TransGrid

New South Wales

Transmission Annual Planning Report 2017

Purpose of the Transmission Annual Planning Report

The National Electricity Rules (NER) require us to undertake an annual planning review and publish the results by 30 June each year. The purpose of the review is to identify an optimum level of transmission investment to enable us to deliver required services at an efficient cost.

The review involves joint planning with each of the distribution network service providers in New South Wales (Ausgrid, Endeavour Energy, and Essential Energy) and the Australian Capital Territory (ActewAGL) as well as with Powerlink in Queensland, AusNet Services in Victoria, ElectraNet in South Australia and the Australian Energy Market Operator (AEMO). The objective of joint planning is to work together to develop the overall grid in the most efficient way for the benefit of consumers.

At the beginning of the planning review, connection point demand forecasts for summer and winter are provided by each of the distribution network service providers and reviewed. The reviewed connection point forecasts and AEMO's regional demand forecast for NSW (including ACT) are used as inputs to our analysis of present and emerging network constraints and asset renewal requirements. In particular, our review:

- Identifies emerging constraints within the network and possible options to alleviate them
- Assesses assets identified as reaching the end of their serviceable lives, and considers options to address this
- Provides information to interested parties so that they may propose options to meet those needs, which may involve non-network components.

Identified needs and opportunities are optimised within our network investment process, which is designed to respond to the changing needs of stakeholders and ensure the efficient delivery of our capital program.

As the Jurisdictional Planning Body for NSW, we provide input to AEMO's Electricity Statement of Opportunities (ESOO) and National Transmission Network Development Plan (NTNDP). Broadly, the ESOO considers the adequacy of generation while the NTNDP provides an overview of the adequacy of key parts of the interconnected transmission network across the NEM. Both reports serve as inputs to the Transmission Annual Planning Report, and we report on relevant matters arising from these publications.

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Version	Date Issued	Comment
0	30 June 2017	Original issue

Foreword

Australia is in the midst of an energy transformation, primarily driven by community expectations, retirement of existing generation and advances in renewable energy technologies. This transformation brings new challenges for the power system in providing a secure and reliable electricity supply for all consumers.

This Transmission Annual Planning Report (TAPR) provides an assessment of the capability and limitations of the New South Wales transmission network over the next ten years. It outlines the outcomes of our annual planning review and provides advance information to stakeholders and market participants on the nature and location of emerging network constraints.

The exit of coal-fired baseload generation over the last five years has created a tight supply/demand balance in some states. For the first time in 12 years, NSW was only able to meet maximum demand by curtailing load last summer. This is of significant concern. The reduced capacity of the power system as a whole has also resulted in continuing high wholesale market prices.

In our ongoing engagement with electricity users, everyone from large businesses to representatives of end users have emphasised to us that reliable, affordable energy is essential to the modern business and lifestyle in today's economy. Clearly, the National Electricity Market has failed those it was meant to serve – all electricity consumers.

In 2016, the Australian Government commissioned an Independent Review into the Future Security of the National Electricity Market led by Dr Alan Finkel. The review has developed a blueprint for the future security of the NEM characterised by an orderly transition, better system planning and stronger governance.

In response to the current challenges facing the power system, and consistent with the Finkel blueprint, we have developed a plan to transition to the energy system of the future.

Our plan will deliver a low cost platform that will underpin the transition to low emissions generation, maintain system security and reduce inflated wholesale market prices across the NEM. Electricity users will benefit from the competitive pressure applied by new generation and stronger interconnection, and be able to participate in the energy system by providing demand management and energy storage.

While a growing number of consumers are installing rooftop solar panels and now storage to supply part of their energy needs, large-scale generation featuring an increasing proportion of intermittent renewable generation will continue to supply most of the state's energy requirements.

We were the first Transmission Network Service Provider (TNSP) to publish information on the best opportunities for renewable generation connections to our network. Due to significant interest and a strong pipeline of connection applications, the network capacity in these areas is fast becoming limited. We have updated our existing connection opportunities in this report and are proposing to take action to increase the network capacity to these areas.

Our plan identifies optimum locations for renewable energy precincts that provide commercially viable renewable generation opportunities and minimise the network extensions required to provide the necessary transmission capacity.

Over the next ten years, energy consumption and maximum demand[1] are expected to continue to grow.

