2020 ISP Appendix 3. Network Investments

July 2020

Important notice

PURPOSE

This is Appendix 3 to the Final 2020 Integrated System Plan, available at https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp.

DISCLAIMER

VERSION CONTROL

Version	Release date	Changes
1.0	30/7/2020	Initial release

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2020 ISP Appendices

Summary

This Network Investments appendix provides technical detail on the network investments which form the optimal development path. These network investments can be classified into committed, actionable (with and without staging), future projects with preparatory activities, and future projects where no action is required before the 2022 ISP.

Key insights

The national transmission network (the network) will continue to be fundamental in realising an efficient, reliable, and secure power system, but the role of the network will shift from one based predominantly on bulk energy transfer to one that also includes the network's critical role in enabling essential power system services and supporting new generation development. To support this evolution, this ISP recommends:

- Increased interconnection between regions to enable more efficient sharing of resources and, where possible, to also serve to connect to REZs.
- Facilitating connection of new renewable generation with REZ network expansion.
- Reinforcing sections of the network to ensure congestion on the network is minimised as the location of new generation moves from coal centres to REZs.
- Making the power system resilient to climate and other events through increased interconnection with geographical diverse paths[1].
- Recognising key decision points to adapt the network plan to policy, technical and market changes.

To achieve this, AEMO recommends network investment which yields some 6,000 MW of increased interconnector capability and increases REZ hosting capacity by 23 GW in the Central scenario, including:

- Six **actionable projects** that should now progress regulatory approval:
  - **VNI Minor** – an upgrade to the existing Victoria to New South Wales Interconnector (VNI) to improve transfer from Victoria to New South Wales.
  - **Project EnergyConnect** – a proposed 330 kV interconnector between South Australia and New South Wales.
  - **HumeLink** – a proposed major transmission line in New South Wales to connect the Snowy Mountains hydroelectric scheme to the Greater Sydney load centre.
  - **Central-West Orana REZ Transmission Link** – expansion of the network to connect 3,000 MW of new generation which is expected as part of the New South Wales Electricity Strategy[2].
  - **VNI West** – a proposed interconnector between Victoria and New South Wales.
  - **Marinus Link** – a proposed HVDC link between Tasmania and Victoria.
- Six **future ISP projects that require preparatory activities** so the next scheduled ISP (in 2022) has better information to determine their optimal timing.
- Three **future ISP projects with no action required** until the 2022 ISP.

[1] See Appendix 8 for further detail.

[2] See https://energy.nsw.gov.au/government-and-regulation/electricity-strategy.

A3.1. Introduction

This appendix is part of the 2020 ISP, providing more detail on the network investments which form the optimal development path. These network investments can be classified into the following depending on their status and required timing:

- **Committed grid projects**.
- **Actionable ISP projects**, including projects with decision rules.
- **Future ISP projects**, which include:
  - Projects which preparatory activities are required.
  - Projects which no action is required until the next ISP.

These network investments ensure there is sufficient interconnection so resources can be shared between regions, REZs are able to transfer their energy to the load centres, and the power system is secure and reliable.

The appendix is set out in the following sections:

- A3.2 – an overview of network investments in the optimal development path. This section outlines individual projects and their respective status, and summarises the key information including cost, timing and classification. It also covers decision rules that affect the optimal development path given uncertain events, as well as a summary of the key non-network opportunities identified in the development path.
- A3.3 – describes the committed network projects including their timing, costs, technical detail and related projects. Committed network projects are projects which have gone through the Regulatory Investment Test for Transmission (RIT-T) process and received contingent project approval from the AER.
  - This section also includes a description of potential non-network opportunities and alternative network options which were considered but not ultimately not selected for the optimal development path
- A3.4 – describes the optimal timing, costs, technical detail and related projects of actionable projects. Actionable ISP projects are projects which are underway or should commence immediately in order to reduce costs, enhance system resilience and optionality. It includes actionable ISP projects with decision rules to be met. Their decision rules can be assessed during the RIT-T process and will be confirmed by AEMO during an ISP feedback loop process with the TNSP.
  - This section also includes a description of potential non-network opportunities and alternative network options of the actionable projects which were considered.
- A3.5 and A3.6 – describes the optimal timing, costs, technical detail and related projects for the two types of future ISP projects. These are:
  - Projects for which preparatory activities are required.
  - Projects for which no action is required until the next ISP.
- A3.7 – compares the network congestion observed to date with the projects on the optimal development path, demonstrating how network congestion is addressed by these projects.
- A3.8 – lists the options which were not progressed as a direct alternative to a project on the optimal development path and explains why they were not progressed.

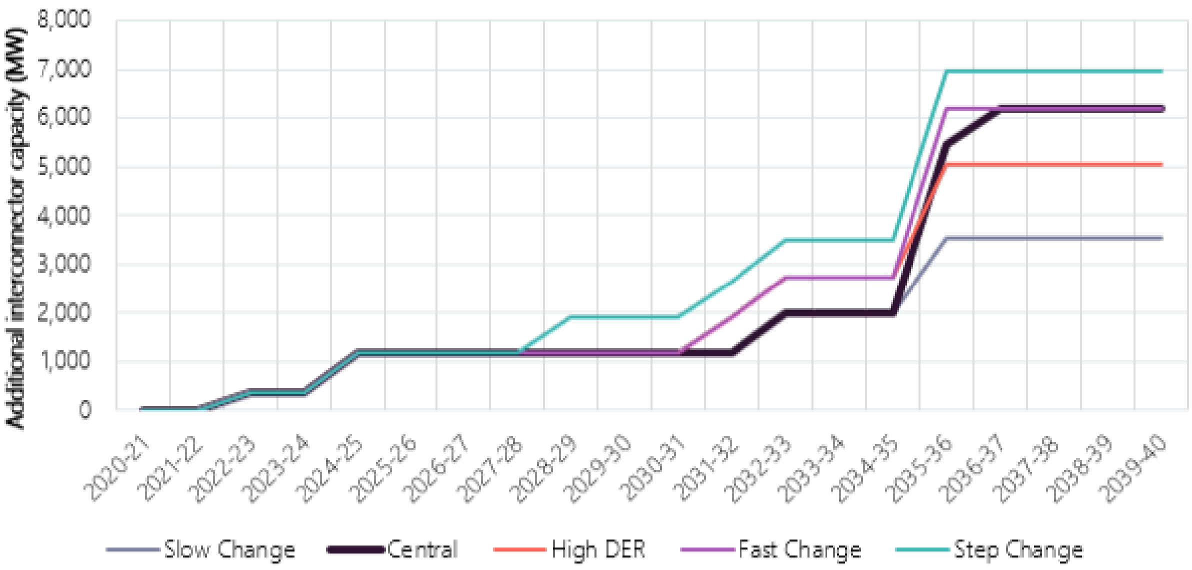
A3.2. Network investments in the optimal development path

The optimal development path includes a set of network investments which are coordinated and integrated with projected development of new generation, storage, and DER, to deliver the best outcomes for consumers across a range of scenarios and sensitivities[3]. The optimal development path results in the network having greater capability in order to meet the future power system needs. In short, this capability can be demonstrated by two overarching metrics[4]:

- An increase in interconnector capability, and, in conjunction,
- An increase in capability to connect and transfer generation from REZs to load centres or to increase interstate trading.

The net increase in interconnector capacity from the optimal development path investment is shown in Figure 1. In all scenarios, a significant increase in capacity is developed – more than double the existing interconnector capacity in all except the Slow Change scenario.

Figure 1 Additional interconnector capacity in the optimal development path



Note: Decision rules may affect the optimal timing of interconnector upgrades.

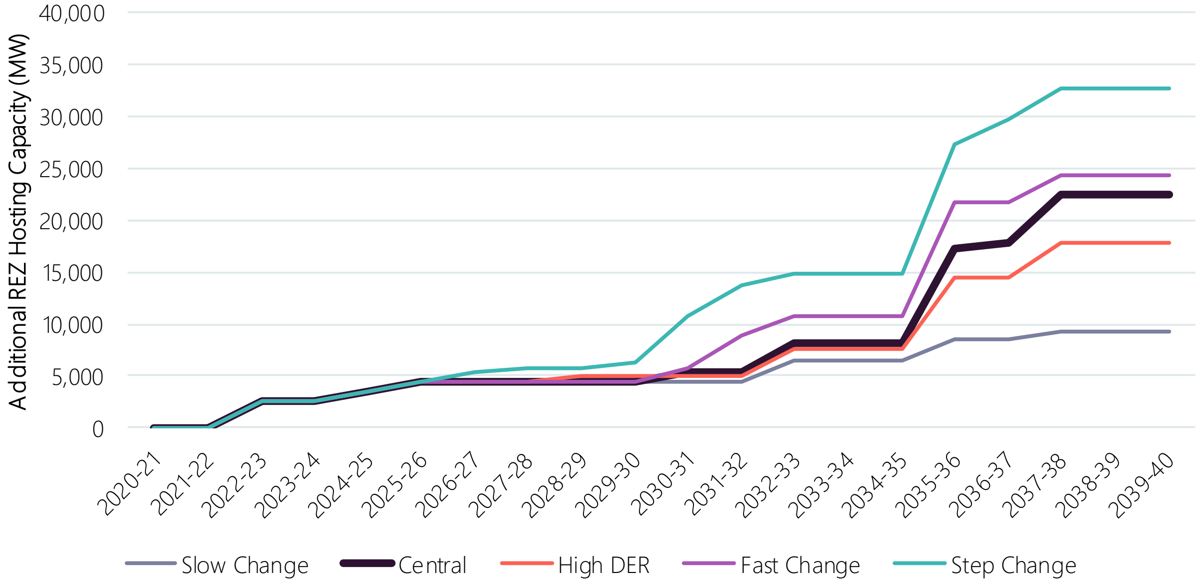
Likewise, the optimal development path investment yields a significant increase in the network's ability to host VRE in REZs, as shown in Figure 2. In all scenarios, a significant increase in REZ hosting capacity is delivered to

[3] The scenarios and sensitivities can be found in Appendix 2.

[4] The investment required to maintain system security is covered in Appendix 7.

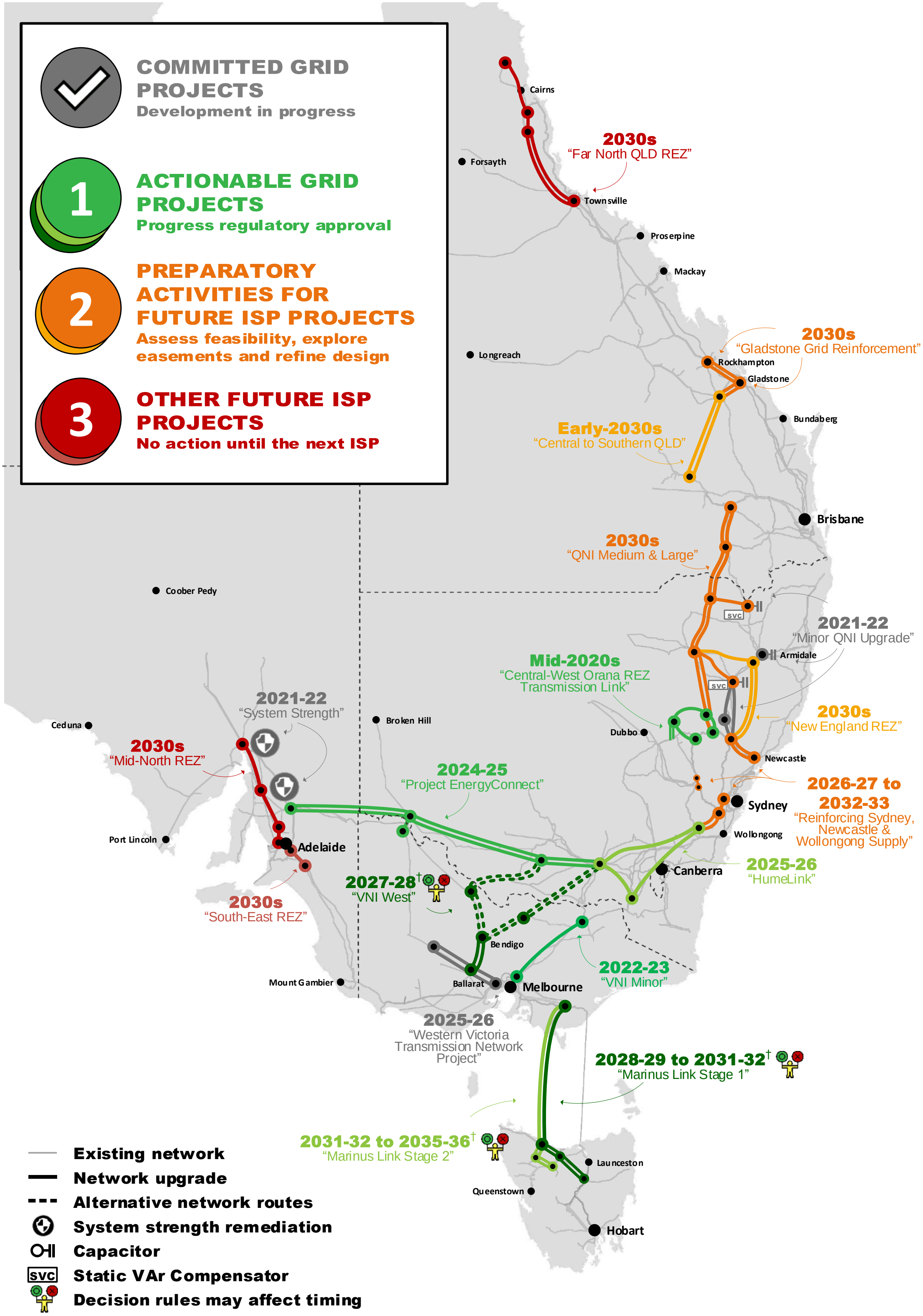
provide sufficient capability to connect generation located in REZ to the load centres and reduce network congestion.

Figure 2 Increase in REZ hosting capacity



The optimal development path includes a range of projects from Far North Queensland to Tasmania and includes interconnector projects, transmission to connect REZs, system security investments, and network upgrades to reinforce the network following the retirement of thermal plant. These projects can be seen in Figure 3.

Figure 3 Optimal development path



† The timing of this actionable project is dependent on decision rules.

A3.2.1 Committed ISP projects

Committed ISP projects are network projects identified by the 2018 ISP[5] which have now completed their regulatory approval processes. These projects are outlined in the following table.

Table 1 Committed ISP projects

Project	Scheduled timing	Approval status	Network capability improvement[A]
SA system strength remediation[B]	2021-22[C]	Complete	Maintain system security
QNI Minor[D]	2021-22	Complete	NSW-QLD (North): +150 MW NSW-QLD (South): +165 MW to 215 MW
Western Victoria Transmission Network Project[E]	2025-26[F]	Complete	The Western Vic Augmentation will increase the hosting capacity in the Western VIC REZ to cater for all existing and committed generation[G] with approximately 450 MW of remaining hosting capacity.

A. The transfer capacities shown in this table are notional limits at the time of high summer demand in the importing region.
B. AER, Final Decision: ElectraNet Contingent Project – Main Grid System Strength, at https://www.aer.gov.au/system/files/AER%20-%20Final%20Decision%20-%20ElectraNet%20-%20SA%20system%20strength%20contingent%20project%20-%2016%20August%202019.pdf.
C. As a part of the South Australia system strength remediation project, ElectraNet is currently on track to energise Davenport synchronous condensers in Q4 2020 and Robertstown synchronous condensers in Q2 2021. Any changes to power system limits are likely to be staged for testing purposes.
D. AER, Final Decision: TransGrid – QNI minor upgrade contingent project, at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/transgrid-qni-minor-upgrade-contingent-project/final-decision.
E. No contingent project approval process required; revenue approval complete.
F. Date of expected delivery by 2025.
G. As at the time of Western Victoria RIT-T Project Assessment Conclusions Report (PACR).

A3.2.2 Actionable ISP Projects

Actionable ISP projects are network projects which are underway or should commence regulatory approval immediately. For projects not yet underway, a date for which a Project Assessment Draft Report (PADR)[6] must be completed is provided.

Table 2 Actionable ISP projects

Project	Timing in the optimal development path	Approval status	Cost range [ISP modelled cost]	Network capability improvement†
VNI Minor **PADR completed in 2019**	2022-23	RIT-T Complete NSW: Pending TransGrid CPA VIC: Committed	$74 million to $137 million [$105.5 million]	VIC-NSW (North): +170 MW

[5] At https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2018-integrated-system-plan-isp.
[6] The PADR is a stage in the regulatory approval process in which the TNSP determines a draft outcome to meet the identified need.

Project	Timing in the optimal development path	Approval status	Cost range [ISP modelled cost]	Network capability improvement†
Project EnergyConnect **PADR completed in 2018**	2024-25 (with staging from late 2022)	RIT-T complete Pending CPA	$1,393 million to $2,587 million [$1,990 million]	SA-NSW +800 MW SA –VIC +100 MW Riverland REZ: +800 MW Murray River REZ: + 600 MW South-west NSW REZ: +380 MW
HumeLink **PADR completed February 2020**	2025-26	PADR complete Pending PACR (late 2020)	$1,470 million to $2,730 million [$2,100 million]	Snowy to Sydney +2,230 MW to 2,570 MW Wagga Wagga REZ: +1,000 MW
Central-West Orana REZ Transmission Link **PADR required by December 2021**	2024-25	RIT-T not yet initiated	$450 million to $850 million [$650 million]	Central West – Orana REZ: +3,000 MW
VNI West‡ **(with decision rules)** **PADR required by March 2021**	2027-28 (conditional on decision rules being satisfied)	PSCR Complete Pending PADR (~late 2020)	$1,211 million to $2,249 million [$1,730 million]	VIC-NSW (North): +1,930 MW# VIC-NSW (South): +1,800 MW Central North Vic REZ: +2,000 MW Western Victoria REZ: +1,000 MW
Marinus Link **(with decision rules)** **PADR completed in December 2019**	Project Stage 1 (1st cable): 2028-29 (conditional on decision rules being satisfied) Project Stage 2 (2nd cable): 2031-32 (conditional on decision rules being satisfied)	PADR complete Pending PACR	Marinus Link with one 750 MW cable – $1,292 million to $2,399 million. [$1,845 million] Marinus Link with two 750 MW cables – $2,209 million to $4,102 million. [$3,155 million]	TAS – VIC (both directions): - Stage 1: +750 MW - Stage 2: +1500 MW (combined stage 1 and stage 2) REZ hosting capacity increase: - Stage 1: +540 MW Midlands - Stage 2: +600 MW North West Tasmania, +1,080 MW Midlands (combined stage 1 and stage 2)

† The transfer capacities shown in this table are notional limit at the time of high summer demand in the importing region. Tasmania peak demand occurs in winter and notional transfer capacity of VIC-TAS interconnector represents for winter as well.
‡ This is for VNI West (Shepparton). For the alternative VNI West (Kerang) please see section A3.4.5.2.
# Calculated with VNI Minor already in service.

A3.2.3 Future ISP projects

Future ISP projects are transmission investments which in some scenarios would enable efficient development of VRE and storage systems required in the longer term but are not required yet or may not be optimal in some scenarios. In some cases, this ISP recommends preparatory activities now – in other cases, no action is needed until the next scheduled ISP (in 2022). Other future grid projects that do not have actions in this ISP can be found in Section A3.6.

The future ISP projects identified in this ISP are described in Table 3.

