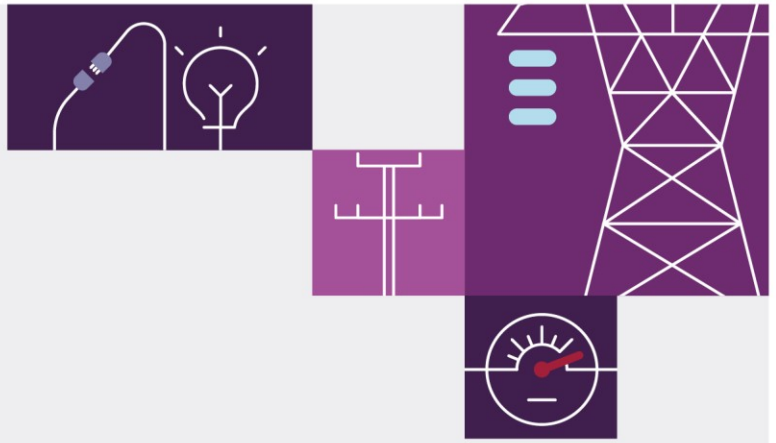


Appendix 5. Network investments

June 2022

Appendix to the 2022 ISP for the
National Electricity Market





Important notice

Purpose

This is Appendix 5 to the 2022 *Integrated System Plan* (ISP), available at <https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp>.

AEMO publishes the 2022 ISP under the National Electricity Rules. This publication has been prepared by AEMO using information available at 15 October 2021 (for Draft 2022 ISP modelling) and 19 May 2022 (for 2022 ISP modelling). AEMO has acknowledged throughout the document where modelling has been updated to reflect the latest inputs and assumptions. Information made available after these dates has been included in this publication where practical.

Disclaimer

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Version control

Version	Release date	Changes
1.0	30/6/2022	Initial release.

ISP Appendices

Appendix 1. Stakeholder Engagement

Consultation in development of 2022 ISP

Consultation on Draft ISP

Reflection and continuous improvement

Appendix 2. ISP Development Opportunities

A rapidly changing NEM will transform energy supply

ISP development outlooks across scenarios

Influence of sensitivities on ISP developments

Appendix 3. Renewable Energy Zones

REZ candidates

Social license

REZ development overview

REZ design reports

REZ scorecards

Appendix 4. System Operability

NEM-wide operability outlook

Appendix 5. Network Investments

Transmission development overview

Committed and anticipated ISP projects

Actionable projects

Future ISP projects

Appendix 6. Cost Benefit Analysis

Approach to the cost benefit analysis

Sensitivity to recent input changes

Determining the least-cost development path for each scenario

Determining the set of candidate development paths to assess the optimal development path

Assessing the candidate development paths

Exploring the risks and benefits of actionable project timings

Testing the resilience of the candidate development paths

NEM-wide distributional effects

Appendix 7. Power System Security

Relationship to other AEMO planning work

System strength outlook

Inertia outlook



Contents

A5.1	Introduction	5
A5.2	Transmission development overview	6
A5.3	Committed and anticipated ISP projects	11
A5.4	Actionable projects	19
A5.5	Future ISP projects	29

Tables

Table 1	Indicative transmission and REZ augmentations required later in the horizon	39
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Figures

Figure 1	Summary of the ISP optimal development path	7
Figure 2	New network investments required in the ODP	8



A5.1 Introduction

This Appendix 5¹ provides detail on the network investments in the optimal development path (ODP) for the 2022 ISP. These network investments ensure there is sufficient network capacity so that resources can be shared between regions, REZ) are able to transfer their energy to the load centres, and the power system is secure and reliable. It sets out:

- **A5.2 Transmission development overview** – this section contains an overview of the network investments in the optimal development path.
- **A5.3 Committed and anticipated ISP projects** – this section describes the committed network projects and anticipated projected including timing, cost and technical details. These projects already have regulatory approval and are highly likely to proceed.
- **A5.4 Actionable projects** – this section describes the optimal timing, costs and technical detail for both actionable ISP projects and projects that are actionable New South Wales projects; the latter projects will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework. All actionable projects are underway or should commence the relevant regulatory process immediately after publication of the 2022 ISP.
- **A5.5 Future ISP projects** – this section describes the optimal timing, costs and technical detail for the future ISP Projects. These projects will deliver net market benefits to consumers but are not needed until later in the horizon.

¹ The outcomes presented in this appendix are based on CDP 11 which features actionable timings for Marinus Link and HumeLink, as well as a staged delivery of VNI West. CDP11 was chosen because it represents a likely path of development for the NEM, it presents a consistent transmission investment path for all scenarios, and the long-term development outcomes for generation investments are similar to those that would result from the ODP. The accompanying Generation Outlook data files contain ISP development opportunity information for other CDPs. See Appendix 6 for more details.



A5.2 Transmission development overview

The development path identified by AEMO as the ODP in the ISP includes a set of network investments which are coordinated and integrated with the projected development of new generation, storage, and DER, to deliver the best outcomes for consumers across a range of scenarios and sensitivities. These network investments are categorised as:

- **Flow path augmentations** – upgrades to the portion of the transmission network used to transport significant amounts of electricity across the backbone of the interconnected network to load centres.
- **REZ expansions** – expansion of the network required to connect renewable generation in areas where clusters of large-scale renewable energy can be developed using economies of scale.

Depending on the timing and urgency of a transmission project, it becomes classified as:

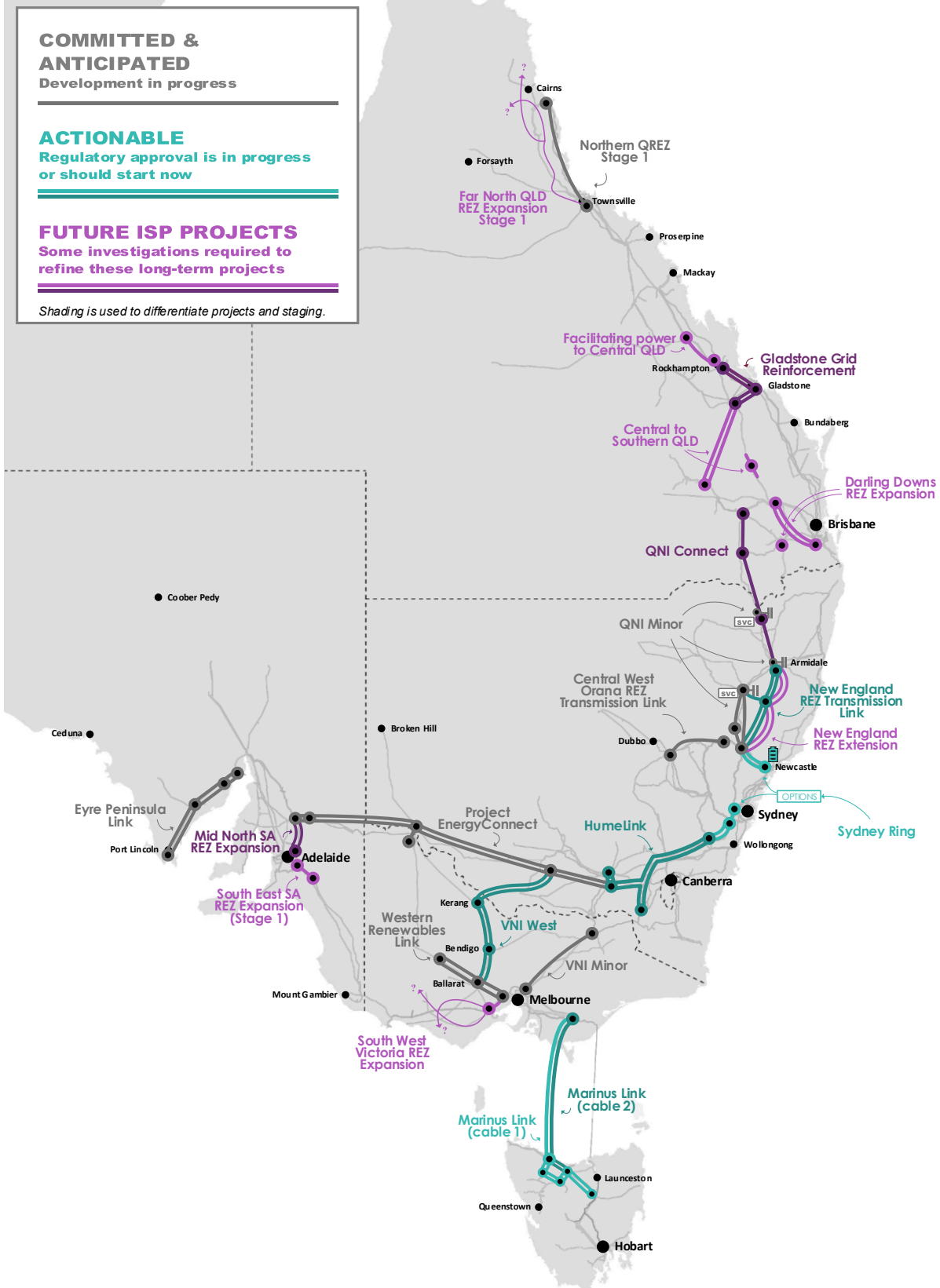
- **Committed and anticipated ISP projects** meet all five commitment criteria (relating to site acquisition, components ordered, planning approvals, finance completed, and construction timing is set²). Anticipated projects are in the process of meeting three out of five commitment criteria.
- **Actionable projects** deliver positive net market benefits to consumers in the most likely scenario if progressed before the next ISP, and so are already underway or should commence the relevant regulatory frameworks: the ISP framework for actionable ISP projects, requiring a Project Assessment Draft Report (PADR) under the RIT-T, unless already complete, be published by the date specified in the ISP, or the *Electricity Infrastructure Investment Act 2020* (NSW) for the actionable New South Wales projects.
- **Future ISP projects** will deliver net market benefits to consumers but are not needed until later in the horizon.

