailed summary of these options is provided in Section 6.1.2.

The remainder of Chapter 6 provides further detail on each of the credible options, and outlines other network options which have been considered, but not progressed as credible options. It also outlines technical requirements for non-network options to address the identified need of this RIT-T.

6.1.1 Considerations in identifying credible options

The credible options identified in this PSCR have been determined by considering network augmentations that would meet the identified need described in Chapter 4, i.e. for additional transfer capacity between New South Wales and Victoria to realise net market benefits[42] by:

realising net market benefits by:

- Efficiently maintaining supply reliability in Victoria following the closure of further coal-fired generation and the decline in ageing generator reliability – including mitigation of the risk that existing plant closes earlier than expected.
- Facilitating efficient development and dispatch of generation in areas with high quality renewable resources in Victoria and southern New South Wales through improved network capacity and access to demand centres.
- Enabling more efficient resource sharing between NEM regions.

Generation and energy resource growth

As described in Section 2.2, there is significant interest in the development of renewable generation in western and northern Victoria, and southern New South Wales[43]. Given the intermittent nature of this

[42] The present value of net economic benefit to all those who produce, consume and transport electricity in the market.
[43] For the latest available information on future generation interest, see AEMO's NEM generation maps, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Network-connections/NEM-generation-maps.

renewable generation, and to ensure efficient dispatch and reliability of supply, it is imperative that this generation is:

- Interconnected with other generation such that benefits from renewable resource diversity can be gained.
- Sufficiently connected to areas of existing and projected pumped hydro storage, such that the variable supply can be firmed and made more dispatchable.
- Sufficiently connected to major load centres via high capacity transmission such that the growth in renewable generation does not result in low cost generation being constrained off.

In addition to existing pumped hydro storage in the Snowy mountains in New South Wales, the Snowy 2.0 project[44], with an approximate generation capacity of 2,040 MW, is expected to be fully operational in 2025. Provided the necessary transmission infrastructure is constructed, the significant pumped hydro storage in this area could serve as "storage" for any surplus renewable generation in areas where there is significant projected generation growth. Doing so, and providing major load centres within Victoria and New South Wales with access to firmed energy, would likely defer investment in other more expensive resources such as peaking gas generation or shallow storage systems[45].

Several existing and projected network constraints may impact the efficient development, dispatch, and sharing of resources across the NEM, which in turn may impact the supply reliability outlook for different states. These constraints (as discussed in Chapter 3), and the locations of these resources, have been considered in identifying credible options of this RIT-T, and in determining routes for new transmission.

Route diversity

The potential value of diversifying geographic interconnector routes between Victoria and New South Wales was considered when determining the credible options.

The key benefit of route diversity is in unlocking geographically diverse generation, which is particularly important in the context of Australia's renewable future. Route diversity also increases the availability of interconnection between Victoria and New South Wales, and creates a more resilient power system as it mitigates against the potential impacts of extreme weather and natural disasters, eg bushfires, which can cause equipment in common locations to fail.

While there is value associated with geographic interconnector diversity, there may also be potential economic efficiencies to be leveraged through partial reliance upon existing transmission infrastructure and transmission easements. Partial reliance may also reduce some social and environmental impacts of new transmission projects. This has also been considered in identifying credible options.

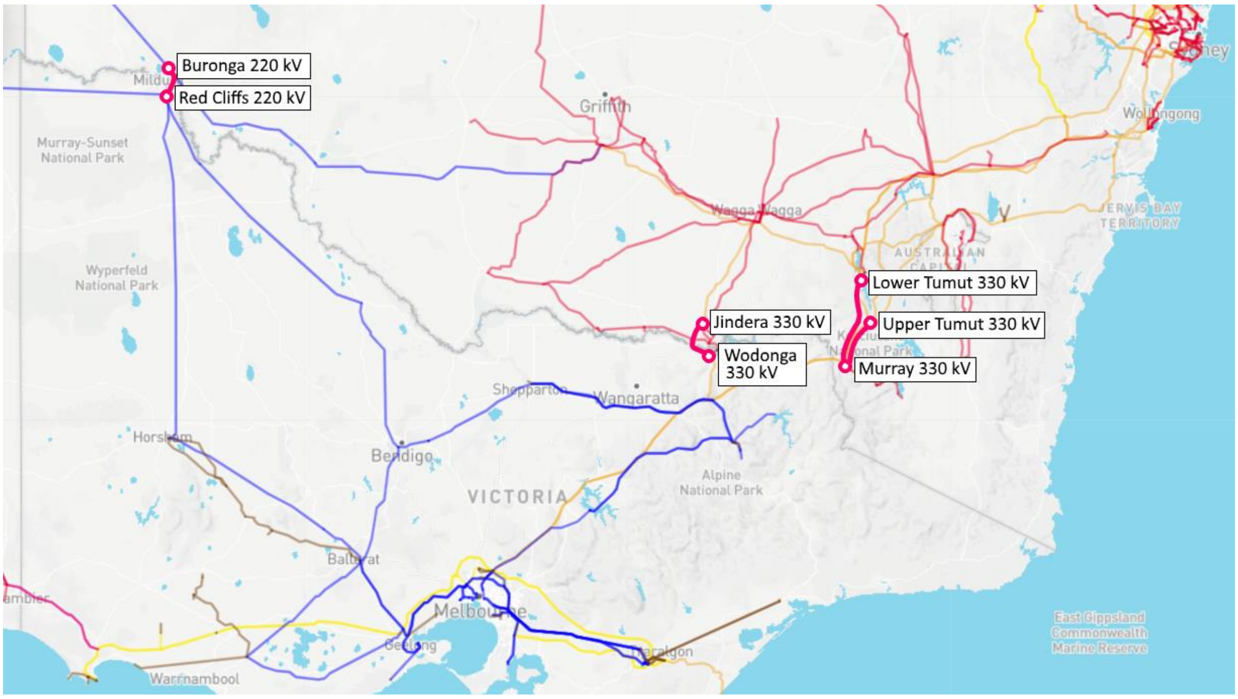
As shown in Figure 6, Victoria and New South Wales are currently interconnected via three main geographic routes. These are:

- The 220 kV transmission line between Red Cliffs and Buronga.
- The 330 kV transmission line between Wodonga and Jindera.
- The 330 kV transmission lines between Murray and Upper Tumut, and Murray and Lower Tumut.

[44] Snowy Hydro, Snowy 2.0 Project and Business Case Overview, February 2019, available at: https://www.snowyhydro.com.au/wp-content/uploads/2019/03/Snowy2_OverviewFeb19.pdf

[45] In referring to energy storage systems, 'depth' often refers to the energy to capacity ratio. 'Shallow' or short-term storage systems have relatively low energy to capacity ratios, such that they operate for relatively short periods before exhausting their storage reserves, whereas a 'deep' storage system has a high energy to capacity ratio, such that it can operate for long periods at high output before exhausting its energy storages. Storage 'depth' is independent of the peak capacity of the system; rather, it is a reference to how long that storage would last.

Figure 6 Existing Victoria to New South Wales interconnection routes



Impacts of other RIT-Ts

The options considered in other progressing RIT-Ts (discussed in Chapter 5) may alleviate some of the constraints identified in this report, and the impacts of these RIT-Ts have been considered in determining and assessing the options presented in this PSCR. In addition to WVTNP and Project EnergyConnect[46] that have completed the RIT-T process, the proposed preferred option in the VNI Upgrade RIT-T and anticipated works as part of the HumeLink RIT-T[47] have been considered.