We are progressing the Regulatory Investment Test for Transmission (RIT-T) consultation for the Powering Sydney's Future project to ensure security of supply to Inner Sydney. The Project Assessment Draft Report (PADR), published in May 2017, has proposed the largest deferral of capital expenditure in the NEM to date through the use of non-network solutions. The RIT-T is expected to be completed in August 2017, and together with continued stakeholder engagement it will ensure the best outcome for consumers is achieved.

More broadly, we continue to improve our operating and asset management processes to maximise the value to energy consumers delivered by our existing network assets. TransGrid is accredited to the global ISO55001 asset management standard and we use a comprehensive risk-based approach to asset refurbishment and replacement. We prudently manage our portfolio of forecast network developments by:

- Engaging with stakeholders early in the planning process and ensuring that communication and genuine consultation remains open to deliver the best outcomes for consumers
- Considering all options to address emerging security of supply issues
- Continuing to optimise all projects within the planning horizon to ensure efficient delivery of the required network developments.

Extreme weather events and the increasing penetration of intermittent generation have caused concern following system events such as the state-wide blackout in South Australia in late 2016. Without doubt, the NSW network has the capability to underpin the NEM through the energy transformation to provide a secure, affordable and low-emissions energy supply. The proposed developments set out in this report will ensure that the transmission network provides a stable platform for a smooth transition to the energy system of the future.

We look forward to ensuring that TransGrid is best placed to meet your energy supply needs now and into the future.

Gerard Reiter
Executive Manager/
Network Planning & Operations
June 2017

1 Maximum demand is demand measured at a point in time, typically in megawatts (MW) at the transmission level

About TransGrid

TransGrid operates and manages the high voltage electricity transmission network in NSW and the ACT. The network connects more than 3 million homes, businesses and communities to a safe, reliable and affordable supply of electricity.

The transmission network transports electricity from generation sources such as wind, solar, hydro, gas and coal power plants to large directly connected industrial customers and the distribution networks that deliver it to homes and businesses.

Comprising 100 substations, approximately 13,000 kilometres of high voltage transmission lines and cables and five interconnections to Queensland and Victoria, the network underpins economic growth and facilitates energy trading between Australia's largest states.

Figure 1 sets out TransGrid's role in the electricity supply chain. Figures 2 and 3 show TransGrid's network.

