Expanding NSW-QLD transmission transfer capacity

Inputs and Methodology Consultation Paper

December 2018

Important notice

TransGrid and Powerlink have prepared this document as an additional consultation step to provide the public, stakeholders, and interested parties information on how inherent uncertainty in future market development will be addressed in the quantitative modelling for this Regulatory Investment Test for Transmission (RIT-T).

TransGrid and Powerlink seek feedback on the information provided herein and its appropriateness for assessing the benefits of credible options.

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1 Introduction

1.1 Purpose

TransGrid and Powerlink publish this report to provide information and seek feedback from the general public, stakeholders, and interested parties on the proposed scope, input assumptions, methodologies, components of market benefits, and other information contained herein for the Expanding NSW-QLD Transmission Transfer Capacity RIT-T.[1]

Consistent with TransGrid and Powerlink's corporate objectives of open consultation, this paper is published in addition to that prescribed under the RIT-T to provide an additional degree of transparency in the process and quality to this RIT-T.

TransGrid and Powerlink value external feedback in guiding the assessment of credible options to address the identified need and are committed to engaging interested parties through the RIT-T consultation process.

TransGrid and Powerlink are seeking feedback on the following items:

- Do the proposed scenarios sufficiently cover credible future energy scenarios? In particular, responses to:
    - Are the proposed electricity demand assumptions appropriate? Or should a wider range of demand be used?
    - Are the drivers and treatment of retirement candidates appropriate? and
    - How should the uncertainty in climate change initiatives be captured?
- Are the key driver input assumptions appropriate for the proposed scenarios?
- Are the key drivers given appropriate emphasis? Are there any other factors that could play significant roles in driving results?
- What scenario weightings should be used? And how should these be established?
- Are the proposed methodologies to assess technical feasibility and economic benefits adequate and fit-for-purpose?
- Are the metrics and framework for assessing the different classes of benefits correct and suitable? Are there any other considerations that must be included in the assessment?
- Does this document appropriately and effectively explain the methodologies, inputs, and scenarios outlined in the Project Specification Consultation Report (PSCR) [2] for the Expanding NSW-QLD Transmission Transfer Capacity RIT-T?
- Any other feedback about this document.

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[1] The purpose of the RIT-T is to identify the option which maximises net economic benefits and, where applicable, meets the relevant jurisdictional or Electricity Rule based reliability standards. The RIT-T provides a single framework for all transmission investments and removes the distinction in the regulatory test between reliability driven projects and projects motivated by the delivery of market benefits. Australian Energy Regulator's *"Regulatory investment test for transmission (RIT-T) and application guidelines 2010,"* available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/regulatory-investment-test-for-transmission-rit-t-and-application-guidelines-2010, viewed on 22nd November 2018.

[2] TransGrid and Powerlink's *"Expanding NSW-Qld transmission transfer capacity Project Specification Consultation Report,"* available at https://www.transgrid.com.au/what-we-do/projects/current-projects/ExpandingNSWQLDTransmissionTransferCapacity and https://www.powerlink.com.au/expanding-nsw-qld-transmission-transfer-capacity, viewed on 22nd November 2018.

1.2 Background

The RIT-T to address the existing and forecast congestion between Queensland and New South Wales is initiated under considerable uncertainty with regard to the future development of the NEM. The transition towards lower carbon emissions, rapidly evolving technologies, and changing customer needs means that policy decisions and technological innovation have heightened roles in driving market outcomes in the long term. The result of the increased influence of these inherently less predictable factors is that a wide range of future market outcomes are possible over the lifetime of the proposed investments.

In November 2018, TransGrid and Powerlink published the PSCR for Expanding NSW-QLD Transmission Transfer Capacity RIT-T[3] as the first stage of the RIT-T consultation process that is promulgated by Australian Energy Regulator (AER) and prescribed under section 5.16 of the National Electricity Rules (NER).

The PSCR was published to seek consultation on the existing and forecast congestion on the inter-regional transfer between Queensland and New South Wales, and to present credible options to address the network limitation. The identified need is largely driven by the changing generation supply mix across the NEM resulting from the penetration of variable renewable energy generation and expected exit of synchronous generators. TransGrid and Powerlink believe that there are significant potential market benefits from addressing the existing and emerging network limitation. This view is aligned with the conclusions and recommendations contained in AEMO's inaugural 2018 Integrated System Plan (ISP).[4]

The ISP recommends that a strategic and coordinated transmission network development be pursued to support the NEM's transition to a low-emission future. It suggests that in addition to the development of Renewable Energy Zones (REZ)[5] in the NEM, augmentation of inter-regional transfer capacities is needed. One of these inter-regional augmentations is the upgrade of the Queensland – New South Wales Interconnector (QNI) which the ISP states will provide generation cost savings and generation capital deferment savings.

In the PSCR, TransGrid and Powerlink present several credible network and non-network options that could alleviate the existing and emerging network limitation. The PSCR also describes the technical scope and high-level cost estimates for these options and the key classes of market benefits that will be quantified.

This consultation paper is a supporting document to the PSCR for the Expanding NSW-QLD Transmission Transfer Capacity RIT-T.

1.3 Submissions and timeline

TransGrid and Powerlink welcome written submissions on the information and specific items contained in this inputs and methodology consultation report. Submissions are due on or before 22 February 2019. Submissions are particularly sought on the questions listed in section 1.1.

Submissions should be emailed to regulatory.consultation@transgrid.com.au

Submissions will be published on the TransGrid and Powerlink websites. If you do not wish for your submission to be made publicly available, please clearly specify this at the time of lodgement.

TransGrid and Powerlink plan to hold stakeholder workshops in Sydney and Brisbane. Please send in your interest if you wish to participate in this workshop. Details will be sent out closer to the time.

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3 TransGrid and Powerlink's *"Expanding NSW-Qld transmission transfer capacity Project Specification Consultation Report,"* available at https://www.transgrid.com.au/what-we-do/projects/current-projects/ExpandingNSWQLDTransmissionTransferCapacity and https://www.powerlink.com.au/expanding-nsw-qld-transmission-transfer-capacity, viewed on 22nd November 2018.

4 Australian Energy Market Operator's "*Integrated System Plan*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan, viewed on 22nd November 2018.

5 Australian Energy Market Operator's "*Integrated System Plan*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan, viewed on 22nd November 2018.

TransGrid and Powerlink intend to review, respond, and publish submissions received from this consultation and the PSCR prior to commencing the second stage of the RIT-T consultation process.

The next formal stage of this RIT-T culminates in the publication of the Project Assessment Draft Report (PADR)[6] within twelve months from the completion of the PSCR consultation period, or within a longer period as agreed to by the AER. This stage will involve detailed technical and market benefit assessment of the credible options, full quantitative analysis of both network and non-network options, and assessment of relevant submissions to the PSCR.

6 The second stage of the RIT-T process culminates to publication of a Project Assessment Draft Report. Australian Energy Regulator's "*RIT-T and RIT-D application guidelines (minor amendments) 2017*," available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/rit-t-and-rit-d-application-guidelines-minor-amendments-2017, viewed on 22nd November 2018.

2 Proposed scope

The proposed network options in the Expanding NSW-QLD Transmission Transfer Capacity RIT-T include long-lived assets that may remain operational beyond forty years. Over the course of that lifespan, there are significant risks and uncertainties in the energy industry that, if not properly assessed and accounted, could render the investments inefficient. Hence, the RIT-T assessment necessitates that investment decisions be evaluated under different reasonable scenarios and that the derived conclusions be robust and consistent across a wide range of reasonable scenarios.

Scenarios employing different combinations of reasonable key driver assumptions, largely adopted from the 2018 ISP, will be used to test the economic merits of credible options.

TransGrid and Powerlink are confident that these scenarios appropriately and extensively cover known uncertainties relevant to the Expanding NSW-QLD Transmission Transfer Capacity RIT-T at the time of publication.

2.1 Scenarios

TransGrid and Powerlink intend to assess the credible options proposed in the Expanding NSW-QLD Transmission Transfer Capacity RIT-T under the following four scenarios. While the Project Specification Consultation Report (PSCR)[7] listed three scenarios, feedback from a forum held in Sydney regarding modelling assumptions has been incorporated by including a fourth scenario. TransGrid and Powerlink will, in this document, refer to the 'Neutral scenario' described in the PSCR as 'Neutral scenario with proportionate share of emissions reduction target'. The newly added fourth scenario will be described as 'Neutral scenario with stronger emissions reduction target'. Aligned with RIT-T guidelines[8] requirements, these scenarios are carefully selected such that key drivers affecting the values and ranking of market benefits are appropriately and extensively explored. These reflect the 2018 ISP scenarios updated with later released data from AEMO.

Generally, the drivers with largest influence on analysis results are grouped in five key input classes: consumption forecast and consumer behaviour, generation technology cost projections, fuel supply forecasts, climate and energy policies, and industry developments.

A summary of reasonable input parameters for these scenarios is presented in Table 1 and described in proceeding sections.

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[7] TransGrid and Powerlink's *"Expanding NSW-Qld transmission transfer capacity Project Specification Consultation Report,"* available at https://www.transgrid.com.au/what-we-do/projects/current-projects/ExpandingNSWQLDTransmissionTransferCapacity and https://www.powerlink.com.au/expanding-nsw-qld-transmission-transfer-capacity, viewed on 22nd November 2018.

[8] Australian Energy Regulator's *"RIT-T and RIT-D application guidelines (minor amendments) 2017,"* available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/rit-t-and-rit-d-application-guidelines-minor-amendments-2017, viewed on 22nd November, 2018.