As mentioned in Chapter 5, while the preferred option proposed in the Marinus Link PADR is expected to provide reliability benefits, it does not address other network constraints which limit the efficient development and dispatch of renewable generation in high quality areas in Victoria and New South Wales, and does not improve resource sharing between Victoria and New South Wales. The preferred option in the Marinus Link RIT-T has not been included as part of this PSCR's preliminary identification and assessment of credible options; however, sensitivities will be included as required in PADR modelling to explore the potential impacts of the MarinusLink RIT-T.

AEMO and TransGrid will closely monitor the status of progressing RIT-Ts, and any material changes will be accounted for in the RIT-T modelling.

Section 3 illustrates network constraints, potential locations of generation growth, and WVTNP and Project EnergyConnect works which have been considered in selecting the credible options presented in this PSCR. This figure also illustrates the preferred option of the VNI Upgrade RIT-T, and one of the proposed options of the HumeLink RIT-T, to highlight the potential future network upgrades that may unlock transfer capacity both on the Victoria to New South Wales interconnector and between areas of projected renewable generation growth and pumped hydro storage.

[46] Project EnergyConnect RIT-T complete subject to AER final RIT-T determination.

[47] Option 3C of the HumeLink RIT-T PSCR has been included in preliminary option studies, and relevant Option 3C works are included in option diagrams presented in Section 6.2 of this PSCR. This HumeLink option has been considered in this PSCR because it is consistent with the option described in the 2019 ISP input and assumptions workbook, however it is not assumed committed nor as the preferred option of its RIT-T.

6.1.2 Credible network options and cost estimates

There are a number of possible combined permutations of the credible options listed in Section 6.1. This section presents the credible options that are considered to be most commercially and technically feasible in terms of the criteria in clause 5.15.2 of the NER (with respect to, among other things, cost, timing, and ability to meet the identified need).

Other options which have been considered but were not deemed to be credible options are presented in Section 6.3.

Indicative cost estimates and typical expected delivery lead times from the expected RIT-T completion in 2022, considering currently anticipated procurement, planning, construction, and commissioning activities, are presented in the table below. Cost estimates presented reflect options that are constructed with overhead transmission lines and air-insulated switchgear[48]. These estimates may differ from the ISP, VAPR, and other estimates, because they have been refined and developed using the latest available information. The credible options considered and their cost estimates, including details such as operation and maintenance costs, construction and commissioning timelines, and additional site-specific requirements, will be refined through the PADR stage of the RIT-T, taking into account any updated information and submissions from stakeholders. Indicative commissioning dates are included in the more detailed option analysis in Section 6.2.

Estimated notional increases in the export and import transfer capacity of Victoria to New South Wales interconnection (VNI) are also presented in the table below. These estimates are based on preliminary analysis consistent with ISP assumptions, and are calculated by first estimating the total VNI transfer capacity provided with the respective credible option in service, and then subtracting the assumed notional VNI transfer capacity under a do-nothing scenario. The do-nothing VNI transfer capacity applied in this calculation assumes:

- 870 MW of Victoria to New South Wales (export) capacity (700 MW of existing export capacity[49] and approximately 170 MW of additional export capacity provided by the preferred option of the VNI Upgrade RIT-T[50])
- 400 MW of existing New South Wales to Victoria (import) capacity[51]

Estimated increases in VNI transfer capacity will be assessed in greater detail during the PADR stage of the RIT-T, taking into account a range of different generation dispatch and load conditions to test the robustness of these estimates, and to assess the power flow sharing capability across different interconnection paths.

Indicative estimates of the additional generation capacity that each of the credible options may unlock in REZs is provided in the detailed option descriptions in Section 6.2. These estimates represent the generation hosting capacity that credible options may unlock in a REZ to supply load in that REZ's respective region during high demand conditions. These estimates will also be refined through the PADR stage of the RIT-T.

[48] Underground cabling and gas-insulated switch-gear (GIS) were assessed as alternative construction solution. Preliminary cost estimations indicate that these constructions solutions are cost prohibitive.

[49] Minimum of Victoria to New South Wales nominal capacity range presented in Table 3 of the 2017 *Interconnector Capabilities* report, available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2017/Interconnector-Capabilities.pdf

[50] *Victoria to New South Wales Interconnector Upgrade RIT-T PADR*, available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2019/VNI-RIT-T/Victoria-to-New-South-Wales-Interconnector-Upgrade-RIT-T-PADR.pdf

[51] Minimum of New South Wales to Victoria nominal capacity range presented in Table 3 of the 2017 *Interconnector Capabilities* report, available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2017/Interconnector-Capabilities.pdf

Table 9 Summary of credible network options

Option		Estimated cost ($M)[A]	Estimated lead time (years)[52]	Notional VNI export increase (MW)[B]	Notional VNI import increase (MW)[C]	Approximate Route Length[D] (km)
Augmentation to existing VNI corridor						
VNI 5A	**New 330 kV transmission lines from South Morang to Dederang to Murray with New South Wales upgrades**	815	6-8	380	1,000	350
Augmentation on new corridor via Bendigo/Shepparton						
VNI 6	**New 500 kV transmission lines from North Ballarat – Shepparton – Wagga**	1,335	6-8	1,930	1,800	440
VNI 6-V1	**New 500 kV transmission lines from North Ballarat – Bendigo – Wagga**	1,290	6-8	1,930	1,800	440
VNI 6-V2	**New 500 kV transmission lines from North Ballarat – Bendigo – Shepparton – Wagga**	1,455	6-8	1,930	1,800	440
Augmentation on new corridor via Kerang						
VNI 7	**New 500 kV transmission lines from North Ballarat – Bendigo – Kerang – Darlington Point – Wagga**	1,855	6-8	1,930	1,800	605
VNI 8	**New 330 kV transmission lines from North Ballarat – Kerang – Darlington Point – Wagga**	1,445	6-8	1,130	800	605

Option Expansions		Estimated cost ($M)[A]	Estimated lead time (years)[52]	Generation capacity unlocked (MW)	Approximate Route Length[D] (km)
Additional expansions to unlock REZs[E]					
A	**New transmission lines to unlock generation capacity from Kerang – Wemen – Red Cliffs (REZ V2)**	320[F]	6-7[F]	2000[G]	233[F]
B	**New transmission lines to unlock generation capacity from Shepparton – Glenrowan (REZ V6)**	100[F]	6-7[F]	2000[G]	71[F]

A. *Option cost estimates provided here have an accuracy of +/- 50 percent, commensurate with the development stage of the project. Specifically, the costs provided here must not be interpreted as a cap or maximum cost but rather as the midpoint of range of possible cost outcomes.* The costs have been prepared through desktop studies, utilising preliminary plant and material cost data available at the date of preparation to provide for inter-option comparison. An extensive range of factors will affect the final project cost. For the transmission line component, these factors include (but are not limited to) environmental approvals, land acquisition, easement requirements, construction implications arising from route dynamics, currency fluctuations and construction contractor costs during

[52] The estimated lead time includes environmental and development approvals processes. Given the multi-jurisdictional nature of each of the credible options considered, the estimated approvals processes are expected to be commensurate across all options. Further detailed analysis will be carried out in preparation for the PADR across all options.

the proposed construction period etc. As such, the Estimated Costs specified are indicative only and will be further refined during the PADR and PACR stages of the project.