The network projects in the ODP are shown in Figure 1.

² See AEMO ISP Methodology August 2021, at <https://aemo.com.au/-/media/files/major-publications/isp/2021/2021-isp-methodology.pdf?la=en>.



Figure 1 Summary of the ISP optimal development path



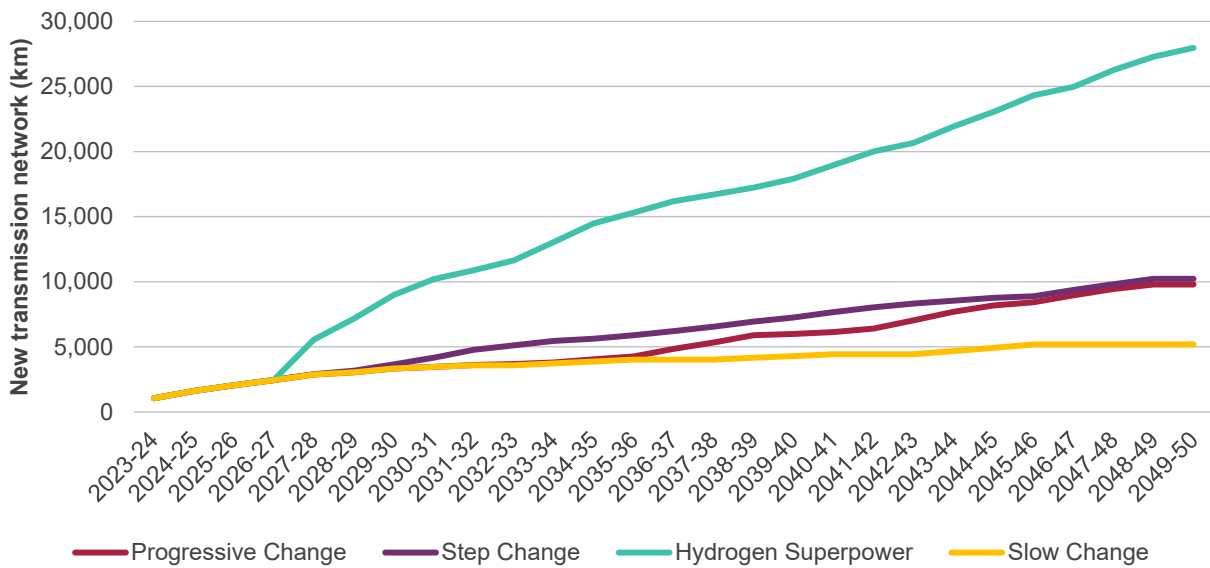
† Additional projects to expand REZs and upgrade flow paths after 2040 are highly uncertain, vary significantly between scenarios, and are not shown in this map. See Section A5.5.12 for more information.



A5.2.1 Transmission development

The ISP identifies between 5,000 km and 28,000 km of new transmission network investment is required to connect new generation and storage opportunities to demand centres. Figure 2 highlights the new network investments required per year across all scenarios. Under both the *Step Change* and *Progressive Change* scenarios approximately 10,000 km of transmission is required, but with initially earlier build times in the *Step Change* scenario.

Figure 2 New transmission network investments required in the ODP³

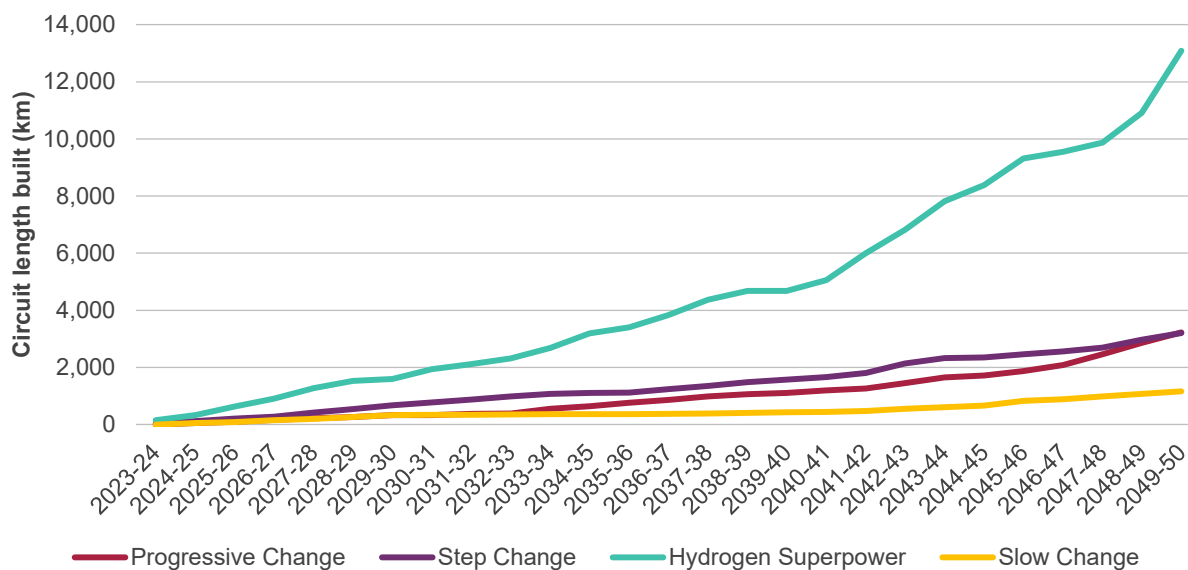


In addition to the transmission network required, between 1,000 km and 13,100 km of connection assets are required to connect the generation identified in this ISP to the transmission network. Figure 3 highlights the length of connection assets required per year across all scenarios. Approximately 3,200 km of connection assets are required under both the *Step Change* and *Progressive Change* scenarios by 2050, bringing the total network investment required under these scenarios to approximately 13,200 km.

³ For the *Hydrogen Superpower* scenario augmentation line lengths later in the scenario are based on generic projects with a distance from the REZ to the nearest demand centre, as detailed in the Inputs and Assumptions workbook.



Figure 3 New network required to connect generation to the transmission network



A5.2.2 Preparatory activities

AEMO may trigger preparatory activities for future ISP projects including REZ stages. Preparatory activities – activities to design and investigate the costs and benefits of these projects – are required to better inform future ISPs.

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 2023 for each project listed below:

- QNI Connect, a 500 kV option for both New South Wales and Queensland scope and the 330 kV option for New South Wales scope.
- Darling Downs (Stage 1).
- South East SA REZ Expansion (Stage 1).
- Mid-North SA REZ Expansion.
- South West Victoria REZ Expansion.

A5.2.3 Transmission costs

AEMO has undertaken significant steps towards improving the accuracy and transparency of transmission costs used for the 2022 ISP, following feedback from stakeholders on the 2020 ISP. The resulting *2021 Transmission Cost Report*⁴ and associated public database are world-leading initiatives in transparency and information provision in relation to regulated transmission builds.

AEMO published the *Transmission Cost Report* in July 2021, setting out:

- The methodology used for transmission cost estimation and review of TNSP cost estimates,
- A transparent Transmission Cost Database,

⁴ At <https://aemo.com.au/en/consultations/current-and-closed-consultations/transmission-costs-for-the-2022-integrated-system-plan>.



- A breakdown of the design, capacity and cost estimates for each augmentation option, and
- Generator connection and system strength remediation costs.

A challenge remaining is that there is no standardisation on the specific class or accuracy level for project cost estimates between the ISP, RIT-T and Contingent Project Application (CPA) processes. It is envisaged that the AEMC will include this consideration in its 'Transmission Planning and Investment Review'⁵ and through the 'Material change in network infrastructure project costs'⁶ rule change.

Since the *Transmission Cost Report* was issued in July 2021, further updates have been made to the Transmission Cost Database to improve the representation of the property and biodiversity costs. While there have been significant changes to these individual cost components, there have been relatively minor changes to the total costs of ISP projects estimated by AEMO, with the majority of project costs within 5% of the original estimate. As a result, no changes have been made to cost assumptions in the 2022 ISP modelling. The latest version of the Transmission Cost Database and an updated user manual is available on AEMO's website⁷.

⁵ At <https://www.aemc.gov.au/market-reviews-advice/transmission-planning-and-investment-review>.

⁶ At <https://www.aemc.gov.au/rule-changes/material-change-network-infrastructure-project-costs>.

⁷ AEMO. *Current Inputs, Assumptions and Scenarios*, at <https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios>.



A5.3 Committed and anticipated ISP projects

AEMO includes all committed and anticipated transmission projects in all scenarios. The projects are modelled with a fixed time across each scenario. Currently, AEMO has modelled three committed transmission projects and four anticipated projects. The details of these projects are discussed below.

A5.3.1 Eyre Peninsula Link

Summary							
<p>The Eyre Peninsula Link project involves the augmentation of the transmission network on the Eyre Peninsula in South Australia. This project will replace an ageing 132 kV single-circuit from Cultana to Yadnarie to Port Lincoln with a high thermal capacity new double-circuit line that simultaneously ensures reliable electricity supply to the Eyre Peninsula. ElectraNet completed the RIT-T and gained regulatory approval from the AER in September 2020[†]. This is a committed project and currently on track for completion by end of 2022.</p>							
Existing network capability							
<p>The Eyre Peninsula is currently served by a radial 132 kV transmission line which runs from Cultana to Yadnarie to Port Lincoln.</p>							
Augmentation sequences							
Description	Status	Network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Option 1:</p> <ul style="list-style-type: none"> A new 132 kV double-circuit line from Cultana to Yadnarie (constructed with the option to be energised at 275 kV if required in the future). A new 132 kV double-circuit line from Yadnarie to Port Lincoln. 	Committed	Cultana-Yadnarie 300 MVA Yadnarie-Port Lincoln 240 MVA	Committed project	Early-2023 [‡]			

[†] AER. ElectraNet – Eyre Peninsula Reinforcement contingent project, at <https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/electranet-%E2%80%93-eyre-peninsula-reinforcement-contingent-project>.