Table 3 Future ISP projects with preparatory activities

Project	Timing		Cost Range [Modelled cost]	Network capability improvement[E]
QNI Medium and Large	2032-33 to 2035-36	RIT-T not started	QNI Medium: $1,481 million to $2,750 million [$2,115 million] QNI Large: $802 million to1,489 million [$1,145 million]	QNI Medium: +832 MW (NSW to QLD) +760 MW (QLD to NSW) North West NSW: +1,000 MW Darling Downs: +1,000 MW QNI Large: (combined improvement) +2,372 MW (NSW to QLD) +2,130 MW (QLD to NSW) North West NSW: +2,000 MW Darling Downs: +2,000 MW
Central to Southern Queensland Transmission Link	Early 2030s	RIT-T not started	$300 million to $560 million [$432 million]	Transfer across CQ-SQ: +900 MW
Gladstone Grid Reinforcement	2030s	RIT-T not started	$300 million to $560 million [$432 million]	Fitzroy REZ: +800 MW
Reinforcing Sydney, Newcastle and Wollongong Supply	2026-27 to 2032-33	RIT-T not started	Uncertain – Pending Preparatory Activities[A]	Stages 1 & 2: Between 5,000 MW and 6,000 MW
New England REZ Network Expansion	2030s[D]	RIT-T not started	Stage 1: $720 million to $1,330 million [$1,025 million] Stage 2: $220 million to $420 million [$315 million]	Stage 1: +3,000 MW to 4,000 MW Stage 2: +4,000 to 5,000 MW (including Stage 1)
North West NSW REZ network expansion[B,C]	2030s, based on connection interest	RIT-T not started	Stage 1: $ 320 million to $590 million [$455 million] Stage 2: $70 million to $140 million [$105 million] Stage 3: $220 million to $420 million [$320 million]	Additional REZ hosting capacity Stage 1: +1,000 MW Stage 2: +3,000 MW (4,000 MW in total)

A. Due to the nature of this project, the cost estimates of this project are extremely uncertain. Preparatory activities will develop these cost estimates (see section A3.5.3).
B. Stage 1 is the bringing forward of some sections of QNI Medium; see section A3.5.1 for details.
C. This includes any parts of QNI Medium and Large that were not constructed in Stage 1.
D. New South Wales Government may accelerate this project to meet the announced renewables targets for this REZ (media announcement, 10 July 2020, at https://energy.nsw.gov.au/renewables/renewable-energy-zones).
E. The transfer capacities shown in this table are notional limit at the time of high summer demand in the importing region. Tasmania peak demand occurs in winter and notional transfer capacity of VIC-TAS interconnector represents for winter as well.

A3.2.4 Summary of variations to the optimal development path

In developing this ISP, AEMO has considered events that might vary from scenarios used, such as developers building generation at different times or different locations, or changes to government policies and initiatives.

A3.2.4.1 Victoria's alternative paths

The optimal development path identifies that Victoria can meet the VRET and have a reliable and secure system with minimal additional transmission built beyond the Western Victoria Transmission Network Project (see Section A3.3.2) and VNI Minor (see Section A3.4.1) before 2030. However, if generation is developed in other areas, such as the Murray River REZ, additional transmission infrastructure may become optimal.

The three possible overarching paths to efficiently meet the VRET are:

- Optimal generation planting, based on least-cost ISP modelling assumptions, which makes the most efficient use of resource potential and network hosting capacity. This is the strategy described in the optimal development path.
- A focus on developing the Central North Victoria REZ, requiring additional transmission to Shepparton, which improves the case for Shepparton route being the preferred option for VNI West. This also presents the opportunity for VNI West via Shepparton to be partly or wholly developed early in the optimal development path, to align with generation. This option is described in Section A3.4.5.1. For more on the economic considerations of bringing forward VNI West via Shepparton, see Appendix 2.
- A focus on developing the Murray River REZ, requiring additional transmission to Kerang and potentially Red Cliffs, which improves the case for VNI West via Kerang being the preferred option for VNI West. This also presents the opportunity for VNI West via Kerang to be partly or wholly developed early in the optimal development path, to align with generation. This network option is described in Section A3.4.5.2. For more on the economic considerations of bringing forward VNI West via Kerang, see Appendix 2.

A3.2.4.2 Alternative path for QNI Medium and Large and the New England REZ

The optimal development path considers significant generation development in the North West New South Wales REZ. This focus on North West New South Wales is linked with the QNI Medium and Large network augmentation which connects to the Central West-Orana New South Wales REZ, traverses north to the North West New South Wales REZ (providing a strong connection of the generation developed there), and onwards towards Darling Downs REZ in Queensland.

If the New England REZ is favoured by generation developers[7], this could materially change the preferred option for a section of QNI Medium and Large to traverse the New England REZ instead of the North West New South Wales REZ, making the QNI Medium and Large route significantly different. For more detail, see section A3.5.1.2

A3.2.5 Summary of non-network opportunities

There are a number of identified needs which can partly or wholly be addressed by non-network alternatives.

For clarity, when this ISP refers to non-network options, it refers to a number of options including:

- Embedded generation such as home battery systems.
- Residential behavioural demand side response.
- Automated demand reduction via DRED or other systems.
- Distribution network voltage control.

[7] As part of the New South Wales Electricity Strategy; see https://energy.nsw.gov.au/government-and-regulation/electricity-strategy.

- Industrial load reduction.
- Virtual transmission lines[8].

Importantly, a non-network option does not have to fully meet the identified need to have benefit. Non-network options can defer the optimal timing of investment, provide option value, and reduce the total amount of network investment required.

A3.2.5.1 Consultation on non-network opportunities

A consultation was run from December 2019 to March 2020 to call for non-network options for the two actionable ISP projects identified in the Draft 2020 ISP – QNI Medium and Large, and VNI West. A new consultation from July 2020 is calling for non-network options for the Central-West Orana Transmission Link.

Central-West Orana REZ Transmission Link

AEMO has initiated a consultation process for the Central-West Orana REZ Transmission Link in accordance with clause 5.22.14(c)(1) of the NER. AEMO welcomes potential non-network service providers making submissions on potential solutions they believe can address the identified need outlined in this ISP.

During high VRE there will be network constraints which provide opportunities for strategically placed battery storage and/or pumped hydro. These could defer the optimal timing, reduce the scale, or increase the capability of network augmentation. The Central-West Orana REZ has access to pumped hydro resources which, if strategically developed, can increase the hosting capacity of this REZ.

QNI Medium and Large

A total of six submissions were received for the QNI Medium non-network consultation, of which four were confidential. Several of these proposed installation of batteries at either end of the QNI corridor to form 'virtual transmission lines'[9]. AEMO values the input from stakeholders who have submitted responses to the non-network consultation. Each proposal was assessed for the ISP and shared with the respective TNSPs – Powerlink and TransGrid (after authorisation was received for confidential responses).

The concept of virtual transmission lines offers an exciting opportunity as an alternative or partial alternative to traditional network augmentation in the development of the future power system. Depending on the technology, this may be suitable as part of a hybrid alternative for the proposed QNI Medium project. However, during finalisation of the modelling and assessments for the final ISP and considering feedback received during the consultation, QNI Medium is no longer actionable even though it remains on the optimal development path.

AEMO considers that virtual transmission lines coupled with suitable wide area protection systems could provide a technically feasible solution (factoring in sufficient lead-time constraints to meet the identified need) to increasing the capacity of QNI, and will work with Powerlink and TransGrid to explore options to justify and implement a solution (potentially under a new RIT-T) – see Section A3.5.1.3.

VNI West

Submissions relating to the VNI West consultation were directed to the RIT-T[10] process being run in parallel to the ISP by the TNSPs (AEMO Victorian Planning and TransGrid) and are therefore not included in this report. A number of submissions were received and can be found on AEMO's website[11] (see Section A3.4.5.3).

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[8] A virtual transmission lines are included in the 'non-network' section of this document however it can be a 'non-network' or a 'network' option. It may form part of the TNSP's regulated asset base depending on how the virtual transmission line is funded if it is included.

[9] Virtual transmission lines are comprised of devices, such as batteries, which sit on either side of a transmission corridor. For a contingency of one circuit, one device injects power, and the other device absorbs power to counteract the effect of a contingency event. See Appendix 9for more details.

[10] AEMO. *Victoria to New South Wales Interconnector West (VNI West) regulatory investment test for transmission (RIT-T)*, at https://aemo.com.au/en/initiatives/major-programs/victoria-to-new-south-wales-interconnector-west-regulatory-investment-test-for-transmission.

[11] AEMO, https://aemo.com.au/initiatives/major-programs/victoria-to-new-south-wales-interconnector-west-regulatory-investment-test-for-transmission/stakeholder-consultation.

A3.3. Committed ISP projects

Committed network projects are projects which have gone through the RIT-T process and received funding approval (for example, approval of a contingent project application from the AER). The following three projects, that were identified as actionable in the 2018 ISP, are now committed:

- **South Australia system strength remediation** – to install four synchronous condensers to meeting the ongoing need for system strength to ensure the secure and reliable operation of the power system in South Australia
- **Western Victoria Transmission Network Project** – to support additional generation connections in the Western Victoria region, through upgrades to the existing 220 kV network and new 500 kV and 220 kV network.
- **QNI Minor –** to expand transfer capacity between New South Wales and Queensland in the near term through uprating the 330 kV network between Liddell and Tamworth and installing dynamic reactive support.

The Victorian components of the VNI minor upgrade are also considered committed, while the New South Wales components are pending regulatory approval (see Section A3.4.1).

A3.3.1 South Australia system strength remediation

The 2018 ISP recommended synchronous condensers as an urgent for system strength remediation. ElectraNet has since gained regulatory approval to install two synchronous condensers at Davenport and two at Robertstown[12].

Table 4 South Australia system strength remediation summary

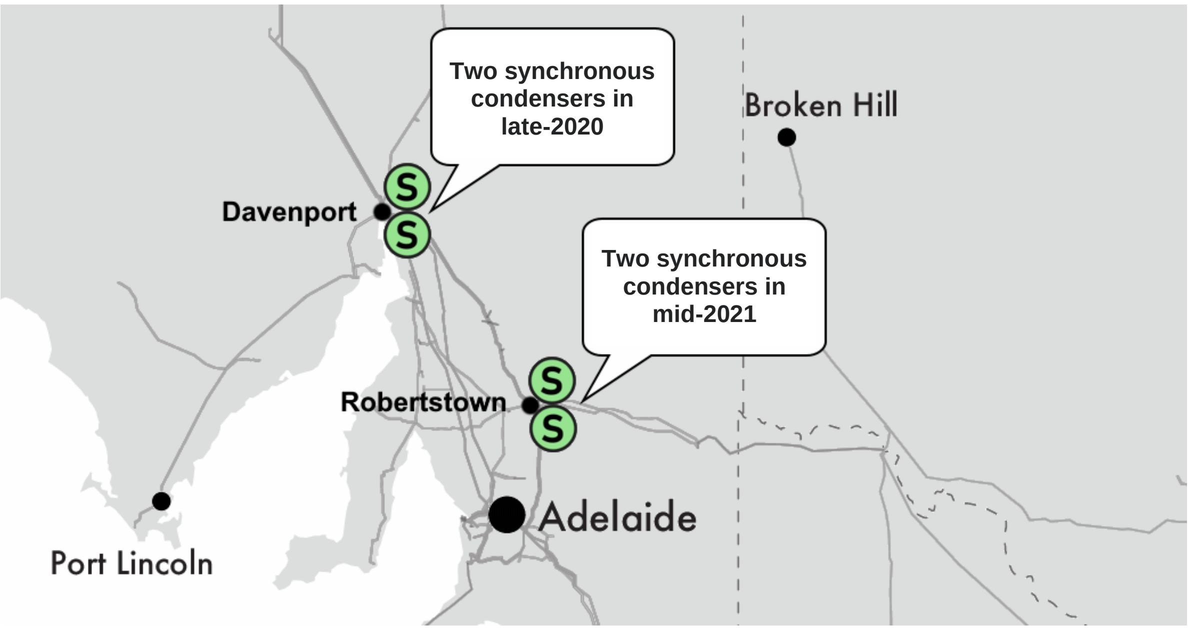
Timing	Davenport synchronous condensers energised in Q4 2020 and Robertstown energised in Q2 2021.
Description	This project is committed and includes installation of: • Two high inertia synchronous condensers at Davenport 275 kV substation. • Two high inertia synchronous condensers at Robertstown 275 kV substation. Each of the four synchronous condensers provide 575 MVA nominal fault current and 1,100 MWs of inertia. Figure 4 highlights the location of the four synchronous condensers.
Identified need	AEMO declared a system strength gap in December 2016. In 2017, the Fault Level rule change[B] required TNSPs to maintain a minimum level of system strength, as defined by AEMO. In 2018 AEMO also declared an inertia gap in South Australia, recommending high-inertia synchronous condensers in South Australia that would address both the inertia shortfall and the declared system strength gap.

[12] ElectraNet. Strengthening South Australia's power system, at https://www.electranet.com.au/what-we-do/projects/power-system-strength/.

Responsible TNSP(s)	ElectraNet
Drivers of benefits	Maintaining power system security

A. See https://www.aer.gov.au/news-release/aer-approves-electranet-spending-on-south-australia-system-strength.
B. See AEMC: Managing Power System Fault Levels, at https://www.aemc.gov.au/rule-changes/managing-power-system-fault-levels.

Figure 4 Synchronous condenser locations and commissioning dates



A3.3.2 Western Victoria Transmission Network Project

The Western Victoria Transmission Network Project is a combination of 500 kV and 220 kV transmission augmentations to alleviate constraints identified on the 220 kV network between Moorabool and Horsham.

These constraints are due to the development of large-scale renewable generation within the area. Table 5 and Table 6 provide information on this project.

Table 5 Western Victorian Transmission Network Project overview

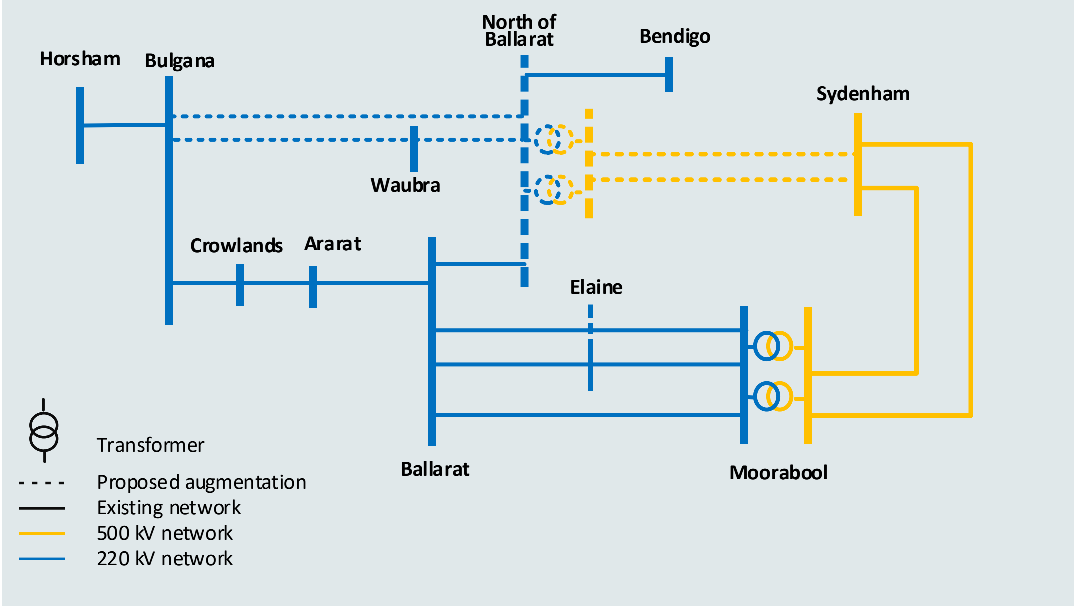
Timing	Western Victoria Transmission Network Project is a committed project. The short-term augmentation is expected to be complete by 2021, and the medium-term augmentation, which is currently on track, is to be commissioned by 2025.
Description	**Stage 1:** • The installation of wind monitoring equipment and the upgrade of station limiting transmission plant on the 220 kV network between Bendigo and Red Cliffs and on the Moorabool-Terang-Ballarat 220 kV lines. **Stage 2:** • A new terminal station north of Ballarat and new 220 kV double circuit transmission lines from the new terminal station north of Ballarat to Bulgana (via Waubra). • A New 500 kV double circuit transmission lines from Sydenham to the new terminal station north of Ballarat connecting two new 1,000 megavolt amperes (MVA) 500/220 kV transformers at the new terminal station.

Approximate network capability improvement	The Western Victoria Augmentation will increase the hosting capacity in the Western Victoria REZ to cater for all existing and committed generation [A] with 450 MW of remaining hosting capacity.
Identified need	The identified need for the Western Victoria augmentation is to increase the thermal capacity of the Western Victoria power system, reducing constraints on the network that would restrict generation within this REZ. It will deliver net market benefits and support the energy market transition by reducing the capital cost and dispatch cost of generation in the long term[B].
Responsible TNSP(s)	AEMO Victorian Planning
Non-network opportunity	Investigated as part of the Western Vic RIT-T.
Drivers of benefits	Currently the generation interest within the Western Victoria REZ exceeds the capacity of the transmission network. With the growth of inverter-based generation in this area, generator outputs are being constrained due to thermal and stability limitations. Network security issues also arise due to diminishing system strength within the area. The level of VRE is expected to increase beyond present levels when Victoria's VRET is met. The Western Victoria Transmission Network Project seeks to minimise network congestion and facilitate more efficient generation dispatch in the Western Victoria REZ whilst allowing for more efficient generation connections. The project will also improve the capacity of the existing Victoria to New South Wales interconnector and enable the future transmission network expansion from Victoria to New South Wales

A. As at time of Western Vic RIT-T PACR.
B. AEMO, Western Victoria Renewable Integration Project Assessment Conclusions Report, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2019/PACR/Western-Victoria-RIT-T-PACR.pdf.

Table 6 Western Victoria Transmission Network Project detail

Augmentation detail	The installation of wind monitoring equipment and the upgrade of station limiting transmission plant on the: • Red Cliffs–Wemen 220 kV line. • Wemen–Kerang 220 kV line. • Kerang–Bendigo 220 kV line. • Moorabool–Terang 220 kV line. • Ballarat–Terang 220 kV line. The medium-term augmentation includes: • A new terminal station at north of Ballarat. • A new 500 kV double circuit transmission line from Sydenham to the new terminal station north of Ballarat. • A new 220 kV double circuit transmission line from the new terminal station North of Ballarat to Bulgana (via Waubra). • 2 x 500/220 kV transformers at the new terminal station north of Ballarat. • Cut-in the existing Ballarat–Bendigo 220 kV line at the new terminal station north of Ballarat. • Moving the Waubra Terminal Station connection from the existing Ballarat–Ararat 220 kV line to one of the new terminal station north of Ballarat–Bulgana 220 kV lines. • Cut-in the existing Moorabool–Ballarat No. 2 220 kV line at Elaine Terminal Station.
Limits addressed	Thermal and voltage limitations in the Western Vic 220 kV network.

Network Diagram	

A3.3.3 QNI Minor

A minor upgrade to the New South Wales to Queensland interconnector was recommended as urgently needed in the 2018 ISP.

Since that time, Powerlink and TransGrid have completed a RIT-T[13] to confirm the optimal solution and gained regulatory approval from the AER. The outcome from this RIT-T, which was published on 20 December 2019, confirms the solution recommended in the 2018 ISP. Table 7 and Table 8 provide information on this project.

Table 7 QNI Minor overview

Timing	This upgrade has completed the RIT-T process and is currently on track to undergo commissioning in 2021-22	
Description	The preferred QNI Minor upgrade known as "QNI Option 1A" is a minor upgrade of the existing interconnector with uprating to increase thermal capacity of the existing transmission lines and installation of additional new capacitor banks and Static Var Compensators (SVCs).	
Approximate network capability improvement	NSW to QLD (at time of peak demand, Forward direction)	+150 MW
	QLD to NSW (at time of peak demand), Reverse direction)	Approximately +165 MW to +215 MW
Identified need	The identified need for the minor New South Wales to Queensland upgrade, as determined by Powerlink and TransGrid, is to increase overall net market benefits in the NEM through relieving existing and forecast congestion on the transmission network between New South Wales and Queensland.	
Responsible TNSP(s)	TransGrid and Powerlink	

[13] Powerlink and TransGrid, *Expanding New South Wales – Queensland Transmission Transfer Capacity*, at https://www.transgrid.com.au/what-we-do/projects/regulatory-investment-tests/Documents/Expanding%20NSW-QLD%20Transmission%20Transfer%20Capacity%20Project%20Assessment%20Conclusions%20Report%20%28PACR%29%20-%20Full%20Report.pdf.