B. VNI export represents directional transfer from Victoria to New South Wales.

C. VNI import represents directional transfer from New South Wales to Victoria.

D. Route length estimates have been prepared on a network point-to-point straight line basis to provide for inter-option comparison. Route length estimates will be further refined during the PADR and PACR, subject to further analysis and estimation, and may differ significantly. Should a project be justified at the conclusion of the RIT-T process, the project route will be determined through additional and extensive analysis, stakeholder and community engagement and regulatory approvals.

E. Additional works through areas of projected generation growth may be considered as expansions to the credible options to better meet the identified need of this RIT-T, and they do not serve as stand-alone credible options in this RIT-T. Further detail is provided in section 6.2.

F. The size, capacity, route, length, cost and delivery lead times of augmentations to unlock REZs is dependent on the voltage level and number of circuits required to unlock the expected generation capacity on the network. The size, cost and delivery lead time estimates provided in this table represent double-circuit 220 kV transmission lines from Kerang – Wemen – Red Cliffs (for REZ Expansion A) and double-circuit 220 kV transmission lines from Shepparton to Glenrowan (for REZ Expansion B). These expansions may need to extend further (such as to Bendigo or North Ballarat) depending on the credible option they are being considered in conjunction with. Expected generation capacity and the net benefits in unlocking it will further be explored in the PADR stage, and necessary expansions to unlock REZs will be refined. Further detail on the incremental cost of all possible REZ expansion works considered in this PSCR is provided in Appendix A1.

G. Potential generation capacity unlocked in the transmission network as specified by the expansion. This is ultimately dependent on the voltage level and number of circuits included in the augmentation. These expansions will not, by themselves, provide additional VNI transfer capability.

AEMO and TransGrid note that rate design and cost recovery mechanism for projects like this need to be designed such that investors have a fair and predictable recovery mechanism to minimise the cost of capital for this project (and other major regulated investments in energy infrastructure).

In addition to the primary options and possible REZ expansions being considered above, variations or combinations of options may be considered in realising the greatest net market benefits. Further detail on each option is provided below.

6.2 Description of credible network options

VNI 5A (existing VNI corridor)

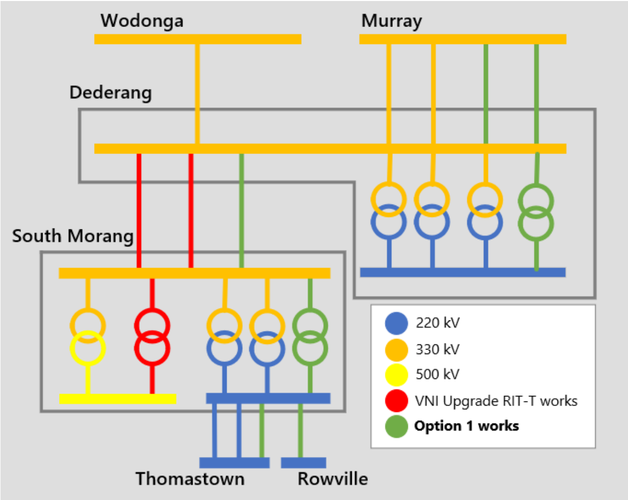
VNI 5A is intended to strengthen the existing Victoria to New South Wales corridor between South Morang and Murray by addressing VNI import and export limitations (discussed in Section 3) beyond the level expected from the preferred option of the VNI Upgrade RIT-T..

This option is also intended to address existing and potential constraints in the Snowy area, which may otherwise limit major load centres, including Melbourne, from accessing firm supply from existing and proposed pumped hydro storage in the Snowy Mountains region.

This option is expected to unlock transmission capacity in the Ovens Murray REZ V1 (per Figure 3) but will not provide additional transmission capacity in northern and western Victoria, and south-western New South Wales, where there is a significant amount of renewable generation development in progress and projected to continue. It therefore provides limited benefits in facilitating the efficient development, dispatch, and sharing of renewable generation in these high quality renewable areas. Further investment could be considered to strengthen transmission in these areas, provided there are benefits in doing so. This will be explored further in the PADR stage of this RIT-T.

This option does not provide a diversified interconnector route between Victoria and New South Wales, which would be conducive to system resilience. However, as the transmission infrastructure in this option may partially utilise spare width within existing easements, there may be some economic efficiencies through reduced easement and planning costs.

VNI 5A – New 330 kV transmission lines from South Morang to Dederang to Murray with New South Wales upgrades



VNI 5A involves constructing one new 330 kV single circuit line from South Morang to Dederang Terminal Stations with series compensation, a new 330 kV double circuit line from Dederang to Murray Terminal Stations, and new 330/220 kV transformers at Dederang and South Morang Terminal Stations, using high capacity equipment. It also involves the uprating of multiple 330 kV lines in New South Wales, potential reactive plant within existing terminal stations along the route, and a cut-in of the existing 220 kV Rowville to Thomastown line at South Morang to form a third 220 kV South Morang to Thomastown line.

Preliminary modelling indicates that this option may provide[53]:

- Additional 380 MW of VNI export capacity.
- Additional 1,000 MW of VNI import capacity.
- Additional 1,000 MW of generation capacity on the network in Ovens Murray REZ V1 (see Figure 3).

The estimated capital cost of this option is approximately $815 million. Following completion of the RIT-T process, delivery is expected to take six to eight years, with indicative completion by 2028-30. This is subject to obtaining necessary environmental and development approvals.

This option assumes completion of the VNI Upgrade RIT-T preferred option as well as anticipated works as part of the HumeLink RIT-T. If these projects do not become committed, additional augmentations will be considered as necessary as part of this option.

This option, or parts thereof, may also be considered in combination with options considered under new interconnector routes, as an additional scenario, to explore whether marginal net benefits exist when combining these options. This will be explored further in the PADR stage of this RIT-T.

A detailed list of this option's components and associated costs is included in Appendix A1. Further detail on the additional augmentations required in lieu of the VNI Upgrade RIT-T and HumeLink RIT-T works is provided in Appendix A1. These additional augmentations do not form part of VNI 5A at this stage.

VNI 6 to VNI 8 (new interconnector corridors)

These options involve the construction of transmission on a new interconnector route between Victoria and New South Wales, providing a high capacity link between the 500 kV Sydenham to North Ballarat corridor[54,55] delivered by WVTNP and the Snowy region in New South Wales. These options involve delivery of transmission infrastructure within new transmission easements. Estimated costs for easements and planning for these options are, on a per kilometre basis, generally assumed to be higher than the network upgrades considered in VNI 5A. These options are, however, expected to deliver more benefits, by:

- Unlocking areas with high quality renewable resources in Victoria and south-western New South Wales, and providing access to existing and projected pumped hydro storage in the Snowy region.

[53] Subject to detailed modelling of all potential steady-state and transient limitations.

[54] New 500/220 kV terminal station north of Ballarat as part of the Western Victoria Transmission Network Project . This terminal station connects to Sydenham via high capacity 500 kV double circuit lines as part of this project.

[55] There may be potential alternatives to the North Ballarat terminal station for new interconnector route starting points in Victoria. These will be explored further during the PADR stage of this RIT-T.

- Providing additional transmission from generation and other energy resources to load centres in Victoria and New South Wales to support these states during high demand periods.
- Providing larger overall transfer capability between Victoria and New South Wales.
- Diversifying interconnector paths.

The staged development of these options may also provide additional benefits, as certain option components (such as additional transmission capacity in certain network areas) may be required sooner than others to meet specific needs as they arise, such as the facilitation of resource development and dispatch. This and other staged alternatives will be explored during the PADR stage to determine a proposed preferred option that maximises net benefit. These other staged alternatives include:

- Initial stringing as single-circuit lines, with construction of transmission towers to facilitate connection of additional circuits in future.
- For VNI 6 and 7, initial operation at 330 kV but constructed to allow operation at 500 kV in future, including provisions at substations for 500 kV operation.