[‡] This service date reflects the latest advice provided by ElectraNet



A5.3.2 Queensland to New South Wales Interconnector Minor (QNI Minor)

Summary							
<p>A minor upgrade to QNI was recommended as urgently needed in the 2018 ISP. Since that time, Powerlink and Transgrid have completed a RIT-T to confirm the optimal solution. The outcome from this RIT-T, which was published in the Project Assessment Conclusions Report (PACR) on 20 December 2019*, confirms the solution recommended in the 2018 ISP. This project gained regulatory approval from the AER in March 2020†. This is a committed project and currently on track for completion by mid-2023‡.</p>							
Existing network capability							
<p>QNI transfer capability is influenced by output of Sapphire generation and generation at 132 kV or lower voltages and load in Northern New South Wales. New South Wales to Queensland transfer capability via QNI is limited by voltage or transient stability limits or thermal capacity of 330 kV lines between Liddell and Muswellbrook/Tamworth. With Sapphire generation at full output of 270 MW, New South Wales to Queensland (northerly direction) transfer capability via QNI ranges from 455 MW to 565 MW. With no Sapphire generation, New South Wales to Queensland transfer capability via QNI ranges from 190 MW to 300 MW.</p> <p>Queensland to New South Wales (southerly direction) transfer capability via QNI is limited by voltage or stability limits or thermal capacity of 330 kV lines within northern New South Wales. With Sapphire generation at full output of 270 MW, Queensland to New South Wales transfer capability via QNI ranges from 815 MW to 915 MW. With no Sapphire generation, Queensland to New South Wales transfer capability via QNI ranges from 1,095 to 1,145 MW.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Option 1:</p> <ul style="list-style-type: none"> • Uprating of Liddell-Muswellbrook, Muswellbrook-Tamworth and Liddell-Tamworth 330 kV lines. • Install -100/+350 MVAR static var compensators at each of the Dumesq and Tamworth substations. • Install 240 MVAR, 330 kV shunt capacitor banks at each of the Dumesq and Tamworth substations. • Install 220 MVAR, 330 kV shunt capacitor banks at Armidale substation. 	Committed	<p>Northerly direction 150 MW</p> <p>Southerly direction 145-245 MW</p>	Committed project	Mid-2023			

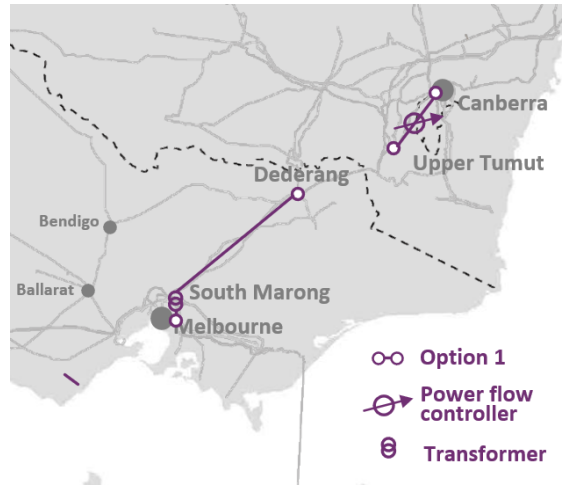
* Transgrid and Powerlink. *Expanding NSW-QLD transmission transfer capacity PACR*, at <https://www.transgrid.com.au/media/xblbtudu/expanding-nsw-qld-transmission-transfer-capacity-project-assessment-conclusions-report-pacr-full-report.pdf>.

† AER. *Expanding NSW-QLD Transmission Transfer Capacity RIT-T*, at <https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/transgrid-expanding-nsw-qld-transmission-transfer-capacity-regulatory-investment-test-transmission-rit-t>.

‡ This timing is when full capacity is expected to be available following commissioning and interconnector testing. The timing is as per the QNI Upgrade Project Test Program for Inter-Network Test, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/qld-to-nsw-interconnector-qni-upgrade/final-inter-network-test-program-document.pdf?la=en.



A5.3.3 Victoria to New South Wales Interconnector Minor (VNI Minor)

Summary							
<p>A minor upgrade to the VNI was recommended for immediate action in the 2018 ISP. Since that time, AEMO and Transgrid completed a RIT-T to confirm the optimal solution. The outcome from this RIT-T, which was published in the project assessment conclusions report in February 2020[*], largely confirms the solution recommended in the 2018 ISP. This project gained regulatory approval from the AER in April 2021[†]. This project is a committed project.</p> <p>The VNI Minor project is to increase the Victoria to New South Wales transfer capability by up to 170 MW by increasing the thermal capacity of limiting elements.</p>							
Existing network capability							
<p>At times of high demand in New South Wales, Victoria to New South Wales transfer capability is limited to 700 MW by thermal capacity of South Morang 500/330 kV transformer, South Morang–Dederang 330 kV lines and Upper Tumut–Canberra 330 kV lines.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Option 1:</p> <ul style="list-style-type: none"> • Uprate South Morang–Dederang 330 kV line. • An additional new 500/330 kV transformer at South Morang. • Power flow controllers on Upper Tumut–Yass and Upper Tumut–Canberra 330 kV lines. 	Committed	VIC to NSW direction up to 170 MW	Committed project	November 2022 [‡]			

* AEMO and Transgrid. *Victoria to New South Wales Interconnector Upgrade PACR*, at <https://www.transgrid.com.au/media/24nhbaux/victoria-to-new-south-wales-interconnector-upgrade-rit-t-pacr.pdf>.

† AER. *Transgrid – Expanding Victoria-New South Wales Transmission Transfer Capacity (VNI) Contingent Project Application*, at <https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/transgrid-%E2%80%93-expanding-victoria-new-south-wales-transmission-transfer-capacity-vni-contingent-project-application>.

‡ This service date refers to full capacity available. .



A5.3.4 Northern Queensland REZ (QREZ) Stage 1

Summary							
<p>In August 2020, the Queensland Government committed \$145 million to establish three REZs in Queensland. It was further announced in May 2021 that the northern zone (which includes the Far North Queensland region) would direct \$40 million of this committed funding in transmission infrastructure to establish the Northern QREZ[†].</p> <p>The scope of the network upgrades is to establish a third 275 kV connection into the Woree Substation, with all associated works to commence Quarter 4 2021 and to be completed by September 2023. Works associated falls outside the bounds of the RIT-T due to the external nature of the funding provided which will facilitate non-regulated opportunities and developments in Far North Queensland.</p>				<p>The map shows the northern coastline of Queensland with several towns marked: Cairns, Forsyth, Townsville, and Proserpine. A purple line labeled 'Option 1' indicates a transmission route starting from Cairns, heading south, then east, and finally south again towards Townsville.</p>			
Existing network capability							
<p>While there is thermal capacity for additional generation within this zone, without the coastal 275 kV circuit upgrade, future VRE generators need additional investment. The upgrade also improves reliability to the Cairns area and provides greater resilience to Far North Queensland.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<ul style="list-style-type: none"> • Conversion of one side of the coastal 132 kV double-circuit transmission line to permanently operate at 275 kV, as the third transmission line between Ross and Woree substations. • Associated line reactor at the Woree Substation end. • Establishment of a 275 kV bus at Woree Substation. • Construction of a 275 kV bay at Ross Substation. • Installation of a 275/132 kV transformer at Tully Substation 	Anticipated	Allow for up to 500 MW of new generation.	Anticipated project.	September 2023			

[†] See <https://www.powerlink.com.au/sites/default/files/2021-09/Powerlink%20Queensland%20-%20Developing%20the%20Northern%20QREZ%20-%20Final%20Report.pdf>.



A5.3.5 Central-West Orana REZ Transmission Link

Summary							
<p>Central-West Orana REZ has been identified by the New South Wales Government as the state's first pilot REZ. The NSW <i>Electricity Infrastructure Investment Act 2020</i> legislates the REZ be declared with an intended 3,000 MW of additional transmission network capacity within the Central-West Orana region of the state. REZ design and community engagement is currently progressing. In early November 2021, Central-West Orana was formally declared a Renewable Energy Zone as the first step to formalising the REZ under the <i>Electricity Infrastructure Investment Act 2020</i>.</p>							
Existing network capability							
<p>The project to establish the Central-West Orana REZ is considered anticipated, and as such the existing network capability is approximately 3,900 MW.</p> <p>Due to the nature of the project, which is currently going through consultation on corridor selection, specific information on the project is not able to be provided.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>New transmission lines connecting to a 500 kV and 330 kV loop in the vicinity of the Wollar, Wellington and Mt Piper substations within the Central-West Orana REZ indicative location. Additional 330 kV circuits between Bayswater to Liddell, and Mount Piper to Wallerawang are also anticipated.</p>	Anticipated	3,000	Anticipated project.	Mid-2025			



A5.3.6 Project EnergyConnect

Summary							
<p>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 REZ.</p> <p>ElectraNet and Transgrid gained regulatory approval from the AER in May 2021*. Project EnergyConnect is expected to be completed, including inter-network testing and the release of full capacity by July 2026†.</p>							
Existing network capability							
Presently no inter-connection between South Australia and New South Wales.							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Stage 1:</p> <ul style="list-style-type: none"> A new Robertstown to Bunday 275 kV double-circuit line strung one circuit initially. A new Bunday to Buronga 330 kV double-circuit line strung one circuit initially. A new Buronga to Red Cliffs 220 kV double-circuit line strung one circuit only. A new 330/275 kV substation and a 330/275 kV transformer at Bunday. A new 330/220 kV substation, a 330/220 kV transformer and a 330 kV phase shifting transformer at Buronga. Static and dynamic reactive plant at Bunday and Buronga. <p>Stage 2:</p> <ul style="list-style-type: none"> Second 275 kV circuit strung on the Robertstown–Bunday 275 kV double-circuit line. 	Anticipated	800 MW In both directions of NSW-SA REZ network limit increase: 800 MW in S2, 800 MW in N5	Anticipated project	July-2026†			



<ul style="list-style-type: none"> • Second 330 kV circuit strung on the Bunday–Buronga 330 kV double-circuit line. • A new 330 kV double-circuit line from Buronga to Dinawan. • A new 500 kV double-circuit line from Dinawan to Wagga Wagga operating initially at 330 kV[†]. • Two additional new 330/275 kV transformers at Bunday. • A new 330 kV switching station at Dinawan. • Additional new 330 kV phase shifting transformers at Buronga. • Additional new 330/220 kV transformers at Buronga. • Turning the existing 275 kV line between Para and Robertstown into Tungillo. • Static and dynamic reactive plant at Bunday, Robertstown, Buronga and Dinawan. • A special protection scheme to detect and manage the loss of either of the AC interconnectors connecting to South Australia. 				
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* AER. *Transgrid and ElectraNet – Project EnergyConnect contingent project*, at <https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/transgrid-and-electranet-%E2%80%93-project-energyconnect-contingent-project>.