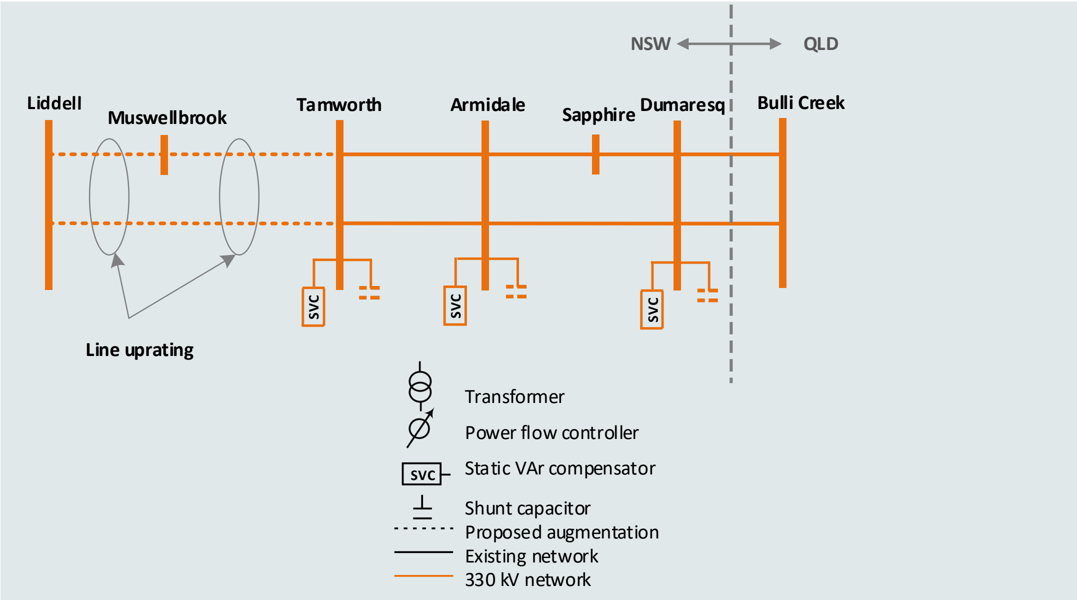
Non-network opportunity	Non network options were considered but not ultimately pursued. Powerlink and TransGrid identified that QNI Option 1A delivers the greatest expected net benefits of all above alternative options considered and is the 'preferred option' in their PADR[C].
Drivers of benefits	The QNI Minor PACR[D] states that the preferred option is expected to: • reduce the need for new generation and large-scale storage in New South Wales to meet demand following Liddell Power Station's forecast retirement over 2022 and 2023 • lower the aggregate generator fuel costs required to meet demand in the National Electricity Market (NEM) going forward; • avoid capital costs associated with enabling greater integration of renewables in the NEM.

A. AER, Final Decision, QNI Minor Upgrade https://www.aer.gov.au/system/files/AER%20-%20Final%20Decision%20-%20TransGrid%20-%20QNI%20minor%20upgrade%20contingent%20project%20-%20April%202020.pdf.
B. QNI transfer capability is influenced by generation connection along the transmission corridor.
C. See https://www.transnetwork.com.au/what-we-do/projects/current-projects/ExpandingNSWQLDTransmissionTransferCapacity/Documents/Expanding%20NSW-QLD%20Transmission%20Transfer%20Capacity%20PADR%20-%20Full%20Report.pdf.
D. See https://www.transnetwork.com.au/what-we-do/projects/regulatory-investment-tests/Documents/Expanding%20NSW-QLD%20Transmission%20Transfer%20Capacity%20Project%20Assessment%20Conclusions%20Report%20%28PACR%29%20-%20Full%20Report.pdf.

Table 8 QNI Minor detail

Augmentation detail	The committed upgrade (QNI Option 1A) involves: Uprating of following transmission lines from the existing design operating temperature of 85°C to 120°C. • Liddell–Tamworth 330 kV line. • Liddell–Muswellbrook 330 kV line. • Muswellbrook–Tamworth 330 kV line. • Installation of shunt capacitor banks at Armidale, Dumaresq, and Tamworth substations. • Installation of dynamic reactive plant at Tamworth and Dumaresq.
Limits addressed	In normal system operation, the transfer from Queensland to New South Wales is mainly limited by the following constraints: • Stability limits for faults on either Sapphire to Armidale or Armidale to Dumaresq line. • Thermal capacity of the 330 kV lines within northern New South Wales. • Oscillatory stability upper limit of 1,200 MW. In normal system operation, the transfer from New South Wales to Queensland is mainly limited by the following constraints: • Stability limits on loss of the largest Queensland unit. • Transient stability associated with transmission line faults in the Hunter Valley. • Voltage collapse for trip of the Liddell to Muswellbrook 330 kV line. • Thermal capacity of the 330 kV and 132 kV transmission lines within northern New South Wales.

Network diagram



A3.3.3.1 Alternative options

A number of alternative options were included in Powerlink and TransGrid's PADR[14] on expanding New South Wales to Queensland transmission transfer capacity:

- Option 1B – uprate Liddell–Tamworth and Liddell–Muswellbrook–Tamworth 330 kV lines.
- Option 1C – install new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks at Armidale, Dumaresq, and Tamworth.
- Option 1D – cut-in Armidale–Dumaresq 330 kV line 83 at Sapphire substation and establish a mid-point switching station between Dumaresq and Bulli Creek.
- A virtual transmission line comprised of grid-connected battery systems. This option targets both northerly and southerly QNI stability and thermal limits by installing a Battery Energy Storage System (BESS), controlled by a System Integrity Protection Scheme (SIPS) at two ends of the QNI corridor. The operation of each BESS would mimic a 'virtual transmission line' following a transmission line contingency. Following two BESS options were considered:
  - Option 5A – small-scale BESS (2 x 40 MW / 20 MWh) located at Liddell in New South Wales and Halys in Queensland.
  - Option 5B – large-scale BESS (2 x 200 MW / 100 MWh) located at Liddell in New South Wales and Calvale in Queensland.

Powerlink and TransGrid identified that QNI Option 1A delivers the greatest expected net benefits of all above alternative options considered and is the 'preferred option' in their Project Assessment Conclusions Report (PACR)[15].

A3.3.3.2 Non-network opportunity

Non-network options have been investigated in the QNI Minor RIT-T. A number of options were received which helped inform the non-network options for QNI Medium.

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[14] Powerlink and TransGrid, *Expanding New South Wales – Queensland Transmission Transfer Capacity*, at https://www.transgrid.com.au/what-we-do/projects/current-projects/ExpandingNSWQLDTransmissionTransferCapacity/Documents/Expanding%20NSW-QLD%20Transmission%20Transfer%20Capacity%20PADR%20-%20Full%20Report.pdf.

[15] Powerlink and TransGrid, *Expanding New South Wales – Queensland Transmission Transfer Capacity*, at https://www.transgrid.com.au/what-we-do/regulatory-investment-tests/Documents/Expanding%20NSW-QLD%20Transmission%20Transfer%20Capacity%20Project%20Assessment%20Conclusions%20Report%20%28PACR%29%20-%20Full%20Report.pdf.

A3.4. Actionable ISP projects

Actionable ISP projects are critical to address cost, security and reliability issues. These projects are either already progressing or should commence their RIT-T after the publication of this ISP.

The following are actionable ISP projects in this ISP:

- **VNI Minor** – upgrade to the existing VNI to improve transfer from Victoria to New South Wales.
- **Project EnergyConnect** – a proposed 330 kV interconnector between South Australia and New South Wales.
- **HumeLink** – a proposed major transmission line in New South Wales to connect the Snowy Mountains hydroelectric scheme to the Greater Sydney load centre.
- **Central-West Orana REZ Transmission Link** – expansion of the network to add 3,000 MW of generation hosting capacity as part of the New South Wales Electricity Strategy[16].

The following are actionable ISP projects with early works to start as soon as possible and with decision rules. The decision rules identified in this ISP for these actionable ISP projects can be assessed during the RIT-T process and will be confirmed by AEMO as part of the ISP feedback loop process with the TNSP[17]:

- **VNI West** – A proposed interconnector between Victoria and New South Wales.
- **Marinus Link (stage 1 and stage 2)** – Two proposed HVDC links between Tasmania and Victoria.

A3.4.1 VNI Minor

A minor upgrade to the Victoria to New South Wales Interconnector (VNI) was recommended for immediate action in the 2018 ISP. Since that time, AEMO and TransGrid completed a RIT-T[18] to confirm the optimal solution and gain regulatory approval. The PACR, the final report of the RIT-T, was published in February 2020. Its outcome is largely consistent with the solution recommended in the 2018 ISP.

Procurement and installation of the Victorian component of this project is currently on track to be commissioned in 2022-23.

[16] See https://energy.nsw.gov.au/government-and-regulation/electricity-strategy.

[17] Clause 5.16A.5 of the NER.

[18] AEMO and TransGrid. *Victoria to New South Wales Interconnector Upgrade Regulatory Investment Test for Transmission*, at https://aemo.com.au/initiatives/major-programs/victoria-to-new-south-wales-interconnector-west-regulatory-investment-test-for-transmission.

A3.4.1.1 Preferred option

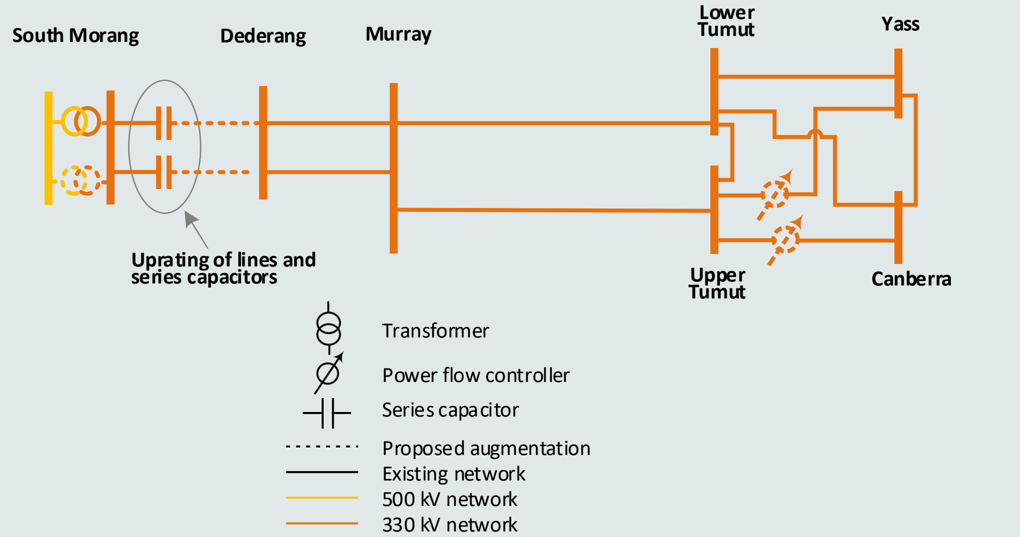
Table 9 VNI Minor overview

Timing[A]	The VNI Minor upgrade is currently on track to be commissioned in 2022-23. AEMO's 2020 ISP modelling indicates that this project will provide value as soon as it can be completed.	
Description of ISP candidate option	A minor upgrade of the existing Victoria – New South Wales interconnector with the installation of an additional 500/330 kV transformer, uprating to increase thermal capacity of the existing transmission, and installation of power flow controllers to manage the overload of transmission lines.	
Cost	$74 million to $137 million	
Approximate network capability improvement	VIC to NSW Transfer (at time of peak demand)	+170 MW
Identified need	The identified need for VNI Minor, as determined by AEMO and TransGrid, is "*to realise net market benefits by increasing the power transfer capability from Victoria to New South Wales*"[B].	
Responsible TNSP(s)	AEMO Victorian Planning and TransGrid	
Non-network opportunity	Non-network alternatives were investigated in the RIT-T but not chosen as the preferred option.	
Drivers of benefits	• Reducing dispatch costs, through more efficient dispatch of generation in Victoria and New South Wales. • Reducing capital costs associated with new generation build in New South Wales.	

A. The earliest time by when the project has been found to needed in the optimal development path, allowing for practical delivery times. Regulatory approval is generally required years before construction can be completed. All dates are indicative, and on a financial year basis. For example, 2023-24 represents the financial year ending June 2024.
B. AEMO and TransGrid. *Victoria to New South Wales Interconnector Upgrade Regulatory Investment Test for Transmission*. Available at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/victorian_transmission/2020/vni-rit-t/victoria-to-new-south-wales-interconnector-upgrade-rit-t-pacr.pdf.
C. Refer to PADR for details on Non-network options https://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.

Table 10 VNI Minor detail

Augmentation detail	• Installation of a new 1,000 MVA 500/330 kV transformer at South Morang Terminal Station. • Uprating of the South Morang – Dederang 330 kV lines from the existing design operating temperature of 75°C to 82°C and uprating of associated series capacitors to match increased line rating. • Installation of modular power flow controllers on both the Upper Tumut – Canberra and Upper Tumut – Yass 330 kV lines to increase transfer capability between Lower Tumut/Upper Tumut and Canberra/Yass.
Limits addressed	In normal system operation, the transfer from Victoria to New South Wales is mainly limited by the following constraints: • Thermal capacity of: – South Morang 500/330 kV transformers. – South Morang–Dederang 330 kV lines. – Upper Tumut–Canberra 330 kV line. – Dederang–Mount Beauty 220 kV lines. – Murray–Lower Tumut 330 kV line. – Murray–Upper Tumut 330 kV line. • Voltage stability for potential loss of Alcoa Portland potlines.

	• Transient stability for a potential fault on a Hazelwood–South Morang 500 kV line. In normal system operation, the transfer from New South Wales to Victoria is mainly limited by the following constraints: • Thermal capacity of: – Murray–Dederang 330 kV lines. – South Morang–Dederang 330 kV lines. – Dederang–Mount Beauty 220 kV lines. – Mount Beauty–Eildon 220 kV lines. – Eildon–Thomastown 220 kV line. – Bendigo–Shepparton 220 kV line. • Voltage collapse for a potential outage of largest generating unit in Victoria or Basslink. The proposed VNI Minor augmentation was economically justified to address the most critical constraint during export from VIC to NSW. These constraints include: Thermal capacity of: – South Morang–Dederang 330 kV lines. – South Morang 500/330 kV transformers. – Upper Tumut–Canberra 330 kV line.
Network diagram	

A3.4.1.2 Alternative options

A number of alternative options were included in AEMO and TransGrid's PADR[19]. These were:

- Replacing the existing South Morang F2 transformer with a transformer with higher capacity as an alternative to an additional South Morang 500/330 kV transformer.
- Additional 330 kV circuit(s) in parallel with the existing 330 kV South Morang – Dederang lines. Replacing the existing 330 kV South Morang – Dederang lines with higher capacity conductors as an alternative to uprating existing 330 kV lines between South Morang and Dederang.
- Additional 500 kV single circuit line between Snowy and Bannaby as an alternative to uprating existing 330 kV lines between Snowy and Sydney.
- A non-network option of a BESS, which improves the stability limit.

[19] 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.

AEMO and TransGrid's PACR found Option 2 for VNI Minor delivers the greatest expected net benefits of all above alternative options considered and is the 'preferred option'.

A3.4.1.3 Non-network opportunity

Non-network options were investigated in the VNI Minor RIT-T.

A3.4.1.4 Associated augmentations

Not applicable.

A3.4.2 Project EnergyConnect

Project EnergyConnect is a new 330 kV interconnector between New South Wales and South Australia. The interconnector runs from Robertstown in South Australia to Wagga Wagga in New South Wales, via the most north section of the transmission network in Victoria. It traverses between east and west, linking the REZ of Riverland, Murray River, and South West New South Wales, providing additional hosting capacity in these REZs.

The RIT-T has been completed and approved by the AER[20]. This upgrade is currently on track to be commissioned in 2023-24.

A3.4.2.1 Preferred option

Table 11 Project EnergyConnect overview

Timing	Project EnergyConnect is an actionable project and is timed optimally in 2024-25 across all scenarios. The implementation of this project is tracking ahead of schedule with commissioning targeted in stages between late 2022 and late 2023. The additional single circuit from Buronga to Red Cliffs is proposed with double circuit towers. The second circuit is planned to be added with increased renewable generation in Murray River REZ.	
Description of ISP candidate option	Project EnergyConnect is a new double circuit 330 kV transmission line between Robertstown, Buronga, Dinawan and Wagga Wagga, and an additional 220 kV line between Red Cliffs and Buronga. Included are additional transformers at Robertstown and Buronga, reactive plant, and special protection schemes.	
Cost	The capital cost estimate is $1,393 million to $2,587 million.	
Approximate network capability improvement	SA to NSW (at time of peak demand, both directions)	+800 MW
	SA to VIC (at time of peak demand, both directions)[A]	+100 MW
	Additional REZ hosting capacity	Riverland: +800 MW South-West NSW: +600 MW Murray River: +380 MW
Identified need	The identified need for Project EnergyConnect is to deliver net market benefits through: • Energy: Lowering dispatch costs, initially in South Australia, through increasing access to supply options across regions. • Transformation: Facilitating the transition to a lower carbon emissions future and the adoption of new technologies, through improving access to high quality renewable resources across regions. • Security: Enhancing security of electricity supply in South Australia, including management of inertia, frequency response and system strength in South Australia.	
Responsible TNSPs	ElectraNet and TransGrid	

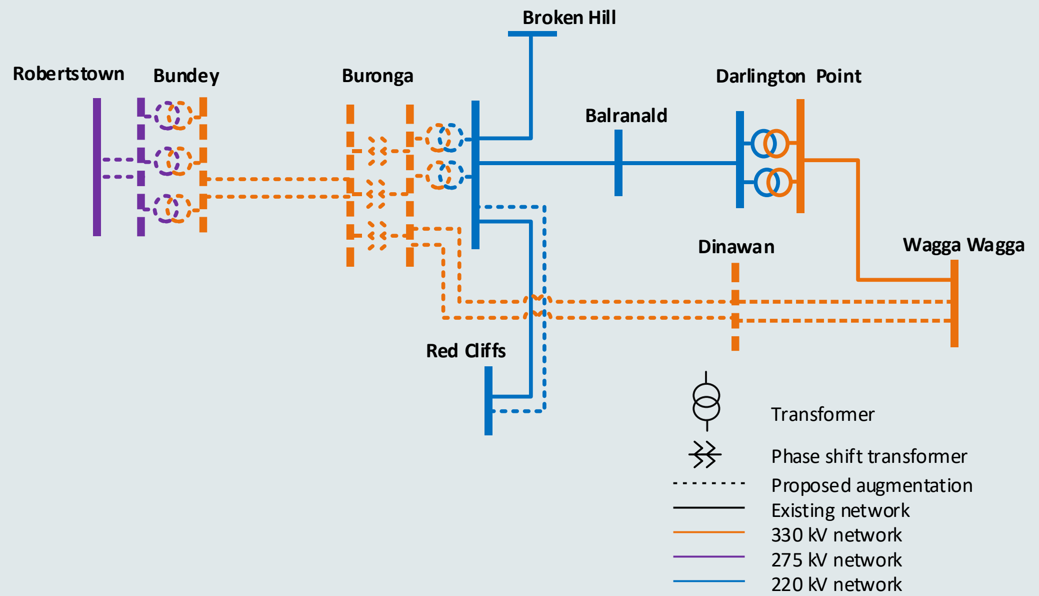
[20] ElectraNet. *Project EnergyConnect*, at https://www.electranet.com.au/projects/south-australian-energy-transformation/.

Non-network opportunity	Non-network alternatives were investigated but not pursued in the Project EnergyConnect RIT-T[B].
Drivers of benefits	• Lowering dispatch costs, initially in South Australia, through increasing access to supply options across regions. • Facilitating the transition to a lower carbon emissions future and the adoption of new technologies, through improving access to high quality renewable resources across regions. • Enhancing security of electricity supply in South Australia.

A. With the implementation of special protection scheme to prevent potential loss of one AC interconnector with South Australia for a non-credible loss of other AC interconnector with South Australia, the overall transfer capacity of both AC interconnectors with South Australia (New South Wales – South Australia and Victoria – South Australia) is limited to 1,300 MW import into South Australia and 1,450 MW export from South Australia.