These options and their detailed component design assume the completion of works associated with WVTNP and Project EnergyConnect.

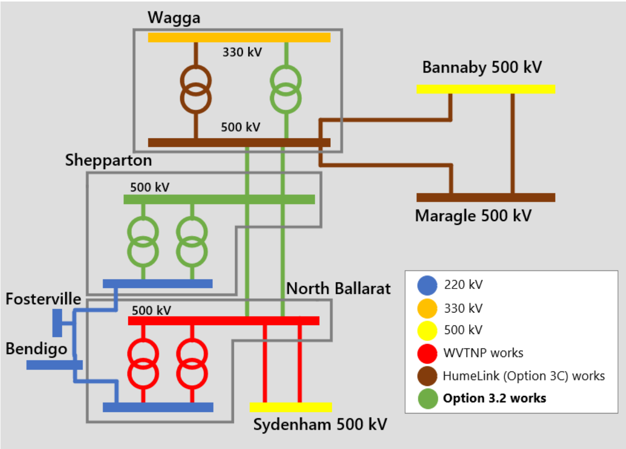
They also assume the completion of anticipated works as part of the VNI Upgrade and HumeLink RIT-Ts. If augmentations as part of these projects do not become committed, they may be considered as necessary in this RIT-T. Currently these augmentations do not form part of the costs associated with options considered in this RIT-T. Detailed option design will be refined further in the PADR stage, and outcomes of RIT-Ts with these anticipated works will be monitored closely to determine the required option components.

These options provide a new diversified interconnector route, which is conducive to unlocking the benefits discussed in Section 6.1.1. However, they are not able to benefit from spare transmission easement width, and will require easements to be assembled. Costs and lead times will be further refined during the PADR stage.

As presented further in this chapter, these options may be considered in conjunction with additional transmission augmentations to unlock areas within Victoria and southern New South Wales where there is significant interest in renewable generation growth, and where there is risk of this generation being constrained due to existing and future network constraints. See expansions A and B of Table 8 for additional transmission augmentations that are currently being considered to unlock high quality renewable resource areas. The exact requirements of these augmentations (such as voltage and number of circuits) will be explored further in the PADR stage, and are dependent on the expected renewable generation growth in these areas.

Given that each of these options creates a new diversified interconnector route, it is important that the new route works effectively with existing routes in terms of utilisation and power flow sharing. Components such as power flow controllers are included as part of the options to improve power sharing capability, however additional components may be required to achieve optimal power flow sharing across all interconnector routes between Victoria to New South Wales. The exact requirements to achieve this will be explored further in the PADR stage, and are dependent on the future planting and retirement of generation, as well as expected generation dispatch outcomes and load conditions.

VNI 6 – New 500 kV transmission lines from North Ballarat – Shepparton – Wagga



VNI 6 involves constructing new 500 kV double circuit lines from North Ballarat – Shepparton – Wagga, new 500 kV terminal station equipment with two 500/220 kV transformers at Shepparton Terminal Station, and a new 500/330 kV transformer at Wagga Wagga Substation, using high capacity equipment. This option will require additional power flow controllers within existing terminal stations and potential reactive plant within existing and new terminal stations along the route.

Preliminary modelling indicates that this option may provide[56]:

- Additional 1,930 MW of VNI export capacity.
- Additional 1,800 MW of VNI import capacity.
- Additional 1,000 MW of generation capacity on the network in Western Victoria REZ V3 and 2,000 MW of generation capacity on the network in Central North Vic REZ V6 (see Figure 3) – due to the high capacity link connecting from North Ballarat Terminal Station and extending to Shepparton Terminal Station.

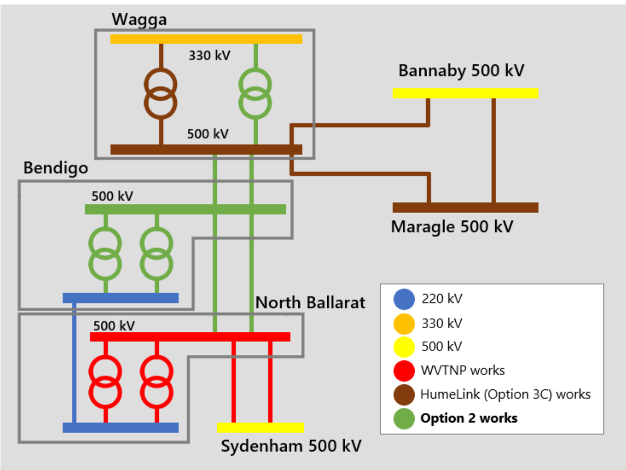
The estimated capital cost of this option is approximately $1,335 million. Following completion of the RIT-T process, delivery is expected to take six to eight years, with indicative completion by 2028-30. This is subject to obtaining necessary environmental and development approvals.

Additional transmission augmentations may be considered in conjunction with this option to unlock additional generation capacity in areas of high quality renewable resources:

- North Ballarat – (Bendigo)[57] – Kerang – Red Cliffs: to unlock additional capacity in Murray River REZ V2 (Expansion A of Table 8).
- Shepparton – Glenrowan: to unlock additional capacity in Central North Vic REZ V6 (Expansion B).

A detailed list of this option's components and associated costs is included in Appendix A1.

VNI 6 – Variation 1 – New 500 kV transmission lines from North Ballarat – Bendigo – Wagga



VNI 6-V1 involves constructing new 500 kV double circuit lines from North Ballarat – Bendigo – Wagga, new 500 kV terminal station equipment with two 500/220 kV transformers at Bendigo Terminal Station, and a new 500/330 kV transformer at Wagga Wagga Substation, using high capacity equipment. This option will require additional power flow controllers within existing terminal stations and potential reactive plant within existing and new terminal stations along the route.

Preliminary modelling indicates that this option may provide[58]:

- Additional 1,930 MW of VNI export capacity.
- Additional 1,800 MW of VNI import capacity.

[56] Subject to detailed modelling of all potential steady-state and transient limitations.
[57] This augmentation may either connect to or bypass Bendigo, depending on analysis which will be further explored during the PADR stage.
[58] Subject to detailed modelling of all potential steady-state and transient limitations.

- Additional 1,000 MW of generation capacity on the network in Western Victoria REZ V3 (see Figure 3) – due to the high capacity link connecting from North Ballarat Terminal Station.

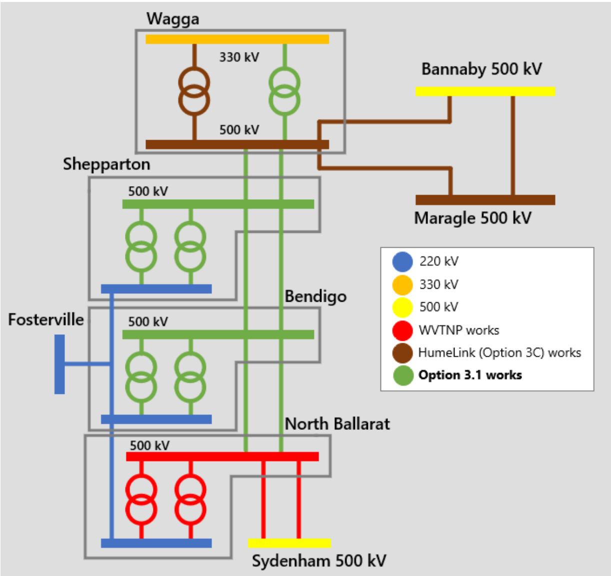
The estimated capital cost of this option is approximately $1,290 million. Following completion of the RIT-T process, delivery is expected to take six to eight years, with indicative completion by 2028-30. This is subject to obtaining necessary environmental and development approvals.