Table 1 Proposed scenario's key drivers input parameters

Key input classes	Key drivers input parameter	Fast change scenario	Neutral scenario with proportionate share of emissions reduction target	Neutral scenario with stronger share of emissions reduction target	Slow change scenario
Consumption forecast and consumer behaviour	Underlying consumption	AEMO 2018 ESOO Strong	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Weak
	Rooftop photo-voltaic (PV) penetration	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral
	Small-scale battery penetration and charging and discharging pattern	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral
	Demand side participation (DSP)	AEMO 2018 ESOO Weak	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Strong
	Electric vehicles	AEMO 2018 ESOO Strong	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Neutral	AEMO 2018 ESOO Weak
Generation technology cost projections	New entrant capital cost for Wind, Solar, Open-Cycle Gas Turbine (OCGT), Combined-Cycle Gas Turbine (CCGT), Pumped Hydro Storage, Coal, Biomass, Solar Thermal Central Receiver and Batteries	AEMO 2018 ISP Neutral reduction scenario for wind and solar AEMO 2018 ISP Rapid reduction scenario for pump storage hydro, batteries, and solar thermal	AEMO 2018 ISP Neutral reduction scenario	AEMO 2018 ISP Neutral reduction scenario	AEMO 2018 ISP Slow reduction scenario for wind and solar AEMO 2018 ISP Neutral reduction scenario for pump storage hydro, batteries, and solar thermal
	Retirements of coal fired power stations[9]	Half of coal power stations' capacity is retired 5 years earlier than end-of-technical-lives	Retired by announced retirement date or end-of-technical-lives	Half of coal power stations' capacity is retired 2 years earlier than end-of-technical-lives	Half of coal power stations' capacity is retired 5 years later than end-of-technical-lives
Fuel supply forecast	Coal and gas fuel cost	AEMO 2018 ISP Strong scenario	AEMO 2018 ISP Neutral scenario	AEMO 2018 ISP Neutral scenario	AEMO 2018 ISP Weak scenario
Climate and energy policies	Federal Large-scale Renewable Energy Target (LRET)	33 TWh by 2020 to 2030 or a penalty of $92.86 for every MWh of violation (including GreenPower and ACT scheme).			
	COP21 commitment (Paris agreement)	52% reduction from 2005 by 2030, then a linear extrapolation beyond 2030 to 90%	28% reduction from 2005 by 2030, then a linear extrapolation	52% reduction from 2005 by 2030, then a linear extrapolation	28% reduction from 2005 by 2030, then a linear extrapolation

[9] Higher levels of renewable energy generation create an oversupply during certain periods of the day, displacing conventional generation and result in earlier retirement. This phenomena is amplified in a high load growth scenario, with correspondingly higher levels of renewable energy generation.

Key input classes	Key drivers input parameter	Fast change scenario	Neutral scenario with proportionate share of emissions reduction target	Neutral scenario with stronger share of emissions reduction target	Slow change scenario
		reduction of 2005 emissions by 2050	beyond 2030 to 70% reduction of 2016 emissions by 2050	beyond 2030 to 90% reduction of 2005 emissions by 2050	beyond 2030 to 70% reduction of 2016 emissions by 2050
	Victorian Renewable Energy Target (VRET)	25% RE by 2020, 40% RE by 2025 and 50% by 2030			
	Queensland Renewable Energy Target (QRET)	50% by 2030			
Industry developments	South Australia Energy Transformation RIT-T	The proposed SA to NSW interconnector is assumed constructed by 2023[10] and the timing will be tested as a sensitivity			
	Victoria to NSW Interconnector Upgrade	The preferred option is assumed constructed by 2020 and the timing will be tested as a sensitivity			
	Western Victoria Renewable Integration RIT-T	The preferred option is assumed constructed by 2023 and the timing will be tested as a sensitivity			
	MarinusLink and Battery of the Nation	The preferred option is assumed constructed by 2033 and the timing will be tested as a sensitivity	Excluded		
	Snowy 2.0, SnowyLink North, and SnowyLink South	Snowy2.0 generation and SnowyLink North will be included by 2025 and the timing will be tested as a sensitivity SnowyLink South will be included by 2034 and the timing will be tested as a sensitivity			

The 2018 ISP provides a comprehensive set of data. Recent updates on a number of input assumptions, including generator forced outage rates and consumption forecast and consumer behaviour are included in the 2018 Electricity Statement of Opportunities (ESOO)[11] document published by AEMO.

TransGrid and Powerlink note the importance of ensuring the outcome of this RIT-T assessment is robust to different assumptions about how the energy sector may develop. Since interconnector investments are long-lived assets, it is important that the market benefits associated with these investments do not depend on a narrow view of potential future outcomes, given future uncertainty.

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[10] ElectraNet's *"SA Energy Transformation RIT-T Project Assessment Draft Report,"* available at https://www.electranet.com.au/projects/south-australian-energy-transformation/, viewed on 22nd November 2018, has options for new South Australia New South Wales interconnected commissioned between 2022 and 2024.

[11] Australian Energy Market Operator's *"2018 Electricity Statement of Opportunities,"* available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities, viewed on 22nd November 2018.

At this stage, based on the ISP assessment and the preliminary modelling undertaken during 2017, TransGrid and Powerlink consider that the following inputs are candidates for detailed sensitivity testing:

- electricity demand, New South Wales demand in particular, as highlighted in the ISP;
- retirement dates of coal generators (particularly Vales Point, Eraring and Bayswater in New South Wales and Gladstone and Tarong in Queensland); and
- capital costs of new generating units and the credible options.

The recently released NSW Transmission Infrastructure Strategy and other key updates to energy policy or commitments will be factored into the scenarios or sensitivities as part of the analysis undertaken and reported in the Project Assessment Draft Report (PADR).

TransGrid and Powerlink request feedback on the selected scenarios, sources of input assumptions such as generation capital, fuel costs assumptions and industry transmission projects. In particular, TransGrid and Powerlink seek responses to:

- *are the proposed electricity demand assumptions appropriate? or should a wider range of demand be used?*
- *are the drivers and treatment of retirement candidates appropriate? and*
- *how should the uncertainty in climate change initiatives be captured?*

2.1.1 Fast change scenario

The Fast change scenario explores market benefits in a world with high economic activity across Australia. This results in higher underlying electricity and gas consumption. As a consequence, gas prices are high and both large-scale utility connected generation and small-scale distributed energy resources are built. Faster generation technology capital cost reduction for several generation technologies is likely in this scenario.

Additionally, more aggressive emission reduction polices are assumed to be in place to ensure that the underlying high economic activity does not result in breaches of carbon emission abatement commitments. Generation retirements are likely to be dictated by this higher emission reduction policy targets with capacity retiring prior to end of technical life. Queensland and Victorian renewable energy policies are in place and the recommended augmentation option resulting from the SA Energy Transformation RIT-T, Victoria to NSW Interconnector Upgrade, Western Victoria Renewable Integration, MarinusLink, and Snowy 2.0 are assumed to be committed. The recently released NSW Transmission Infrastructure Strategy will also be factored into the scenario.

This scenario is aligned with AEMO's 2018 ISP[12] Fast change scenario[13] while using recent assumptions.

Due to the likelihood, significance, and size of the proposed SA to NSW interconnector, Victoria to NSW Interconnector Upgrade, Western Victoria Renewable Integration RIT-T, MarinusLink, and Snowy 2.0, they are assumed constructed for this scenario. If no further commitment becomes available during the options assessment, a sensitivity of these projects not going ahead will be modelled.

2.1.2 Neutral scenario with proportionate share of emissions reduction target

The Neutral scenario with proportionate share of emissions reduction target reflects a medium outlook for economic activity and development. This scenario assumes neutral underlying electricity consumption and

[12] Australian Energy Market Operator's "*Integrated System Plan*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan, viewed on 22nd November 2018.

[13] Australian Energy Market Operator's *"2018 Integrated System Plan database*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/ISP-database, viewed on 22nd November 2018.

fuel prices. A neutral uptake of small-scale distributed energy resources and systems, including small-scale batteries, is expected.

Generation retirements are dictated by asset technical life.

The electricity generation fleet will be developed to meet the Large-scale Renewable Energy Target and 21st Conference of Parties (COP21) commitment of 28% emission reduction by 2030 aligned with AEMO's 2018 ISP.

Queensland and Victorian renewable energy policies will be pursued. The recently released NSW Transmission Infrastructure Strategy will also be factored into the scenario.

This scenario is aligned with AEMO's 2018 ISP[14] Neutral scenario[15] while using recent assumptions.

Due to the likelihood, significance, and size of the proposed SA to NSW interconnector, Victoria to NSW Interconnector Upgrade, Western Victoria Renewable Integration RIT-T, and Snowy 2.0, they are assumed constructed for this scenario. If no further commitment becomes available during the options assessment, a sensitivity of these projects not going ahead will be modelled.

2.1.3 Neutral scenario with stronger share of emissions reduction target

The Neutral scenario with stronger share of emissions reduction target reflects a medium outlook for economic activity and development. This scenario assumes neutral underlying electricity consumption and fuel prices. A neutral uptake of small-scale distributed energy resources and systems, including small-scale batteries, is expected.

This scenario explores an alternate Conference of Parties (COP21) commitment of 52% emission reduction by 2030. Generation retirements are likely to be dictated by this higher emission reduction policy targets with capacity retiring prior to end of technical life.

Queensland and Victorian renewable energy policies will be pursued. The recently released NSW Transmission Infrastructure Strategy will also be factored into the scenario.

Due to the likelihood, significance, and size of the proposed SA to NSW interconnector, Snowy 2.0, Victoria to NSW Interconnector Upgrade, and Western Victoria Renewable Integration RIT-T, they are assumed constructed for this scenario. If no further commitment becomes available during the options assessment, a sensitivity of these projects not going ahead will be modelled.

2.1.4 Slow change scenario

The Slow change scenario explores weak economic activity across Australia which would result in weaker underlying electricity consumption, lower fuel price, and slower uptake of small-scale distributed energy resources and systems, including small-scale batteries. Slower generation technology capital cost reduction is likely in this scenario.

Queensland and Victorian renewable energy policies are in place and will be pursued. The recently released NSW Transmission Infrastructure Strategy will also be factored into the scenario. With lower demand growths and corresponding lower renewable capacities expected in this slow change scenario, coal fired generators are expected to remain in service longer. Retirements are modelled incrementally with ½ capacity retiring 5 years after the stations end-of-live.

This scenario is aligned with the AEMO's 2018 ISP[16] Slow change scenario[17] while using recent assumptions.

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[14] Australian Energy Market Operator's "*Integrated System Plan*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan, viewed on 22nd November 2018.

[15] Australian Energy Market Operator's *"2018 Integrated System Plan database*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/ISP-database, viewed on 22nd November 2018.