B. See https://www.projectenergyconnect.com.au/.

Table 12 Project EnergyConnect detail

Augmentation detail	Project EnergyConnect involves: • A new 275 kV double circuit line between Robertstown and Bundey • A new Bundey–Buronga–Dinawan–Wagga Wagga 330 kV double circuit line. • A new double circuit 220 kV line between Buronga and Red Cliffs to replace the existing 220 kV single circuit line. • New 3 x 275/330 kV transformers at Bundey. • New 330 kV phase shift transformers at Buronga†. • New 330/220 kV transformers at Buronga†. • New 330 kV substations at Bundey and Dinawan. • Augmentation of existing substations at Robertstown, Buronga, Wagga Wagga and Red Cliffs. • Turn in the existing Robertstown–Para 275 kV line into Tungkillo. • Static and dynamic reactive plant at Bundey, Buronga, and Dinawan substations. • A special protection scheme to detect and manage loss of either interconnection of Victoria – South Australia or New South Wales – South Australia. † The exact number of 330 kV phase shift transformers and 330/220 kV transformers at Buronga are still being reviewed by TransGrid.
Limits addressed	Project EnergyConnect represents an essential new transmission connection between South Australia and New South Wales and does not specifically address a particular congested region. However, it does improve network capacity in the general South-West New South Wales region.
Network diagram	

A3.4.2.2 Alternative options

Alternative options were investigated as part of the South Australia Energy Transformation RIT-T.

A3.4.2.3 Non-network opportunity

Non-network augmentations were investigated as part of the South Australia Energy Transformation RIT-T[21].

A3.4.3 HumeLink

HumeLink is a proposed transmission network augmentation that reinforces the New South Wales southern shared network to increase transfer capacity to the state's demand centre. The proposed transmission upgrades span a distance of approximately 630 km. TransGrid is currently undertaking a RIT-T to identify the preferred option to augment this corridor[22]. The PADR, the second report of the RIT-T, was published in January 2020[23].

A3.4.3.1 Preferred option

Table 13 HumeLink overview

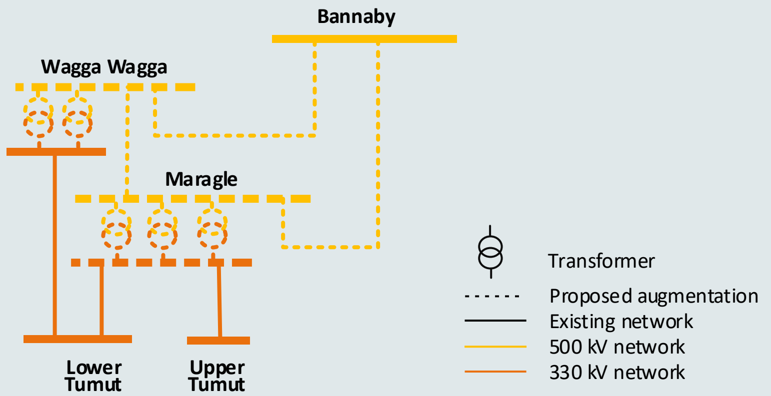
Timing	HumeLink is an actionable project and is timed for 2025-26 across all scenarios.	
Description of ISP candidate option	The ISP modelled a triangle configuration with a 500 kV transmission line from Maragle to Bannaby to Wagga Wagga and back to Maragle). This route provides access to Wagga Wagga and Southern New South Wales Tablelands REZs and provides a 500 kV access point at Wagga Wagga for future network expansion between New South Wales and Victoria.	
Cost	$1,470 million to $2,730 million	
Approximate network capability improvement	Tumut to Sydney Transfer (at time of peak demand)	2,230 MW to 2,570 MW
	Additional REZ hosting capacity	Wagga Wagga: +1,000 MW Tumut: +2,040 MW hydro generation
Identified need	The identified need for HumeLink is to deliver a net market benefit by: • Increasing the transfer capacity and stability limits between the Snowy Mountains and major load centres of Sydney, Newcastle and Wollongong. • Enabling greater access to lower-cost generation to meet demand in these major load centres; and • Facilitating the development of renewable generation in high quality renewable resource areas in southern NSW, which will further lower the overall investment and dispatch costs in meeting NSW demand whilst also ensuring that emissions targets are met at the lowest overall cost to consumers.	
Responsible TNSP(s)	TransGrid	
Non-network opportunity	Investigated as part of the RIT-T.	
Drivers of benefits	Without HumeLink, the capacity from Snowy 2.0 and other generation in southern New South Wales will not be able to reach major load centres. At present, access to existing and new capacity around the Snowy Mountains is limited by constraints on the 330 kV and 132 kV transmission network between the Snowy Mountains and Sydney.	

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

[22] See https://www.transgrid.com.au/HumeLink.

[23] See https://www.transgrid.com.au/what-we-do/projects/current-projects/Reinforcing%20the%20NSW%20Southern%20Shared%20Network/Documents/TransGrid%20HumeLink%20PADR%20-%20FINAL%20(AMENDED).pdf.

Table 14 HumeLink detail

Augmentation detail	For the 2020 ISP, a triangle linking Maragle, Wagga Wagga and Bannaby (Option 3C in RIT-T application) at 500 kV voltage level. It is modelled along with Snowy 2.0 generation, and other interconnector and REZ developments in the NEM. The selected option involves: • A new 500 kV single circuit from Maragle to Bannaby. • A new 500 kV single circuit from Maragle to Wagga Wagga. • A new 500 kV single circuit from Wagga Wagga to Bannaby. • Cut-in Lower Tumut – Upper Tumut 330 kV line at Maragle. • Three 500/330 kV 1,500 MVA transformers at Maragle. • Two 500/330 kV 1,500 MVA transformers at Wagga Wagga.
Limits addressed	The transfer capability from Snowy to Sydney is limited by transmission line thermal capacity, voltage stability, and transient stability. The capability of this corridor at any particular time is dependent on a number of factors, including demand levels, generation dispatch, status and availability of transmission equipment, and operating conditions of the network. In normal system operation, transfer is limited by the following constraints: • Thermal capacity of: – Lower Tumut–Yass 330 kV line. – Lower Tumut–Canberra 330 kV line. – Canberra–Yass 330 kV line. – Yass–Marulan 330 kV line. – Kangaroo Valley–Dapto 330 kV line. – Bannaby–Gullen Range. – Bannaby–Sydney West. • Voltage stability limit between Upper Tumut/Lower Tumut and Bannaby.
Network diagram	

A3.4.3.2 Alternative options

Alternative options were considered in the HumeLink RIT-T. All provided a similar capability improvement between Tumut and Sydney, but less market benefit and system security.

A3.4.3.3 Non-network opportunity

Non-network options have been investigated in the PADR of the HumeLink RIT-T[24].

[24] At https://www.transgrid.com.au/what-we-do/projects/current-projects/Reinforcing%20the%20NSW%20Southern%20Shared%20Network/Documents/TransGrid%20HumeLink%20PADR%20-%20FINAL%20(AMENDED).pdf.

A3.4.3.4 Associated augmentations

Table 15 Associated augmentations for HumeLink

Augmentation	Description	Section reference
VNI West	VNI West can be considered as an extension of HumeLink, which extends south from Wagga Wagga to Victoria.	A3.4.5

A3.4.4 Central-West Orana REZ Transmission Link

The Central-West Orana REZ is highlighted in the New South Wales Government's Electricity Strategy[25] for development as the first co-ordinated REZ in New South Wales. It is expected that the proposed transmission upgrades would unlock 3,000 MW of new generation capacity in the Central-West Orana REZ, by the mid-2020s[26]. TransGrid is working with the New South Wales Government to plan new transmission infrastructure in the REZ and will start engaging with local communities over the coming months. Community feedback will be used to help plan the route, minimise project impacts and maximise benefits[27].

A3.4.4.1 Preferred option

Table 16 Central-West Orana REZ Transmission Link overview

Timing	Central-West Orana REZ Transmission Link is an actionable project and is timed for 2024-25.	
Description of ISP candidate option	A 500 kV/ 330kV loop which traverses the Central-West region	
Cost	$450 million to $850 million	
Approximate network capability improvement	Additional REZ hosting capacity	Central West NSW: +3,000 MW
Identified need	To increase the capability of the transmission network to enable the connection of expected generation in the Central-West Orana REZ • increasing the transfer capacity between expected generation in the Central-West Orana REZ and the existing 500 kV transmission network between Bayswater, Wollar and Mount Piper; and • ensuring sufficient resilience to avoid material reductions in transfer capacity during an outage of a transmission element, or as otherwise consistent with the NSW Government's Central-West Orana REZ program, including any change of law.	
Responsible TNSP(s)	TransGrid	
Non-network opportunity	During high VRE and low demand periods there is likely opportunities for strategically placed battery storage and/or pumped hydro to optimise network utilisation and/or reduce the size of the network augmentation	
Drivers of benefits	Access to increased amounts of renewable generation in Central-West Orana region.	

[25] At https://energy.nsw.gov.au/government-and-regulation/electricity-strategy.

[26] See https://energy.nsw.gov.au/renewables/renewable-energy-zones.

[27] See https://www.transgrid.com.au/what-we-do/projects/current-projects/CentralWest.

Table 17 Central-West Orana REZ Transmission Link detail

Augmentation detail	Augmentation to be developed as part of the RIT-T.
Limits addressed	The Central-West Orana REZ is currently connected by an existing 330 kV and 132 kV network. The existing capacity in this network is significantly less than the 3,000 MW targeted by the New South Wales Government. Additionally, the existing network does not traverse where significant generator interest is located.

A3.4.4.2 Alternative options

Some alternative options are variations of a loop design, which have at least two points of connection to the existing network. These variations include the route, location of generation connection hubs, where the loop starts and ends on the existing network, and sections of the loop at 330 kV.

Other alternative options are radial configurations. Radial options would negatively impact generation during network outages, and there would be more security and operational issues to address, such as low system strength. For further details on managing local power system requirements refer to Appendix 5.

A3.4.4.3 Non-network opportunity

The identified need for the Central-West Orana Transmission Link can partially be met by non-network alternatives.

Table 18 Central-West Orana Transmission Link – non-network opportunity

Opportunity description	The identified need is to increase the overall net market benefits in the NEM by increasing the capability of the network connecting the Central-West Orana REZ to the major load centres in New South Wales. The Central-West Orana REZ is as defined in the New South Wales Electricity Strategy. It is AEMO's view that a non-network option, or combination of non-network options can partially or wholly meet this need. During high VRE there will be network constraints which provide opportunities for strategically placed battery storage and/or pumped hydro. These could defer the reduce the scale or increase the capability of network augmentation. Central-West Orana has access to good pumped hydro resources which, if strategically developed, can increase the hosting capacity within this REZ.
Timing	From 2024-25
Technical guide	AEMO is not prescriptive at this early regarding the role of non-network options and operating profiles for these solutions. AEMO is interested to hear from parties regarding the potential for non-network options to satisfy, or contribute to satisfying, the identified need, and from potential proponents of such non-network options.

A3.4.4.4 Associated augmentations

Table 19 Associated augmentations to Central-West Orana REZ Transmission Link

Augmentation	Description	Section reference
QNI Medium and Large	One of the new Central-West Orana Transmission Link substations could be a connection point for a QNI upgrade.	A3.5.1

A3.4.5 VNI West

VNI West is a large new interconnector between Victoria and New South Wales, with a route which is significantly west of the existing VNI path. VNI West should be progressed for completion as soon as practicable, which is by 2027-28. Early works for this project should commence as soon as possible for completion in late 2024.

This project is currently AEMO's preferred option to maintain system security and reliability in Victoria. It provides a prudent pathway to access sufficient dispatchable capacity to deliver into Victoria and, therefore, avoids the risk associated with earlier than planned exit of a major generator.

There are a number of factors which will ultimately determine the preferred route, which are beyond the scope of the ISP. These include:

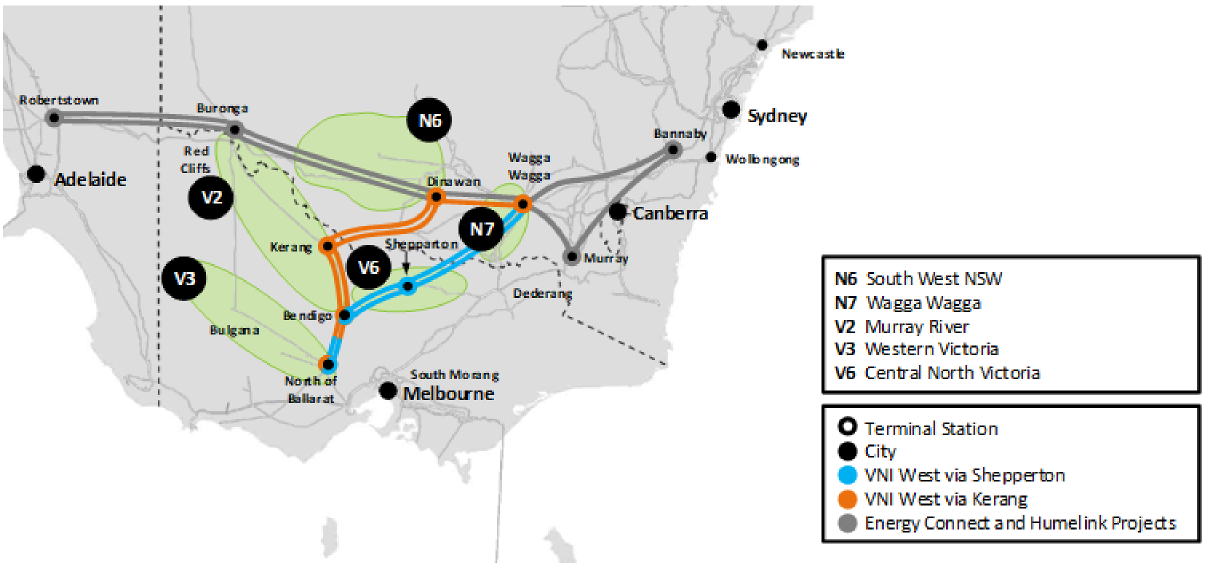
- Location of generator interest in Victoria.
- Future government policy.
- Land, planning and environment considerations.
- Additional resilience benefits.

This section describes the candidate options for VNI West (see Figure 5). The preferred options for this actionable project are VNI West from a new substation north of Ballarat via Shepparton to Wagga Wagga (which opens up the Central North REZ), or VNI West via Kerang and Dinawan to Wagga Wagga (which opens up the Murray River REZ).

Despite differences in costs, these two options are very close in terms of net market benefits. The preferred route will be determined in the RIT-T. Variations of these options may also be tested if appropriate, including variations to the terminal stations and where they connect to the New South Wales network.

Further information on the bring forward case for VNI West is provided in section D of the ISP.

Figure 5 Victoria – New South Wales Interconnector options



A3.4.5.1 VNI West (Shepparton route)

This option to address the identified need entails a new interconnector to address the identified need, which is indicatively from a terminal station north of Ballarat[28] to Wagga Wagga via Bendigo and Shepparton, with approximately 440 km route length.

[28] Developed as part of the Western Victoria Transmission Network Project.

Table 20 VNI West (Shepparton) overview

Timing	2027-28 or later	
Description of ISP candidate option	A 500 kV HVAC double circuit line between a new terminal station north of Ballarat – Shepparton – Wagga Wagga [A]	
Cost	$1,211 million to $2,249 million	
Approximate network capability improvement	Increase in VIC-NSW transfer (at time of peak demand)[A]	+1,930 MW North +1,800 MW South
	Additional REZ hosting capacity	Western Victoria: +1,000 MW Central North Vic: +2,000 MW
Identified need for project	The identified need is for additional transfer capacity between New South Wales and Victoria, to realise 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 this 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.	
Responsible TNSP(s)	AEMO Victorian Planning and TransGrid	
Non-network opportunity	Being consulted and investigated as part of the RIT-T	
Drivers of benefits	VNI West via Shepparton provides benefits from: • Increased connection to the Central North and Western Vic REZ. • Increased resilience in Victoria through the additional interconnection to New South Wales. • Increased capability to export VRE to New South Wales.	

A. This path travels towards Bendigo, but a new terminal station near Bendigo is not included.
B. Calculated with VNI Minor already in service.

Table 21 VNI West (Shepparton) detail

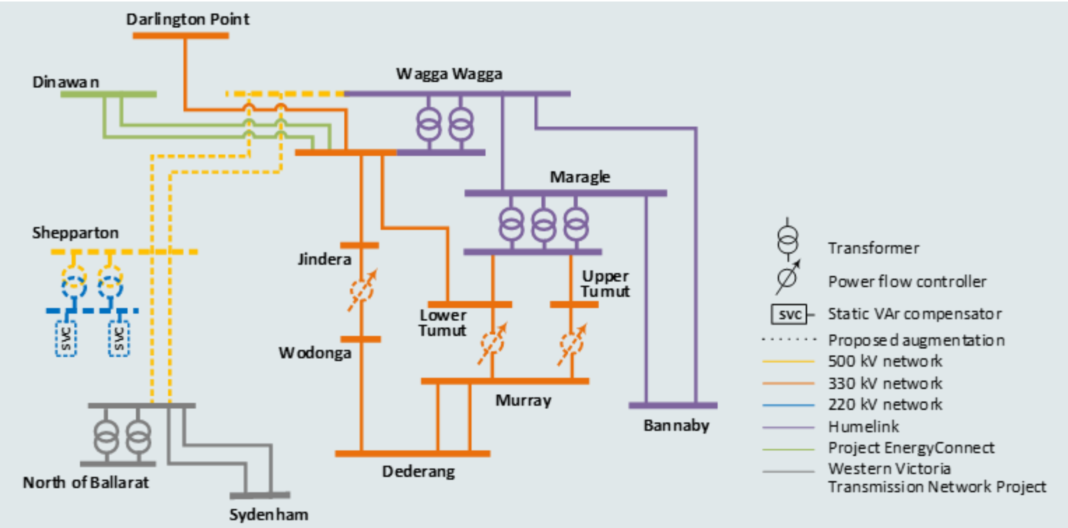
Augmentation detail	VNI West (Shepparton) involves the following augmentations: • Two 500 kV lines from a new terminal station north of Ballarat to Shepparton[A]. • Two 500 kV lines from Shepparton to Wagga Wagga. • Two 500/220 kV 1,000 MVA transformers at Shepparton. • Power flow controllers to prevent overloading on 330 kV lines between Upper/Lower Tumut and South Morang. Possible locations are on the Murray–Lower Tumut, Murray–Upper Tumut and Wodonga–Jindera 330 kV lines. • Additional reactive plant at a new terminal station north of Ballarat, Shepparton, and Wagga Wagga.
Limits addressed	The transfer capability across the Victoria to New South Wales interconnector is limited by transmission line thermal capacity, voltage stability, and transient stability. The capability across this interconnector at any particular time is dependent on a number of factors, including demand levels, generation dispatch, status and availability of transmission equipment, and operating conditions of the network. In normal system operation, the transfer from Victoria to New South Wales is mainly limited by the following constraints: • Thermal capacity of: – South Morang 500/330 kV transformers. – South Morang–Dederang 330 kV lines.

- – Upper Tumut–Canberra 330 kV line.
- – Dederang–Mount Beauty 220 kV lines.
- – Murray–Lower Tumut 330 kV line.
- – Murray–Upper Tumut 330 kV line.
- Voltage stability for potential loss of Alcoa Portland potlines.
- Transient stability for a potential fault on a Hazelwood–South Morang 500 kV line.

For normal system operation, the transfer from New South Wales to Victoria is mainly limited by the following constraints:

- Thermal capacity of:
  - Murray–Dederang 330 kV lines.
  - South Morang–Dederang 330 kV lines.
  - Dederang-Mount Beauty 220 kV lines.
  - Mount Beauty–Eildon 220 kV lines.
  - Eildon-Thomastown 220 kV line.
  - Bendigo-Shepparton 220 kV line.
- Voltage collapse for a potential outage of the largest generating unit in Victoria, or of Basslink.

Network diagram



A. This path travels towards Bendigo, but a new terminal station near Bendigo is not included.

A3.4.5.2 VNI West (Kerang route)

An alternative route to address the identified need is from a new terminal station north of Ballarat to Wagga Wagga via Bendigo, Kerang and Dinawan. VNI Minor (VNI Option 1) and HumeLink is assumed to be in place.