Additional transmission augmentations may be considered in conjunction with this option to unlock additional generation capacity in identified areas of high quality renewable resources:

- Bendigo – Kerang – Red Cliffs: to unlock additional capacity in Murray River REZ V2 (REZ Expansion A of Table 8).
- Bendigo – Shepparton – Glenrowan: to unlock additional capacity in Central North Vic REZ V6 (REZ Expansion B of Table 8).

A detailed list of this option's components and associated costs is included in Appendix A1.

VNI 6 – Variation 2 – New 500 kV transmission lines from North Ballarat – Bendigo – Shepparton – Wagga



VNI 6-V2 involves constructing new 500 kV double circuit lines from North Ballarat – Bendigo – Shepparton – Wagga, new 500 kV terminal station equipment with two 500/220 kV transformers at Bendigo and Shepparton Terminal Stations, and a new 500/330 kV transformer at Wagga Wagga Substation, using high capacity equipment. This option will require power flow controllers within existing terminal stations and potential reactive plant within existing and new terminal stations along the route.

Preliminary modelling indicates that this option may provide the following[59]:

- Additional 1,930 MW of VNI export capacity.
- Additional 1,800 MW of VNI import capacity.
- Additional 1,000 MW of generation capacity on the network in Western Victoria REZ V3 and 2,000 MW of generation capacity on the network in Central North Vic REZ V6 (see Figure 3) – due to the high capacity link connecting from North Ballarat Terminal Station and extending to Shepparton Terminal Station.

The estimated capital cost of this option is approximately $1,455 million. Following completion of the RIT-T process, delivery is expected to take six to eight years, with indicative completion by 2028-30. This is subject to obtaining necessary environmental and development approvals.

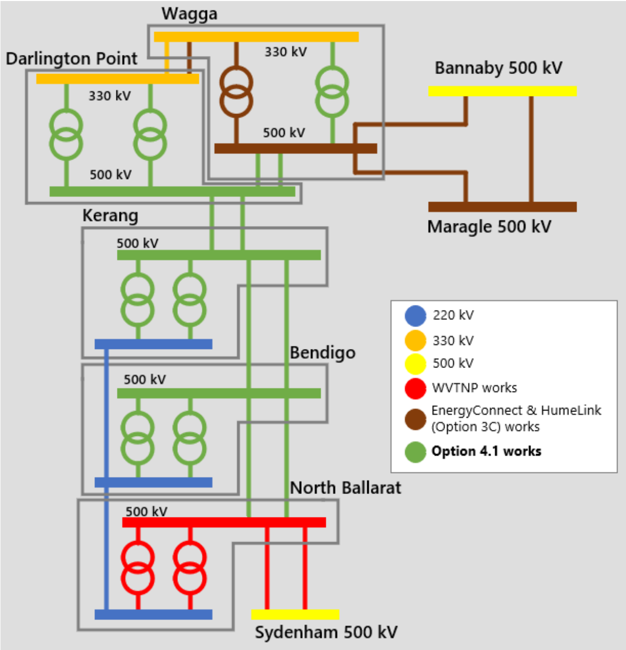
Additional transmission augmentations may be considered in conjunction with this option to unlock additional generation capacity in identified areas of high quality renewable resources:

- Bendigo – Kerang – Red Cliffs: to unlock additional capacity in Murray River REZ V2 (Expansion A of Table 8).
- Shepparton – Glenrowan: to unlock additional capacity in Central North Vic REZ V6 (Expansion B).

A detailed list of this option's components and associated costs is included in Appendix A1.

[59] Subject to detailed modelling of all potential steady-state and transient limitations.

VNI 7 – New 500 kV transmission lines from North Ballarat – Bendigo – Kerang – Darlington Point – Wagga



VNI 7 involves constructing new 500 kV double circuit lines from North Ballarat – Bendigo – Kerang – Darlington Point - Wagga, new 500 kV terminal station equipment with two 500/220 kV transformers at Bendigo and Kerang Terminal Stations, new 500 kV terminal station equipment with two 500/330 kV transformers at Darlington Point Substation, and a new 500/330 kV transformer at Wagga Wagga Substation, using high capacity equipment. This option will require additional power flow controllers within existing terminal stations and potential reactive plant within existing and new terminal stations along the route.

Preliminary modelling indicates that this option may provide[60]:

- Additional 1,930 MW of VNI export capacity.
- Additional 1,800 MW of VNI import capacity.
- Additional 1,000 MW of generation capacity on the network in Western Victoria REZ V3 and 2,000 MW of generation capacity on the network in Murray River REZ V2 (see Figure 3) – due to the high capacity link connecting from North Ballarat Terminal Station and extending to Kerang Terminal Station.
- Additional 1,000 MW of generation capacity on the network in South West NSW REZ N6 – due to the high capacity link extending through Darlington Point Substation.

The estimated capital cost of this option is approximately $1,855 million. Following completion of the RIT-T process, delivery is expected to take six to eight years, with indicative completion by 2028-30. This is subject to obtaining necessary environmental and development approvals.

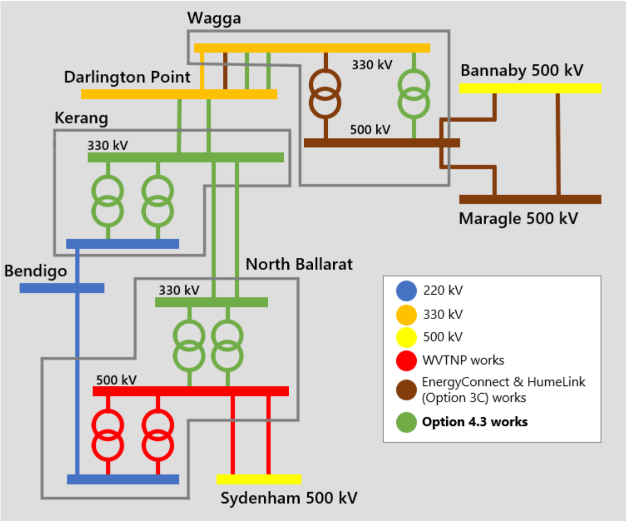
Additional transmission augmentations may be considered in conjunction with this option to unlock additional generation capacity in identified areas of high quality renewable resources:

- Kerang – Wemen – Red Cliffs: to unlock additional capacity in Murray River REZ V2 (Expansion A of Table 8).
- Bendigo – Shepparton – Glenrowan: to unlock additional capacity in Central North Vic REZ V6 (Expansion B).

A detailed list of this option's components and associated costs is included in Appendix A1.

[60] Subject to detailed modelling of all potential steady-state and transient limitations.

VNI 8 – New 330 kV transmission lines from North Ballarat – Kerang – Darlington Point – Wagga



VNI 8 involves constructing new 330 kV double circuit lines from North Ballarat – Kerang – Darlington Point - Wagga, new 330 kV terminal station equipment with two 500/330 kV transformers at North Ballarat Terminal Station and two 330/220 kV transformers at Kerang Terminal Station, and a new 500/330 kV transformer at Wagga Wagga Substation, using high capacity equipment. This option will require additional power flow controllers within existing terminal stations and potential reactive plant within existing and new terminal stations along the route.