Due to the likelihood, significance, and size of the proposed SA to NSW interconnector, Victoria to NSW Interconnector Upgrade, Western Victoria Renewable Integration RIT-T, and Snowy 2.0, they are assumed constructed for this scenario. If no further commitment becomes available during the options assessment, a sensitivity of these projects not going ahead will be modelled.

2.1.5 Scenario weighting

While default weightings are proposed to represent the likelihood of each scenario, TransGrid and Powerlink intend to consult on weightings throughout the consultation process.

Updates to weightings, if any, will be made known to stakeholders through the RIT-T consultation process.

Table 2 Proposed scenario weightings

Scenario	Fast change scenario	Neutral scenario with proportionate share of emissions reduction target	Neutral scenario with stronger share of emissions reduction target	Slow change scenario
Weighting	25%	25%	25%	25%

TransGrid and Powerlink request feedback on the scenario weightings and suggested methodology to establish these.

2.2 Key input and modelling parameters

TransGrid and Powerlink plan to adopt the relevant inputs and other information provided in TransGrid's and Powerlink's 2018 Transmission Annual Planning Reports (TAPR),[18,19] 2018 ISP,[20] NSW Transmission Infrastructure Strategy,[21] and 2018 ESOO.[22]

Key inputs are detailed in the assumptions spreadsheet.

TransGrid and Powerlink will endeavour to employ recent updates to any of these assumptions during the analysis stage of the consultation.

2.2.1 NEM electricity consumption

Electricity consumption is a key input impacting the economics of generation and transmission projects. As there has been traditionally a high correlation between economic activity and grid-supplied (operational) electricity consumption, economic activity had always been a strong predictor of the operational electricity

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16 Australian Energy Market Operator's "*Integrated System Plan*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan, viewed on 22nd November 2018.

17 Australian Energy Market Operator's *"2018 Integrated System Plan database*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/ISP-database, viewed on 22nd November 2018.

18 TransGrid's "*Transmission Annual Planning Report*," available at https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning, viewed 22nd November 2018.

19 Powerlink Queensland's "*Transmission Annual Planning Report 2018*," available at https://www.powerlink.com.au/reports/transmission-annual-planning-report-2018, viewed on 22nd November 2018.

20 Australian Energy Market Operator's "*Integrated System Plan*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan, viewed on 22nd November 2018.

21 NSW Government's *"Transmission Infrastructure Strategy,"* available at https://energy.nsw.gov.au/renewables/clean-energy-initiatives/transmission-infrastructure-strategy, viewed on 22nd November 2018.

22 Australian Energy Market Operator's "*2018 Electricity Statement of Opportunities,"* available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities, viewed on 22nd November 2018.

consumption forecast. However, the uptake of small-scale generators decreases the correlation between the grid-supplied electricity consumption and economic activity.

Assessing the impact of the economy on operational electricity consumption requires forecasting each consumption component using separate and different methods.

The following components of operational peak demand and electricity consumption are forecast separately then aggregated. Detailed discussion of these components can be found in AEMO's forecasting reports.[23]

- Residential
- Commercial
- Industrial
- Electric Vehicles
- Energy efficiencies
- Rooftop PV
- Small-scale batteries
- Voluntary load curtailment (Demand Side Participation)
- Intra-regional losses

To assess the reliability of the future electricity system under the various scenarios and development options, the modelling will consider weather related 10% Probability of Exceedance (PoE) and 50% PoE peak demand forecasts, weighted at 0.304 and 0.696, respectively.[24]

TransGrid and Powerlink will base the demand on hourly or half-hourly traces using seven years of historical profiles aligned with the weather data used for wind and solar assumptions. TransGrid and Powerlink propose to use years 2010-11 to 2016-17 as good quality near-term forecasts exist for wind speed, solar irradiation, and demand for these years. The wind speed forecasts prior to 2010-11 are from a different source and of poorer quality. TransGrid and Powerlink will endeavour to include demand, wind, and solar traces for 2017-18 as they are currently being processed.

2.2.2 Generation development

The size, type, and location of generation determine where power is supplied from and subsequently influence the potential benefits of the credible options.

For the purpose of the Expanding NSW-QLD Transmission Transfer Capacity RIT-T, TransGrid and Powerlink propose to model all existing generators, committed, anticipated[25] new generator projects, and publicly-announced generator retirements. Additionally, publicly-announced generator mothballing and return-to-service will be treated as committed developments.

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[23] Australian Energy Market Operator's *"Electricity Demand Forecasting Methodology Information Paper,"* available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities, viewed on 22nd November 2018.

Australian Energy Market Operator's *"National Electricity Market Demand Forecasting Methodology Issues Paper Consultation,"* available at https://www.aemo.com.au/Stakeholder-Consultation/Consultations/National-Electricity-Market-Demand-Forecasting-Methodology-Issues-Paper-Consultation, viewed on 22nd November 2018.

[24] Australian Energy Market Operator's *"Market Modelling Methodology and Input Assumptions,"* available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database, viewed on 22nd November 2018.

[25] Australian Energy Regulator's *"Regulatory investment test for transmission,"* available at https://www.aer.gov.au/system/files/Final%20RIT-T%20-%2029%20June%202010.pdf, viewed on 22nd November 2018.

Potential new generation requirements for serving future electricity consumption will be investigated in the modelling for each scenario to minimise system costs. Their associated capital costs, operating costs, and other parameters will be included in the assessment.

Expansion candidates

The type and location of new entrant generators significantly impact transmission network power flows and potential market benefits from the augmentation options. Therefore, it is important that all credible generation technologies be considered as expansion candidates. However, including every possibility rapidly increases the problem complexity and simulation time. To manage the time and complexity, TransGrid and Powerlink will only nominate highly likely future generation technologies as expansion candidates.

TransGrid and Powerlink will only consider wind, large-scale transmission-connected single axis tracking solar, large-scale transmission-connected batteries, solar thermal, combined-cycle gas turbines (CCGT), open-cycle gas turbines (OCGT), biomass, coal, and pumped-hydro storage as expansion candidates. It is assumed that new ocean and nuclear generation technologies are unlikely to be built in Australia in the foreseeable future as economic and social license for these technologies does not exist.

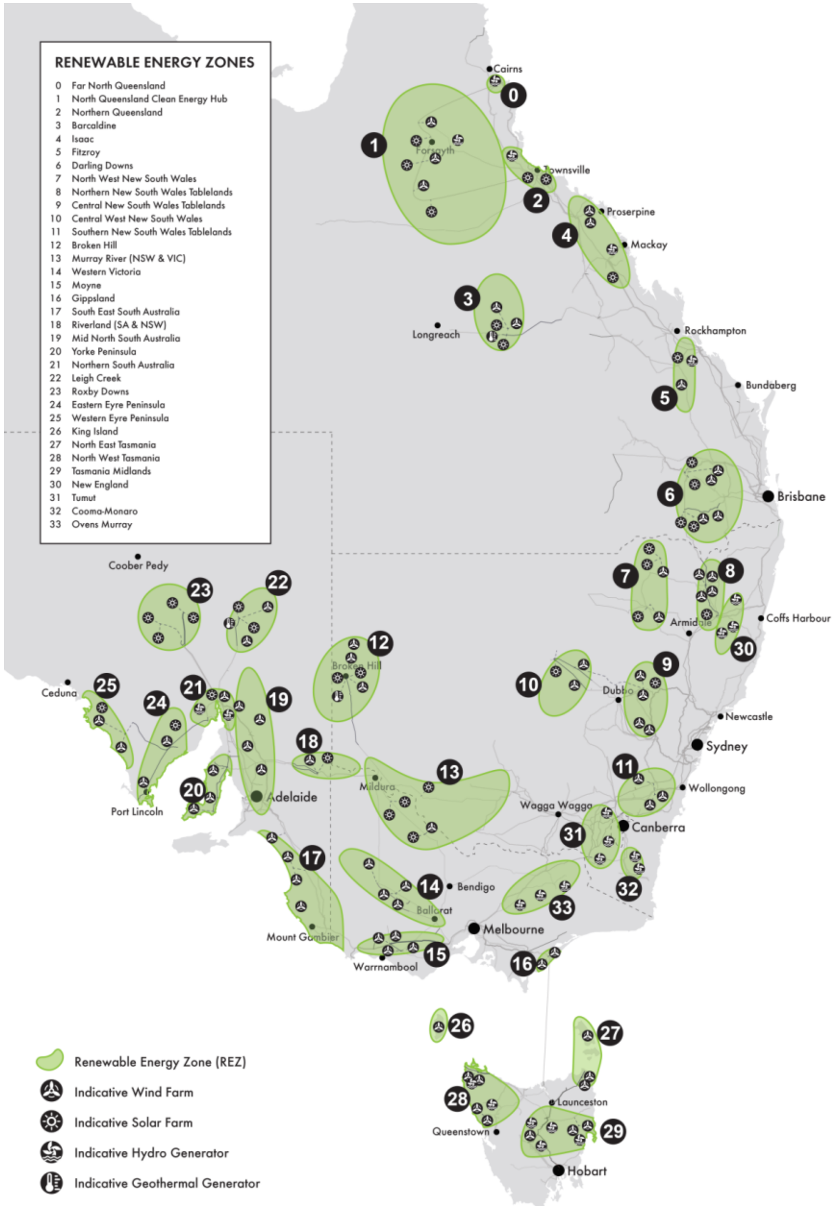
Furthermore, not all generation technologies are relevant for all REZs as some do not have all resource types to support all generation technologies (e.g. not enough elevation for pumped-hydro storage). Building on the 2018 ISP, two wind candidate projects with different resource profiles and one candidate project per relevant generation technology type will be tested to capture diversity of resources within each REZ. Candidate REZs are illustrated as Figure 1.

Expansion candidates that may not necessarily connect within REZ and may connect to the existing and available network zone such as CCGTs and OCGTs are also investigated if economical.

Similar to interconnector flows, intra-regional transmission utilisation and congestion is dependent on generation expansion. As such, the modelling of key intra-regional limitations is important in determining the optimal generation and transmission expansion plan. TransGrid and Powerlink will monitor intra-regional congestion levels and assess whether intra-regional augmentation results in greater net market benefits or whether it's more efficient to allow some level of congestion (with associated spillage), refer to chapter 3 .