Table 22 VNI West (Kerang) overview

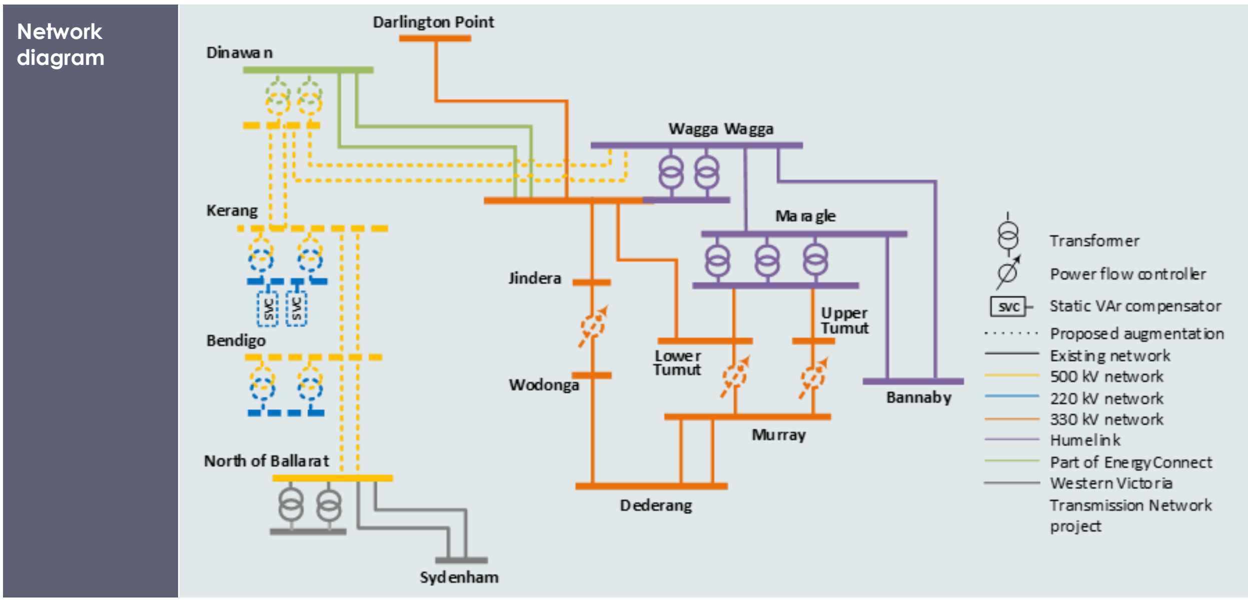
Timing	2027-28 or later	
Description of ISP candidate option	A 500 kV HVAC double circuit line between a new terminal station north of Ballarat – Bendigo – Kerang – Dinawan – Wagga Wagga	
Cost	$1,687 million to $3,133 million	
Approximate network	Increase in VIC-NSW transfer (at time of peak demand) [A]	+1,930MW North +1,800 MW South

capability improvement	Additional REZ hosting capacity	South West NSW: +1,000 MW Murray River: +2,000 MW Western Victoria: +1,000 MW
Identified need for project	The identified need is for additional transfer capacity between New South Wales and Victoria, to realise 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 this 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.	
Responsible TNSP(s)	AEMO (Victorian Planning) and TransGrid	
Non-network opportunity	Being consulted and investigated as part of the RIT-T	
Drivers of benefits	VNI West (Kerang) provides benefits from: • Increased connection to the South West NSW, Murray River and Western Vic REZ. • Increased resilience in Victoria through the additional interconnection to New South Wales. • Increased capability to export VRE to New South Wales	

A. Calculated with VNI Minor already in service.

Table 23 VNI West (Kerang) detail

Augmentation detail	VNI West (via Kerang) involves following augmentation: • Two 500 kV lines from a new terminal station north of Ballarat to Bendigo. • Two 500 kV lines from Bendigo to Kerang. • Two 500 kV lines from Kerang to Dinawan. • Two 500 kV lines from Dinawan to Wagga Wagga. • Two 500/220 kV 1,000 MVA transformers at each of Bendigo and Kerang Terminal Stations. • Two 500/330 kV 1,500 MVA transformers at Dinawan. • Power flow controllers to prevent overloading on 330 kV lines between Upper/Lower Tumut and South Morang. Possible locations are on the Murray–Lower Tumut, Murray–Upper Tumut and Wodonga–Jindera 330 kV lines. • Additional reactive plant at Bendigo, Kerang, Dinawan and Wagga Wagga.
Limits addressed	As per VNI West (via Shepparton) option.



A3.4.5.3 Alternative network options and next steps

A number of alternative credible network options were assessed and discounted in this ISP (see Section A3.8.2). This detailed assessment has resulted in two remaining ISP candidate options as preferred:

- VNI West (Shepparton route) – as per Section A3.4.5.1.
- VNI West (Kerang route) – as per Section A3.4.5.2.

AEMO therefore requires that the VNI West RIT-T excludes network options discounted in this ISP, and assesses and refines the two remaining ISP candidate options for VNI West.

A3.4.5.4 Non-network opportunity

The VNI West Project Specification Consultation Report (PSCR) sought submissions from providers of potential non-network solutions for information on options that may be capable of addressing or partially addressing the identified need of VNI West. Through the consultation process, AEMO and TransGrid engaged with a number of non-network providers to discuss options proposed in submissions, and for feedback on how these options should be considered in the RIT-T.

This feedback has now been incorporated, and modelling is being undertaken to identify and assess credible non-network options, to identify the optimal size, technology, location, and staging that has the potential to meet the identified need and deliver market benefits. This includes investigating the benefits of a virtual transmission line, which involves the installation and pairing of two battery energy storage solutions at two substations to relieve the limitations on the existing New South Wales to Victoria interconnector. AEMO and TransGrid will continue to progress this analysis over the coming months and publish for consultation the outcome of this analysis in the VNI West PADR.

A3.4.5.5 Associated augmentations

Table 24 Associated augmentations to VNI West

Augmentation	Description	Section reference
Project EnergyConnect	VNI West (Kerang) connects to Project EnergyConnect in the NSW network.	A3.4.2
HumeLink	HumeLink complements VNI West by completing the interconnection to Sydney.	A3.4.3

A3.4.6 Marinus Link (Stage 1 and Stage 2)

Marinus Link is a second, and potentially third, HVDC cable connecting Victoria to Tasmania, with associated HVAC transmission. TasNetworks is currently undertaking a RIT-T to identify the preferred option and net market benefit[29]. The PADR, the second report of the RIT-T, was published in December 2019[30].

This is an actionable ISP project for which AEMO recommends early works to commence as soon as practicable, and with each of the future project stages subject to decision rules (see Section D of the ISP body, and Appendix 2).

A3.4.6.1 Preferred option

Table 25 Marinus Link Stage 1 and 2 overviews

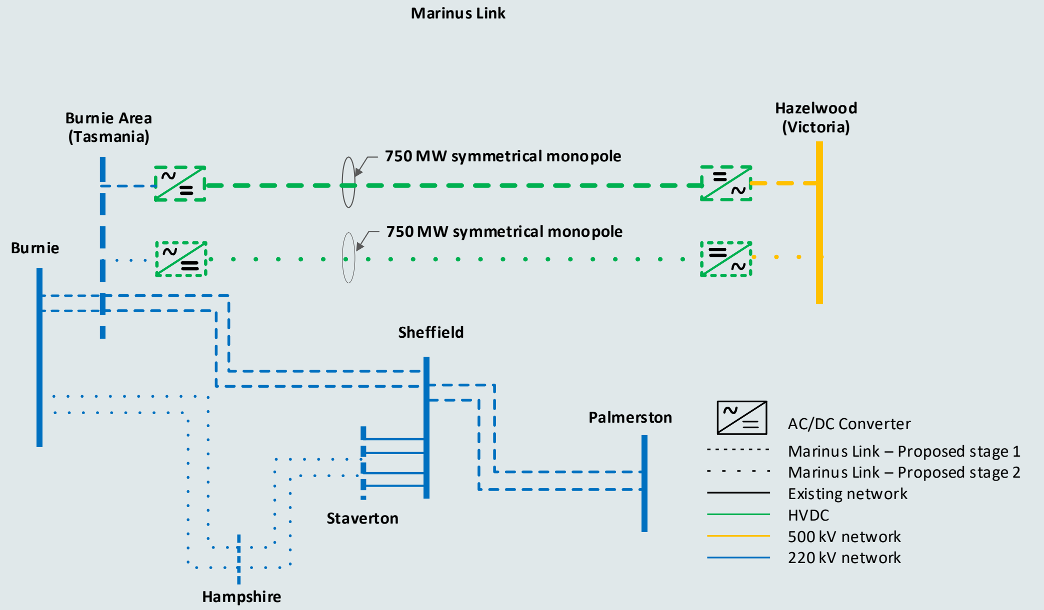
Timing	First cable: from 2028-29 or later Second cable: from 2031-32 or later	
Description of ISP candidate option	Marinus Link is a second, and potentially third, HVDC cable interconnection between Tasmania and Victoria. It is proposed with a transfer capability of 750 MW (one cable) or 1,500 MW (two cables).	
Cost estimate	Marinus Link with one 750 MW cable: $1,292 million to $2,399 million [Discussed in section A3.4.6] Marinus Link with two 750 MW cables: $2,209 million to $4,102 million These cost estimates represent for both cables installed within four years.	
Approximate network capability improvement	TAS – VIC (both directions)	Stage 1: +750 MW Stage 2: +750 MW, i.e. total +1,500 MW combined Stage 1 & 2
	Additional REZ hosting capacity	Stage 1: Tasmania Midlands: +540 MW Stage 2: North West Tasmania: +600 MW
Identified need for project	The characteristics of customer demand, generation, and storage resources vary significantly between Tasmania and the rest of the NEM. Increased interconnection capacity between Tasmania and the other NEM regions has the potential to realise a net economic benefit by capitalising on this diversity.	
Responsible TNSP(s)	TasNetworks and AEMO Victorian Planning	

[29] See https://www.marinuslink.com.au/rit-t-process/.

[30] At https://www.marinuslink.com.au/wp-content/uploads/2019/12/rit-t-project-assessment-draft-report.pdf.

Non-network opportunity	None
Drivers of benefits	Key drivers include: • Thermal coal power retirements in Victoria. • Access to high-quality wind resources in Tasmania. • Deep storage capability of Tasmanian hydro generation. • Access to low cost pumped storage capability in Tasmania.

Table 26 Marinus Link Stage 1 and 2 detail

Augmentation detail	Marinus Link with two 750 MW interconnector involves: • Two 750 MW HVDC interconnector using voltage source converter technology and monopole configuration. Converter stations located in the Burnie area in Tasmania and the Hazelwood area in Victoria. • AC network augmentations in Tasmania comprise: – A new 220 kV switching station in the Burnie area adjacent to the converter station. – A new double-circuit 220 kV transmission line from Burnie to Sheffield. – A new 220 kV double circuit line from Hampshire to Burnie. – A new 220 kV double circuit line from Hampshire to Staverton. – 220 kV switching station at Staverton. – Cut-in two Sheffield-Mersey Forth double circuit 220 kV lines at Staverton. – A 220 kV double circuit line from Sheffield to Palmerston. • AC network augmentations in Victoria comprise: – A 500 kV connection asset for connection of the converter station in the Hazelwood area to the Hazelwood 500 kV terminal station.
Limits addressed	The transfer capability across the Tasmania and Victoria interconnector is limited by the transmission capacity of the HVDC cable (Basslink) between Tasmania and Victoria. In addition, with a second interconnector in the Burnie area, the thermal capacity of the following transmission lines becomes the limitation: • Burnie–Sheffield 220 kV line. • Sheffield–Palmerston 220 kV line.
Network diagram	

A3.4.6.2 Non-network opportunity

TasNetworks is not aware of any non-network alternatives to deliver an increase in interconnection capacity between Tasmania and Victoria[31].

A3.4.6.3 Associated augmentations

Not applicable.

[31] TasNetworks. *Project Specification Consultation Report – Additional interconnection between Victoria and Tasmania,* at https://www.marinuslink.com.au/wp-content/uploads/2019/05/Project-Specification-Consultation-Report.pdf.

A3.5. Future ISP projects with preparatory activities

These projects would reduce costs, and enhance system resilience and optionality. They are not yet 'actionable' under the new ISP Rules, but are expected to become actionable in the future and are part of the optimal development path.

For each of these future ISP Projects, AEMO requires the responsible TNSP to carry out preparatory activities including publishing a report on the outcome of these activities by 30 June 2021:

- **QNI Medium and Large interconnector upgrades**[32].
- **Central to Southern Queensland Transmission Link**.
- **Gladstone Grid Reinforcement.**
- **Reinforcing Sydney, Newcastle and Wollongong Supply reinforcement**.
- **New England REZ network expansion**[33]**.**
- **North West New South Wales REZ network expansion**.

Further details are provided in Table 27.

Table 27 Future ISP projects for which preparatory activities are required

Project	Indicative timing[A]	Status	Responsible TNSP(s)	Preparatory activities required
QNI Medium and Large	2032-33 to 2035-36	RIT-T not started	Powerlink and TransGrid	AEMO requires that the responsible TNSPs undertake the following preparatory activities by 30 June 2021 on each project: • Preliminary engineering design. • Desktop easement assessment. • Cost estimates based on preliminary engineering design and route selection.
Central to Southern Queensland Transmission Link	Early-2030s	RIT-T not started	Powerlink	
Gladstone Grid Reinforcement	2030s	RIT-T not started	Powerlink	
Reinforcing Sydney, Newcastle and Wollongong Supply	Between 2026-27 and 2032-33	RIT-T not started	TransGrid	

32 Some parts of these upgrades may be needed earlier if the New England REZ development is accelerated through New South Wales Government policy.

33 The New England REZ network expansion may be accelerated through New South Wales Government policy (New South Wales Government. *New England to light up with second New South Wales Renewable Energy Zone*, at https://www.nsw.gov.au/media-releases/new-england-to-light-up-second-nsw-renewable-energy-zone).

Project	Indicative timing[A]	Status	Responsible TNSP(s)	Preparatory activities required
New England New South Wales REZ Network Expansion[B]	2030s	RIT-T not started	TransGrid	• Preliminary assessment of environmental and planning approvals. • Appropriate stakeholder engagement.
North West New South Wales REZ Network Expansion	2030s	RIT-T not started	TransGrid	

A. The earliest time by when the full ISP project has been found to needed in the optimal development path. All dates are indicative, and on a financial year basis.
B. The requirement for preparatory activities may be accelerated for the New England REZ network expansion if that development is accelerated through New South Wales Government policy (see at https://www.nsw.gov.au/media-releases/new-england-to-light-up-second-nsw-renewable-energy-zone).

A3.5.1 QNI Medium and Large

AEMO recommends preparatory activities for a staged delivery of QNI Medium and Large. These augmentations are identified as part of the optimal development path – this is strongly linked to the closure of the next New South Wales and/or Queensland black coal generators after Liddell Power Station.

Following the development of a QNI Medium, a larger QNI upgrade is identified on the optimal development path, to increase the capacity of the network to host renewable energy and share both storage and firming services between the regions. QNI Large is essentially a second stage, stringing a second 500 kV line on the same route.

QNI Medium and Large provides additional REZ hosting capacity in New South Wales to the North West NSW REZ, as it is a westerly route. However, there is an alternative route for a portion of QNI Medium and Large, which would have one of the 500 kV lines initially traversing an easterly path and connecting the New England REZ.

New England REZ has also been identified as 'priority' by the New South Wales Government Electricity Strategy[34].

A3.5.1.1 Preferred option – QNI Medium and Large via North West NSW REZ

Table 28 QNI Medium and Large overview

Timing	The staged delivery of QNI Medium and Large is timed for 2033 for Medium and 2036 for Large in the optimal development path. This timing is for all scenarios aside from Slow Change.	
Description	QNI Medium comprises: • A single 500 kV circuit between New South Wales and Queensland strung on a double circuit tower via the western part of the existing QNI including terminal stations and supporting plant. • The proposed route goes through the North West New South Wales and Darling Downs REZs. This augmentation can be expanded with a second stage to form the Large QNI Upgrade. QNI Large comprises: • A second 500 kV circuit between New South Wales and Queensland strung on the double circuit tower which was proposed in QNI medium stage.	
Cost	QNI Medium $1,481 million to $2,750 million. QNI Large (second stage only) $802 million to $1,489 million.	
	Forward direction (NSW to QLD)[A]	+832 MW (Medium)

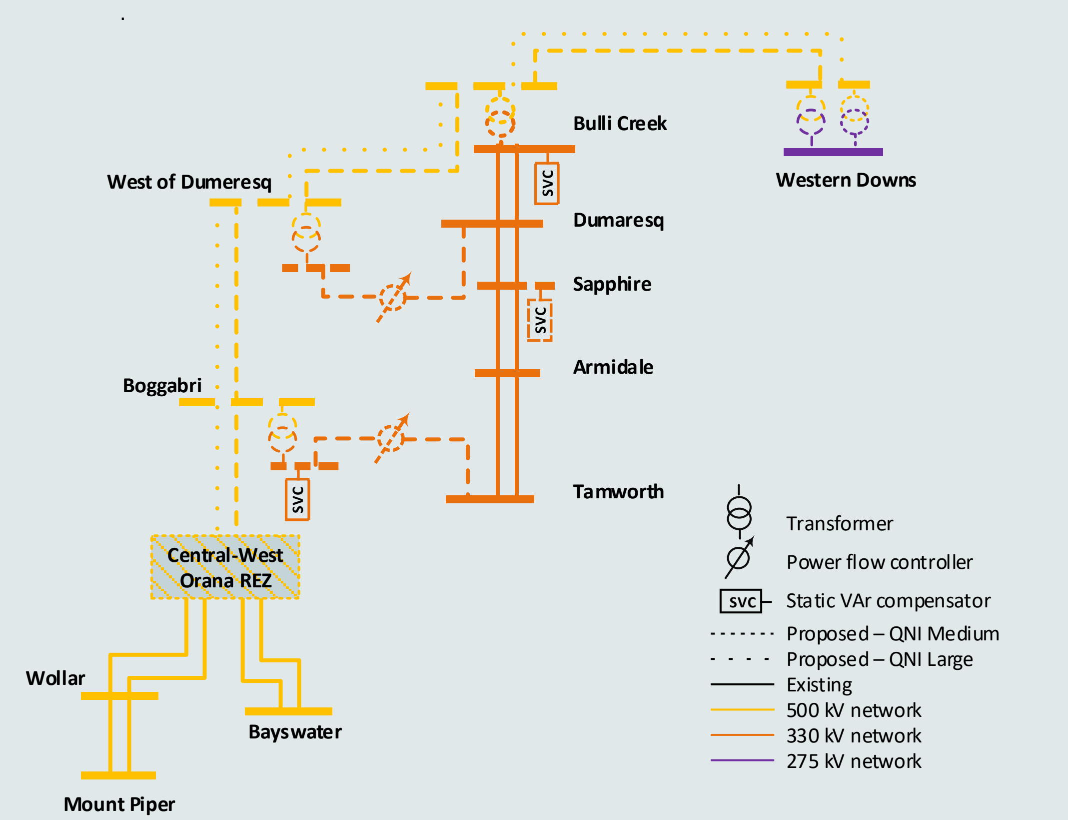
[34] New South Wales Government, https://energy.nsw.gov.au/renewables/renewable-energy-zones.

Approximate network capability improvement		+2,372 (Combined Medium and Large)
	Reverse direction (QLD to NSW)[A]	+760 MW (Medium) +2,130 MW (Combined Medium and Large)
	Additional REZ hosting capacity	North West NSW: +1,000MW (Medium), +2,000 MW (Combined Medium and Large) Darling Downs: +1,000 MW (Medium), +2,000 MW (Combined Medium and Large)
Responsible TNSP(s)	TransGrid and Powerlink	
Non-network opportunity	Options include: • Battery Energy Storage Systems. • Pumped Hydro Energy Storage (PHES). • Other forms of dispatchable generation	
Drivers of benefits	QNI Medium's benefit comes from providing support to export excess renewable generation in Queensland and/or increase efficient access to renewable generation at REZs in both Queensland and New South Wales. It also helps share resources more efficiently between regions as aging black coal-fired generators retire.	

A This is calculated with QNI minor already operational.