This option is expected to provide similar types of benefits to option 7, with a lower scale of benefits due to the reduced capacity. Due to the number of options considered in this RIT-T, it is impractical to test each one at differing voltage levels. Therefore, VNI 7 and VNI 8 will be used to compare the differences in net benefits provided by a 330 kV network augmentation and a 500 kV network augmentation.

Preliminary modelling indicates that this option may provide[61]:

- Additional 1,130 MW of VNI export capacity.
- Additional 800 MW of VNI import capacity.
- Additional 1,000 MW of generation capacity on the network in Western Victoria REZ V3 and 1,000 MW of generation capacity on the network in Murray River REZ V2 (see Figure 3) – due to the high capacity (but lower capacity than VNI 7) link connecting from North Ballarat Terminal Station and extending to Kerang Terminal Station.
- Additional 1,000 MW of generation capacity on the network in South West NSW REZ N6 – due to the high capacity link extending through Darlington Point Substation.

The estimated capital cost of this option is approximately $1,445 million. Following completion of the RIT-T process, delivery is expected to take six to eight years, with indicative completion by 2028-30. This is subject to obtaining necessary environmental and development approvals.

Additional transmission augmentations on the following network may be considered in conjunction with this option to unlock additional generation capacity in identified areas of high quality renewable resources:

- Kerang – Wemen – Red Cliffs: to unlock additional capacity in Murray River REZ V2 (Expansion A of Table 8).
- North Ballarat – (Bendigo)[62] – Shepparton – Glenrowan: to unlock additional capacity in Central North Vic REZ V6 (Expansion B).

A detailed list of this option's components and associated costs is included in Appendix A1.

Additional expansions to unlock REZs

As noted in the sections above, AEMO and TransGrid are considering augmentations on existing transmission paths to better facilitate the development and dispatch of generation in high quality renewable resource areas. These augmentations would most efficiently be built in combination with the respective options considered under proposed new interconnector routes (VNI 6 to 8), which involve the construction of high

[61] Subject to detailed modelling of all potential steady-state and transient limitations.

[62] This augmentation may either connect to or bypass Bendigo, depending on net benefits which will be further explored during the PADR stage.

capacity transmission lines that either pass through identified areas of high quality renewable resources, or require incremental transmission upgrades to unlock such areas.

Transmission augmentations which are currently being considered to unlock additional generation capacity in areas of high quality resources include:

- **Expansion A**: New transmission lines to unlock capacity in Murray River REZ V2 (on the network between Kerang – Wemen – Red Cliffs Terminal Stations).
- **Expansion B**: New transmission lines to unlock capacity in Central North Vic REZ V6 (on the network between Shepparton – Glenrowan Terminal Stations).

As mentioned, these augmentations would be most cost-effective in conjunction with VNI 6 to 8, as this will result in less extensive additional upgrades to unlock REZ capacity than if they were considered in conjunction with VNI 5A. The staged development of these REZ augmentations is an important consideration in maximising the benefits associated with unlocking generation capacity in high quality renewable resource areas. Staged developments will be explored during the PADR stage of this RIT-T.

As previously mentioned, it is important to consider the power sharing capability of options with existing transmission. This is pertinent to new transmission on a diversified interconnector route, which may reduce the utilisation of existing interconnector routes, as well as new high-voltage transmission that runs parallel to existing 220 kV transmission in areas of projected renewable generation growth, such as western and northern Victoria, and southern New South Wales. In these areas, while it is important to relieve congestion that results in the constraining of low-cost generation, it is also important that augmentations on existing transmission paths effectively share power flows with already existing transmission capacity, such that unnecessary costs and operational risks are avoided.

Augmentations on existing transmission paths, particularly in regional areas of the network, would also require the management of new contingencies, particularly during planned network outages that would mean generation would need to be constrained such that power system security is maintained following the credible outage of any remaining parallel circuit. This matter, in addition to other costs and operational concerns, such as an increase in generator connection costs to connect to higher voltage transmission, are also important factors in determining augmentations to unlock capacity in areas of projected generation growth. These factors will be considered in more detail during the PADR stage of this RIT-T.

Expansion A – New transmission lines to unlock generation capacity from Kerang – Wemen – Red Cliffs

Expansion A involves constructing new transmission lines from Red Cliffs to Wemen to Kerang Terminal Stations, with potential to extend either to North Ballarat Terminal Station, Bendigo Terminal Station, or both, depending on the option with which it is being considered in conjunction. These transmission lines may be considered at either single-circuit or double-circuit, and at either 220 kV, 330 kV, or 500 kV voltage levels with associated station works and transformation.

The estimated capital cost of this augmentation depends on the option with which it is considered in conjunction. More detailed cost information is provided in Appendix A1.

Expansion B – New transmission lines to unlock generation capacity from Shepparton – Glenrowan

Expansion B involves constructing new transmission lines from Glenrowan to Shepparton Terminal Stations, with potential to extend either to North Ballarat Terminal Station or Bendigo Terminal Station, depending on the option with which it is being considered in conjunction. These transmission lines may be considered at either single-circuit or double-circuit, and at either 220 kV, 330 kV, or 500 kV voltage levels with associated station works and transformation.

The estimated capital cost of this augmentation depends on the option with which it is considered in conjunction. More detailed cost information is provided in Appendix A1.

Potential additional variation

AEMO and TransGrid are aware of a site at Donnybrook in Victoria which could be utilised as a potential alternate landing point to South Morang and North Ballarat Terminal Stations in options VNI 5A and VNI 6, respectively. This alternate location was considered as a potential variation to VNI 5A and VNI 6, respectively. This variation is expected to accrue similar economic benefits to the VNI 5A and 6 options with respect to the identified need, but will require additional capital cost to establish a new 500 kV terminal station at Donnybrook, reducing the net benefits of the respective options.

AEMO and TransGrid will assess the feasibility of this variation through the PADR process.

6.3 Network options considered but not progressed

New HVDC link between Sydenham and Snowy area

AEMO and TransGrid considered a potential new 2,000 MW high voltage direct current (HVDC) option, but concluded it was not a credible option on the grounds that it would be more expensive and less flexible than an equivalent alternating current (AC) solution.

The option considered involves a new HVDC path which directly connects large Victorian demand centres in the greater Melbourne and Geelong area with the Snowy mountains area in New South Wales. Two new 1,000 MW HVDC transmission lines would connect from Sydenham Terminal Station to the Snowy area with HVDC converter stations at both locations.

This option may improve the reliability outlook for Victoria, as it would allow generation in New South Wales, including pumped hydro storage in the Snowy Mountains, to supply Melbourne demand. However, a HVDC option would also be significantly less flexible than an equivalent AC solution in unlocking areas of projected future renewable generation growth in northern and western Victoria, and south-western New South Wales, as this would require the establishment of an AC-DC converter station at each connection location.

Preliminary estimation indicates that this option would be more expensive than an equivalent AC option with comparable capacity as it requires the establishment of AC-DC converter stations at each node. As the HVDC option is less suitable for facilitating efficient renewable generation development, and is expected to provide fewer net benefits, it has not been progressed as a credible option.

6.4 Non-network options

Non-network options may be available to address or partially address the identified need. For example, the use of an automatic load, generation, and/or battery response could minimise the impact of thermal limitations by allowing for the use of short-term five-minute ratings.