The capital costs for most of the relevant technologies, especially for those that are more likely to rapidly expand in the electricity industry, are expected to decrease over time. This learning rate is an input to the model and is incorporated in the generation technology capital cost assumptions.

Figure 1 – Candidate Renewable Energy Zones*



* Diagram reproduced from AEMO's 2018 Integrated System Plan

Large-scale transmission-connected battery storage developments

Existing, committed and anticipated large-scale transmission-connected battery storage facilities will be modelled and retired at the end of their stated lifetime. These projects will then be replaced if economic.

Aligned with the 2018 ISP, a battery expansion candidate will be nominated for each REZ and will be limited to 2 hour storage types for tractability of simulations.

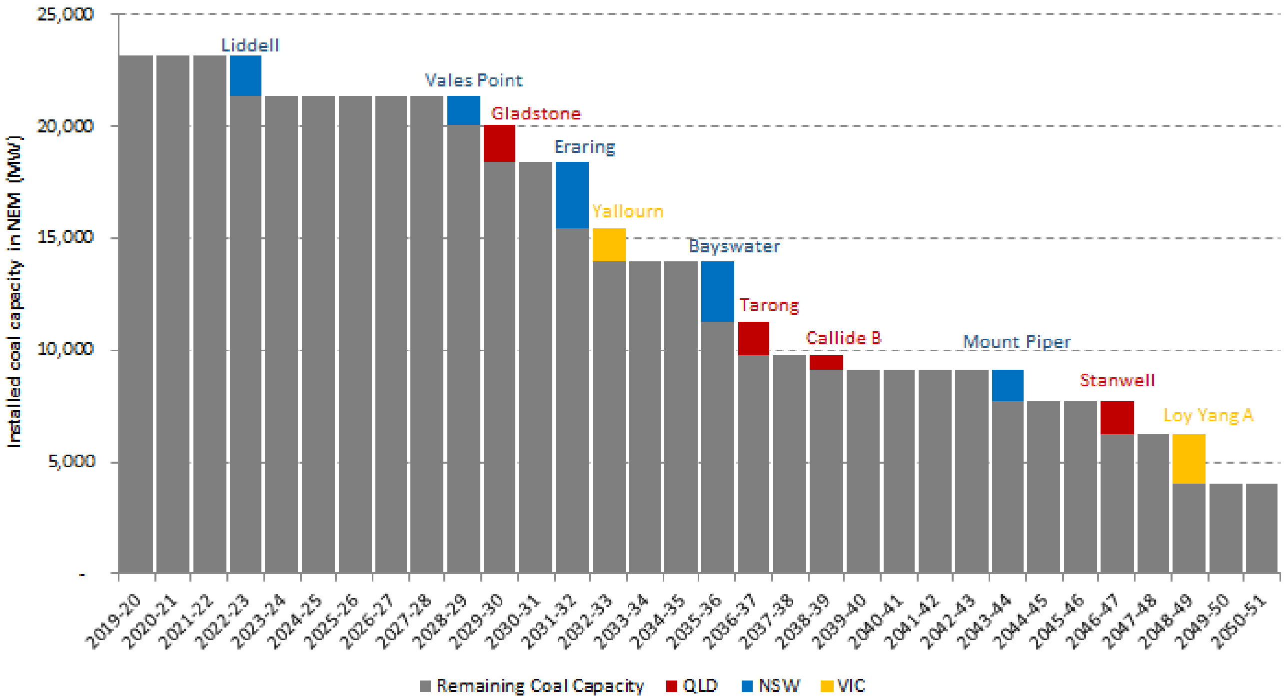
TransGrid and Powerlink intend to use the latest available battery storage technical and economic assumptions such as charging/discharging rates, efficiency, outage rates, maintenance rates, operating and maintenance costs, capital costs and asset life from the 2018 ISP.

Retirement candidates

As most retiring generators are likely to be coal-fired and gas-powered generators with relatively large firm capacities, assumptions around credible retirements are relevant to network utilisation forecasts and to the Expanding NSW-QLD Transmission Transfer Capacity RIT-T. For example, the closures of large power stations such as Hazelwood Power Station in Victoria and Northern Power Station in South Australia have resulted in a significant shift in the supply-demand balance[26] and have changed the network needs and potential benefits of transmission augmentations.

TransGrid and Powerlink consider all currently operating fossil fuelled generators as retirement candidates within the outlook period. Consistent with the 2018 ISP, coal generators' end of technical lives are shown in Figure 2. Retirement timings are expected to be determined by both asset life and economics. Early retirement is modelled in the Fast change scenario and Neutral scenario with stronger share of emissions reduction target by retiring half the relevant station's capacity 5 and 2 years early respectively. Delayed retirement is modelled in the Slow pace scenario by retiring half the relevant station's capacity 5 years later.

Figure 2 – NEM coal-fired generation fleet operating life assumption to 2050



Generator economic parameters

The resultant generation development schedule is dependent upon numerous factors including capital costs, fixed operation and maintenance costs, rehabilitation costs, and retirement costs.

Recent developments and uptake of power electronics and renewable generation technologies have seen significant reductions in the capital cost of wind and solar farm projects. These variable renewable energy projects are now cost-competitive compared to traditional technologies.

Generally, technology capital costs are assumed to decrease faster in the Fast change scenario as the higher demand for the new technology increases its learning rates and vice versa. Hence, in the Fast change

[26] TransGrid's "*Transmission Annual Planning Report*," available at https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning, viewed 22nd November 2018.

scenario, TransGrid and Powerlink intend to explore lower capital cost projections due to expected higher demand for additional generation developments.

Other costs such as fixed operation and maintenance costs, variable operation and maintenance costs, efficiencies, will be sourced from the 2018 ISP.

Generator technical capability

Generation technologies' technical capability affects how economically feasible or technically advanced they are for deployment. Generator technical capability is assumed to be the same across all scenarios.

TransGrid and Powerlink intend to use the latest generator technical capability assumptions from the 2018 ISP, 2018 ESOO, and Generation Information page[27] such as:

- generator installed, firm, and rated capacities,
- ramp rates, auxiliary loads, heat rates, and emissions rates,
- reservoirs' initial dam levels, capacities, and inflow sequences.

Generator outage rates

Generator availability is modelled by considering planned maintenance and unplanned (or forced) outage rates based on historical generator performance. For each generation technology type, the following are sourced from the most recent available data from 2018 ISP or 2018 ESOO:

- generator rating for partially available and fully unavailable states,[28]
- mean time to repair or mean time to transition between states,
- planned maintenance outage and unplanned outage states and rates.

2.2.3 Fuel costs and availabilities

Coal prices

A significant share of the current NEM generated electrical energy, and system operation costs originate from coal-fired generation. As such, coal prices are important in estimating system cost and market benefits that may come from network augmentation projects.

TransGrid and Powerlink propose to use AEMO's latest coal price forecasts from the 2018 ISP.

Gas prices

The recent retirements of coal-fired generators and the transition to a low-emission generation fleet have left some NEM regions reliant on variable renewable energy and gas-powered generators. In a scenario where this transition progresses further, gas-powered generators are expected to be the marginal plant, hence gas price assumptions are important. Since transmission augmentations generally allow lower-cost generation to displace marginal plants from the merit order, the fuel cost saving from avoiding gas generation is sensitive to gas price assumptions.

Gas price projections between scenarios may be different as they incorporate different assumptions on key drivers such as coal seam gas (CSG) consumption forecast, and gas supply forecast.

TransGrid and Powerlink will use the latest gas price forecasts from the 2018 ISP.

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[27] Australian Energy Market Operator *"Generation Information Page,"* available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information, viewed 22nd November 2018.

[28] A state in the context of outages are maximum generation levels after deration following a partial of full outage.

Biomass fuel prices

Biomass costs are sourced from the 2018 ISP.

Intermittent renewable resources

Forecast solar and wind generation profiles for each REZ in the NEM will be based on seven years of chronological meteorological data to reflect historical variability of resources in the NEM. This provides an improvement over the 2018 ISP modelling which used a single historical trace. These profiles represent the expected regional exposure of variable renewable energy farms to wind speed and solar irradiation, and will also be correlated to regional demand profiles. The seven profiles will be repeated sequentially throughout the modelling horizon.

Historical hourly or half-hourly wind speed and solar irradiation are entered into a wind turbine and solar plant power curves respectively to derive the normalised generation level for each geographical zone. The normalised generation level represents the average generation level for each MW of wind or solar installed capacity. Detail how this is derived is available in section 3.3.3.

Hydro-electric availability

Hydro generation availability will be based on the average inflow and will be sourced from AEMO's 2018 ISP.[29]

2.2.4 Network model

For the Market Dispatch Simulation described in Chapter 3, TransGrid and Powerlink will adopt the latest network constraint model[30] from AEMO's 2018 ISP and 2018 ESOO. This will be complemented by additional network constraints that TransGrid and Powerlink may find relevant

For practical reasons, initially, only significant inter-regional constraints will be modelled in the Long-term Investment Planning. Then, based on the evaluation of the generation and transmission development schedule resulting at the System Technical Assessment and Market Dispatch Simulation, intra-regional constraints and sub-regional modelling may be required in subsequent iterations of the Long-term Investment Planning.

The credible option will be evaluated for each scenario at different timings.

Generation connection augmentation

Generator expansion will begin with a Long-term Investment Planning simulation without maximum generator connection limits or intra-regional constraints to determine the optimal generation development. This initial development schedule will be evaluated and screened in the Market Dispatch Simulation and System Technical Assessment to determine works which may be necessary to integrate these optimal generation development to the network.

Additional costs associated with such augmentations will be reflected as connection costs in subsequent iterations of generation expansion modelling.

Intra-regional network augmentation

The existing network may not be sufficient to provide unconstrained access to potential new generators or transfer large amounts of power within a region. In most cases, especially at the back-end of the outlook

29 Australian Energy Market Operator's "*Integrated System Plan*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan, viewed on 22nd November 2018.