Table 29 QNI Medium and Large detail

Augmentation detail	The QNI Medium and Large upgrade includes a single 500 kV circuit between New South Wales and Queensland via the western part of the existing QNI. The proposed route goes through the North West New South Wales and Darling Downs REZs. Specifically, Medium includes: • Single circuit 500 kV from a new substation in NSW Central West Orana REZ to Boggabri to West of Dumaresq to Bulli Creek to Western Downs (first circuit strung on a double circuit tower). • New 330 kV single circuit line from Boggabri to Tamworth or future Uralla substation. • New 330 kV single circuit line from West Dumaresq to Dumaresq. • Establishing new 500/330 kV substations at Boggabri site and a new site West of Dumaresq (West Dumaresq). • One 550/330kV 1,500 MVA transformer at Boggabri. • One 500/330 kV 1,500 MVA transformer at west of Dumaresq. • One 500/330 kV 1,500 MVA transformer at Bulli Creek. • One 500/275 kV 1,000 MVA transformer at Western Downs. • New static and dynamic compensation at Boggabri, West Dumaresq, Sapphire, Bulli Creek, and/or Western Downs. Work and investment can be undertaken to make any potential second circuit of the 500 kV (QNI Large) more ready. These works could include: • Easement and land acquisition. • Substation works and bus extension, including provision of additional spare bays. QNI Large comprises: • A second 500 kV circuit from a new substation in NSW Central West Orana REZ to Boggabri to West of Dumaresq to Bulli Creek to Western Downs (second circuit strung on a double circuit tower). • Second 500/275 kV 1,000 MVA transformer at Western Downs. • Power flow controllers on Boggabri-Tamworth and West Dumaresq-Dumaresq 330 kV lines (or 330 kV lines between Armidale-Tamworth-Liddell). • Additional static and dynamic compensation at Boggabri, West Dumaresq, Sapphire, Bulli Creek, and/or Western Downs.

Limits addressed	In normal system operation and with QNI minor upgrade (QNI Option 1A), the transfer from Queensland to New South Wales is mainly limited by the following constraints: • Stability limits for faults on either Sapphire to Armidale, Dumaresq–Sapphire, or Armidale to Dumaresq line. • Thermal capacity of the 330 kV lines within northern New South Wales. • Oscillatory stability upper limit of 1,350-1,450 MW. In normal system operation, the transfer from New South Wales to Queensland is mainly limited by the following constraints: • Stability limits on loss of the largest Queensland unit. • Transient stability associated with transmission line faults in the Hunter Valley. • Voltage collapse for trip of the Liddell to Muswellbrook 330 kV line. • Thermal capacity of the 330 kV and 132 kV transmission lines within northern New South Wales.
Network diagram	

A3.5.1.2 Alternative to QNI Medium and Large, via New England

The major alternative pathway option in New South Wales is the possibility for the route of QNI Medium and Large to traverse and easterly route and connect the New England REZ. This alternative route is essentially splitting in the lower half of the interconnector, with one circuit of QNI to traversing a more eastly path, connecting the New England REZ, with the other circuit maintaining a westerly path and connecting North West New South Wales (see Figure 6). The easterly path is already partially developed as part of the New England REZ network expansion (see Section A3.5.5).

This alternative involves building part of the New England REZ expansion as part of QNI Medium and Large, in turn potentially avoiding building a second circuit between Central West and Boggabri. This option is linked to New England REZ preparatory activities; there is some commonality between the alternative easterly path of QNI and potential network expansions to connect the New England REZ.

Figure 6 Alternative for QNI Medium and Large

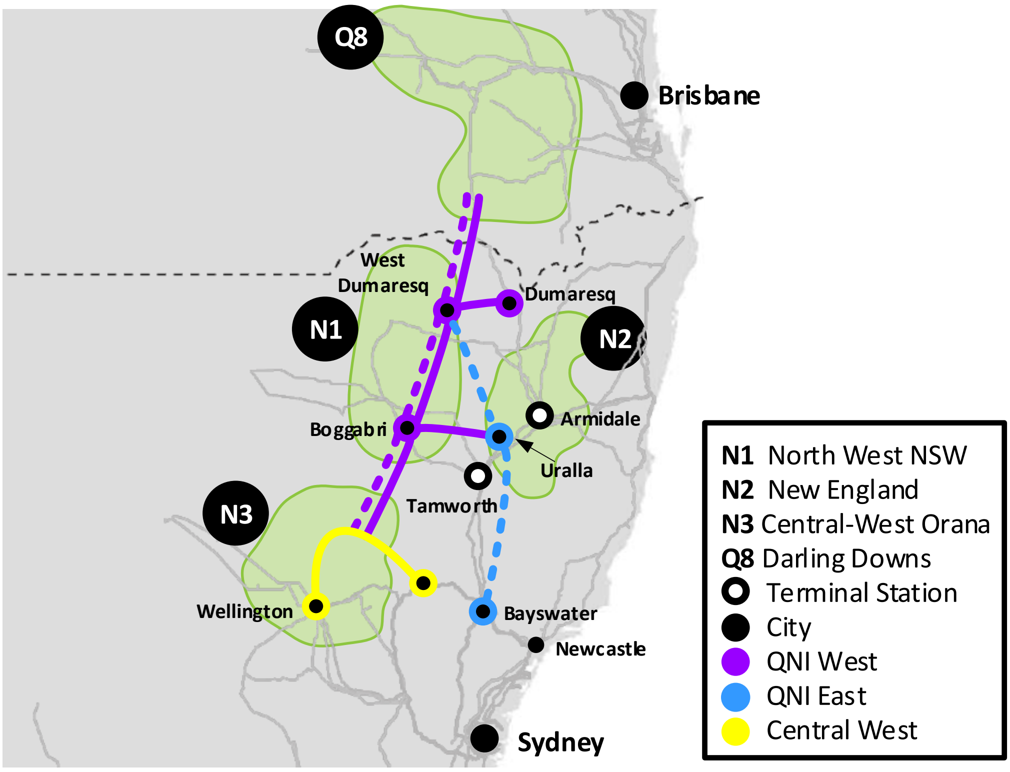


Table 30 Alternative option for QNI Medium and Large

Timing	Similar to preferred option – staged delivery of QNI Medium and Large is timed for 2033 for Medium and 2036 for Large in the optimal development path. This timing is for all scenarios aside from Slow Change.	
Overview	A 500 kV circuit between Bayswater and Uralla, which can be shared with the New England REZ expansion. This would be in place of one of the circuits between Central West and Boggabri. An additional 500 kV circuit between Boggabri and Uralla is required, also shared with Stage 2 of the new England REZ expansion	
Cost	The total cost of this alternative is between $3,100 million and $5,700 million; however, this would avoid the $940 million to $1,750 million New England REZ expansion costs.	
Approximate Network capability improvement	Forward direction (NSW to QLD)	Similar to preferred option
	Reverse direction (QLD to NSW)	Similar to preferred option
	Additional REZ hosting capacity	North West and New England: +2,000 MW[A] Darling Downs: +1,000 MW
Comparison to preferred option	The QNI Medium and Large via New England has some key trade-offs with the preferred option: • It has the same effective transfer capacity between New South Wales and Queensland. • It also increases the network hosting capability of New England, but consequently the additional REZ hosting capacity to North NSW is reduced as it is effectively shared between these two REZ. • It also has a slight increased cost compared to the preferred option as there is an additional section of network (Boggabri to Uralla) being built with double circuit towers instead of single.	

A The 2,000 MW of additional hosting capacity is similar to the preferred option; however, it is shared between the two REZ. Furthermore, this only reflects the hosting capacity provided by a single circuit between Bayswater and Uralla, not the second circuit which is considered in the New England REZ expansion. Two circuits provide 4,000 MW to 5,000 MW as described in A3.5.5

A3.5.1.3 Non-network opportunity

The need for QNI Medium and Large can partially be met by non-network alternatives. A virtual transmission line is a strong option, due to the nature of the limitations across QNI and the relative speed at which virtual transmission lines can be developed[35].

Table 31 QNI Medium and Large – non-network opportunity

Opportunity description	There is a need to maintain reliability, facilitating additional renewable generation in the north and west of NSW to the load centres, and the ability to share resources between regions. It is AEMO's view that a non-network option, or combination of non-network options can partially or wholly meet this need. One or more BESS located in northern New South Wales and southern Queensland could be made available for Special Protection Integrity Protection Scheme (SIPS) operation for severe system events. This option could defer or avoid costs of a large transmission investment. Devices located at strategic locations in New South Wales can also serve to facilitate increased renewable generation in the North West NSW and New England REZs.
Timing	There are benefits accruing from increasing QNI southerly flow from the mid-2020s.
Transfer capability	AEMO assessed the improvement to transfer capability associated with operating a pair of 200 MW BESS, one connected at Calvale 275 kV substation and one connected at Newcastle 330 kV substation. The batteries are armed to operate to reduce QNI flow, immediately after contingencies. Contingencies include the loss of 330 kV lines between Liddell and Western Downs and outage of Kogan Creek generator and the largest generator in New South Wales.
Technical guide	200 to 300 MW BESS located in northern New South Wales with an equivalent size BESS or braking resistor located in southern Queensland. The operation of the virtual transmission lines should be in the sub-second range, with short operating times increasing the transient and voltage stability. Operation within 1,000 ms was shown to improve QNI southerly flow by 200 MW as the thermal limitation is the dominant constraint. For a pair of batteries larger than 300 MW, the improved QNI flow diminishes as the transient stability limit is the dominant limit.
Service specification	Under high transfer conditions, and after a major system event, the solution must mitigate thermal overload and prevent system instability such that the interconnector transfer can be increase during system normal conditions. There must be sufficient capability to inject/absorb power in the order of 15 minutes[A] such that NEMDE can redispatch generation to resecure the system.

A. This will need to be refined/confirmed as the non-network option is further investigated.

A3.5.1.4 Associated augmentations

Table 32 Associated augmentations with QNI Medium and Large

Augmentation	Description	Section reference
New England REZ	Portions of the 500 kV New England REZ expansion between Uralla and Bayswater are common with the alternative easterly QNI Medium route.	A3.5.5
QNI Medium and Large	The QNI Medium and Large path form the backbone of the network connecting the North West NSW REZ. Future REZ expansion will build from the QNI Medium and Large infrastructure.	A3.5.1

[35] A virtual transmission line is potentially a 'non-network' or a 'network' option. It may form part of the TNSP's regulated asset base depending on who the VTL is funded.

A3.5.2 Central Queensland to Southern Queensland Transmission Link

The Central Queensland to Southern Queensland (CQ-SQ) cut-set is defined as the power flow on the following 275 kV lines: Calvale – Halys lines 8810 and 8811, Calliope River – Gin Gin lines 813 and 814, and Wurdong –Teebar Creek[36] line 819. The optimal timing of the CQ-SQ upgrade depends on the generation developed north of CQ-SQ as well as the timing of the retirement of coal power stations in central Queensland.

In 2019-20, there was significant congestion on CQ-SQ, largely during planned network outages that reduced the transfer capacity. Generation connecting north of CQ-SQ will increase congestion on this corridor. When CQ-SQ is at its limit, new generation will compete for market dispatch against approximately 4,700 MW of existing coal-powered generation in Central Queensland.

Table 33 Central Queensland to Southern Queensland Transmission Link overview

Timing	The optimal timing ranges between 2028-29 to 2033-34 depending on scenario. This upgrade together with the upgrade on the Gladstone is being investigated further, however, currently it is expected to be required when additional generation in the north of this limit exceeds approximately 2,000-2,500 MW.	
Description	A new double circuit Calvale to Wandoan South 275 kV line	
Cost	$300 million to $560 million [$432 million used in modelling]	
Approximate network capability improvement	Network transfer capacity	CQ-SQ cut-set: +900 MW
Responsible TNSP(s)	Powerlink	
Non-network opportunity	Network constraints of the CQ-SQ corridor will likely occur in periods of high VRE and low demand as power is forced South to major load centres. Strategically placed and operated non-network solutions such as battery storage and/or pumped hydro can defer the optimal timing and/or reduce the scale of network augmentation.	
Drivers of benefits	Increase in renewable generation in Central and Northern Queensland.	

Table 34 Central Queensland to Southern Queensland Transmission Link detail

Augmentation detail	To increase the capacity of the CQ-SQ cut-set, the following augmentations are required: • A new double circuit Calvale–Wandoan South 275 kV line.
Limits addressed	Power transfer across the CQ-SQ cut-set is limited to prevent voltage and transient instability.

[36] There is an augmentation planned which will reconfigure this network to be Rodds Bay to Teebar Creek in 2022-23.

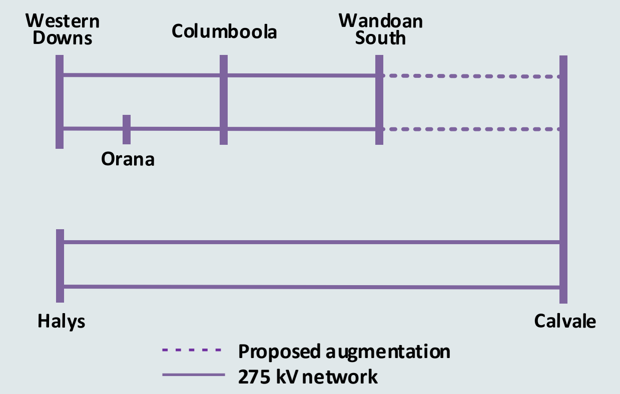
Network diagram	

Table 35 Central Queensland to Southern Queensland – non-network opportunity description

Opportunity description	The deferment of network augmentation coupled with the potential increase in hosting capacity north of the CQ-SQ cut-set could be realised with strategic placement of pumped hydro and/or battery storage. To this end, Isaac, Fitzroy, North Queensland, and Far North Queensland REZs have been identified as areas with potential for significant pumped hydro resources.
Timing	2030s
Potential benefits	Deferral and/or reduced scale of network augmentation in addition to potential increase in hosting capacity north of CQ-SQ.
Service specification	Northern Queensland has access to potentially significant pumped hydro resources which can operate to efficiently supply Queensland load.

A3.5.3 Reinforcing Sydney, Newcastle and Wollongong Supply

AEMO recommends preparatory activities to reinforce supply to Sydney, Newcastle and Wollongong. The transmission network in Sydney and the surrounding area[37] was designed in large part to connect large coal generators in the Hunter Valley to the Sydney load centres. When these coal generators retire, the network has insufficient capability to supply Sydney from generators located outside of the Hunter Valley.

Transmission network augmentation or non-network services are projected to be needed between Marulan and Liddell to supply the Sydney/Newcastle/Wollongong load areas following retirement of coal-powered generation in New South Wales. Due to the difficultly in estimating costs in this area, this ISP does not include cost estimates for the network options. AEMO also recommends that both network and non-network options for this project be explored.

Table 36 Reinforcing Sydney, Newcastle and Wollongong Supply overview

Timing	2026-27 to 2032-33, specifically linked to coal retirements in New South Wales.
Description	Transmission network augmentation or non-network services are projected to be needed between Marulan and Liddell to supply the Sydney/Newcastle/Wollongong load areas following retirement of coal-powered generation in New South Wales. A possible long-term network option is extending 500 kV networks in central New South Wales closer to major load centres. Stage 1: Extending 500 kV network from Bannaby to a new substation between Mt Piper and Kemps Creek (Southern loop) Stage 2: Extend 500 kV network from Bayswater to Eraring (Northern loop)

[37] Essentially this is the Hunter Valley, Greater Sydney area, New South Wales Southern Tablelands, and just west of the Blue Mountains.

Cost	Uncertain – Pending Preparatory Activities	
Approximate network capability improvement	Additional network capacity to supply the Sydney/Newcastle/Wollongong load areas.	Stages 1 & 2: Between 5,000 and 6,000 MW
Responsible TNSP(s)	TransGrid	
Non-network opportunity	Non-network solutions, such as demand management and battery storage within the Sydney/Newcastle/Wollongong areas.	
Drivers of benefits	The key driver is the retirement of coal-powered generation in New South Wales. The sequence of works and the optimal timing highly influenced by load distribution, battery storage locations, and potential line uprating's within Sydney/Wollongong/Newcastle load centre.	

Table 37 Sydney/Newcastle/Wollongong load centre reinforcement detail

Augmentation detail	Stage 1 – Closing the southern portion of the loop. Network augmentation with retirement of Liddell and Vales Point power stations and increased Snowy generation and increased import from Victoria, South Australia, and Queensland: • Uprating of selected highly loaded 330 kV lines between Marulan and Liddell. • Two 500 kV lines from Bannaby to South Creek (closer to Sydney West). • A new 500/330 kV substation at South Creek. • Tap both Eraring–Kemps Creek 500 kV lines at South Creek. • Two 500/330 kV 1,500 MVA transformers at South Creek. • One 500/330 kV 1,500 MVA transformer at Bannaby. • A new 330 kV transmission line from South Creek to Sydney West (8 km). • Tap Sydney West–Bayswater 330 kV line at South Creek. • Tap Sydney West–Regentville 330 kV line at South Creek. • Third Mt Piper–Wallerawang 330 kV line. • Third Bayswater–Liddell 330 kV line. Stage 2 – closing the northern portion of the loop. Network augmentation with additional retirement of Eraring power station and increased generation from North West New South Wales and New England REZs and increased import from Victoria, South Australia, and Queensland: • Two 500 kV lines from Bayswater to Eraring.
Limits addressed	Thermal capacity of the following transmission lines: • Marulan–Avon 330 kV line. • Marulan–Dapto 330 kV line. • Avon–Macarthur 330 kV line. • Macarthur–Kemps Creek 330 kV line. • Bannaby–Sydney West 330 kV line. • Dapto–Sydney South 330 kV line. • Sydney South–Liverpool 330 kV line. • Sydney West–Sydney North. • Mount Piper–Wallerawang 330 kV line. • Wallerawang–Ingleburn 330 kV line. • Wallerawang–Sydney South 330 kV line.

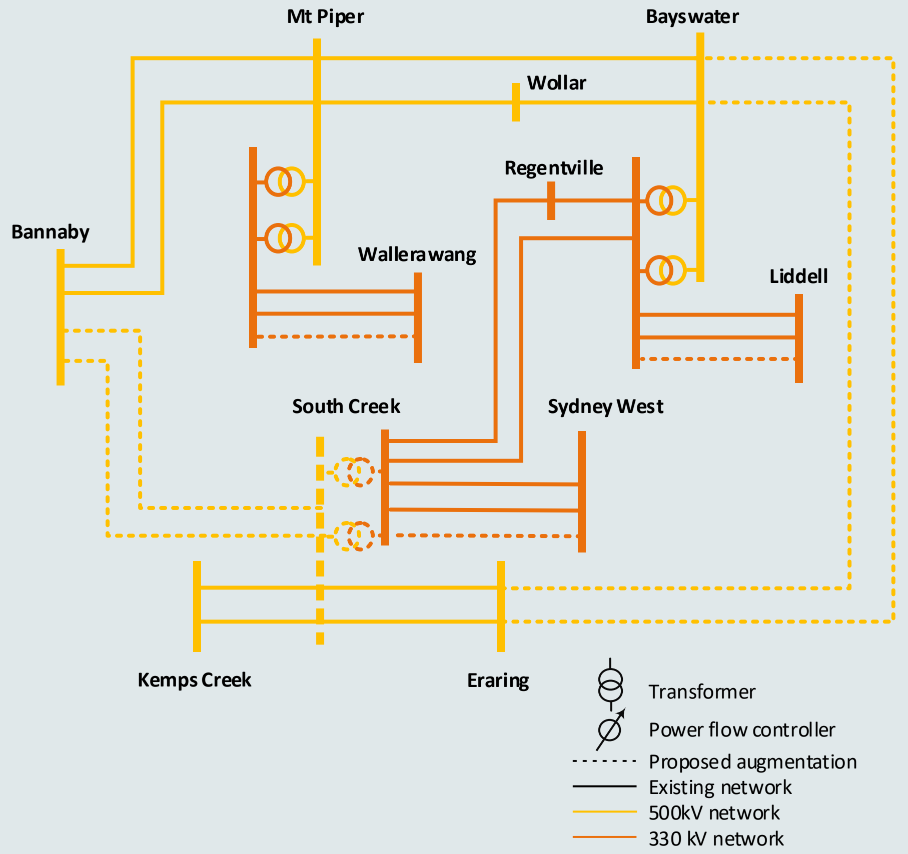
	• Bayswater–Liddell 330 kV line. • Liddell–Newcastle 330 kV line. • Bayswater 500/330 kV transformer.
Network diagram	

Table 38 Reinforcing Sydney, Newcastle and Wollongong Supply – non-network opportunity description

Opportunity description	Due to network constraints, unserved energy could occur during high demand periods. Non-network solutions, such as demand management and battery storage within the Sydney/Newcastle/Wollongong areas, could defer the optimal timing of this network augmentation.
Timing	Staged through to the mid-2030s in line with coal retirement.
Potential benefits	Deferral and/or reduced scale of network augmentation. Improve existing network utilisation with the deployment of utility BESS and demand management through the Sydney/Newcastle/Wollongong area.
Service specification	A service specification is not quantified at this time; however, it is likely that a significant amount of energy and capacity will need to be provided within the Sydney region to replace retired coal-powered generation. The exact size, duration and location will be investigated in future studies and preparatory works.