Figure 1 – TransGrid within the electricity supply chain

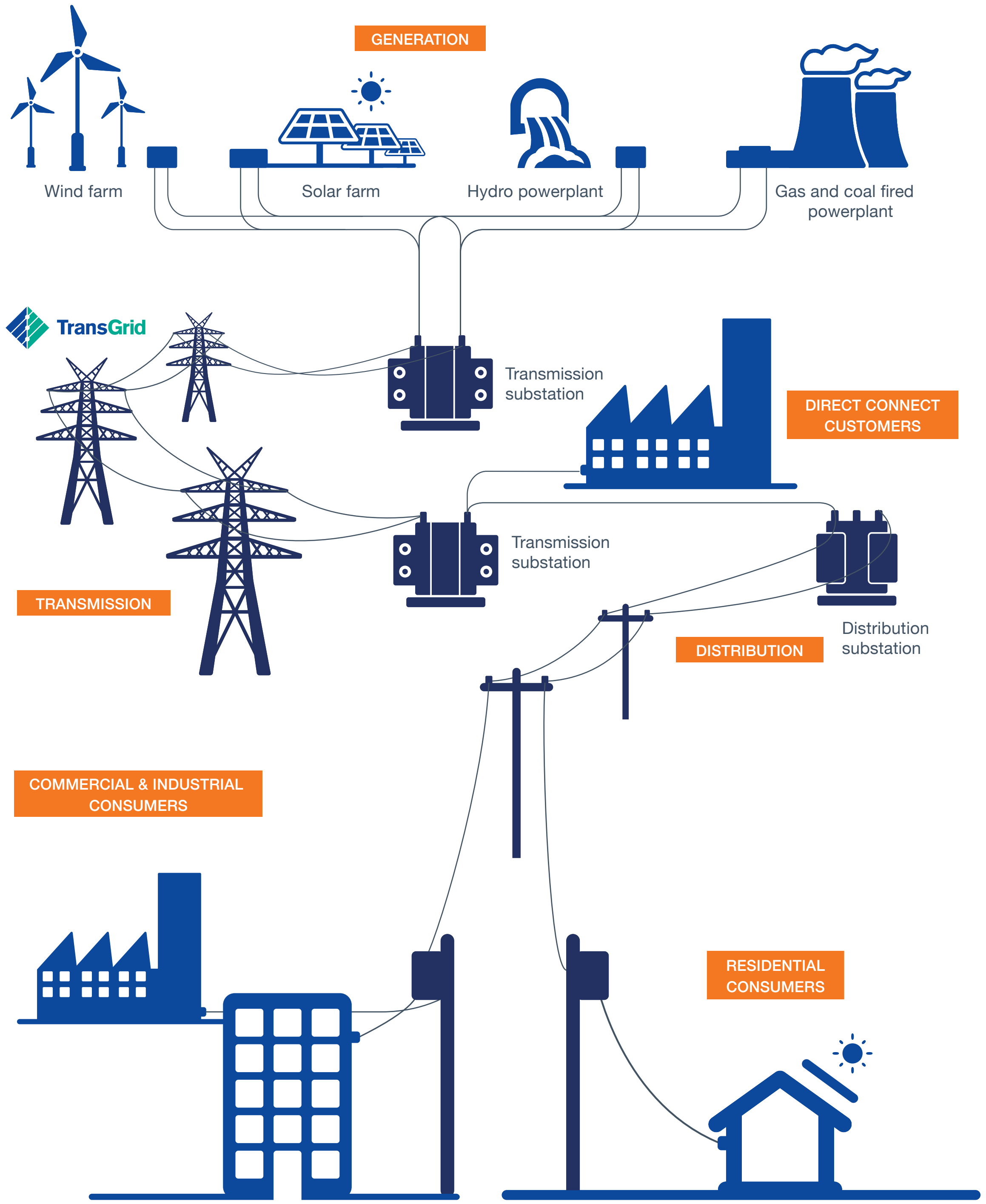
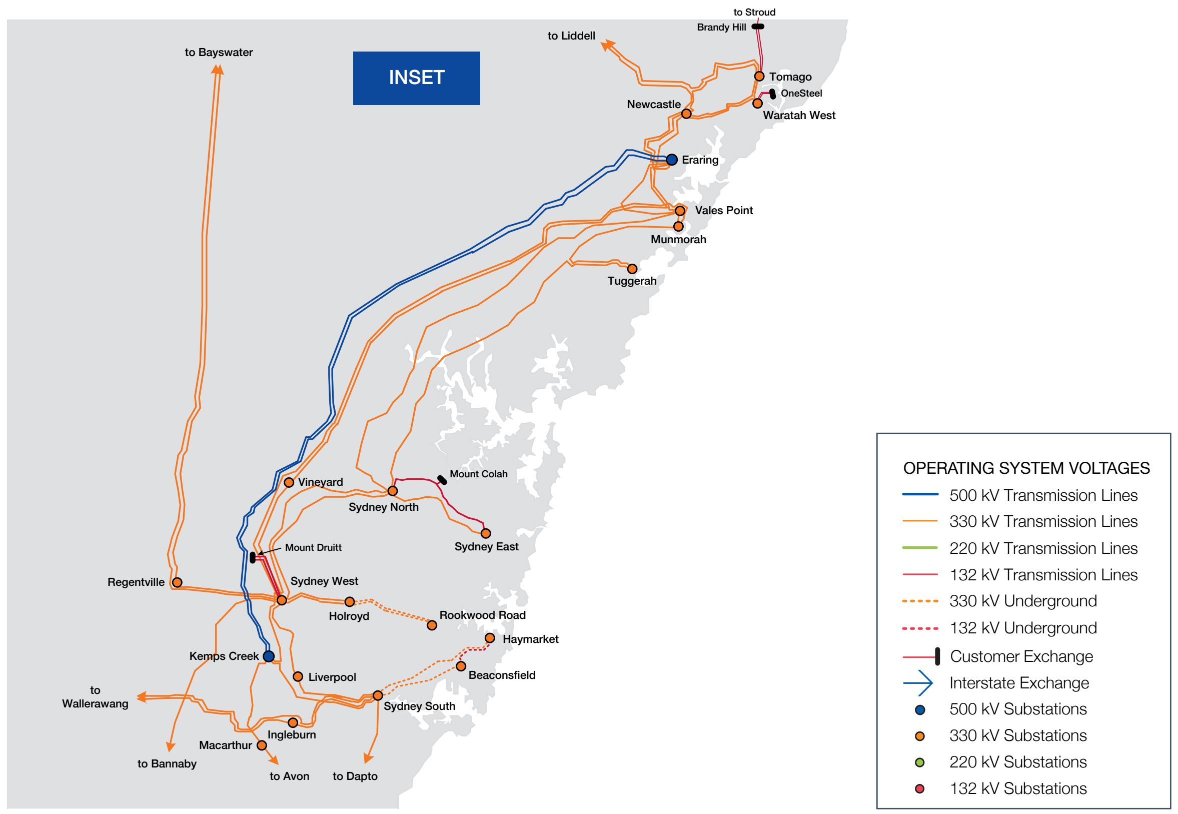