30 A set of constraint equations that is applied on the market model to represent transmission network limitation.
Australian Energy Market Operator's "*2018 Electricity Statement of Opportunities,*" available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities, viewed on 22nd November 2018.

period, intra-regional transmission network augmentation may be needed to connect and transfer power from potential new generators in areas with very high renewable resources to regional load centres.

End of technical life of transmission infrastructure may provide opportunities for modern equivalents or scale efficient replacements. TransGrid and Powerlink will incorporate market impacts surrounding end-of-life transmission replacements and explore opportunities for synergies with expanding the QNI transmission transfer capacity.

The associated cost and amount of intra-regional network augmentation required will be evaluated in the System Technical Assessment (see section 3.2).

Interconnector losses

TransGrid and Powerlink propose to employ the latest notional interconnector loss function representations from AEMO.[31]

For potential new notional interconnectors and intra-regional lines that may need to be modelled, TransGrid and Powerlink will develop loss representations as part of the System Technical Assessment.[32]

Grid impact of potential new generators

The Market Dispatch Simulation will monitor thermal limitations. However, for known stability limitations, expansion candidates' impact will mirror those of known generators (shadow generators).[33] However where this assumption is deemed inappropriate, TransGrid and Powerlink will investigate and model their impact explicitly to a practical degree.

Marginal loss factors

In the NEM, Marginal loss factors (MLFs)[34] are applied to adjust the generator bids to take into account their marginal contribution to transmission losses. They are also used to adjust settlement prices for all generators. Therefore, these factors provide market signals of the effectiveness of a generator at a particular location.

AEMO determines MLFs for the next year by simulating expected power flows. These short-term estimates for MLFs will not hold true in the future as the generation mix, power flows, and losses change. To address this lack of projection, TransGrid and Powerlink propose to use AEMO's latest MLFs estimates over the first five years and will estimate and apply future MLFs for particular generation and transmission development schedules in five year increments resulting from the Market Dispatch Simulation modelling to refine the Long-term Investment Planning.

Transmission line ratings

Static line ratings used in the formulation of thermal constraints will be applied by default. Where thermal limitations are significant and additional information on ratings under different atmospheric conditions is available, seasonal ratings or dynamic line ratings will be used.

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[31] Australian Energy Market Operator's "*Regional Boundaries and Marginal Loss Factors for the 2018-19 Financial Year,"* available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Loss-factor-and-regional-boundaries, viewed on 22nd November 2018.

[32] System Technical Assessment is comprised of evaluation of power system thermal and stability limits for each credible option.

[33] As potential new entrant generators' impacts on the power system are not known, they are assumed to be similar to their shadow generators'.

[34] Australian Energy Market Operator's "*Regional Boundaries and Marginal Loss Factors for the 2018-19 Financial Year,"* available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Loss-factor-and-regional-boundaries, viewed on 22nd November 2018.

2.2.5 Network security policies

Reliability standard

AEMO has published the Reliability Standard Implementation Guideline[35] set out in the National Electricity Rules. This guideline presents the recommended methodology to translate the reliability standard, which is set to a maximum expected unserved energy allowance of 0.002% of any yearly operational consumption, to modelling implementation.

AEMO is tasked to monitor any breach of this standard and declare appropriate lack of reserve conditions. AEMO's response to lack of reserve conditions may include direct action such as:

- directing a generator to reschedule an outage
- using the reliability and emergency reserve trader (RERT)[36] option.

For the purpose of the Expanding NSW-QLD Transmission Transfer Capacity RIT-T, appropriate values of customer reliability[37] are applied for involuntary load curtailment. These values are sufficiently large that the Long-term Investment Planning simulation will rather build new generation or storage capacities than allow excessive levels of load to be curtailed involuntarily. Implicitly, this results in a generation and transmission development schedule that meets the reliability standard. However, TransGrid and Powerlink intend to further monitor the sufficiency of these approaches to plan for the reliability standard through the Market Dispatch Simulation[38] (see section 3.3.2). Depending on the results, adjustments may be implemented on the generation and transmission development plan (see section 3.1), triggering another iteration of the System Technical Assessment and Long-term Investment Planning if required.

System strength

System strength[39] stabilises the power system by ensuring reliable operation of network protection and control systems. It also ensures that generators remain connected and continue to operate following disturbances.

Due to connection of inverter-type generation technologies and the exit of synchronous generators from the market, system strength is expected to decrease over time. Generation connection of inverter-type technologies on the existing network is naturally capped. When system strength deteriorates, additional network connection remediation schemes may be needed. This is captured by using higher connection costs for higher level of local planting.

TransGrid and Powerlink will monitor market dispatch outcomes to ensure system strength costs are appropriately captured in new entrant connection costs.

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[35] Australian Energy Market Operator's, "*Reliability Standard Implementation Guidelines*," available at https://www.aemo.com.au/Stakeholder-Consultation/Consultations/Reliability-Standard-Implementation-Guidelines, viewed on 22nd November 2018.

[36] Australian Energy Market Operator's, "*Reliability and Emergency Reserve Trader*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Emergency-Management/RERT-panel-expressions-of-interest, viewed on 22nd November 2018.

[37] Value of Customer Reliability (VCR) represents a customer's willingness to pay for the reliable supply of electricity. Australian Energy Market Operator's *"Value of Customer Reliability,"* available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Value-of-Customer-Reliability-review, viewed on 22nd November 2018.

[38] Market Dispatch Simulation mimics the National Electricity Market Dispatch Engine in dispatching generation while maintaining the operational capabilities of plant.

[39] "System strength affects the stability and dynamics of generating systems' control systems, and the ability of the power system to both remain stable under normal conditions, and to return to steady-state conditions following a disturbance (e.g. a fault)." Australian Energy Market Operator's "*South Australia System Strength Assessment,"* available at https://www.aemo.com.au/Media-Centre/South-Australia-System-Strength-Assessment, viewed on 22nd November 2018.

2.2.6 Climate and energy policies

Climate and energy policies are expected to drive the development of generation and transmission needs. Therefore, appropriately representing these policies is an important part of quantifying transmission augmentation benefits.

2.2.6.1 Existing policies

Renewable energy targets

The following committed and legislated energy policies will be modelled in all scenarios in for the Expanding NSW-QLD Transmission Transfer Capacity RIT-T as a soft constraint on NEM's total renewable generation using an adjusted prescribed penalty.[40]

- The large-scale renewable energy target (LRET) and small-scale renewable energy scheme (SRES) – Australia has set a target of 33,000 GWh of large-scale[41] by 2020 by requiring retailers to purchase Renewable Energy Certificates[42] (RECs) from renewable energy sources. There is no target bounded by legislation for the small-scale renewable energy scheme.[43]
- ACT 100%[44] – the ACT government legislated a target of 100% renewable energy to supply the territory by 2020.
- Green Power[45] – a federal government program to empower consumers to purchase renewable energy. Green Power electricity is an additional requirement for renewable generation to the LRET and the SRES. This will be modelled as an additional adjustment[46] to the large-scale transmission-connected renewable energy target from across the NEM.

TransGrid and Powerlink will adopt AEMO's modelling and input assumptions on these existing targets.

Victorian Renewable Energy Target

The Victorian Renewable Energy Target (VRET) will be assumed in all scenarios. The VRET aims to increase the percentage of Victorian renewable generation (including Murray hydro generation) to 25% by 2020 and 40% by 2025. It is assumed that the target will be extended to 50% by 2030. The forecast new generation capacity resulting from the VRET, based on the ISP assumptions, will be modelled as a hard constraint.

Specifics and operation of the reverse auction mechanism will not be modelled, however, the latest publicly announced awardees will be included in the model as committed generation development.

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[40] Australian Energy Market Operator's *"2018 Integrated System Plan database*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/ISP-database, viewed on 22nd November 2018.

[41] Clean Energy Regulator's "*Large scale generation certificates,"* available at http://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Power-stations/Large-scale-generation-certificates, viewed on 22nd November 2018.

[42] Clean Energy Regulator's "*The REC Registry," available at* http://www.cleanenergyregulator.gov.au/OSR/REC/The-REC-Registry, viewed on 22nd November 2018.

[43] Clean Energy Regulator's, "*Small-scale Renewable Energy Scheme,"* available at http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/How-the-scheme-works/Small-scale-Renewable-Energy-Scheme, viewed on 14th November 2018.

[44] ACT Government's "*100% renewable energy for Canberra by 2020," available at* https://www.act.gov.au/our-canberra/latest-news/2016/may/100-renewable-energy-for-canberra-by-2020, viewed on 22nd November 2018.

[45] Green Power's "*What is GreenPower?"* available at http://www.greenpower.gov.au/About-Us/What-Is-GreenPower/, viewed on 22nd November 2018.

[46] Adjustments includes conversion from Calendar to financial year targets, incorporating currently banked, adjustment to account for SRMC bidding, and exclusion of STC requirements.

2.2.6.2 Committed ambition

21st Conference of Parties

While the mechanism and the emissions target to support Australia's commitment to 'Paris Agreement'[47] has not been legislated, two potential emission reduction targets which are consistent with current industry practice will be explored in the Expanding NSW-QLD Transmission Transfer Capacity RIT-T. No specific mechanism will be simulated but a generic emission constraint will be applied.

- 28% reduction from 2005 levels by 2030 – consistent with AEMO's modelling assumptions, the Australian government's current emission reduction pledge by 2030 will be modelled as a constraint to cap the NEM's total emission below a linear trajectory between 2020 and 2030. The assumed emission caps' linear trajectory extends beyond 2030 to 70% of 2016 emissions by 2050. This trajectory will be applied for the Neutral scenario with proportionate share of emissions target and Slow change scenario.
- 52% reduction from 2005 levels by 2030 – this aspirational target will similarly be modelled but is a more aggressive emission reduction policy. The assumed emission caps' linear trajectory extends beyond 2030 to 90% of 2005 emissions by 2050. This emission constraint will be applied on the Fast change scenario and Neutral scenario with stronger share of emissions reduction target.

2.2.6.3 Proposed policy

Powering Queensland Plan

TransGrid and Powerlink will model the following relevant Powering Queensland Plan[48] provisions:

- the Queensland Renewable Energy Target (QRET) of 50% of Queensland consumption to be provided by renewable generation by 2030.
- 400 MW of diversified renewable energy across the state.