A3.5.4 Gladstone grid reinforcement

Following the closure of Gladstone Power Station, network upgrades will be required to supply major loads in the Gladstone area. Furthermore, with the significant increase in generation projected for the Far North, Isaac, and Fitzroy REZs, the thermal capacity of the network between Bouldercombe, Raglan, Larcom Creek, and Calliope River will be reached. Upgrading the CQ-SQ cut-set will further highlight the need for the upgrade on this network, as addressing this limitation will shift the limitations further north under high VRE output.

Table 39 Gladstone grid reinforcement overview

Timing	2030s. This upgrade together with the upgrade on the CQ-SQ limit is being investigated further, however, currently it is expected to be required when additional generation in the north of this limit exceeds approximately 2,000 to 2,500 MW. Timing could be brought forward with retirement of Gladstone generation[A].	
Description	To address the thermal constraints transmission network between Calliope River in the south and Bouldercombe in the north requires rebuilding and reconfiguring, as well as new 275 kV network between Calvale and Larcom Creek. A third 132/275 kV Calliope River transformer is also required.	
Cost	$300 million to $560 million	
Approximate network capability improvement	Additional REZ hosting capacity	REZ Fitzroy: +700 MW to 800 MW
Responsible TNSP(s)	Powerlink	
Non-network opportunity	Network constraints are likely to occur during high VRE and during low demand.	
Drivers of benefits	Asset renewal, Gladstone retirement and increase in high VRE in Northern Queensland.	

A The potential closure of Boyne Island also influences the size and timing of this future project.

Table 40 Gladstone grid reinforcement detail

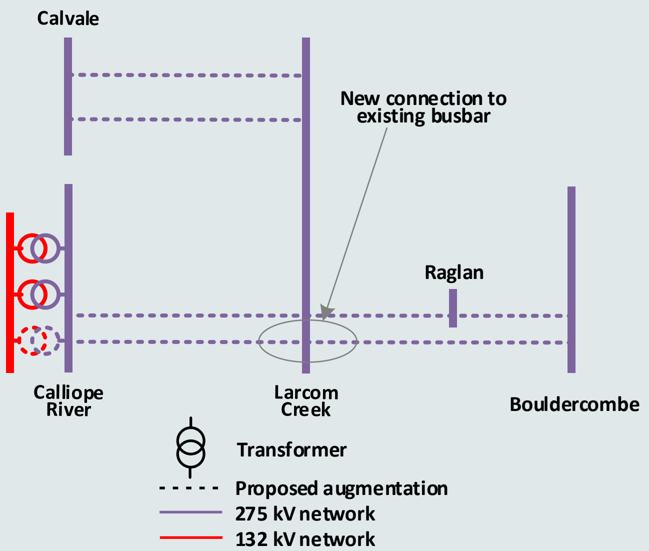
Augmentation detail	The augmentation to address the thermal constraints includes: • Rebuild the Bouldercombe–Raglan–Larcom Creek–Calliope River and the Bouldercombe–Calliope River 275 kV line as a high capacity double circuit line, for a gain of approximately 700-800 MW of additional hosting capacity. • Turn Bouldercombe–Calliope River 275 kV line into Larcom Creek. • A new double circuit Calvale–Larcom Creek 275 kV line. • Third Calliope River 275/132 kV transformer.
Limits addressed	Future limitations are projected to occur as generation retires and Gladstone load is met from alternative transmission paths. Additionally, new generation in the north will cause thermal capacity limitations between Bouldercombe, Raglan, Larcom Creek, and Calliope River.
Network diagram	

Table 41 Gladstone network section reinforcement – non-network opportunity description

Opportunity description	Strategically placed and operated non-network solutions such as battery storage, braking resistors, tripping of renewables/load. and/or pumped hydro can defer the optimal timing and/or reduce the scale of network augmentation. Isaac, Fitzroy, North Queensland, and Far North Queensland have access to areas with potential for good pumped hydro resources which, if strategically developed, can increase the hosting capacity within these REZs.
Timing	See network option timing.
Potential benefits	Deferral and/or reduced scale of network augmentation.
Service specification	BESS strategically placed along the transmission corridor and operating as a virtual transmission lines to assist in network utilisation and system reliability requirements.

A3.5.5 New England REZ Network Expansion

The New England REZ is one of the three REZs identified as a priority in the New South Wales Electricity strategy[38].

Furthermore, as described in Section A3.5.1, there is the potential for a section of one of the QNI Medium and Large circuits to traverse the New England REZ instead of North West New South Wales.

Across all scenarios, except for Slow Change, large transmission augmentation is projected to be required to connect the generation in New England to the Sydney load centre.

Table 42 and Table 43 provide information on the New England Network Expansion design modelled in the ISP.

Table 42 New England REZ Network Expansion overview

Timing	This project is optimally required sometime in the 2030s, but this may be accelerated by the New South Wales Government as part of their announced policy to support development of VRE in this REZ[A]. The delivery of New England Network Expansion is required from mid-2036 in the Central, and High DER scenarios and 2031 in the Step and Fast change scenarios.	
Description	Various upgrades and new network between Bayswater, and Uralla, linking with QNI Medium and Large and North West New South Wales.	
Cost	Stage 1: $720 to $1,330 million Stage 2: $220 to $420 million	
Approximate network capability improvement	Additional REZ hosting capacity	New England: Stage 1: 4,000 MW to 4,500 MW Stage 2: 5,000 MW to 6,000 MW (including stage 1)[B, C]
Responsible TNSP(s)	TransGrid	

[38] New South Wales Government, New South Wales Electricity Strategy, https://energy.nsw.gov.au/government-and-regulation/electricity-strategy.

Non-network opportunity	Network constraints are likely to occur during high VRE. Strategically placed and operated non-network solutions, such as battery storage and/or pumped hydro, can defer the optimal timing and/or reduce the scale of network augmentation. New England has good pumped hydro resources and, if strategically developed, can increase the hosting capacity within this REZ.
Drivers of benefits	Shared network to facilitate the connection of renewable generation and to unlock geographic areas not catered for with the existing network.

A. New South Wales Government. New England to light up with second New South Wales Renewable Energy Zone, at https://www.nsw.gov.au/media-releases/new-england-to-light-up-second-nsw-renewable-energy-zone.

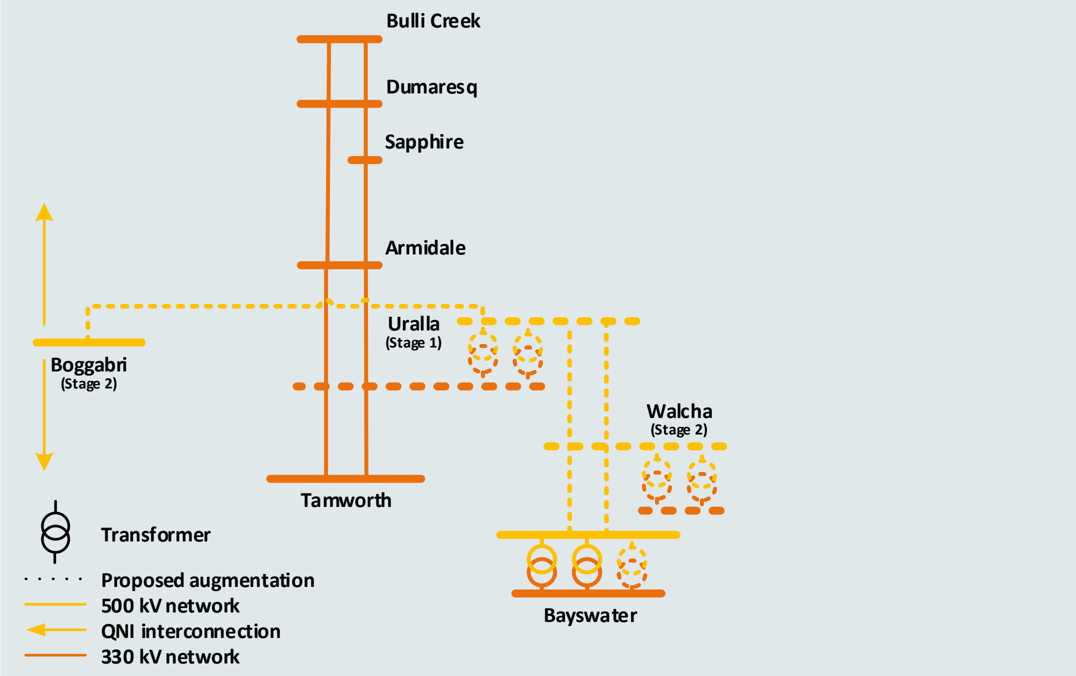
B. Stage 2 is sufficient to host the amount of generation projected in all ISP scenarios. Options to increase this to 8,000 MW to match the target from the New South Wales Government will be explored in the preparatory activities for QNI Medium and Large, North West New South Wales REZ, and New England REZ. See Appendix 5 for further details.

C. Capacity is dependent on development of North West New South Wales REZ and QNI transfers, resource diversity and the amount of storage to connect in this area. Storage was assumed for this zone. Stage 2 is sufficient to host the amount of generation projected in all ISP scenarios. Options to increase this to 8,000 MW to match the target from NSW Government will be explored in the preparatory activities for QNI Medium and Large, North West NSW REZ and New England REZ.

Table 43 New England REZ Network Expansion detail

Augmentation detail	Augmentations, across two stages, comprise of: Stage 1[A] • Uprate Armidale–Tamworth 330 kV lines 85 and 86 • Establish a new Uralla 500/330 kV substation • Turn both Armidale–Tamworth 330 kV lines 85 and 86 into Uralla • A new double circuit Uralla–Bayswater 500 kV line • Two 500/330 kV 1,500 MVA Uralla transformers • Additional reactive support • Establish a new 500/300 kV substation at Walcha • Cut Uralla–Bayswater 500 kV lines into Walcha • Two 500/330 kV 1,500 MVA Walcha transformers • One 500/330 kV 1,500 MVA Bayswater transformer Estimated cost is ~ $720 million to $1,330 million Stage 2: • A new single circuit Boggabri–Uralla 500 kV line[B] Estimated cost is ~ $220 million to $420 million Total estimated cost is ~ $940 million to 1,750 million
Limits addressed	The 330 kV network between Armidale and Bayswater

Network diagram



A. Additional to the REZ expansion listed in Table 7, network augmentation between Bayswater, New Castle and Sydney may be required due to the increase in VRE in North West New South Wales, New England and Central-West Orana.
B. Common between North West New South Wales REZ and New England REZ

Table 44 New England – non-network opportunity description

Opportunity description	During high VRE network constraints are likely to occur.
Timing	2030s (or earlier as per the network option)
Potential benefits	Deferral and/or reduced scale of network augmentation.
Service specification	New England has good pumped hydro resources and, if strategically developed, can increase the hosting capacity within this REZ.

A3.5.6 North West New South Wales Network Expansion

Development in North West New South Wales is supported by QNI Medium and Large upgrades which essentially provides additional REZ hosting capacity to North West New South Wales. The additional capacity provided by QNI Medium is utilised immediately in the Central and High DER scenarios and is required one year prior to QNI Medium in the Step and Fast Change scenarios.

Table 45 and Table 46 provide information on the North West New South Wales Network Expansion design modelled in the ISP.

Table 45 North West New South Wales Transmission Link overview

Timing	Sometime in the 2030s, depending on connection interest.
Description	This development is in three stages: Stage 1: Bring forward the Boggabri and Wollar sections of QNI Medium Stage 2: Additional transformation at Boggabri and West of Dumaresq after QNI Medium and Large Stage 3: A new 500 kV line connecting North West New South Wales REZ to New England (this is common with New England Stage 2)

Cost	Stage 1: $ 320 million to $590 million Stage 2: $70 million to $140 million Stage 3: $220 million to $420 million	
Approximate network capability improvement	North West New South Wales additional REZ hosting capacity	Stage 1: +1,000 MW Stage 2 and 3: +3,000 MW (4,000 MW in total)
Responsible TNSP(s)	TransGrid	
Non-network opportunity	Network constraints are likely to occur during high VRE. Strategically placed and operated non-network solutions, such as battery storage, can defer the optimal timing and/or reduce the scale of network augmentation.	
Drivers of benefits	Shared network to facilitate the connection of renewable generation and to unlock geographic areas not catered for with existing network.	

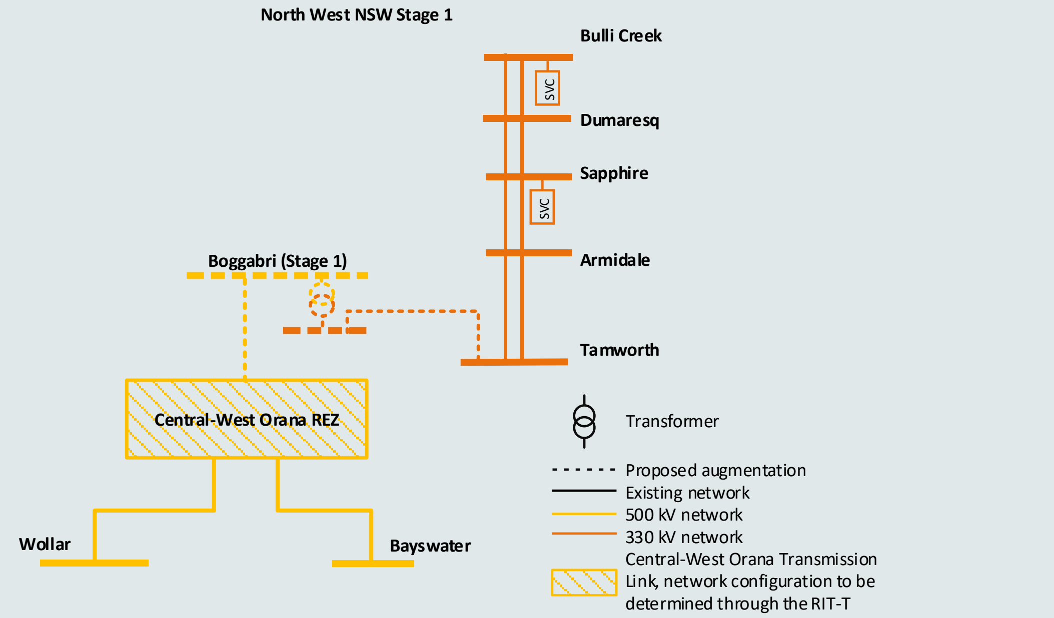
A. Only possible with the QNI Medium and Large development

Table 46 North West New South Wales Transmission Link detail

Augmentation detail	Stage 1 (+1,000 MW) • Bring forward QNI Medium • Establish a new 500/330 kV at Boggabri • A new single circuit Boggabri–Tamworth 330 kV line • A new double circuit 500 kV line, strung one side, from this new substation via Central-West Orana to Boggabri • 500/330 kV transformation at Boggabri. Estimated cost is ~ $320 million to $590 million Stage 2: • This occurs after the development of QNI Medium and Large • Establish additional 500/330 kV transformation at Boggabri • Establish additional 500/330 kV transformation at West of Dumaresq • Estimated cost is ~ $70 million to $140 million Stage 3: (+3,000 MW for stage 2 and stage 3): • A new single circuit Boggabri–Uralla 500 kV line (this is common with New England Stage 2) Estimated cost is ~ $220 million to $420 million
Limits addressed	Without QNI Medium and Large, the limiting factor of this REZ is the regional 132 kV network.

Network diagram

Stage 1:



Stage 2 and 3:

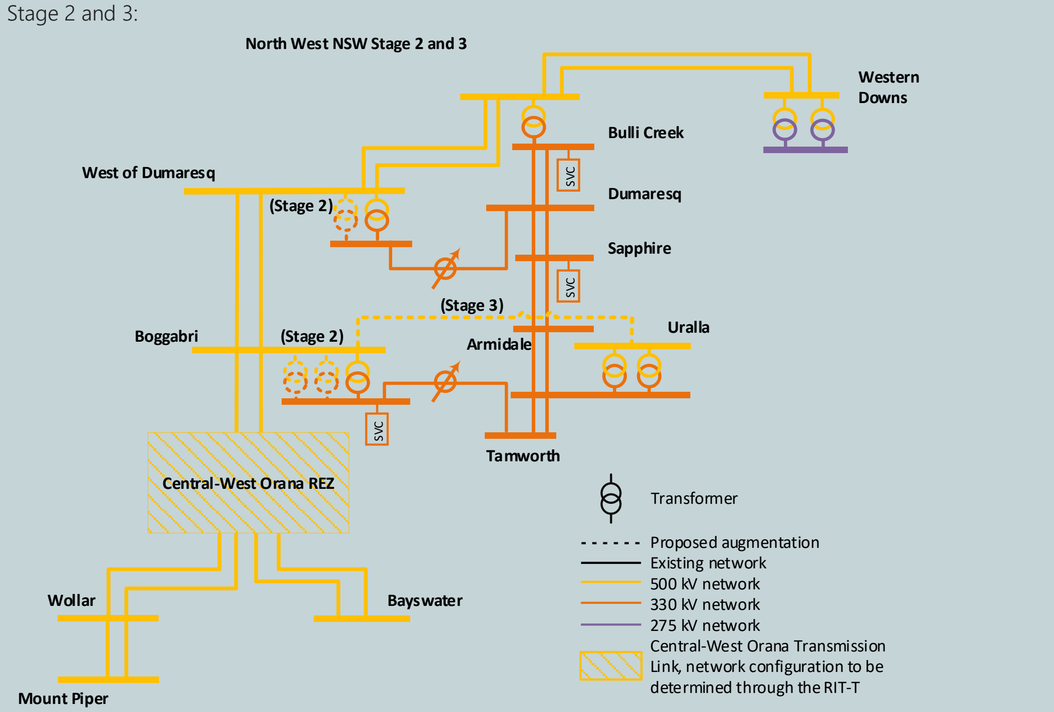


Table 47 North West New South Wales Transmission Link – non-network opportunity description

Opportunity description	During high VRE network constraints are likely to occur.
Timing	Early to mid-2030s
Potential benefits	Deferral and/or reduced scale of network augmentation.
Service specification	BESS systems strategically developed, can increase the hosting capacity within this REZ and defer and avoid the need for network augmentation.

A3.6. Other future ISP projects

This section describes projects which are part of the optimal development path, but for which no further action is required before the 2022 ISP. There are three projects listed in this section:

- An upgrade of the Mid North network in South Australia.
- An upgrade of Far North Queensland network.
- The South East South Australia network expansion.

A3.6.1 Mid North South Australia network project

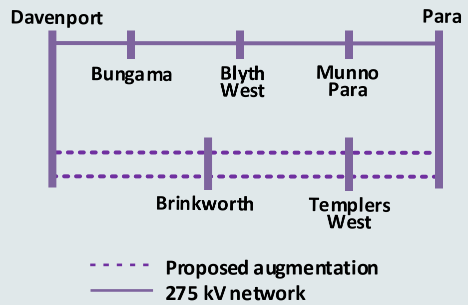
Due to the nature of the South Australian network, generation north and west[39] of Davenport contributes to congestion in the Mid North REZ. Consequently, addressing the Mid North congestion increases the generation hosting capacity of Mid North REZ, and the REZs to the north and west (Mid North, Northern South Australia, Leigh Creek, Roxby Downs, and Eastern and Western Eyre Peninsula).

Table 48 Mid North South Australia network project overview

Timing	This augmentation is optimally timed in 2035-36 in the Central scenario and 2034-35 in the Step Change scenario and is triggered when the total generation in Mid North, Northern South Australia, Leigh Creek, and Roxby Downs exceeds 1,000 MW. The optimal timing of this augmentation is heavily influenced by the retirement of gas generation and the configuration of the network in the Adelaide area.	
Description	Rebuild of Davenport-Brinkworth-Templers West-Para 275 kV line	
Cost	$420 million to $770 million	
Approximate network capability improvement	Additional REZ hosting capacity	+1,000 MW
Responsible TNSP(s)	ElectraNet	
Non-network opportunity	None	
Drivers of benefits	Alleviation of constraints between Davenport and Adelaide and between Davenport and Robertstown such that the hosting capacity of wind can increase.	