Figure 2 – TransGrid's electricity network map

Figure 3 – TransGrid's electricity network map – Inset



Executive summary

At TransGrid, we're focused on providing safe, reliable, affordable transmission services which are sustainable over time – meeting your energy needs now, and into the future.

Chapter 1:

The energy system of the future

The energy system of the future will feature customer choice and control, enabled by an increasingly interconnected network. Generation will comprise a mix of large-scale generation and distributed energy resources (DER). Participants will be able to share resources and services, with the network providing the platform for energy transport and power system stability.

Retirement of baseload power stations will reduce the firm generation capacity in NSW and put the power system under pressure to reliably meet the state's maximum demand. New generation, greater interconnection, storage and demand management will provide additional capacity to assist in meeting the maximum demand.

We have developed a plan to transition to the energy system of the future, which identifies optimum locations for renewable energy precincts and the network expansion required to support their development. The plan will deliver a low cost platform to underpin the transition to low emissions generation, maintain system security and reduce inflated wholesale market prices across the NEM.

Chapter 2:

Transmission network developments

We have proposed transmission network developments to extend the network to renewable energy precincts and improve connection to adjacent states to leverage geographical diversity.

In the past year, we have conducted extensive stakeholder consultation on the Powering Sydney's Future Project to maintain a reliable supply to Inner Sydney. The preferred solution to address the emerging reliability risk comprises demand management from 2018/19 to 2021/22 and network augmentation by 2022/23.

We have jointly planned projects with DNSPs to meet the growing demand for electricity in south-west Sydney, north-west Sydney and north-west Canberra.

We have identified projects that are required to meet new jurisdictional reliability standards in selected locations in NSW. We are also delivering projects to provide the ACT with a second geographically independent supply, as required by our transmission license.

We have also proposed a number of low-cost projects that deliver economic benefits across the power system as a whole.

Our asset management strategies and planned projects deliver a low-cost solution to maintaining our infrastructure to ensure a secure and reliable network supply to our customers.

Chapter 3:

Generation connection and network support opportunities

This chapter sets out information on existing network capacity available for new generation in various areas across NSW and opportunities for network support.

Interest in new generation connections exceeds the existing network capacity in many areas of NSW. We have proposed the development of renewable energy precincts to open up additional capacity for new low-emissions generation.

Opportunities for non-network options may arise within five years in the Gunnedah/Narrabri and Broken Hill areas. Non-network options may include demand management, embedded generation and energy storage.

Chapter 4:

Forecasts and planning assumptions

Assumptions on developments across the wider power industry provide a base for our assessments of the network capacity required. Generation retirement and connections, changes in economic activity, new spot loads and retirement of network assets all contribute to the utilisation of the network and its forecast performance.

Over the next ten years, energy consumption and maximum demand are expected to continue to grow at modest rates.

Growth in energy consumption and demand is expected due to economic growth and population growth. Consumer behaviour through uptake of energy efficiency measures, strong penetration of rooftop PV generation, installation of distributed battery systems and a response to increasing market prices have been taken into account in the forecasts, as factors moderating growth.

The 50% probability of exceedance (POE) summer maximum demand under AEMO's neutral economic growth scenario is expected to grow by around 0.3% and winter maximum demand by around 0.6% annually over the planning horizon.

Forecasts based on aggregated Bulk Supply Point (BSP) data suggest stronger summer and winter maximum demand growth of 1.0% and 1.5% respectively.

We have also assessed power system security over the next ten years against the criteria for stability of the power system. We have identified some stability services that may be required following further retirement of baseload generation and/or connection of new inverter-based generation.