For transfer between Victoria and New South Wales, this could take the form of a combined demand and generation/battery response, with adequate demand response located in New South Wales and a generation or battery response located in Victoria for export, and vice versa for import. Such demand and generation/battery responses would need to work in combination to reduce loading on thermally limited lines during high transfer conditions, such that allowable transfer increases are commensurate with credible network options considered in this PSCR. Non-network solutions may also alleviate intra-regional constraints and unlock REZ capacity.

TransGrid, through its HumeLink RIT-T, is considering non-network options to relieve transmission constraints between the Snowy Mountains and major New South Wales load centres. Options considered in the first instance are those that are able to reduce load in central or northern New South Wales at times of high transfer between the Snowy Mountains and Sydney, Newcastle and Wollongong.

There is opportunity to consider jointly designed non-network options during the progression of this RIT-T, through strong coordination between AEMO and TransGrid and collaboration in considering and responding to feedback/submissions received from proponents of such non-network options. Such options would need to have demand and battery/generation response capabilities in both Victoria and New South Wales, to relieve transmission constraints under both Victoria to New South Wales import and export conditions.

A Battery Energy Storage System (BESS) was considered in the VNI Upgrade RIT-T to help improve stability limits in northern Victoria. This type of solution could also be considered in other areas of the network to help relieve stability limits in Victoria and New South Wales.

6.4.1 Information to be provided by proponents of a non-network option

The above is not an exhaustive list of potential non-network services. AEMO would welcome potential non-market service providers making submissions on potential non-network options they believe can address the identified need outlined in this PSCR.

Submissions should include details on:

- Organisational information.
- Relevant experience.
- Technical details of the service, including location and operating profile.
- Cost of service, separating capital and operational expenditure.
- Confirmation of timelines in providing the service.

7. Materiality of benefits

7.1 Classes of market benefit expected to be material to the RIT-T

The purpose of a RIT-T is to identify an option that addresses the identified need and maximises the present value of the net economic benefit to all those who produce, consume, and transport electricity in the market[63].

The NER require that the categories of market benefit identified in the test are included in the RIT-T assessment, unless the TNSP can demonstrate that:

- A specific class of market benefit is unlikely to affect materially the outcome of the RIT-T assessment of the credible options; or
- The estimated cost of undertaking the analysis to quantify that market benefit is likely to be disproportionate to the "scale, size and potential benefits of each credible option being considered".

In this case, to satisfy the RIT-T, there must be net market benefits associated with implementing the preferred option. Several feasible options may provide market benefits beyond the identified need, such as increased system strength, voltage support, or the ability to optimise fuel costs over time with storage devices. These market benefits will be considered in this RIT-T. Credible options that result in increased interconnection may also improve the power system's resilience to non-credible contingencies, changing operating patterns, and other possible market changes (such as early withdrawal of existing generating units). Such high-impact, low probability events can carry significant cost implications, and any related market benefits will also be considered.

The classes of market benefits considered most relevant to this RIT-T are outlined below.

Changes in fuel consumption arising through different patterns of generation dispatch

- Increasing transfer capacity is expected to promote more efficient sharing of generation resources between states. This represents an increase in productive efficiency, through better utilisation of lower-cost fuel sources.
- In addition, some option components (such as storage devices), may also allow inter-temporal optimisation between times where fuel costs are high and other times where fuel costs are low.

Changes in voluntary load curtailment and involuntary load shedding

- Increasing transfer capacity will improve the availability of supply at times of high demand in Victoria and New South Wales and therefore help meet reliability requirements. This is expected to reduce voluntary load curtailment and involuntary load shedding.
- Increasing interconnection between Victoria and New South Wales will also mitigate the risk of separation, thereby increasing the probability of maintaining system stability following the loss of a single interconnector, which would reduce the risk of involuntary load shedding.

Changes in costs to other parties due to differences in the timing of new plant, differences in capital costs and differences in operational and maintenance costs

- Increasing the transfer capacity will allow more efficient sharing of generation resources between states, and unlock intermittent generation access to NEM-wide balancing services such as energy storage. This may avoid (or defer) the need for new investment to maintain the same level of reliability and dispatchable supply.

[63] Refer to Clause 5.16.1 (b) of the NER.

- In addition, some option components (such as synchronous condensers and new high voltage transmission lines) can provide voltage control and system strength services, which reduce the need for investments by other parties.

Differences in the timing of transmission investment

- The implementation of options that increase transfer capacity between Victoria and New South Wales may also relieve other transmission network limitations, and may defer the need for new investment in intra-regional transmission to connect generation developments in remote areas.

Changes in network losses

- Additional interconnection, particularly through a new route, will impact network losses as the flows from generation to load centres will change. Increased interconnection will also strengthen the grid, making it more robust against increasing network losses as more generation is connected, and it will facilitate the efficient connection of renewable generation by having transmission paths pass directly through renewable resource rich areas.

Option value benefit

- Uncertainties in generation expansion and transmission development in other regions means there is value in retaining flexibility to respond to new information as or when it emerges. The ability to roll out network and non-network solutions incrementally may provide option value benefits, and would allow better management of uncertainty in generation and transmission development projections. The ability to design network solutions with optionality for scale-efficient expansion in future may also provide benefits.

7.2 Classes of market benefit not expected to be material to the RIT-T

The following classes of market benefits are not likely to be material to this RIT-T assessment.

Changes in ancillary services costs.

- There is no expected change to the costs of frequency control ancillary services (FCAS), network support and control ancillary services (NSCAS), and system restart ancillary services (SRAS) as a result of the augmentation options being considered. These costs are therefore not expected to be material to the outcome of the RIT-T assessment.

Competition benefits.

- While increasing the ability for resource sharing between states is likely to increase competition and therefore provide a competition benefit, this class of benefit is not expected to impact the ranking of options in this RIT-T as the potential competition benefits are unlikely to differ substantially across all credible options. This does not rule out consideration of competition benefits at a later stage if appropriate.

Negative of any penalty payable for not meeting the renewable energy target.

- The large-scale renewable energy target (LRET) will be modelled as a 'hard target' in this RIT-T, meaning that the target will always be achieved. Therefore, there will be no market benefits in relation to changes in the penalties paid for not meeting the LRET as result of any of the credible options.

A1. Detailed costing information

Option cost estimates provided have an accuracy of +/- 50 percent, commensurate with the development stage of the project. Specifically, the costs provided here must not be interpreted as a cap or maximum cost but rather as the midpoint of range of possible cost outcomes. The costs have been prepared through desktop studies, utilising preliminary plant and material cost data available at the date of preparation to provide for inter-option comparison. An extensive range of factors will affect the final project cost. For the transmission line component, these factors include (but are not limited to) environmental approvals, land acquisition, easement requirements, construction implications arising from route dynamics, currency fluctuations and construction contractor costs during the proposed construction period etc. As such, the Estimated Costs specified are indicative only and will be further refined during the PADR and PACR stages of this project.