[39] This is essential generation in Northern South Australia, Leigh Creek, Roxby Downs, East Eyre Peninsula, and West Eyre Peninsula.

Table 49 Mid North South Australia network project detail

Augmentation detail	To alleviate constraints between Davenport and Adelaide and between Davenport and Robertstown, increasing the hosting capacity by approximately 1,000 MW, the following augmentation is required: • Rebuild the single circuit Davenport–Brinkworth–Templers West–Para 275 kV line at a high capacity double circuit line, and/or • Reconfiguration of 132 kV network in the Mid-North REZ to ensure balance flows between the 275 kV and the 132 kV.
Limits addressed	Alleviation of constraints between Davenport and Adelaide and between Davenport.
Network diagram	

A3.6.2 Far North Queensland Network and REZ Expansion

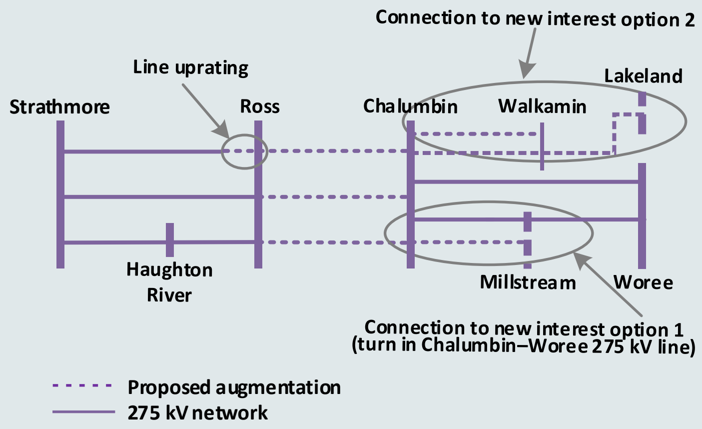
This network expansion is designed to enable the connection and transfer of energy from potential wind farms in Far North Queensland to the wider network.

Table 50 Far North Queensland network and REZ expansion overview

Timing	The optimal timing for this augmentation is linked to the connection of wind farms in the Far North Queensland REZ exceeding 700 MW above what is currently committed and commissioned, which in the modelling typically coincides with coal retirements. For the Central, Fast and Higher DER scenario, both Stage 1 and Stage 2 are required by 2035-36 to 2037-38. For the Step Change scenario, timing is brought forward to 2030-31.	
Description	This project includes reinforcement of the existing network and an extension of the network to facilitate renewable connection. The reinforcement includes a rebuild of the double circuit Ross–Chalumbin 275 kV line, and a new 275 kV single circuit Ross–Chalumbin 275 kV line with an uprating of the lower rated 8 km section of the Ross–Strathmore 275 kV line. The extension involves either a new 275 network to Lakeland or Millstream depending on generation interest. This option does not include potential system strength remediation costs associated with the Ross system strength shortfall.	
Cost	Reinforcement of the existing network: • Stage 1: $400 million to $740 million • Stage 2: $280 million to $530 million REZ expansion: $90 million to $570 million	
Approximate network capability improvement	Additional REZ hosting capacity	Stage 1: +500 MW Stage 2: +700 MW
Responsible TNSP(s)	Powerlink	

Non-network opportunity	There are no non-network options put forward. During high VRE and low demand periods there will be network constraints which provide opportunities for strategically placed battery storage.
Drivers of benefits	Generation of energy from quality wind resources in the region to the wider network.

Table 51 Far North Queensland Network and REZ expansion detail

<table>
<tr><td>Augmentation detail</td><td>
Existing network reinforcement
<u>Stage 1</u>
• Rebuild Chalumbin–Ross 275 kV double circuit line
Estimated cost ~ $400 million to $740 million
<u>Stage 2</u>
• Uprating the lower rated Ross–Strathmore 275 kV line (~$10 million to $15 million)
• Build 3rd 275 kV Chalumbin–Ross single circuit line
Estimated cost ~ $280 million to $530 million
Network extension to facilitate renewable connection
<u>Option 1 – Development interest towards Millstream</u>
• Build new 275 kV substation North of Millstream
• Build a new 275 kV Chalumbin–North of Millstream single circuit line
• Turn existing Chalumbin–Woree 275 kV line into Millstream
Estimated cost ~ $90 million to $160 million
<u>Option 2 – Development interest towards Lakeland</u>
• Build new 275 kV substation at Lakeland
• Build a new 275 kV double circuit Chalumbin–Walkamin line
• Build a new 275 kV Lakeland–Walkamin single circuit line
• Estimated cost ~ $310 million to $570 million
</td></tr>
<tr><td>Limits addressed</td><td>Aging assets in Far North Queensland which require replacement.</td></tr>
<tr><td>Network diagram</td><td>


</td></tr>
</table>

Table 52 Far North Queensland REZ expansion – non-network opportunity description

Opportunity description	During high VRE and low demand, network constraints are likely to occur. A network and non-network option, such as battery storage or pumped hydro, can assist in relieving congestion.
Timing	Staged through to 2030s
Potential benefits	Deferral and/or reduced scale of network augmentation
Service specification	BESS strategically placed along the transmission corridor and operating as a virtual transmission line to assist in network utilisation and system reliability requirements.

A3.6.3 South East South Australia network expansion

Hosting capacity in South Australia is approaching capacity and requires augmentation to facilitate the connection of wind generation west of the Heywood interconnector.

Table 53 South East South Australia network expansion overview

Timing	2030-31 in Step Change and 2037-38 to 2039-40 in Central, Fast, and High DER scenarios.	
Description	String vacant circuit between Tailem Bend and Tungkillo with reactive compensation. Where necessary manage generation with control schemes such as runback schemes.	
Cost	$20 million to $80 million	
Approximate network capability improvement	Additional REZ hosting capacity	+400 to 600 MW
Responsible TNSP(s)	ElectraNet	
Non-network opportunity	Network constraints are likely to occur in the South East South Australia REZ during high wind output, and are worsened by low demand. Non-network solutions such as large-scale storage (battery storage and/or pumped hydro) can defer the optimal timing of network augmentation.	
Drivers of benefits	Increased renewable generation within South East South Australia.	

Table 54 South East South Australia network expansion detail

Augmentation detail	To increase the hosting capacity of the South East South Australia REZ beyond 55 MW, the following augmentation is proposed: • String the vacant circuit on the Tungkillo – Tailem Bend 275 kV line. • Install necessary dynamic reactive support. • If wind generation is in the southerly side of the REZ, alternative network augmentation may be required. This augmentation would be more costly.
Limits addressed	Projected network constraints to occur in the South East South Australia REZ during high wind output.

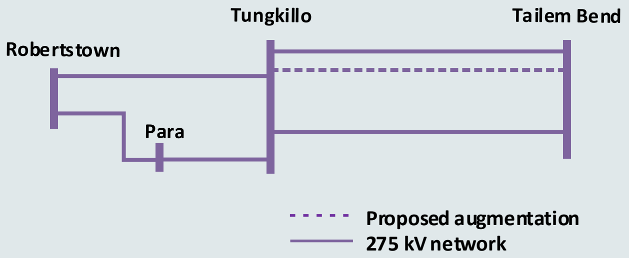
Network diagram	

Table 55 South East South Australia– non-network opportunity description

Opportunity description	Since network constraints are likely to occur in the South East South Australia REZ during high wind output, non-network solutions such as large-scale storage (battery storage and/or pumped hydro) can defer the optimal timing of network augmentation. The South East South Australia REZ has limited pumped hydro resources, so possible non-network solutions include large-scale batteries to assist in the deferral of network augmentations.
Timing	2030s
Potential benefits	Deferral and/or reduced scale of network augmentation.
Service specification	Storage strategically located which can operate to efficiently supply South Australian load.

A3.7. Addressing network congestion

This section presents recent network congestion observed in the NEM and how the projects on the optimal development path can address future network congestion.

Congestion occurs when generation is dispatched out of merit order due to limitations in the network. Typically, this means cheaper generation is curtailed at the expense of more expensive generation to ensure the system remains within its limits. In extreme cases, congestion can result in unserved energy as the electricity generated cannot supply the load without exceeding the capability of the network[40].

The projects on the optimal development path can be directly linked to the parts of the network where network congestion already occurs. Projects to address congestion typically involve:

- Upgrading the existing transmission equipment – raising the physical network limit.
- Implementing control schemes to manage post contingent network overloads.
- Creating a parallel path to the existing network, which provides an additional electrical path.
- Creating an entirely new flow path, which tends to re-distribute the network loading across the system.

Some level of network congestion occurs even in an efficiently designed power system. The cost to develop a network which has no congestion would be prohibitively high and would not result in the best outcome for consumers.

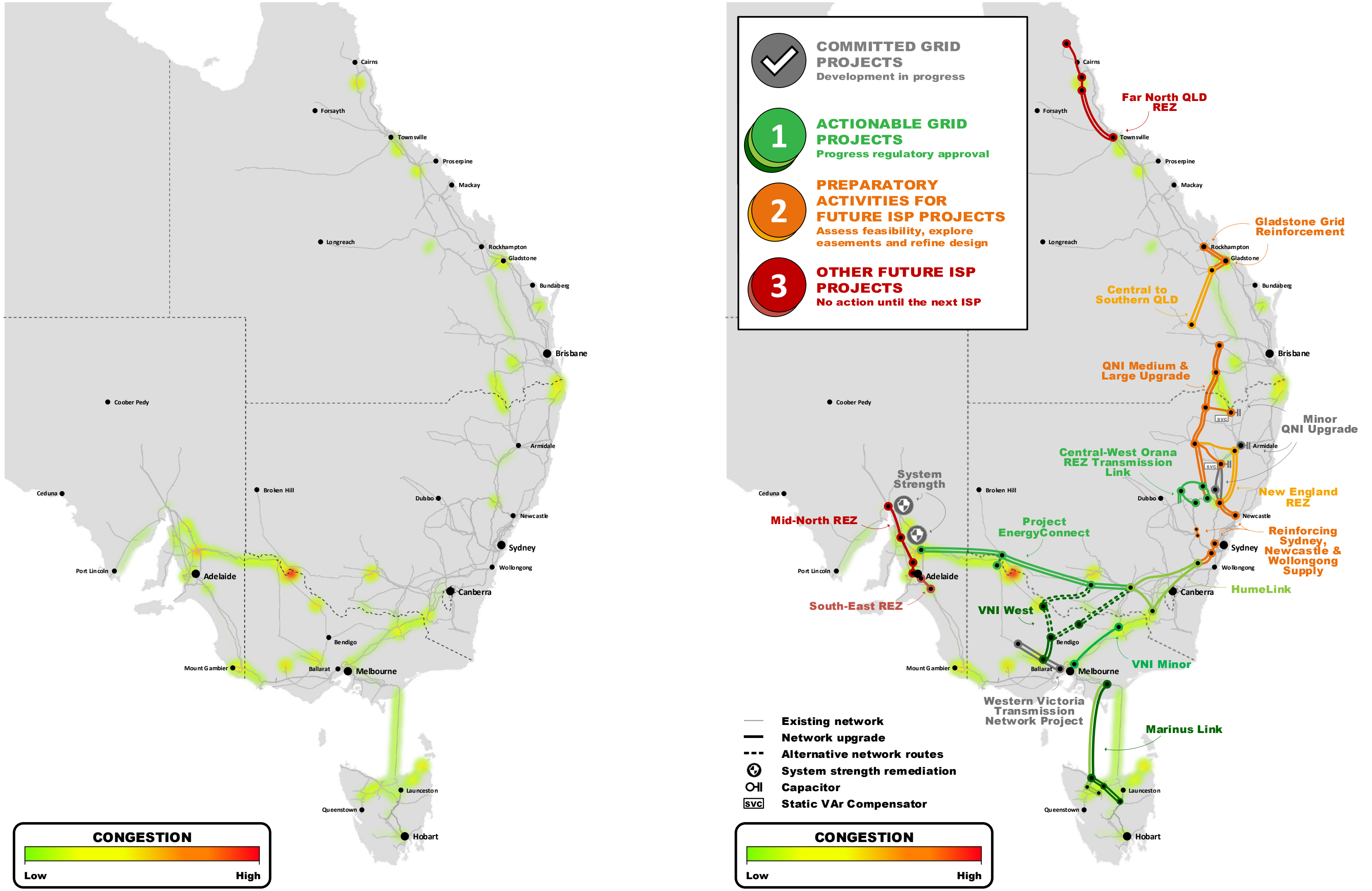
Network augmentations, as part of the optimal development path, seek to address network congestion in an economic way, ultimately resulting in net market benefits[41].

Figure 7 compares areas of network congestion and the corresponding network investment to demonstrate how the projects on the optimal development path address potential future congestion.

[40] For more detail see https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource.

[41] See Appendix 2 for further details.

Figure 7 2019-20 system normal congestion in the NEM without (left) and with (right) ISP projects



A3.8. Alternatives considered

A number of additional options were considered in determining the optimal development path, but excluded on cost, technical or merit grounds. This section lists options considered and rejected in the analysis[42].

A3.8.1 Options to increase interconnection between Queensland and New South Wales

Table 56 Discounted options to increase interconnection between Queensland and New South Wales

Option	Description	Cost	Transfer capacity improvement[A]	REZ capability	Reason not chosen
QNI Option 2	QNI Option 2 is a single circuit 330 kV line from Liddell to Tamworth to Armidale to Dumaresq to Bulli Creek to Braemar. An additional 1500 MVA of transformation at Braemar as well as static and dynamic reactive plant is required along the route.	\$777 million to \$1,443 million	+702 MW from NSW-QLD +660 MW QLD-NSW	+600 MW to Darling Downs +600 MW to New England	Does not provide route diversity. Does not provide significant additional REZ hosting capacity.
QNI Option 3A	QNI Option 3A is a double circuit 330 kV line from Armidale to Dumaresq to Bulli Creek and uprating existing 330 kV transmission lines between Tamworth and Armidale. This option is a first stage of QNI Option 3B. Establish new 500/330 kV substation at Uralla and install additional 1500 MVA of transformation at Braemar as well as static and dynamic reactive plant is required along the route.	\$511 million to \$949 million	100 MW from QLD to NSW	+1,200 MW to Darling Downs +1,200 MW to New England	Not as cost effective as the preferred option. Does not provide significant additional REZ hosting capacity.

[42] For more information see the Input and Assumptions Workbook available in the 2020 ISP Database, at https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2020-integrated-system-plan-isp/2019-isp-database.

Option	Description	Cost	Transfer capacity improvement[A]	REZ capability	Reason not chosen
QNI Option 3B	QNI Option 3B is a double circuit 330 kV line from Liddell to Braemar via Uralla, Sapphire, Dumaresq and Bulli Creek. It passes through adjacent to the existing QNI route.	$1,372 million to $2,548 million	+1,150 MW from NSW to QLD + 1,115 MW from QLD to NSW.		
QNI Option 3C	QNI Option 3C is two 500 kV circuits from Wollar/Bayswater to Uralla and two 330 kV circuits from Uralla to Braemar via Sapphire, Dumaresq and Bulli Creek.	$1,855 million to-$3,445 million	+1,420 MW from NSW to QLD +1,265 MW from QLD to NSW	+1,200 MW to Darling Downs +2,000 MW to New England	Considered as an alternative.
QNI Option 4A	QNI Option 4A is back-to-back HVDC converters at Bulli Creek to increase transfer in both directions between New South Wales and Queensland with a system integrity protection scheme (SIPS).	$749 million-$1,391 million	+797 MW from NSW to QLD +470 MW from QLD to NSW	None	Does not facilitate REZ connection compared to preferred option.
QNI Option 4B	QNI Option 4B is a HVDC link between Lismore in New South Wales and Mudgeeraba in Queensland. This involves dismantling the existing Directlink and extending the existing HVDC connection between Mudgeeraba 275 kV and Lismore 330 kV substations.	$546 million to $1,014 million	+367 MW from NSW to QLD No increase for QLD to NSW	None	Does not facilitate REZ connection compared to preferred option.
QNI Option 4C	QNI Option 4C is two 1,000 MW HVDC bi-pole transmission lines between Bayswater and Western Downs with a SIPS.	$1,911 million to $3,549 million	+2,192 MW from NSW to QLD +1,680 MW from QLD to NSW	None	Connection of renewables generation to HVDC is more complex than to HVAC systems, with a higher cost.
QNI Option 5	QNI Option 5 is a non-network option. This involves installation of a 600 MW battery energy storage system (BESS) capable of discharging the total stored energy for approximately 15 minutes at Halys and Liddell.	$910 million to $1,690 million	+740 MW from NSW to QLD +325 MW from QLD to NSW	None	This will be considered as part of the non-network investigation.

A. Numbers calculated with QNI Minor in service

A3.8.2 Options to increase interconnection between New South Wales and Victoria

Multiple alternatives to VNI West, as described in the following table, were considered and assessed in the ISP. AEMO's analysis has identified two options that are preferred. AEMO therefore recommends the two options specified in Section A3.4.5 as ISP candidate options for VNI West.

Table 57 Discounted options to increase interconnection between New South Wales and Victoria

Option	Description	Cost	Transfer capacity improvement	REZ capability	Reason not chosen
VNI option 3	VNI Option 3 is an incremental network augmentation, which includes a series capacitor on the Wodonga–Dederang 330 kV line, a power flow controller on the Jindera–Wodonga 330 kV line, an additional 330/220 kV transformer at Dederang, and additional reactive plant.	$126 million to $234 million	+300 MW NSW to VIC	None	Larger augmentation required. Does not provide significant additional REZ hosting capacity
VNI Option 4	VNI Option 4 includes VNI Option 1 and a new 330 kV transmission line from Dederang to Yass via Jindera and Wagga Wagga.	$634 million to $1,177 million	+600 MW VIC to NSW +300 NSW to VIC	None	Larger augmentation required. Does not provide significant additional REZ hosting capacity.
VNI option 5A	VNI Option 5 is a new transmission line along the existing easement from South Morang to Murray via Dederang (VNI Option 5A), with approximately 350 km route length.	$742 million to $1,378 million	+550 MW VIC to NSW +1,000 MW NSW to VIC	+1,000 MW to Ovens Murray	Does not provide route diversity. Does not provide significant additional REZ hosting capacity.
VNI option 9	VNI Option 9 is VNI Option 7 (or alternatively VNI West via Shepparton) plus an extension from Bannaby to Sydney to remove network constraints between Bannaby, Marulan, Kangaroo Valley and the Sydney West/Sydney South area.	$2,135 million to $3,965 million	+200 MW VIC to NSW (above VNI Option 7) No additional improvement NSW to VIC (above VNI Option 7)	None	Extension considered in part of Reinforcing Sydney, Newcastle and Wollongong
VNI Option 10	VNI Option 10 is VNI Option 9 plus third 500 kV line from Wagga/Maragle to Bannaby. The third line can be second circuit in a double circuit tower configuration	$2,212 million to $4,108 million	No additional improvement for VIC to NSW and NSW to VIC (above VNI Option 7) +1,500 MW from Snowy to Sydney	None	Extension considered to increase transfer from Snowy to Sydney with high import from VIC and SA and high Snowy generation
VNI option 11	VNI Option 11 is a HVDC transmission option. It involves 2,000 MW HVDC-VSC bi-pole transmission line from Donnybrook to Wagga Wagga with an additional converter station in between to host VRE.	$1,875 million to $3,485 million	+1,750 MW NSW to VIC +1,750 MW VIC to NSW	+2,000 MW to Central North Victoria	This option is more expensive than the preferred options, when considering the need to host VRE in nearby REZs.

Possible connection at Donnybrook

Donnybrook is between South Morang and Sydenham. It is a possible alternative starting point for VNI Option 5A, instead of South Morang, and for VNI West (Shepparton) and VNI West (Kerang), instead of the new terminal station north of Ballarat. VNI Option 5A would also require a 550/330 kV transformer at Donnybrook.

A3.8.3 Option to build interconnection between South Australia and Queensland

The South Australia to Queensland interconnector option involves two 700 MW HVDC transmission lines (1,450 km) from Davenport in South Australia to Western Downs in Queensland, with an intermediate converter station at Broken Hill for renewable generation connection. The project has been estimated to cost between $1,803 million and $3,348 million. This option provides a transfer capability of 700 MW between South Australia and Queensland. It was assessed and rejected in the analysis, as it did not deliver net market benefits comparable to the range of other options and the recommended option of Project EnergyConnect. Accordingly, it does not form part of the optimal development path.