† See <https://www.minister.industry.gov.au/ministers/taylor/media-releases/government-supporting-delivery-critical-transmission-infrastructure-southwest-nsw>.

‡ This service date refers to full capacity available following completion of inter-network testing, timing is updated according to the latest advice provided by the relevant TNSPs. The ISP modelling, using information available at the time, modelled the service date as July 2025.



A5.3.7 Western Renewables Link

Summary							
<p>The Western Renewables Link (formerly named “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 in Western Victoria. These augmentations will address network constraints due to the existing and committed large-scale renewable generation within the area. A RIT-T was completed in July 2019[†]. Minor transmission line augmentations, including wind monitoring and upgrading station limiting transmission plant, on the Red Cliffs to Wemen to Kerang to Bendigo, and Moorabool to Terang to Ballarat, 220 kV transmission lines, were completed in 2021 through AusNet Services’ Network Capability Incentive Project Action Plan (NCIPAP). The remainder of the augmentation includes construction of new 500 kV and 220 kV transmission lines and a new 500/220 kV terminal station near Ballarat. This project is classified as an anticipated project, and is expected to be completed in mid-2026.</p>							
Existing network capability							
<p>The existing network capability does not allow full dispatch of existing and committed renewable generation in Western Victoria and Murray REZ at times of high generation output.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Option 1:</p> <ul style="list-style-type: none"> A new 220 kV double-circuit transmission lines from Bulgana Terminal Station to Waubra Terminal Station to the new terminal station north of Ballarat. A new 500 kV double-circuit transmission lines from Sydenham to a new terminal station north of Ballarat with 50 MVA reactors on each end of each circuit. A new 500/220 kV terminal station north of Ballarat with two new 1,000 MVA 500/220 kV transformers. 	Anticipated	This option accommodates existing plus committed generation in V3.	Anticipated project.	July 2026*			

[†] AEMO. Western Victoria Renewable Integration, at https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/victorian_transmission/2019/pacr/western-victoria-rit-t-pacr.pdf.

* This service date refers to full capacity available following completion of all testing.



A5.4 Actionable projects

Five actionable projects are identified:

- Three actionable ISP projects - where the relevant TNSP must assess the project under the RIT-T by considering the ISP candidate option identified in this section as one of the RIT-T credible options.
- Two actionable New South Wales projects – where augmentations will be assessed under the *Electricity Infrastructure Investment Act 2020 (NSW)* rather than through the RIT-T.

A5.4.1 HumeLink

Summary				
<p>HumeLink is a proposed transmission network augmentation that reinforces the New South Wales southern shared network to increase transfer capacity to New South Wales load centres. Transgrid completed this RIT-T in December 2021*. In January 2022, AEMO completed the ISP feedback loop†, which confirmed that early works for HumeLink remains aligned with the ISP.</p> <p>HumeLink is a staged actionable ISP project with early works to be completed by approximately 2024 and project implementation by July 2026. This delivery timeline protects consumers against schedule slippage or further coal closures. This project is staged consistent with the Draft ISP retaining the option to pause the project if circumstances change.</p>				
Existing network capability				
<p>The maximum transfer capability from SNSW to CNSW is 2,700 MW at peak demand and summer typical and 2,950 MW at winter reference periods. The maximum transfer capability is limited by thermal capacity of Yass–Collector–Marulan, Yass–Marulan or Crookwell–Bannaby 330 kV lines following a credible contingency.</p> <p>The maximum transfer capability from CNSW to SNSW is 2,320 MW at peak demand and summer typical and 2,590 MW at winter reference periods. The maximum transfer capability is limited by thermal capacity of Yass–Canberra or Marulan–Collector–Yass or Gullen Range–Bannaby 330 kV lines following a credible contingency.</p>				
ISP candidate option				
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Timing

Actionable ISP projects

<ul style="list-style-type: none"> • New Wagga Wagga 500/330 kV substation and 330kV double-circuit connection to the existing Wagga Wagga 330kV substation. • Three new 500 kV transmission lines: <ul style="list-style-type: none"> – Between Maragle and Bannaby 500 kV substations, – Between Maragle and new Wagga Wagga 500 kV substations, and – Between new Wagga Wagga and Bannaby 500 kV substations. • Three 500/330 kV 1,500 MVA transformers at Maragle. • Two 500/330 kV 1,500 MVA transformers at new Wagga Wagga. • 500 kV Line shunt reactors at the ends of Maragle – Bannaby, Maragle – new Wagga Wagga and new Wagga Wagga – Bannaby 500 kV line. 	<p>Actionable with early works</p>	<p>2,200 MW in both directions. REZ network limit increase: 1,500 MW in N6, 2,200 MW in N6+N7, 1,000 MW in N5.</p>	<p>3,315 (including \$330 million for early works‡)</p>	<p>Early works: To be completed by approximately 2023-24 Implementation: Target July 2026</p>
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* Transgrid. *HumeLink RIT-T*, at <https://www.transgrid.com.au/projects-innovation/humelink>.

† AEMO. Feedback Loop Notices, at <https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/integrated-system-plan-feedback-loop-notice>

‡ The early works for HumeLink are assumed to cost \$330m, of which \$50m would need to be re-spent at a later date if the project was delayed for an extended period.



A5.4.2 New England REZ Transmission Link

Summary

The NSW *Electricity Infrastructure Investment Act 2020* legislates the New England REZ be declared with an intended 8,000 MW of additional transmission network capacity. New England is located to the east of and along the existing QNI. Network expansion from Central New South Wales (CNSW) to connect to the New England REZ would help increase transfer capacity for QNI upgrade options.

New England REZ has moderate to good wind and solar resources in close proximity to the 330 kV network. Interest in the area includes large-scale solar and wind generation as well as pumped hydro generation. As generation further increases in North West New South Wales and New England REZs, increased connection capacity between the two REZs may be required. The sharing of resources across the network augmentation will allow for better transmission utilisation and reduction in transmission build.

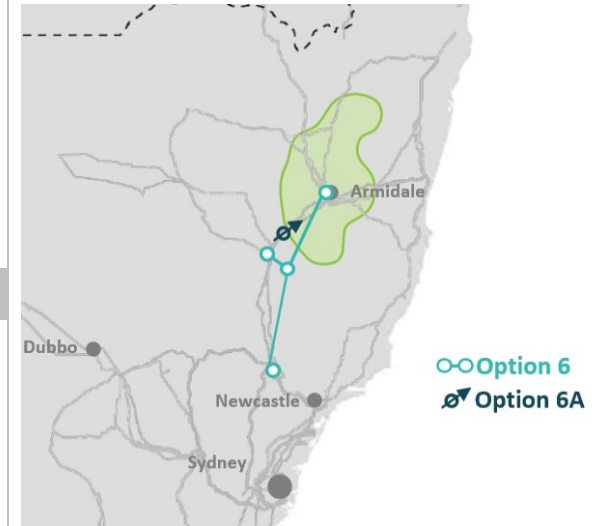
As an actionable New South Wales project for delivery in 2027-28, this project will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework.

Existing network capability

The existing network capacity, following completion of the committed QNI Minor upgrade, is limited by transient and voltage stability on the circuits between Bulli Creek, Sapphire and Dumaresq. Thermal limits on the 330 kV circuits between Armidale, Tamworth, Muswellbrook and Liddell can also restrict flows on this network.

CNSW to NNSW maximum transfer capability is 910 MW at peak demand, summer typical and winter reference periods. The maximum transfer capability is limited by voltage stability for loss of Kogan Creek generator.

NNSW to CNSW maximum transfer capability is 930 MW at peak demand and summer typical periods and 1,025 MW at winter reference period. The maximum transfer capability is limited by thermal capacity of Armidale–Tamworth 330 kV lines following a credible contingency†.