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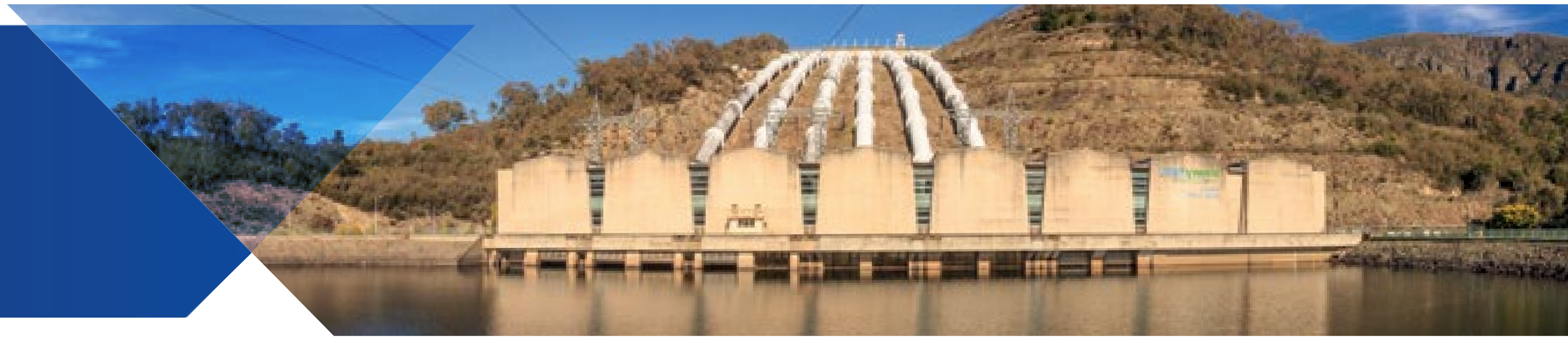
Chapter 1

The energy system of the future

- Demand for electricity is increasing
- Ageing baseload power stations will close
- The best renewable resources for new generation are in areas with limited transmission capacity
- The wholesale market price is unsustainably high and can be lowered through improved competition
- We have developed a plan to transition to the energy system of the future that will address the projected shortfall in generation, open new renewable energy precincts, place downward pressure on the wholesale market price and maintain the resilience of the power system.

1 The energy system of the future



Australia is in the midst of an energy transformation. This is primarily driven by community expectations, retirement of existing generation and advances in renewable energy technologies.

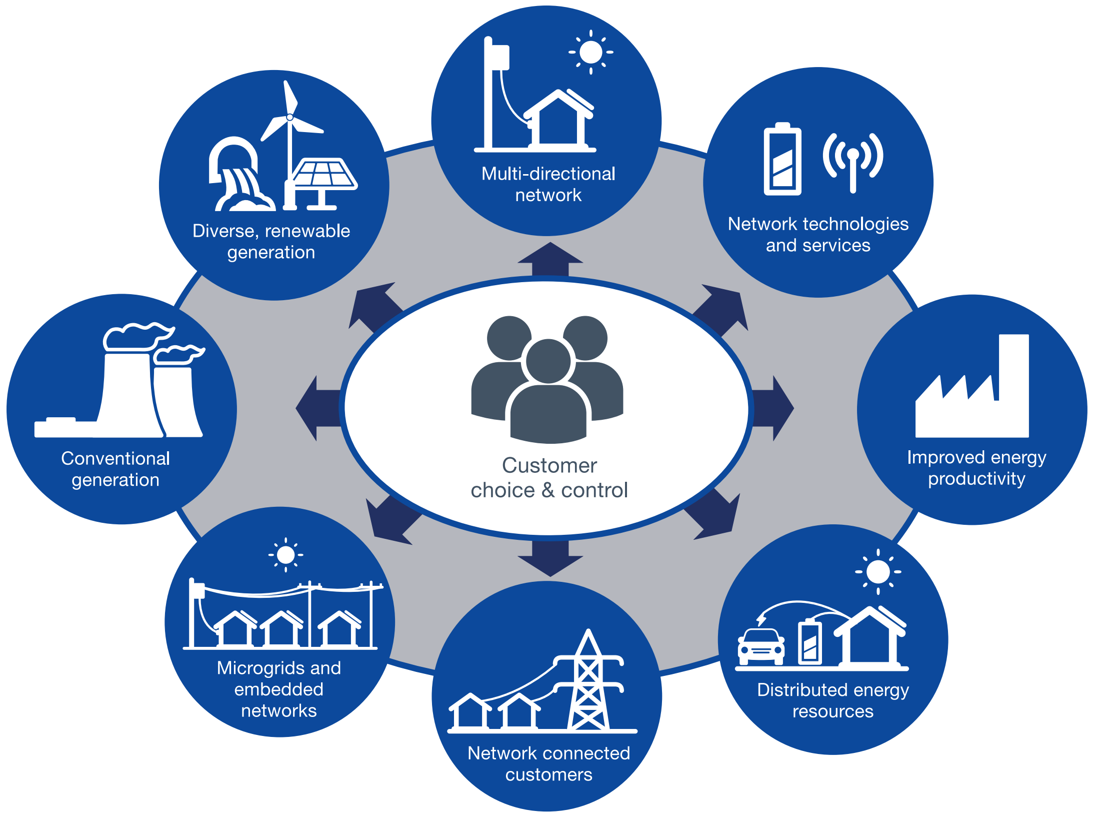
Consumers have expressed to TransGrid their strong support for the objectives of energy security and reliability, affordability and reduced emissions.