Similar to the limitations applied on COP21 commitment, the mechanism to facilitate the 50% by 2030 is not explicitly modelled, but is rather represented as a generic constraint. Committed and anticipated new generation capacities resulting from these policies will be reflected as soon as the information becomes available.

2.2.7 Financial assumptions

TransGrid and Powerlink use a discounted cash flow calculation to quantify the present day value of costs and benefits. Consistent with the RIT guidelines,[49] TransGrid and Powerlink will use the following assumptions across all scenarios:

- Inflation – for those cost input assumptions that are in previous years' dollars, 1.5% inflation[50] will be applied to adjust them to the current real dollar.
- Goods and services tax – all costs are exclusive of Goods and Service Tax.
- Discount rate – TransGrid and Powerlink will apply the latest commercial discount rate, 7.04%[51] in quantifying future costs and benefits. A lower discount rate equal to the regulated WACC, 4.6%,[52] and

[47] The 'Paris Agreement' requires a limit on global temperature rises to 2 degrees and the pursuit of a limit on global warming of 1.5 degrees. United Nations Climate Change, available at https://unfccc.int/news/finale-cop21, viewed 22nd November 2018.

[48] Department of Natural Resources, Mines and Energy's *"Powering Queensland Plan: an integrated energy strategy for the state,"* available at https://www.dnrme.qld.gov.au/energy/initiatives/powering-queensland, viewed on 22nd November 2018.

[49] The second stage of the RIT-T process culminates to publication of a Project Assessment Draft Report. Australian Energy Regulator's *"RIT-T and RIT-D application guidelines (minor amendments) 2017,"* available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/rit-t-and-rit-d-application-guidelines-minor-amendments-2017, viewed on 22nd November 2018.

[50] Australian Bureau of Statistics' *"Price Indexes and Inflation,"* available at http://www.abs.gov.au/Price-Indexes-and-Inflation, viewed on 22nd November 2018.

a symmetrical higher rate or 9.48% will also be tested as sensitivities.[53] TransGrid and Powerlink are intending to consult regarding the appropriateness of the rate assumptions.

- Weighted average cost of capital (WACC) – The WACC for transmission network capital cost will be taken from the latest TNSP revenue determination.[54] The AER has determined this to be 4.6%.[55]
- Value of customer reliability – To quantify the cost savings from reduced involuntary load curtailment due to network augmentation, TransGrid and Powerlink propose to apply the Value of Customer Reliability (VCR).[56]
- Outlook period and end-effects – TransGrid and Powerlink intend to consider a 25-year period in assessing the Expanding NSW-QLD Transmission Transfer Capacity RIT-T and a perpetuity approach[57] to estimate costs and benefits for years beyond that outlook period.

The sensitivity of the market benefits to the discount rates and WACC will be explored in the assessment stage.

2.3 Industry developments and uncertainties

A number of transmission developments at varying stages of progress have the potential to significantly impact market benefits of an expansion of NSW-QLD transmission transfer capacity. Some have been in public discussion, and can be easily modelled, while others are concepts that have yet to undergo public consultation. TransGrid and Powerlink will endeavour to model updated developments through the course of the consultation process.

South Australia Energy Transformation (SAET) RIT-T

ElectraNet is undertaking a RIT-T consultation to test interconnector options that will deliver maximum net market benefits. The SAET PADR[58] suggested that a new inter-regional 330 kV transmission line from Robertstown in South Australia to Buronga in New South Wales would provide benefits from 2023 and is recommended. ElectraNet is currently seeking feedback on the PADR and are shortly expected to publish a Project Assessment Consultation Report (PACR).

Due to the likelihood, size, cost and potential impact of this project, this project will be incorporated in all scenarios and its timing will be tested as part of a sensitivity.

Western Victoria Renewables Integration RIT-T

AEMO is also undertaking a RIT-T consultation to determine options that will deliver benefits of augmenting the 220 kV network in Western Victoria to connect significant renewable generation interests in the region. Due to significant industry developments, AEMO has delayed the publication of the PADR to December 2018.

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51 Australian Energy Regulator's *"TransGrid – Determination 2018-23,"* available at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/transgrid-determination-2018-23, viewed on 22nd November 2018.

52 Australian Energy Regulator's *"TransGrid – Determination 2018-23,"* available at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/transgrid-determination-2018-23, viewed on 22nd November 2018.

53 Australian Energy Regulator's *"TransGrid – Determination 2018-23,"* available at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/transgrid-determination-2018-23, viewed on 22nd November 2018.

54 Australian Energy Regulator's *"TransGrid – Determination 2018-23,"* available at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/transgrid-determination-2018-23, viewed on 22nd November 2018.

55 Australian Energy Regulator's *"TransGrid – Determination 2018-23,"* available at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/transgrid-determination-2018-23, viewed on 22nd November 2018.

56 Value of Customer Reliability (VCR) represents a customer's willingness to pay for the reliable supply of electricity. Australian Energy Market Operator's *"Value of Customer Reliability,"* available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Value-of-Customer-Reliability-review, viewed on 22nd November 2018.

57 A financial modelling approach to including cash flows beyond the forecast horizon.

58 ElectraNet's *"South Australia Energy Transformation,"* available at https://www.electranet.com.au/projects/south-australian-energy-transformation/#, viewed on 22nd November 2018.

Due to the likelihood, size, cost and potential impact of this project, this project will be incorporated in all scenarios and its timing will be tested as part of a sensitivity.

MarinusLink

TasNetworks is undertaking a RIT-T consultation to test whether another interconnector to Victoria will deliver market benefits. AEMO's Neutral planning scenario forecast 17 GW and 90 GWh of storage by 2040. The MarinusLink increases interconnection capacity to Tasmania, in order to unlock the potential to use existing and pumped-hydro development opportunities.

Due to the likelihood, size, cost and potential impact of this project, this project will be incorporated in the Fast change scenario and its timing will be tested as part of a sensitivity.

Snowy 2.0

The federal government has proposed a 2000 MW pump hydro storage in the Snowy Mountains that will add a week's worth of energy storage. Snowy2.0 generation and SnowyLink North will be included by 2025 and SnowyLink South will be included by 2034.

Due to the likelihood, size, cost and potential impact of this project, this project will be incorporated in all scenarios and its timing will be tested as part of a sensitivity.

3 Market modelling methodology

3.1 Overview of modelling approach

It is accepted practice to employ market simulations to quantify several classes of market benefits such as capital and operating cost savings. A suite of economic and technical evaluation methodologies will be used to assess the credible options presented in the Expanding NSW-QLD Transmission Transfer Capacity RIT-T.

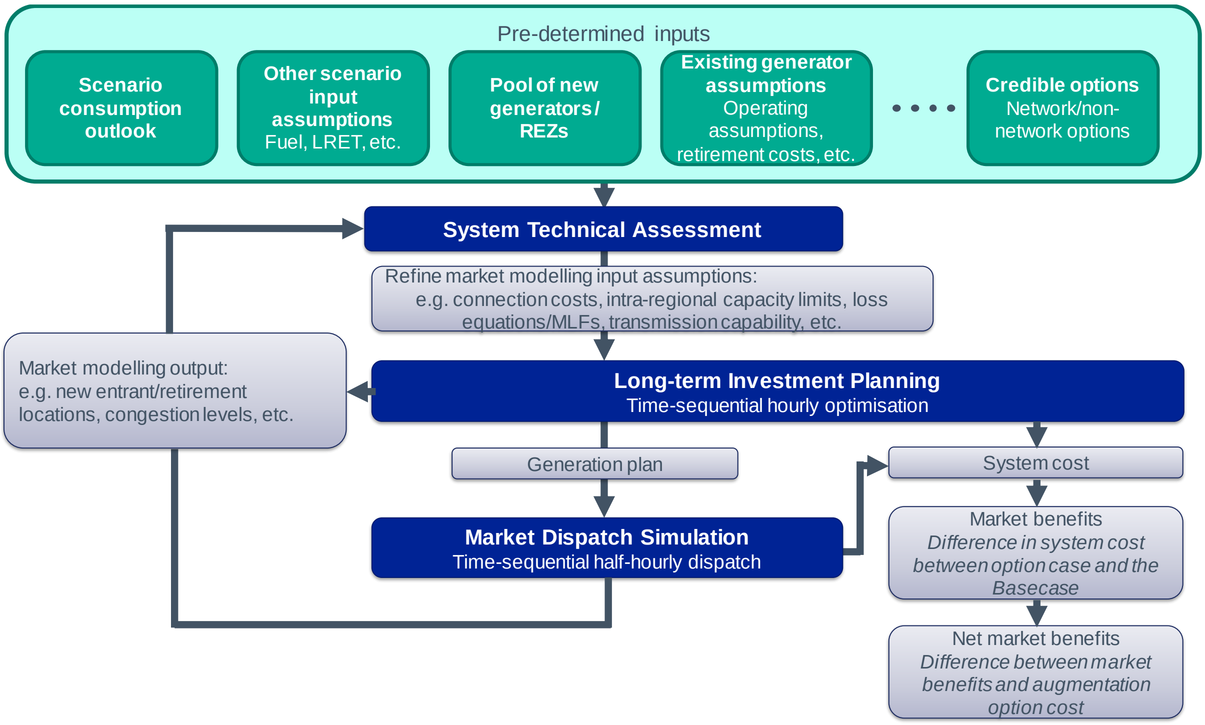
The methodologies involve three interacting activities:

1. System Technical Assessment which evaluates the power system behaviour and performance under each credible option. This assessment ensures market modelling outcomes are physically plausible, follow the operation of the NEM, and the benefits of various options are quantified with sufficient accuracy;
2. Long-term Investment Planning which identifies the optimum generation and transmission infrastructure development schedule while meeting reliability requirements, policy objectives, and technical performance limitations; and
3. Market Dispatch Simulation, which mimics the NEM Dispatch Engine (NEMDE)[59] by determining the least-cost half-hourly dispatch of generation to meet forecast demand while observing plants' and network's technical capabilities. This activity uses the generation and transmission infrastructure development schedule from the Long-term Investment Planning activity, the detailed network representations from the System Technical Assessment activity, and other input assumptions detailed in Chapter 2. The Market Dispatch Simulation assesses the market and network criteria such as security, reliability, losses and congestion to a higher level of resolution and may be used to provide dispatch related components of market benefits.