ISP candidate options				
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Timing
<p>CNSW – NNSW Option 6 & 6A:</p> <ul style="list-style-type: none"> • A new 500 kV double-circuit line from locality of Armidale South to Bayswater via east of Tamworth. • A new 500/330 kV substation with two 1,500 MVA transformers in locality of Armidale South. • A new 500/330 kV substation in locality of east of Tamworth. • A new 330 kV circuit from the locality of east of Tamworth to Tamworth. • A new 330 kV double-circuit line from a new substation in locality of Armidale South to Armidale. • Reconnect both Tamworth–Armidale 330 kV lines from Armidale to a new substation in locality of Armidale South. • 500 kV line shunt reactors at both ends of locality of Armidale South–locality of east of Tamworth and locality of east of Tamworth–Bayswater. • Power flow controllers on the existing Armidale-Tamworth 330 kV circuits. • A +/- 400 MVAr SVC (or potentially synchronous condensers) at locality of east of Tamworth. 	Actionable‡	3,070 MW in both flow directions. Increase of N2 REZ network limit to 3,070 MW	1,905 (±50%)	July 2027

† Transgrid published a Project Assessment Draft Report (PADR) for managing risk on Tamworth – Armidale 330 kV line (Line 86) on 30 May 2022. Options include transfer capability improvement between Tamworth and Armidale. AEMO will consult with Transgrid on these options and their impact on transfer capability. Available at <https://www.transgrid.com.au/projects-innovation/managing-risk-on-line-86-tamworth-armidale>.

‡ New England REZ Transmission Link project is an actionable New South Wales project rather than an actionable ISP project. This project will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework.



A5.4.3 Sydney Ring (Reinforcing Sydney, Newcastle, and Wollongong Supply)

Summary				
<p>The transmission network in the Sydney, Newcastle and Wollongong (SNW) area was originally designed to connect large coal-fired generators in the Hunter Valley to supply the SNW load centres. When coal-fired generators around Newcastle retire, the network has insufficient capability to supply SNW load centres from generators located outside of the SNW area. Additional transmission network augmentation to connect with Central New South Wales (CNSW), local generation within SNW and/or energy storage within SNW is needed to supply the load centres within SNW area.</p> <p>In the 2020 ISP, AEMO recommended that Transgrid complete preparatory activities for reinforcement of SNW supply. Transgrid proposed three options to increase the maximum network transfer capability from CNSW to SNW. Option 1 is a 500 kV double-circuit line between Bayswater and Eraring (Sydney Ring Northern 500 kV loop), Option 2 is a 500 kV double-circuit line between Bannaby and new substation near South Creek (Sydney Ring Southern 500 kV loop), and Option 3 is a combination of both Sydney Ring Northern and Southern 500 kV loops.</p> <p>As an actionable New South Wales project for delivery in 2027-28, this project will progress under the <i>Electricity Infrastructure Investment Act 2020</i> (NSW) rather than the ISP framework. AEMO recommends that a combination of solutions be considered – including a northern network option, a southern network option, virtual transmission (for example, the Waratah Super Battery) and other minor network upgrades.</p>				
Existing network capability				
<p>The existing transfer capability varies depending on load and generation distribution within the Sydney, Newcastle and Wollongong areas.</p> <p>The maximum transfer capability from CNSW to SNW is 7,525 MW at peak demand and summer typical and 7,625 at winter reference periods. With no Eraring and Vales Point generation, the maximum transfer capability reduces to 6,125 MW at peak demand and summer typical and 6,225 MW at winter reference periods. The maximum transfer capability is limited by a number of 330 kV lines between Bannaby and Liddell following a credible contingency.</p>				
ISP candidate options				
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Timing
<p>Option 1: Sydney Ring Northern 500 kV loop: †</p> <ul style="list-style-type: none"> A new 500 kV double-circuit line between Eraring substation and Bayswater substation. A new 500 kV substation near Eraring (Additional scope added by AEMO). Two 500/330 kV 1,500 MVA transformers at Eraring substation. <p><i>Note: This option should consider other minor network upgrades and the feasibility of a SIPS to provide a staged delivery of transfer capacity (e.g. using the Waratah Super Battery* as a virtual transmission line).</i></p>	Actionable ‡	<p>5,000</p> <p>(This capacity increase for accommodation of additional new generation from North of Bayswater and 2/3 generation from Central West NSW)</p>	<p>880</p> <p>(±50%)</p>	July 2027



<p>Option 2: Sydney Ring Southern 500 kV loop:</p> <ul style="list-style-type: none"> • A new 500 kV double-circuit line from the Bannaby substation to a new overhead/underground transition site. • 8 km of tunnel installed underground 500 kV cables from the transition site to new substation in the locality of South Creek (<i>additional scope added by AEMO</i>). • Establish 500/330 kV substation in the locality of South Creek. • Cut-in both Eraring – Kemps Creek 500 kV circuits at the new substation in the locality of South Creek. • Two new 500/330 kV 1,500 MVA transformers at the new substation in the locality of South Creek. • Replace a section of existing Bannaby-Sydney West 330 kV to double-circuit line between the locality of South Creek and Sydney West. • Uprate the existing line between Bannaby and the locality of South Creek from 85°C to 100°C operating temperature. • Cut-in Bayswater – Sydney West 330 kV line at South Creek. • Cut-in Regentville – Sydney West 330 kV line at South Creek. <p><i>Note: This option should consider other minor network upgrades and the feasibility of a SIPS to provide a staged delivery of transfer capacity (e.g. using the Waratah Super Battery* as a virtual transmission line).</i></p>	<p>Alternative option</p>	<p>4,500 (This capacity increase for accommodation of additional new generation from South of Bannaby and 1/3 generation from Central-West NSW)</p>	<p>2,256 (±50%)</p>	<p>Alternative option</p>
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† The northern part of the project is named the Hunter Transmission Project and may include the Waratah Super Battery and related upgrades.

‡ Sydney Ring project is an actionable NSW project rather than an actionable ISP project. This project will progress under the Electricity Infrastructure Investment Act 2020 (NSW) rather than the ISP framework.

* NSW Government. *Waratah Super Battery*, available at <https://www.energy.nsw.gov.au/waratah-super-battery>. The southern Sydney Ring network option may subsequently proceed through the New South Wales, ISP or RIT-T framework.



A5.4.4 Marinus Link

Summary				
<p>Marinus Link is a proposed 1,500 MW capacity undersea and underground electricity interconnection between Tasmania and Victoria which will operating in parallel with the existing Basslink interconnector. It is proposed to be delivered as two 750 MW high voltage direct current (HVDC) developments between Burnie area in Tasmania and Latrobe Valley in Victoria. This project also includes alternating current (AC) transmission network developments within the North West Tasmanian electricity network.</p> <p>TasNetworks has recently completed a RIT-T for this network augmentation. The project assessment conclusions report (PACR), the third report of the RIT-T, was published in June 2021*. Marinus Link is a single actionable ISP project.</p>				
Existing network capability				
<p>The transfer capacity between Tasmania and Victoria is limited by the thermal capability of Basslink (HVDC system between Tasmania and Victoria).</p> <p>Transfer capacity between Tasmania and Victoria is limited to 478 MW (as measured at the receiving end) in both directions at times of peak demand, summer typical and winter reference periods.</p> <p>Additional network upgrades may also be required for the Central Highlands REZ for new generation connecting in the south of the REZ in order to access the network upgrades associated with Marinus Link. In particular incremental upgrades associated with the Waddamana to Palmerston network sections are expected.</p>				
ISP candidate options				
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)**	Timing
<p>Option 1 (Marinus Link – Cable 1)[†]</p> <ul style="list-style-type: none"> • A 750 MW monopole HVDC link between Heybridge (near Burnie) in Tasmania and Latrobe Valley in Victoria. • Construction of a new 220 kV switching station at Heybridge adjacent to the converter station. • Establishment of a new 220 kV switching station at Staverton. • Construction of a new double-circuit 220 kV alternative current (ac) transmission line from Staverton to Heybridge via Hampshire and Burnie. • Construction of a new double-circuit 220 kV AC transmission line from Palmerston to Sheffield. • Cut-in both Sheffield-Mersey Forth double circuit 220 kV lines at Staverton. 	Actionable	<p>Marinus Link: 750 MW in both directions.</p> <p>Basslink and Marinus Link VIC to TAS 978 MW TAS to VIC 1,228 MW REZ T2: 350 MW and T3: 450 MW.</p>	2,380 (±30%)	July 2029

<ul style="list-style-type: none"> A new 500 kV switching station between HVDC converter station and Victorian transmission network in Latrobe Valley. 				
<p>Option 2 (Marinus Link – Cable 2)</p> <ul style="list-style-type: none"> A second 750 MW monopole HVDC link between Heybridge (near Burnie) in Tasmania and Latrobe Valley in Victoria. Construction of a new double-circuit 220 kV transmission line from Heybridge to Sheffield and the decommissioning of the existing 220 kV single-circuit transmission line in this corridor. <p>Pre-requisite: Option 1 (Marinus Link – Cable 1)</p>	Actionable	<p>Marinus Link: 750 MW in both directions. Basslink and Marinus Link Cables 1 and 2 VIC to TAS 1,728 MW TAS to VIC 1,978 MW REZ T2: 800 MW.</p>	<p>1,402 ‡ (±30%)</p> <p><i>Note: This stage is estimated to cost an additional \$600 million if completed more than 3 years after stage 1.</i></p>	July 2031

* TasNetworks. Project Marinus PACR, at <https://www.marinuslink.com.au/wp-content/uploads/2021/06/Project-Marinus-RIT-T-PACR.pdf>.

** Cost estimates for the ISP modelling were sourced from the Project Marinus PACR. In the ISP modelling, AEMO assumed early works cost \$139 million (after discounting \$50 million in grant funding) which was added to cable 1 costs of \$2,081 million, and cable 2 costs \$1,210 million. These figures were escalated from 2020 to 2021 dollars. This results in the costs that were used in ISP modelling – cable 1 costing \$2,302 million and cable 2 costing \$1,255 million. In June 2022, TasNetworks announced that the costs had changed to \$2,380 million and \$1,402 million.

‡ Connection between Staverton and Sheffield will make use of the existing 220 kV transmission lines.

‡ For more information on the additional cost of Marinus Link if the second stage is delayed, refer to section 4 of the *Addendum to the Draft 2022 ISP*, at <https://aemo.com.au/-/media/files/major-publications/isp/2022/addendum/addendum-to-the-draft-2022-isp.pdf?la=en>.