The energy system of the future will feature customer choice and control, enabled by an increasingly interconnected network. Generation will comprise a mix of large-scale generation and distributed energy resources (DER). Participants will be able to share resources and services, with the network providing the platform for energy transport and power system stability.

Large-scale renewable generation is likely to contribute approximately 65% of the generation mix by 2050, with customer-sited DER contributing around 30%.[2]

The energy system of the future is shown in Figure 1.1.

Figure 1.1 – The energy system of the future



The transition to the energy system of the future will comprise four key elements:

1. A pathway towards **generation with a low levelised cost of energy** (LCOE) that meets emissions targets
2. Development of **transmission networks** to integrate large-scale renewable energy whilst ensuring power system stability
3. Mechanisms that provide **ancillary services** at the lowest possible cost
4. **Market design** appropriate to the future energy mix that promotes genuine competition and protects consumers when there is ineffective competition.

These matters are being addressed through various reviews including the Independent Review into the Future Security of the National Electricity Market (Chief Scientist), System Security Market Frameworks Review (AEMC) and various rule changes under consideration by the AEMC.

A plan to transition to the energy system of the future must recognise that:

- Demand for electricity is increasing
- Ageing baseload power stations will close
- The best renewable resources are in areas with limited transmission capacity
- The wholesale market price is unsustainably high and can be lowered through improved competition.

1.1 Development of the transmission network

1.1.1 Demand for electricity is increasing

Maximum demand in NSW has grown consistently over the last three years. Growth has been driven by population growth, hotter summer temperatures and a reduction in electricity prices.

Unprecedented maximum demand in Summer 2016/17, together with some unavailable generation in NSW, resulted in load curtailment on 10 February 2017.

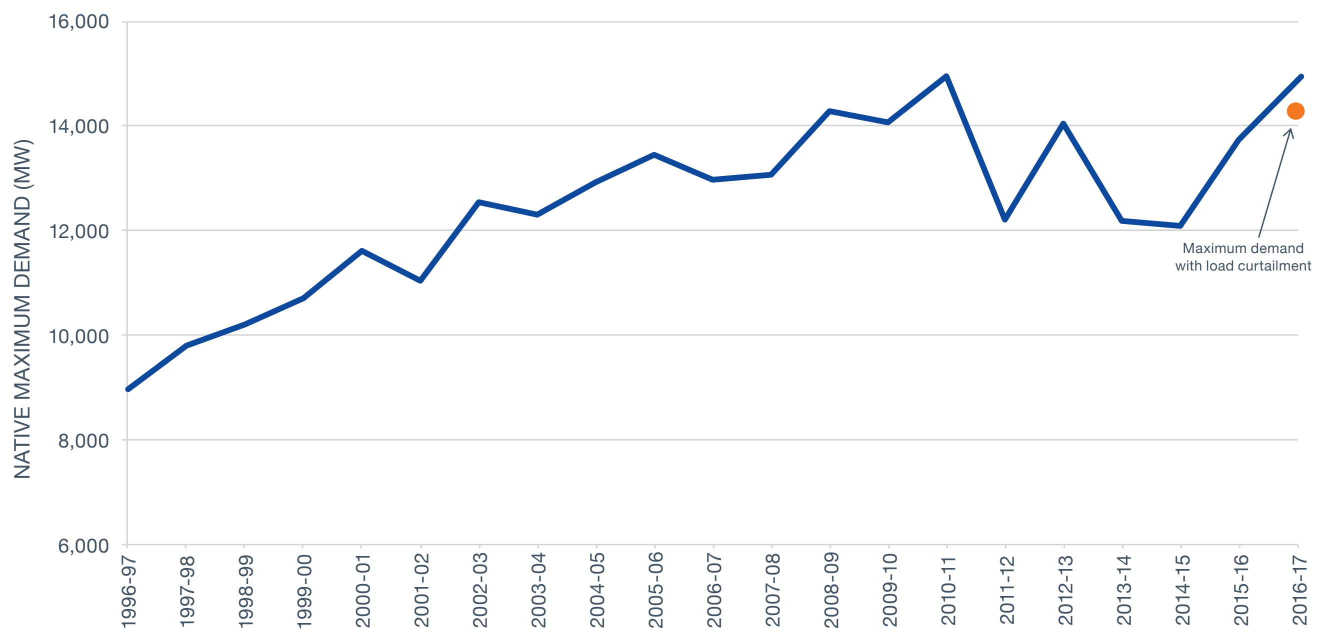
The summer maximum demand trend for NSW is shown in Figure 1.2.