As these three assessment activities investigate different aspects of the whole RIT-T evaluation, they are executed iteratively using each other's outputs and input assumptions outlined in the previous Chapter 2. Figure 3 illustrates the interactions between these activities when assessing credible options. The components of market benefit and the ranking of the options will be based on findings from all of these activities.

59 Australian Energy Market Operator's "*Dispatch Information,*" available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Dispatch-information, viewed on 22nd November 2018.

Figure 3 – Overview of the modelling process and methodologies



3.2 System Technical Assessment

As part of the preparation for this RIT-T, the System Technical Assessment activity devised credible options to deliver transmission capacity increases between Queensland and New South Wales. These credible options have been scoped based on preliminary designs and estimates.

During the iterative assessment, this activity will evaluate the system impact of the outcomes of the Long-term Investment Planning and Market Dispatch Simulation modelling and will develop rules that ensure reasonable representation of the physical power system's technical envelope across a range of situations. It will also identify options for overcoming intra-regional network congestion.

Limiting conditions due to thermal, voltage and transient stability modes of failure have been analysed for a representative number of operating conditions using tools, techniques and assumptions aligned with those followed for the derivation of existing operational limits. These operating conditions represent boundary and typical conditions made up of the combinations of day and night time operation under high, medium and low load conditions. Limit dependencies identified are factored into a mathematical expression suitable for input into the market modelling software package. All potentially critical modes of failure require a mathematical expression to ensure a realistic technical envelope under the range of market conditions.

For example, thermal limits are well known to be dependent on the line ratings which change seasonally (and at times between day and night time). Although thermal limits may be critical under summer day conditions, voltage limits may be critical during winter and both require separate mathematical expressions to ensure realistic market outcomes during each time step of an annual simulation. Similarly, a particular generator's output may have a significant effect on the capability of the interconnector. Since the generator's output may vary during the simulation, depending on the strength of the dependency, it may be important to capture the relationship between the generator output and the limit. In this way the output of the System Technical Assessment will help form critical inputs to the Long-term Investment Planning and ultimately the Market Dispatch Simulation.

The System Technical Assessment will also create other inputs required by the market simulation including inter-regional loss equations. This step forms part of iterations that ensure convergence between input assumptions and market modelling outcomes, such as verifying assumed connection costs for new entrants are consistent with the actual generation planted.

3.3 Market simulation

Forecasting dispatch patterns in the NEM has become increasingly complex in recent times as a result of the large amount of variable renewable generation and storage options. As such, equally complex and innovative methods are required to model capacity and generation development across the NEM.

TransGrid and Powerlink propose to use a linear optimisation approach and perform hourly time-sequential long-term modelling of the whole of the NEM to produce least-cost generation and transmission development schedules.

TransGrid and Powerlink divide this approach into two separate market simulation activities to assess the economic impacts of credible options: one creates an optimal high-level investment plan, and the other explores the appropriateness of the investment schedule given the simplifications made in the linear optimisation.

The Long-term Investment Planning activity solves for the least-cost generation and transmission infrastructure development schedule spanning a long outlook period while meeting energy policies whereas the Market Dispatch Simulation investigates the resulting generation and transmission infrastructure development schedule from a deeper generation and network operational perspective.

Both activities are consistent with an industry-accepted methodology employed in AEMO's modelling including the 2018 ISP.[60]

3.3.1 Long-term Investment Planning

TransGrid and Powerlink intend to apply the Long-term Investment Planning assessment over a 25-year outlook period to produce generation and transmission infrastructure development schedules. The outlook period is chosen to sufficiently capture investment performance in the long-term future while maintaining computational manageability.

The Long-term Investment Planning activity determines the least cost development schedule by assuming perfect foresight of demand, reservoir inflows, generator outages, wind and solar generation profiles, and maintenance over a long outlook period.

The generation and transmission infrastructure development schedule resulting from the Long-term Investment Planning are determined such that:

- it economically meets hourly regional and system-wide demand while accounting for network losses;
- it builds sufficient generation capacity to meet demand while considering potential generator forced outages;
- the cost of unserved energy is balanced with the cost of new generation investment to supply that potential shortfall;
- generator's technical specifications such as minimum stable loading, maximum capacity, and ramp rates are observed;
- notional interconnector flows do not breach technical limits;
- hydro storage levels and battery storage state of charge do not breach maximum and minimum values;
- new generation capacity is connected to locations in the network where it is most economical from a whole of system cost;

60 Australian Energy Market Operator's *"Market Modelling Methodology and Input Assumptions,"* available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database, viewed on 22nd November 2018.

- NEM-wide and state-wide emissions constraints are adhered to;
- NEM-wide and state-wide renewable energy targets are met or else penalties are applied;
- time value of all costs is accounted for;
- generator retirement costs incorporate rehabilitation costs and installation of new facilities such as synchronous condensers to meet system strength and inertia constraints;
- refurbishment costs are captured;
- generator maintenance outages for a whole year are scheduled to represent planned generator outages;
- energy-limited generators such as Tasmanian hydro-electric generators and Snowy Hydro-scheme is scheduled to minimise system costs; and
- the overall system cost spanning the whole outlook period is optimised whilst adhering to constraints.

Model simplifications

The Long-term Investment Planning activity minimises the investment costs and operating costs across the NEM using well-documented mathematical optimisation techniques.[61] The optimisation is computationally onerous requiring simplifications to contain the problem to allow solutions in practical timeframes.

TransGrid and Powerlink propose to simplify the activity's inherent complexity by:

- Initially modelling only prominent inter-regional power system constraints which may be reflected as a simplified limit on the notional interconnectors. In subsequent modelling iterations, relevant intra-regional constraints and adjustments of prominent inter-regional power system constraints, both resulting from System Technical Assessment, will also be reflected.
- Initially applying fixed MLFs for each generator for the outlook period. These will be refined in five yearly blocks in subsequent modelling iterations.
- For each REZ, two wind profiles and one solar profile will be used. The wind profiles will be selected to represent uncorrelated high quality sites within the REZ.
- Modelling of optimal decision making by generators to minimise system cost. In the NEM, generator proponents are free to decide what and where to connect subject to connection requirements. Proponent's incentives are varied and do not typically result in outcomes that minimise system costs.
- Fossil fuel generation retirement at fixed times depending on the end-of-technical operating life (50th year) and scenario.
- Applying generator minimum and maximum capacity factors to represent fossil fuel resource availabilities and limitations, or minimum operating limit for CCGTs.
- Modelling the 10% PoE demand in the Long-term Investment Planning to model planning for 1 in 10 year events. Market Dispatch Simulations (section 3.3.2) will use both 10% PoE and 50% PoE to model expected market outcomes. The results from the 10% PoE and 50% PoE simulations will be weighted at 0.304 and 0.696, respectively.[62]

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[61] IBM's "*IBM Knowledge Center,*" available at https://www.ibm.com/support/knowledgecenter/SSGH4D_15.1.0/kc_gen/com.ibm.xlf151.aix.doc_toc-gen5.html, viewed on 22nd November 2018.

[62] Australian Energy Market Operator's *"Market Modelling Methodology and Input Assumptions,"* available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database, viewed on 22nd November 2018.

- Allowing incremental build[63] of capacities under a number of simulations of different unplanned outage conditions. The number of simulations will be calibrated to ensure convergence in incremental build decisions is reached.

Whilst these simplifications assist in managing the complexity of the methodology, it only renders high-level and coarse estimate of the economic impact of investment decisions. As such, further detailed analysis through the Market Dispatch Simulation is required. The Market Dispatch Simulation may reveal the need to modify and even introduce new modelling rules to the Long-term Investment Planning to ensure consistency amongst the inputs and outcomes of both activities.

Sub-regional modelling

As more inter- and intra-regional constraints are found to be relevant throughout the iterative assessment process, sub-regions may be required to be defined to further evaluate the impact of sub-regional demand and generation diversity.

If this necessary, the following will be defined:

- sub-regional demand and supply,
- intra-regional loss equations, and
- intra-regional constraint or flow limits.

New capacity build

The Long-term Investment Planning activity produces an economical generation development schedule across the outlook period. This generation development schedule details the cheapest generator technology to build whilst meeting policy constraints.

The amount, type, and location of capacities to build are determined based on several criteria:

- balance between the cost of building new generation or battery storage capacities and the cost of unserved energy (VCR) is ensured. Generally, this approach builds sufficient capacity to meet reliability standards.
- limits on the system and state-wise emissions and renewable energy are met or else nominated penalties are incurred.

3.3.2 Market Dispatch Simulation

The Market Dispatch Simulation investigates the market and system operation using the resulting generation and transmission development schedule and the detailed network representation from the System Technical Assessment and the Long-term Investment Planning activities. It sequentially calculates the least variable cost half-hourly generation dispatch that observes inter-regional and intra-regional network technical and security limitations over the outlook period. This simulation is executed to validate the operational plausibility of the generation and transmission development schedule from the Long-term Investment Planning activity.

As it mimics the operation of the NEMDE at greater resolution than the Long-term Investment Planning, market operation is best assessed within this activity. As such, it makes use of additional input including all operational constraints.

Using the same input assumptions as the Long-term Investment Planning, this short-term modelling evaluates whether the simplifications made in the Long-term Investment Planning are valid in a more detailed model,

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[63] Installation of continuous quantities is appropriate when there is a large amount of wind, solar, gas peaking plant, batteries and pumped storage and dividing into increments is arbitrary. The plant characteristics are defined at this level (e.g. minimum load level as a proportion of capacity).

indicating a need for an additional iteration of the Long-term Investment Planning and/or the System Technical Assessment.

Throughout the course of the analysis, TransGrid and Powerlink will model additional constraints and/or augmentation costs in the Long-term Investment Planning model to ensure constraint levels are economic.