A5.4.5 VNI West

Summary				
<p>A RIT-T is in progress for a large new interconnector between Victoria and New South Wales (VNI West) by AEMO and Transgrid. The 2020 ISP recommended two candidate options for VNI West – one via Kerang and one via Shepparton. Since the publication of 2021 Inputs, Assumptions and Scenario Report (IASR) in July 2021, the scope of Project EnergyConnect (see Section A5.3.6) has changed to build the double-circuit lines from Dinawan to Wagga Wagga at 500 kV and operate them initially at 330 kV. This has reduced the cost estimate for the VNI West option via Kerang. The Kerang option also provides increased connection to the South West NSW, Murray River and Western Vic REZs. The ISP therefore selects VNI West via Kerang as the only ISP candidate option for VNI West in the ODP.</p> <p>VNI West is a staged actionable ISP project, Stage 1 is to complete early works by approximately 2026, and stage 2 to be complete implementation by July 2031.</p>				
Existing network capability				
<p>Transfer capability of future options will be modelled with committed projects of VNI minor upgrade and Victoria System Integrity Protection Scheme (SIPS) with battery storage for increased transfer capability from SNSW to Victoria.</p> <p>Victoria to SNSW maximum transfer capability is 870 MW at peak demand and 1,000 MW at summer typical and winter reference periods. The maximum transfer capability is limited by voltage stability or transient stability limit.</p> <p>The maximum transfer capability from SNSW to Victoria is 400 MW at peak demand, summer typical and winter reference periods. This is limited by a voltage stability limit. When available, Victoria's SIPS allows the 330 kV lines between South Morang and Murray to operate at a higher thermal capacity for a short period following a critical contingency.</p>				
ISP candidate options				
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Timing
<p>VNI West (via Kerang)</p> <ul style="list-style-type: none"> A new 500 kV double-circuit line from north of Ballarat to near Bendigo to near Kerang to locality of Dinawan. Upgrade Dinawan to near Wagga Wagga 500 kV double-circuit line from 330 kV to 500 kV operation†. Establish Dinawan 500 kV switchyard with two 500/330 kV 1,500 MVA transformers. New substations near Bendigo and near Kerang. Two 500/220 kV 1,000 MVA transformers at each of the new substations near Bendigo and near Kerang. 220 kV connections from the existing terminal station at Bendigo to new terminal station near Bendigo. 	Actionable with early works	North: 1,930 MW South: 1,800 MW REZ network limit increase: 1,600 MW in V2, 550 MW in V3, 900 MW in N5	2,942 (Including \$491 million for early works†)	Early works: To be completed by approximately 2026 Implementation: July 2031, or earlier with additional support

Future ISP projects



<ul style="list-style-type: none"> • 220 kV connections from the existing terminal station at Kerang to new terminal station near Kerang. • Power flow controllers to prevent overloading on 330 kV lines between Upper/Lower Tumut and South Morang and, 220 kV lines between Dederang and Thomastown. • 500 kV line shunt reactors at both ends of North of Ballarat - near Bendigo, near Bendigo - near Kerang, near Kerang - Dinawan and Dinawan - near Wagga Wagga 500 kV circuits. • Up to +/- 400 MVA dynamic reactive compensation at the new 220 kV terminal station near Kerang. 				
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† The early works for VNI West are assumed to cost \$491m, of which \$25m would need to be re-spent at a later date if the project was delayed for an extended period.

‡ Dinawan to Wagga Wagga double circuit line is already built at 500 kV design, operated at 330 kV, as part of the PEC project.



A5.5 Future ISP projects

Future ISP projects deliver net market benefits to consumers but are not needed until later in the horizon. The optimal timing for OPD 11 is shown.

A5.5.1 Central to Southern Queensland

Summary							
<p>The maximum transfer capability from Central and Northern Queensland (CNQ) to Southern Queensland (SQ) is currently limited to approximately 2,100 MW. Transfers along the corridor is dependant on generation and load in CNQ. As new generation connects in CNQ, congestion along this corridor may increase and generation may be curtailed.</p> <p>In the 2020 ISP, AEMO recommended Powerlink complete preparatory activities to increase transfer capability from CNQ to SQ. In the 2020 and the 2022 ISP, two options were selected. One option makes use of the existing transmission line with a mid-point switching station and the other option includes a new double-circuit transmission line. For the 2024 ISP, since no changes are anticipated for this project, AEMO will escalate the cost from the preparatory activities requested in the 2020 ISP.</p>							
Existing network capability							
<p>CNQ to SQ maximum transfer capability is approximately 2,100 MW. This capability is applicable in peak demand, summer typical, and winter reference periods. The maximum power transfer from CNQ to SQ grid section is limited by transient or voltage stability following a Calvale to Halys 275 kV circuit contingency.</p> <p>In the reverse direction, SQ to CNQ maximum transfer capability is 700 MW at peak demand and summer typical levels and 1,000 MW at winter reference periods. The maximum transfer capability from SQ to CNQ is limited by thermal capacity of the Blackwall – South Pine 275 kV line following a credible contingency.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
Stage 1: <ul style="list-style-type: none"> Mid-point switching substation on the Calvale –Halys 275 kV double-circuit line. 	Future	North: 0 MW South: 300 MW Increase in REZ Network Limit NQ3: 300 MW	55	2030-31	2028-29	2040-41	2028-29
Stage 2†: <ul style="list-style-type: none"> A new 275 kV double-circuit line between Calvale and Wandoan South. 275 kV line shunt reactors at both ends of Calvale – Wandoan South 275 circuits. 	Future	North: 900 MW South: 900 MW Increase in REZ Network Limit NQ3‡: 900 MW	476	2038-39	2038-39	-	2030-31

† Stage 2 costs were provided by Powerlink. Class and the accuracy band as per Powerlink advice.

‡ NQ3 network limit modelled using the sub-regional cut-set, and not a separate limit.



A5.5.2 Darling Downs REZ Expansion

Summary							
<p>The Darling Downs REZ extends from the border of New South Wales near Dumaresq, up to Columboola within the Surat region of Queensland, and has good solar and wind resources. A number of large solar and wind projects are already connected within the zone.</p> <p>Darling Downs REZ expansion is required to support VRE development within this REZ, timed as early as 2025-26 in the <i>Hydrogen scenario</i> and 2028-29 in the <i>Step Change</i> scenario for stage 1. AEMO has identified Darling Downs REZ for preparatory activities.</p>							
Existing network capability							
<p>The Darling Downs REZ has high network capacity and is near QNI and Brisbane. Furthermore, the ultimate retirement of generation within this REZ will allow for increased VRE connections.</p> <p>Under high demand conditions, this corridor can only facilitate 1,300 MW into the greater SEQ area from generation connected around the Bulli Creek area. Generation connected around the Halys area will be required to allow the full 3,000 MW REZ capacity to be able to be utilised. The Middle Ridge site is very constrained – further investigation is required to determine the feasibility of any expansion of this substation.</p> <p>The scope and costs of future larger network upgrades are indicative and require further review in consultation with the TNSP. The timing of these upgrades will also be influenced by generation retirements and any QNI upgrades.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Stage 1:</p> <ul style="list-style-type: none"> Replace existing 1,300 MVA 330/275 kV transformer at Middle Ridge with 1,500 MVA 330/275 kV transformer. Implement a post-contingent bus-splitting scheme at Middle Ridge and a Special Protection scheme involving 300 MW SEQ Battery Energy Storage System (BESS) and generation runback within Q8 REZ. 	Future	800	43 + BESS contract costs	2035-36	2028-29	2047-48	2025-26
<p>Stage 2 (conceptual):</p> <ul style="list-style-type: none"> 500 kV double-circuit network expansion from vicinity of Halys / Western Downs. 	Future	2,500	1,160	2042-43 and 2048-49	2037-38 and 2048-49	-	2030-31 and 2034-35 An additional 3,700 MW REZ network capacity required by 2049-50



A5.5.3 South East South Australia REZ expansion

Summary							
<p>The South East South Australia REZ lies on the major 275 kV route of the South Australia – Victoria Heywood interconnector. The REZ has moderate to good quality wind resources as is evidenced by the high proportion of wind generation (over 300 MW) in or near the South East border with Victoria.</p> <p>Stage 1 of the South East SA REZ expansion is required in the mid to late 2020s in the <i>Hydrogen Superpower</i> scenario and the <i>Step Change</i> scenario to facilitate the connection of generation within this REZ. AEMO requires preparatory activities to be undertaken for stage 1 of the South East SA REZ Expansion project.</p>							<p>○ Stage 1 ○ Stage 2</p>
<p>Existing network capability</p> <p>There is currently no additional network hosting capacity available in this REZ without further augmentation. Network augmentations would be smaller if generation is located relatively close to Adelaide, and larger if located further south towards Mount Gambier.</p> <p>If generation locates nearer to Adelaide, then results show network augmentation may be justified by 2028-29 in the <i>Step Change</i> scenario. Additional augmentation may be required by 2048-49 under the <i>Step Change</i> scenario, however it is noted further work is required to determine suitable larger augmentation options and the associated costs.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Stage 1:</p> <ul style="list-style-type: none"> String vacant circuit on the 275 kV Tungkillo – Taillem Bend line. 100 MVar SVC at Taillem Bend. Assumes following NCIPAP project in place: <ul style="list-style-type: none"> Turn in 275 kV circuit Taillem Bend to Cherry Gardens at Tungkillo[†]. 	Future	600	57	2033-34	2028-29	2045-46	2025-26
<p>Stage 2 (conceptual):</p> <ul style="list-style-type: none"> Additional 275 kV lines between South East-Taillem Bend-Tungkillo, dependant on new generation location. 	Future	950	949	2048-49	2048-49	-	2033-34 An additional 900 MW REZ network capacity required by 2049-50

[†] This upgrade component has been flagged as a NCIPAP upgrade by ElectraNet and is treated as a committed project. Hence, the cost for this component is not included in the expected cost. This project is complimentary to Option 1 and assists in realising the network capacity.