The growth in maximum demand is expected to continue, driven primarily by ongoing population growth and expansion of industry. In the immediate future, growth is forecast mainly in specific regions:

- Inner Sydney is forecast to grow due to renewed economic activity and development of new transport corridors
- North-west and south-west areas of Greater Sydney are forecast to grow due to land releases for residential development and the establishment of new suburbs
- North-west areas of Canberra are forecast to grow due to land releases for residential development and the establishment of new suburbs
- Some areas in regional NSW are forecast to have new industrial loads for activity such as mining and gas exploration.

The demand forecasts are published in Chapter 4 and Appendix 1 of this report.

Figure 1.2 – Summer maximum demand for NSW



2 Energy Networks Australia, Electricity Network Transformation Roadmap: Final Report, April 2017.

Case study 1:

NSW maximum demand event 10 February 2017

In February 2017, a heatwave affecting Australia's eastern states and catastrophic fire danger conditions across the Hunter, Central Ranges and Upper Central West Plains, presented a number of network operation and fire risk challenges.

Network operation

At 8.30am on Friday 10 February, AEMO declared a Level 4 emergency under the Power System Emergency Management Plan. TransGrid initiated and ran an emergency management response from our control centre in Western Sydney.

While the event began mostly as a network operations issue, incidents impacting the transmission network quickly escalated. We deployed field staff to critical substation sites in preparation for any required response, and recalled outage works to ensure reliability of the network.

Electricity demand for NSW peaked at 4.30pm at 14,181 MW. Several factors coincided at approximately 5pm to overload the NSW interconnectors with Qld and Vic including a forced outage of Tallawarra generation (408 MW), inability of Colongra units to start (600 MW) due to low gas pressure in the fuel supply lines, reduction in output from several thermal generators, and reduction of wind and solar PV generation (approx. 300 MW).[3]

A reduction in demand from Tomago Aluminium Company (290 MW) was necessary to restore the power system to a secure state. One of the smelter's three potlines was removed from service at 2.40pm, followed by further potline rotations at 4.55pm and 6.05pm. All potlines were back in service at 7.05pm. No other customer load was shed.

Fire risk

The Level 4 emergency continued into Saturday 11 February, due to fires in NSW. At 8.30am an explosive failure of a current voltage transformer (CVT) on the Muswellbrook to Liddell 330 kV transmission line feeder bay removed that transmission line from service. The line outage reduced

the capability of the Qld to NSW interconnector (QNI). Throughout the day, our staff managed the fire and removed damaged plant. Protection schemes were adjusted and the feeder was returned to service at 6.35pm.

A fire on property adjacent to our Orange 132 kV substation damaged one of the circuits to our Orange North 132 kV switching station, causing the line to trip at 2.22pm. The fire was brought under control after several hours, and a two-day replacement activity was required to remediate the damaged spans.

Storm activity moved in from the west, through the Wagga Wagga district and over the Snowy region. A major interruption at Wagga 330 kV substation occurred following a 330 kV busbar trip at 9.22pm. Trip and lock outs of the 330 kV line between Lower Tumut and Upper Tumut and the 132 kV line between Wagga North and Murrumburrah also occurred around the same time. The storm also caused damage to other assets including a collapsed timber structure and two steel towers.

The NSW power system withstood the extreme events of 10 and 11 February without interruption to supply beyond smelter potlines.