VNI 5A

	Description	Estimated cost ($M)
VNI 5A	New Dederang – South Morang 330 kV single circuit with series compensation and associated station works	415[64]
	New Murray – Dederang 330 kV double circuit and associated station works	300
	New Dederang 330/220 kV transformer	15
	New South Morang 330/220 kV transformer	15
	Cut-in Rowville – Thomastown 220 kV line at South Morang to form third South Morang–Thomastown 220 kV line	10
	Uprating of the Murray to Lower Tumut 330 kV line	15
	Uprating of the Murray to Upper Tumut 330 kV line	15
	Potential reactive plant required – 2 x 150 MVAr shunt capacitors at Wodonga, Jindera or Wagga 330 kV	30
Total		815
Potential Additional Components*	Power flow controller on the Bannaby – Sydney West 330 kV line	80
	Uprating of the Yass to Marulan 330 kV lines	45
	Uprating of the Canberra to Yass 330 kV line	25
	Uprating of the Canberra to Lower Tumut 330 kV line	20
	Uprating of the Canberra to Upper Tumut 330 kV line**	40

* Option components are only required if anticipated works as part of the HumeLink RIT-T do not become committed. These components are included as part of VNI 5 of the Draft 2020 ISP, and are currently not considered as part of VNI 5A.
** Option components are only required if anticipated works as part of the VNI Upgrade RIT-T do not become committed. These components are included as part of VNI 1 of the Draft 2020 ISP, and are currently not considered as part of VNI 5A.

[64] The cost estimation for this component has an accuracy of ±30%. It is consistent with equivalent cost estimation provided for Option 4 of the VNI Upgrade RIT-T PADR, available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2019/VNI-RIT-T/Victoria-to-New-South-Wales-Interconnector-Upgrade-RIT-T-PADR.pdf

VNI 6

	Description	Estimated cost ($M)
VNI 6	New North Ballarat – Shepparton 500 kV double circuit and associated station works	405
	New Shepparton – Wagga 500 kV double circuit and associated station works	490
	2x 500/220 kV transformers at Shepparton Terminal Station	55
	1x 500/330 kV transformer at Wagga Wagga Substation	35
	Potential power flow controllers on: - Murray – Upper Tumut 330 kV line - Murray – Lower Tumut 330 kV line - Lower Tumut – Wagga 330 kV line	240
	Potential reactive plant required - 2 x 200 MVAr SVC* at Shepparton 220kV - 4 x 100 MVAr shunt reactor at Shepparton 500kV - 2 x 100 MVAr shunt reactor at North Ballarat 500kV - 2 x 100 MVAr shunt reactor at Wagga 500kV	110
Total		1335

* Synchronous condensers will also be considered as an alternative solution to providing reactive support.

VNI 6 – Variation 1

	Description	Estimated cost ($M)
VNI 6 – Variation 1	New North Ballarat – Bendigo 500 kV double circuit and associated station works	215
	New Bendigo – Wagga 500 kV double circuit and associated station works	680
	2x 500/220 kV transformers at Bendigo Terminal Station	55
	1x 500/330 kV transformer at Wagga Wagga Substation	35
	Potential power flow controllers on: - Murray – Upper Tumut 330 kV line - Murray – Lower Tumut 330 kV line - Lower Tumut – Wagga 330 kV line	240
	Potential reactive plant required: - 2 x 100 MVAr shunt reactor at North Ballarat 500 kV - 4 x 100 MVAr shunt reactor at Bendigo 500 kV - 2 x 100 MVAr shunt reactor at Wagga 500 kV	65
Total		1290

VNI 6 – Variation 2

	Description	Estimated cost ($M)
VNI 6 – Variation 2	New North Ballarat – Bendigo 500 kV double circuit and associated station works	215
	New Bendigo – Shepparton 500 kV double circuit and associated station works	225
	New Shepparton – Wagga 500 kV double circuit and associated station works	490
	2x 500/220 kV transformers at Bendigo Terminal Station	55
	2x 500/220 kV transformers at Shepparton Terminal Station	55
	1x 500/330 kV transformer at Wagga Wagga Substation	35
	Potential power flow controllers on: - Murray – Upper Tumut 330 kV line - Murray – Lower Tumut 330 kV line - Lower Tumut – Wagga 330 kV line	240
	Potential reactive plant required: - 2 x 200 MVAr SVC* at Shepparton 220kV - 4 x 100 MVAr shunt reactor at Shepparton 500kV - 2 x 100 MVAr shunt reactor at North Ballarat 500kV - 4 x 100 MVAr shunt reactor at Bendigo 500kV - 2 x 100 MVAr shunt reactor at Wagga 500kV	140
Total		1455

* Synchronous condensers will also be considered as an alternative solution to providing reactive support.

VNI 7

	Description	Estimated cost ($M)
VNI 7	New North Ballarat – Bendigo 500 kV double circuit and associated station works	215
	New Bendigo – Kerang 500 kV double circuit and associated station works	260
	New Kerang – Darlington Point 500 kV double circuit and associated works	465
	New Darlington Point – Wagga 500 kV double circuit and associated works	325
	2x 500/220 kV transformers at Bendigo Terminal Station	55
	2x 500/220 kV transformers at Kerang Terminal Station	55
	2x 500/330 kV transformers at Darlington Point Substation	65
	1x 500/330 kV transformer at Wagga Wagga Substation	35
	Potential power flow controllers on: - Murray – Upper Tumut 330 kV line - Murray – Lower Tumut 330 kV line - Lower Tumut – Wagga 330 kV line	240
	Potential reactive plant required	140

	Description	Estimated cost ($M)
	- 2 x 200 MVAr SVC* at Kerang 220kV - 4 x 100 MVAr shunt reactor at Kerang 500kV - 2 x 100 MVAr shunt reactor at Darlington Point 500kV - 2 x 100 MVAr shunt reactor at North Ballarat 500kV - 4 x 100 MVAr shunt reactor at Bendigo 500kV	
Total		1855

* Synchronous condensers will also be considered as an alternative solution to providing reactive support.

VNI 8

	Description	Estimated cost ($M)
VNI 8	New North Ballarat – Kerang 330 kV double circuit and associated station works	355
	New Kerang – Darlington Point 330 kV double circuit and associated works	370
	New Darlington Point – Wagga 330 kV double circuit and associated works	260
	2x 500/330 kV transformers at North Ballarat Terminal Station	60
	2x 330/220 kV transformers at Kerang Terminal Station	40
	1x 500/330 kV transformer at Wagga Wagga Substation	35
	Potential power flow controllers on: - Murray – Upper Tumut 330 kV line - Murray – Lower Tumut 330 kV line - Lower Tumut – Wagga 330 kV line	240
	Potential reactive plant required - 2 x 200 MVAr SVC* at Kerang 220kV - 4 x 50 MVAr shunt reactor at Kerang 330kV - 2 x 50 MVAr shunt reactor at Darlington Point 330kV - 2 x 50 MVAr shunt reactor at North Ballarat 330kV	85
Total		1445

* Synchronous condensers will also be considered as an alternative solution to providing reactive support.

REZ Expansions A and B

	Description	220 kV estimated cost ($M)		330 kV estimated cost ($M)		500 kV estimated cost ($M)	
		Single-circuit	Double-circuit	Single-circuit	Double-circuit	Single-circuit	Double-circuit
Mutual components	New North Ballarat – Bendigo transmission lines and associated works	125	140	210	265	240	280
Expansion A components	New North Ballarat – Kerang transmission lines and associated works	265	290	360	455	445	525
	New Bendigo – Kerang transmission lines and associated works	150	165	205	245	275	325
	New Kerang – Wemen transmission lines and associated works	205	230	265	320	360	425
	New Wemen – Red Cliffs transmission lines and associated works	80	90	130	150	180	210
	New Kerang – Red Cliffs transmission lines and associated works	275	305	345	420	465	550
Expansion B components	New North Ballarat – Shepparton transmission lines and associated works	260	285	355	450	435	515
	New Bendigo – Shepparton 220 kV transmission lines and associated works	145	160	200	240	270	320
	New Shepparton – Glenrowan transmission lines and associated works	90	100	140	165	190	225