Prior to the sequential half-hourly dispatch, the simulation pre-calculates the:

- Generator maintenance schedule – maintenance outages for a whole year are scheduled to represent planned generator outages.
- Fuel schedule – for energy-limited generators such as Tasmanian hydro-electric generators and Snowy Hydro-scheme, fuel (water) usage schedule is determined first based on their forecast inflows, reservoir boundaries, and initial dam levels. The fuel usage schedule then guides the half-hourly, sequential simulation to meet their yearly energy limitation.

The Market Dispatch Simulation software will be run with a full set of intra-regional and inter-regional constraints to ensure system security. Each simulation will be subject to unplanned outages of generators using Monte Carlo[64] simulation to randomly sample generator availabilities.

The Market Dispatch Simulation will be applied to all credible options to obtain the following:

- generation dispatch and outage schedules;
- network flows, congestion, and losses;
- voluntary and involuntary load curtailment except for non-credible events;
- re-assessment of the reliability criterion of 0.002% unserved energy (USE) for both 10% and 50% PoE demands;
- emission production;
- fuel consumption;
- generation cost;
- energy and capacity sharing between adjacent regions; and
- generator MLF projections.

Due diligence of the Market Dispatch Simulation may trigger adjustments to the input assumptions, another System Technical Assessment, and a rerun of the Long-term Investment Planning activities. These adjustments may reflect tighter zonal generator connection limits, connection cost adjustments, adjustment to achieve the reliability criteria, and modelling of newly discovered material intra-regional constraints.

The Market Dispatch Simulation builds on the 2018 ISP methodology by:

- modelling at half-hourly resolution to better capture the variability of renewable generation;
- monitoring thermal loadings under system normal and N-1 contingency conditions;
- assessing congestion and potential cost to overcome congestion both at the connection and intra-regional grid sections;
- potential future MLFs are calculated and incorporated; and
- simulating sufficient number of forced outage patterns to capture impact of randomness on the USE.

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[64] Australian Energy Market Operator's *"Market Modelling Methodology report*," available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/ISP-database, viewed on 22nd November 2018.

3.3.3 Supply bidding and availabilities

For both the Long-term Investment Planning and Market Dispatch Simulation, supply bids and availabilities will be estimated using the following methodologies.

Generation bidding and dispatch

There are three main types of generation that are scheduled:

- The thermal generators which have resources for generally unlimited energy,[65] are bid according to their short-run marginal cost (SRMC), although the minimum load of thermal generators is bid at a negative price to ensure minimum load is always dispatched when available.
- The available capacity of semi-scheduled and non-scheduled wind and solar farms are bid in at variable operations and maintenance costs. They may be dispatched lower than their availability if constraints or oversupply prohibit them from generating more.
- Storage plant of all types (conventional hydro generators with storages, pumped storage hydro generators and battery storages) are operated to minimise the overall system costs. The schedule of storage releases (water releases and pumping for hydro, and discharging and charging for batteries) is optimised across time such that they minimise the use of non-zero cost plants, usually gas turbines and coal plants.

A short-run marginal cost bidding model will be applied for the Expanding NSW-QLD Transmission Transfer Capacity RIT-T for both the Long-term Investment Planning and Market Dispatch Simulation. Bidding at SRMC is a generally-accepted model that assumes perfect competition. However, as this naturally presents unrealistic results, both maximum and minimum capacity factors will be applied for a number of existing fossil-fuelled generators to approximate operational availabilities and behaviours.

Wind and solar available energy projections

All existing, committed and anticipated large-scale, utility-connected wind and solar farms in the NEM will be modelled individually i.e. each farm will have a location-specific generation profile time series based on historical resource availability. The hourly (for Long-term Investment Planning) or half-hourly (for Market Dispatch Simulation) availability profiles will be derived using seven years of historical weather data covering financial years. The availability patterns will be repeated sequentially throughout the modelling horizon.

The availability time series for wind will be derived using simulated wind speeds and directions from the Australia Bureau of Meteorology's Numerical Weather prediction systems, scaled to represent wind speeds at a hub height. Wind speeds will then be converted into power using a generic wind farm power curve. The profiles will then be scaled to achieve average target capacity factors across the seven historical years.

The profiles will effectively reflect inter-annual variations, but at the same time achieve expected long-term capacity factors. This time-sequential method will also preserve correlation between wind production at different sites, solar production at different sites, and demand. This is essential to capture realistic diversity and extremes for a robust investment plan.

Each REZ will include two wind and one solar profiles. The two wind profiles will be selected to represent uncorrelated high quality sites within the REZ.

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65 As distinct from hydro with storages, pumped hydro storages and battery storages which, while dispatchable, have limited energy reservoirs.

4 Cost-benefit analysis

4.1 Quantifying market benefits

Modelling results for each credible option will be compared to a 'do nothing' counterfactual that is simulated as a no QNI upgrade case. Between each pair of simulations (augmentation option and 'do nothing'), all input assumptions will remain identical (including the Monte Carlo sequence of forced outages) except for the capacity of the option investigated. Annual gross market benefit components will be evaluated as the difference between the annual results of the option and 'do nothing' cases.

To evaluate net market benefit and rank the credible options, the capital and operating costs of the augmentation option is subtracted from the gross market benefits.

The option's commissioning year is determined as the feasible timing that delivers maximum net market benefit.

Since the asset life-span is significantly longer than the 25-year outlook period, the discounted value of any residual beyond the outlook period will be included in the net present value calculation (but is not expected to significantly influence the ranking of the options).

4.2 Components of market benefits

TransGrid and Powerlink will estimate the following components of market benefit.

4.2.1 Generation dispatch cost savings

Dispatch cost savings arising from a credible option are composed of:

- Production cost savings – all costs associated with producing electricity such as fuel costs (except water, wind speed, and solar irradiation costs), variable operation and maintenance costs, and auxiliary load costs.
- Interconnector loss savings – since notional interconnectors' loss functions are explicitly modelled, the cost difference from different interconnector losses are accounted in the total production cost savings. Note these can be negative, for example, if greater flows incur greater losses.
- Intra-regional loss savings – since intra-regional losses are already incorporated in the electricity consumption assumptions, corresponding cost savings are already accounted in the production cost savings. If a region is found to require modelling by multiple sub-regions in the Long-term Investment Planning, the losses between the sub-regions will be captured by a loss equation in a similar manner to an interconnector loss equation.
- Storage loss savings – cost of losses arising from operation of storages are implicitly incorporated in the production cost savings.

4.2.2 Generation overhead cost savings

Additional cost savings from the following will be quantified:

- Capital deferment – savings from delaying or avoiding generation investments due to network augmentation.
- Fixed operation and maintenance costs savings – avoided fixed costs of keeping generators in service.

4.2.3 Demand response cost savings

Demand reduction is usually the last resort to maintain system security. Due to potential high cost of the impact of this mechanism, demand reduction is usually activated only at very tight supply-demand situations such as very high peak demand periods, extremely low supply of generation capacity, constrained transmission networks, or following significant forced outages.

Cost savings from reduced load curtailment arise from the following:

- Price-sensitive voluntary load curtailment or Demand Side Participation (DSP) – since network augmentation provides access to cheaper forms of generation which then triggers lower wholesale spot prices, cost savings to the market from lower chances of activating price-sensitive curtailable load could arise. This reduction in unserved energy from augmenting the transmission network will be valued at the corresponding trigger price of the voluntary load curtailment.
- Involuntary load curtailment – when the network is driven to its technical boundaries, the Long-term Investment Planning and Market Dispatch Simulation will both explore all possible dispatch options before involuntary load shedding. Since augmentation increases the network's technical boundaries, additional market benefits could arise from avoided involuntary load curtailment. This reduction in expected unserved energy from augmenting the transmission network will be valued at the VCR.

4.2.4 Transmission cost savings

Interconnectors may provide other transmission cost savings from other parts of the network.

- Connection cost savings – credible options include building new circuits and substations in new areas. If these are in proximity to high value renewable energy resources, or increase system strength, then the augmentation can result in connection cost savings.
- Intra-regional transmission augmentation capital cost savings – the existing network may not have sufficient capacity to supply the total regional load. An interconnector augmentation may defer the need for an intra-regional augmentation if it allows additional capacity to supply this otherwise unserved load. Conversely, an intra-regional augmentation may be required to provide access to existing and potential new generators to supply loads in neighbouring regions. In this case, although the overall cost of transmission is higher, it is more than compensated by the savings as a result of greater utilisation of otherwise constrained generation. Both transmission capital and operating costs will be considered.

4.3 Excluded components of market benefits

The following classes of market benefits will not be quantified for this RIT-T.

- System security benefit – non-credible separation of a region from the rest of the NEM is more relevant for regions that do not have sufficient capacity to serve local load independently. As this is not the case for either Queensland or New South Wales, system security benefits are less relevant for this RIT-T and will not be quantified.
- Competition benefit – when network augmentation allows more generation to supply a specific region, incumbent players who could exercise local market pivotal positions face more competition to serve local demand. Augmentation allows lower-cost energy supply to be available to a captured area, decreases the incumbents' capacity to adopt a non-competitive bidding strategy, and promotes lower wholesale spot market prices.

  Since it is computationally and assumption intensive, TransGrid and Powerlink will only measure competition benefits to further assess and discriminate between options that have relatively-similar ranking if TransGrid and Powerlink believe that these benefits are material in breaking the 'tie.'
- Option value – option value comes from the ability to defer investment decisions until uncertainties are resolved. Option value can only exist for options that:
  - are staged and incremental investment decisions can be made over time,
  - are heavily influenced by an uncertain driver and that the timeline of resolution of the driver's uncertainty is foreseeable,

    - assumptions on the key driver materially influence the ranking of options.

  An option valuation is a computationally intensive task and is applicable to circumstances where it may credibly and materially impact the relative ranking of options. It requires decision tree modelling of wholesale market models incorporating different potential assumptions around the key drivers to map out benefits of the option's flexibility.

  TransGrid and Powerlink propose to only estimate this component to differentiate between similarly ranked options.

- Ancillary market benefits – although options may provide varying degrees of ancillary market savings, TransGrid and Powerlink will exclude ancillary market benefits from the market simulation since this substantially increases the complexity with minimal returns. This is due to the historical cost share of the ancillary market in Queensland and NSW being small compared to the energy market.