A5.5.4 Gladstone Grid Reinforcement

Summary							
<p>Following the retirement or reduced generation from Gladstone Power Station and increased generation in North Queensland, transmission network which supply to the Gladstone area will be constrained. As a result, forecast demand at Boyne Island, Calliope River, Larcom Creek and Raglan substations cannot be supplied. If major industrial loads are electrified, or if large Hydrogen projects progress, there is a potential for a material shift in the supply-demand balance in the Gladstone area.</p> <p>In the 2020 ISP, AEMO recommended Powerlink complete preparatory activities for reinforcement of Central and North Queensland (CNQ) and Gladstone Grid (GG) section. New 275 kV transmission lines are proposed to increase the network transfer capability between CNQ and GG. For the 2024 ISP, since no changes are anticipated for this project, AEMO will escalate the cost from the preparatory activities requested for this flow path in the 2020 ISP.</p>							
Existing network capability							
<p>The maximum power transfer capability is influenced by the amount of generation dispatch within northern and central Queensland, particularly at Gladstone. This limit is influenced by the thermal capacity of the Calvale–Wurdong, Bouldercombe–Calliope River, Bouldercombe–Raglan, Larcom Creek–Calliope River or Calliope River–Wurdong 275 kV circuits.</p> <ul style="list-style-type: none"> • With typical generation output from Stanwell and Callide, CNQ to GG maximum transfer capability is 700 MW at peak demand and summer typical levels, and 1,050 MW at winter reference condition. • In the reverse direction, GG to CNQ maximum transfer capability is 750 MW at peak demand and summer typical levels and approximately 1,100 MW at winter reference periods. 							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Option 1:</p> <ul style="list-style-type: none"> • New 275 kV double-circuit line between Calvale and Calliope River. • Rebuild Calliope River to Larcom Creek 275 kV as a double-circuit line. • Rebuild Larcom Creek to Bouldercombe 275 kV as a double-circuit line with one line tapped at Raglan. • A new (third) 275/132 kV transformer at Calliope River. 	Future	CNQ to GG: 550 MW GG to CNQ: 500 MW	408	2035-36	2030-31	Not required	2030-31



A5.5.5 QNI Connect

Summary							
<p>The Northern New South Wales (NNSW) and Southern Queensland (SQ) corridor represents a portion of the network which forms part of the QNI. Development options on this corridor include the northern sections of proposed QNI Augmentations.</p> <p>A project to increase the transfer capacity of the existing QNI (referred as 'QNI Minor') has been committed.</p> <p>In addition to QNI Minor, in the 2020 ISP, AEMO recommended Powerlink and Transgrid complete preparatory activities for QNI interconnector upgrades. Powerlink and Transgrid proposed two 330 kV options. One option (stage 1) is a single-circuit strung on a 330 kV double-circuit line and the other option (stage 2) is to string a second circuit to the same 330 kV double-circuit line. Transgrid provided the cost estimates for 330 kV options on a confidential basis.</p> <p>QNI Connect is required to increase transfer capacity between Queensland and New South Wales to share renewable energy and firming services between regions. With a timing as early as 2029-30 under the <i>Hydrogen Superpower</i> scenario and 2032-33 in the <i>Step Change</i> scenario, AEMO requires preparatory activities be undertaken for a 500 kV option for both New South Wales and Queensland scope. AEMO also requires preparatory activities for the 330 kV options for the New South Wales scope.</p>							
Existing network capability							
<p>Transfer capability with future options will be modelled with QNI Minor upgrade in service.</p> <ul style="list-style-type: none"> NNSW to SQ maximum transfer capability is 685 MW at peak demand and 745 MW at summer typical and winter reference periods. The maximum transfer capability is limited by voltage or transient stability for loss of the Kogan Creek generator. In the reverse direction, SQ to NNSW maximum transfer capability is 1,205 MW, 1,165 MW and 1,170 MW at peak, summer typical and winter reference periods respectively. The maximum transfer capability is limited by thermal capacity of 330 kV lines between Armidale and Bulli Creek following a credible contingency. 							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
Stage 1 (option 1) [†] : <ul style="list-style-type: none"> A new 330 kV double-circuit line (one circuit strung) from locality of Armidale South to Dumaresq to Bulli Creek to Braemar. A new 330/275 kV transformer at Braemar. Cut-in Armidale–Dumaresq 330 kV line (8C) at Sapphire. 330 kV line shunt reactors at Bulli Creek for the Bulli Creek–Braemar and Dumaresq–Bulli Creek 330 kV circuits. 	Future	North: 910 MW South: 1,080 MW	1,253 (Combined cost of NSW and QLD works)	2036-37	2032-33	2035-36	2029-30

[†] Additional augmentation is required later in the horizon for some scenarios, see Table 1.



A5.5.6 Facilitating power to Central Queensland

Summary							
<p>Upgrade options associated with this flow path may be built when generation in REZs Q1 to Q5 (Northern Queensland) exceeds 2,500 MW. These augmentations facilitate transmission of generation in northern Queensland to load centres in the south.</p>							
Existing network capability							
<p>The current network was designed to facilitate the transmission of power from Central Queensland to support the load in Northern Queensland. Thus, its capacity was designed around North Queensland load, rather than building for future generation projects. As such, the network has the ability to support up to 2,500 MW of generation across the five REZs in Northern Queensland depending also on the level of storage in these REZs.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
Stage 1: <ul style="list-style-type: none"> Construct additional 275 kV circuit from Bouldercombe to Stanwell. String and energise the second Broadsound-Stanwell 275 kV circuit (on existing DCST). 	Future	400	137	2038-39	2033-34	-	2026-27
Stage 2 (conceptual): <ul style="list-style-type: none"> Additional 275 kV double-circuit lines between Central and North Queensland. 	Future	1,400	816	2044-45	2044-45	-	2029-30, An additional 48,000 MW REZ network capacity required by 2049-50

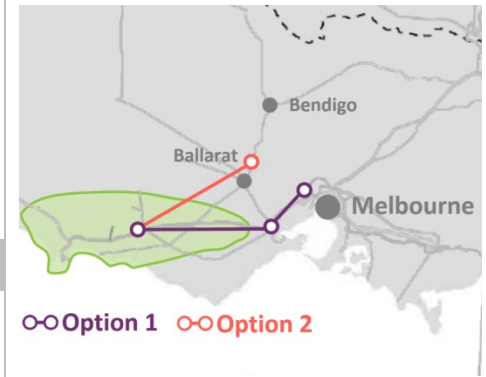


A5.5.7 Mid North South Australia REZ expansion

Summary							
<p>The Mid-North SA REZ has moderate quality wind and solar resources. There are several major wind farms in service in this REZ, totalling over 1,300 MW installed capacity.</p> <p>The Mid North limit represents the generation build limit applied to S3, S4, S5, S6, S7, S8, and S9 REZs. This constraint is necessary because these REZs all must export any additional power generation south towards Adelaide primarily along the existing four 275 kV parallel circuits from Davenport to near Adelaide (Para). This corridor of the network forms a bottleneck for these REZ</p> <p>Stage 1 of the Mid North SA REZ expansion is required in the late 2020s in the <i>Hydrogen Superpower</i> scenario, and early 30s in the <i>Step Change</i> scenario to facilitate the connection of generation within these REZs. AEMO requires preparatory activities to be undertaken for stage 1 of the Mid North SA REZ Expansion project.</p>							
Existing network capability							
<p>The individual REZs which form this group constraint each have their own individual existing network capabilities. The collective generation build from S3 to S9 cannot exceed an additional 1,000 MW without network augmentation between Davenport and Adelaide being required.</p> <p>Additional works in the underlying 132 kV network and implementation of a control scheme will initially be required in order to reach the modelled 1,000 MW headroom.</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
Option 1: <ul style="list-style-type: none"> 275 kV double-circuit lines between Robertstown, Templers West and Para 	Future	950	340	2039-40	2033-34	-	2028-29
Option 2: <ul style="list-style-type: none"> 275 kV double-circuit lines between Davenport and Robertstown 	Future	950	582	2045-46	2041-42	-	2028-29 An additional 20,500 MW REZ network capacity required by 2049-50

A5.5.8 South West Victoria REZ Expansion

Summary



The South West Victoria REZ has moderate to good quality wind resource in close proximity to the 500 kV and 220 kV networks in the area. The total in-service, committed and anticipated wind generation in the area exceeds 2 GW. Due to the large amount of generation flagged for connection in this REZ, and outcomes highlighting potential need for network upgrades prior to 2035, co-ordination of new generation and network expansion may be required. South West Victoria REZ expansion is required in the late 2020s in the *Hydrogen Superpower* scenario, and early 2030s in the *Step Change* scenario to facilitate the connection of generation within this REZ. AEMO requires preparatory activities to be undertaken for South West Victoria REZ expansion project.

Existing network capability

Due to the strong level of connection interest, there are emerging network capacity limits. The current total network hosting capacity is approximately 2,500 MW for this REZ.

Augmentation sequences

Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
Option 1: <ul style="list-style-type: none"> New 500 kV single-circuit line between Mortlake – Moorabool – Sydenham. 	Future	1,500	930	-	2033-34	-	2027-28 (or at the earliest feasible timing)
Option 2: <ul style="list-style-type: none"> New 500 kV single-circuit line between Mortlake - north of Ballarat. Turn Tarrone – Haunted Gully line into Mortlake substation. 	Future	1,200	851	2040-41	-	-	2030-31 An additional 9,000 MW REZ network capacity required by 2049-50



A5.5.9 New England REZ Extension

Summary

The NSW *Electricity Infrastructure Investment Act 2020* legislates the REZ be declared with an intended 8,000 MW of additional transmission network capacity within the New England region of the state. New England REZ is located to the east of and along the existing QNI, and network expansion from CNSW to connect to the New England REZ would also assist to increase transfer capacity for QNI upgrade options.

New England REZ has moderate to good wind and solar resources in close proximity to the 330 kV network. Interest in the area includes large-scale solar and wind generation as well as pumped hydro generation. As generation further increases in North West New South Wales and New England REZs, increased connection capacity between the two REZs is likely to be required. The sharing of resources across the network augmentation will allow for better transmission utilisation and reduction in transmission build.

An actionable ISP project for New England REZ transmission link was identified in Section A1.4.1. With increased renewable generation in New England REZ, further additional new transmission options are required.

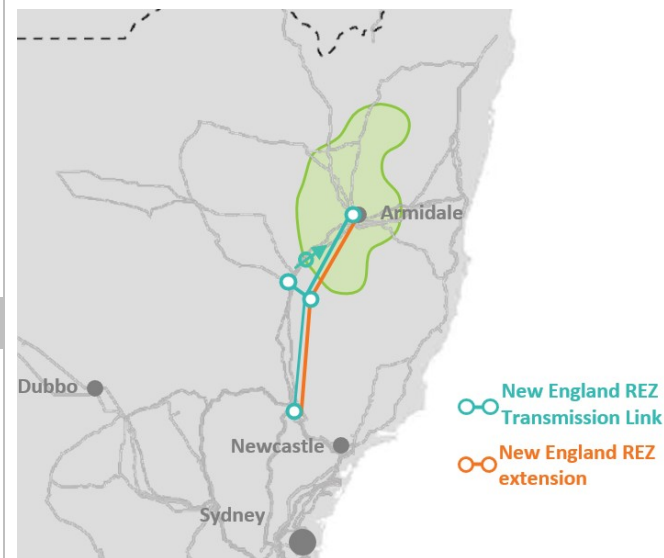
Existing network capability

The existing network capacity, following completion of the committed QNI Minor upgrade, is limited by transient and voltage stability on the circuits between Bulli Creek, Sapphire and Dumaresq. Thermal limits on the 330 kV circuits between Armidale, Tamworth, Muswellbrook and Liddell can also restrict flows on this network.

CNSW to NNSW maximum transfer capability is 910 MW at peak demand, summer typical and winter reference periods. The maximum transfer capability is limited by voltage stability for loss of the Kogan Creek generator.

NNSW to CNSW maximum transfer capability is 930 MW at peak demand and summer typical periods and 1,025 MW at winter reference period. The maximum transfer capability is limited by thermal capacity of Armidale–Tamworth 330 kV lines following a credible contingency.

With the actionable ISP project for New England REZ transmission link as identified in Section A1.4.1 (Options 6 and 6A) CNSW to NNSW transfer capacity increases by 3,070 MW in both directions.



Augmentation sequences

Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
CNSW – NNSW Option 6B: (Pre-requisite: Option 6 and 6A plus) <ul style="list-style-type: none"> An additional new 500 kV double-circuit line from Armidale South to locality of east of Tamworth to Bayswater. An additional 500/330 1,500 MVA transformer at locality of Armidale South. An additional +/- 400 MVAr SVC at locality of east of Tamworth. 500 kV line shunt reactors at both ends of locality of Armidale South–locality of east of Tamworth and locality of east of Tamworth–Bayswater. 	Future	2,750 MW in both flow directions. † Increase of N2 REZ network limit by 2,750 MW	1,237 ‡	2038-39	2035-36	2045-46	2031-32

† Total increase in network capacity with option 6, 6A and 6B is 5,820 MW

‡ Total expected cost of option 6, 6A and 6B is \$3,142 million



A5.5.10 Far North Queensland REZ Expansion

Summary							
<p>The Far North Queensland (FNQ) REZ is at the most northerly section of Powerlink’s network. It has excellent wind and moderate solar resources and has existing wind, solar and hydroelectric power stations.</p> <p>Options proposed to expand network capacity in this REZ progressively increase network capacity and allow for upgrades based on where generation develops.</p> <p>A marginal loss factor (MLF) penalty has been applied to this REZ to capture the anticipated decline in MLFs in this zone as more generation connects. See the section 3 of the Consultation Summary Report.[†]</p>							
Existing network capability							
<p>Maximum export capability from the FNQ REZ is limited by voltage stability for a contingency of a Ross to Chalumbin 275 kV circuit. The existing network will allow for a total of approximately 750 MW of VRE to be connected.</p> <p>Output from this REZ can also be limited by network capacity further south which can result in the need for additional network augmentations. Output from this REZ is limited by downstream network capacity (refer to the 2021 Transmission Cost Report for more information).[‡]</p>							
Augmentation sequences							
Description	Status	Additional network capacity (MW)	Expected cost (\$ million)	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
<p>Stage 1:</p> <ul style="list-style-type: none"> Establish a new 275 kV substation north of Millstream. Build a 275 kV double-circuit line from Chalumbin to Millstream. Rebuild the double-circuit Chalumbin–Ross 275 kV line at a higher capacity (possibly timed with asset replacement). Build additional Chalumbin–Ross 275 kV double-circuit tower but string and energise as a single-circuit line. 	Future	945	1,264	2044-45	2038-39	-	2025-26

[†] At <https://aemo.com.au/consultations/current-and-closed-consultations/2022-draft-isp-consultation>.

[‡] At <https://aemo.com.au/-/media/files/major-publications/isp/2021/transmission-cost-report.pdf?a=en>.



A5.5.11 Other future ISP Projects

In addition to the projects identified in Section A5.5, Table 1 identifies indicative projects required towards the end of the modelling horizon which are expected to evolve from one ISP to the next. These projects are conceptual and vary significantly between scenarios in relation to size of network augmentation and the timing. AEMO welcomes feedback on these projects.

Table 1 Indicative transmission and REZ augmentations required later in the horizon

REZ / flow path upgrade	Augmentation option (REZ network limit increase)*	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
N8 – Cooma-Monaro	Option 2 – 330 kV circuit to Stockdill area (+500 MW).	2034-35	2032-33	2045-46	2026-27
N3 – Central West Orana	Option 1 – Additional 330 kV double-circuit to Mt Piper (+1,500 MW).	2043-44	2040-41	-	2034-35
V3 – Western Victoria	Option 2 – New double-circuit 220 kV line North of Ballarat to Bulgana (+800 MW).	2044-45	2041-42	-	2030-31
	Option 3 – New double-circuit line from Murra Warra-Horsham-Bulgana (+1,000 MW).	2046-47	2042-43	-	2036-37
Q9 - Banana	500 kV double-circuit lines to Wandoan area (+3,000 MW). 500 kV single circuit line to Wandoan area (+3,000 MW)	2044-45, 2048-49	2040-41, 2048-49	-	
	Option1 – 500 kV double circuit lines to Gladstone area (+3000 MW)-Hydrogen scenario	-	-	-	2034-35, 2040-41
S6 – Leigh Creek	Option 1 and 2 – Double-circuit 275 kV lines to Leigh Creek area (+950 MW).	2043-44, 2047-48	2041-42, 2043-44	-	2028-29, 2030-31
Q7 – Wide Bay	Option 1 – Rebuild Woolooga – Palmwoods – South Pine 275 kV single-circuit line as a high capacity double-circuit line (+900 MW).	2043-44	2042-43	-	2030-31
	Option 2 – Rebuild Woolooga – South Pine 275 kV single-circuit line as a high capacity double-circuit line (+900 MW).	2048-49	2048-49	-	2030-31
V6 – Central North Victoria	Option 5 – New 220 kV circuit North of Bendigo to Shepparton area (+700 MW).	2047-48	2046-47	-	2036-37
N3 – Central-West Orana	Option 2 – Additional 500 kV single-circuit to Bayswater (+900 MW).	2048-49	2048-49	-	2038-39
S2 – Riverland	Option 1 – Turn Bunday – Buronga 330 kV No. 1 and No. 2 lines into a new substation at Riverland (+700 MW).	-	2049-50	-	2029-30

REZ / flow path upgrade	Augmentation option (REZ network limit increase)*	Progressive Change	Step Change	Slow Change	Hydrogen Superpower
V2 - Murray River	Option 4 – New 220 kV circuits from Red Cliffs-Wemen-Kerang, post VNI West (+800 MW).	-	2049-50	-	2038-39
QNI Connect (Stage 2)	Stage 2 (option 2) – An additional new 330 kV circuit (second circuit strung) from locality of Armidale South to Dumaresq to Bulli Creek to Braemar. <i>Pre-requisite: QNI Connect (Stage 1).</i>	-	-	-	2030-31
Bayswater to Newcastle port augmentation	New three 500 kV lines from Bayswater to Newcastle port.	-	-	-	2040-41
N2 - New England REZ expansion	CNSW – NNSW Option 9 - 2,000 MW bi-pole HVDC transmission system between locality Bayswater and locality of Armidale South.	-	-	-	2042-43
Victoria – New South Wales interconnector	VNI Option 6 – New 500 kV double-circuit line from north of Melbourne to Wagga Wagga via Central North Victoria.	-	-	-	2045-46

* Option numbers refer to information in the 2021 *Transmission Cost Report*.

† The *Hydrogen Superpower* scenario develops other projects before 2035 including Q9 – Banana REZ network extension to the Gladstone area, T1 – North East Tasmania REZ network extension to George Town, S4-Yorke Peninsula REZ network extension, S5 – Northern SA REZ extensions and S8 – Eyre Peninsula REZ extensions. The more conceptual augmentations in the *Hydrogen Superpower* scenario beyond 2035 are not included