1.1.2 Ageing baseload power stations will close

Ageing baseload power stations will close in the next ten years and will need to be replaced by new generation. The major power stations in the NEM that will reach end of life by 2030 are listed in Table 1.1.

Table 1.1 – Power stations that will reach end of life by 2030

State	Power Station	Capacity	50 Year Life	Comment
NSW	Liddell Power Station	2,000 MW	2022	Retirement announced
	Vales Point Power Station	1,320 MW	2028	
Victoria	Yallourn Power Station	1,450 MW	2025 – 2032	
Queensland	Gladstone Power Station	1,680 MW	2026 – 2032	
	Total	**6,450 MW**		

3 AEMO System Event Report, Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Incident-report-NSW-10-February-2017.pdf. Viewed on 30 May 2017.

Over half the baseload capacity is expected to reach end of life over this period is in NSW.

There will be a shortfall of generation to meet maximum demand in NSW following the expected retirements, and after connection of generation to which TransGrid has made offers to connect. The projected shortfall is shown in Figure 1.3.

A shortfall in generation to meet demand will result in unserved energy. When the shortfall is limited to a small number of high-demand days, the unserved energy can be small. However, as the level of shortfall increases, the unserved energy increases significantly.

The projected unserved energy and cost to consumers is shown in Figure 1.4.

The shortfall can be met by additional new generation, greater interconnection, storage and demand management.

When replacing baseload generation with variable generation, around two to three times the installed capacity is required due to the variability of wind and solar resources. That is, around 10,000 MW of new renewable generation will be required over the next ten years to replace baseload capacity expected to reach end of life in NSW.

This is addressed in our plan to transition to the energy system of the future, shown in Figure 1.7 (page 17).

Figure 1.3 – Projected shortfall in maximum demand at 10% POE generation and demand conditions[4]

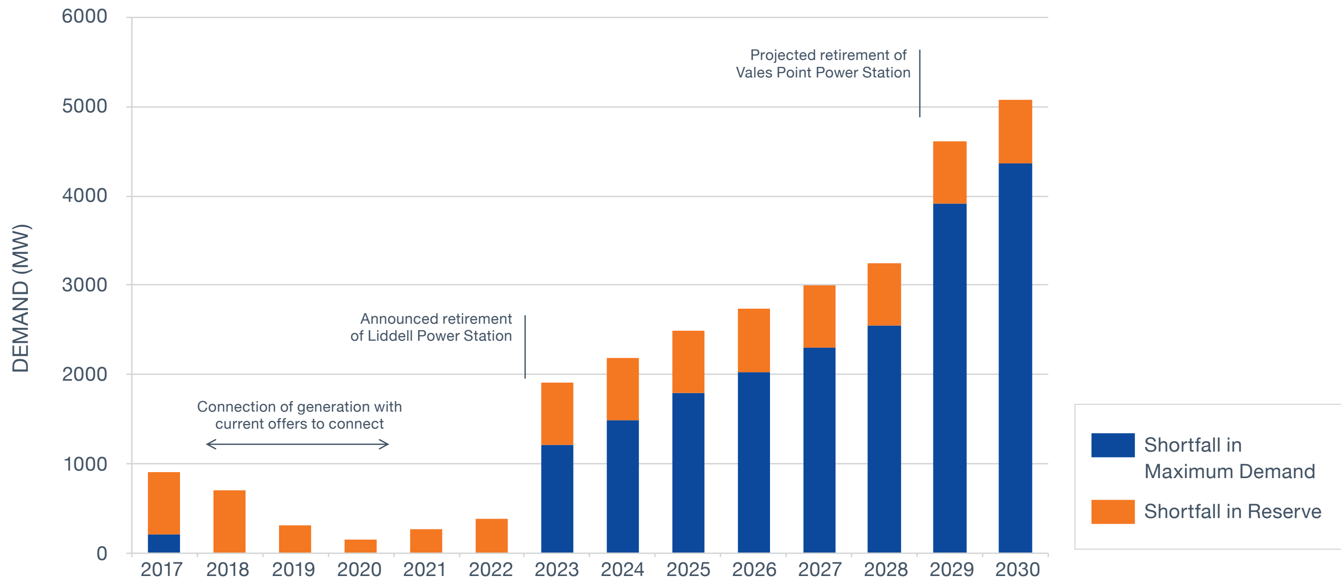
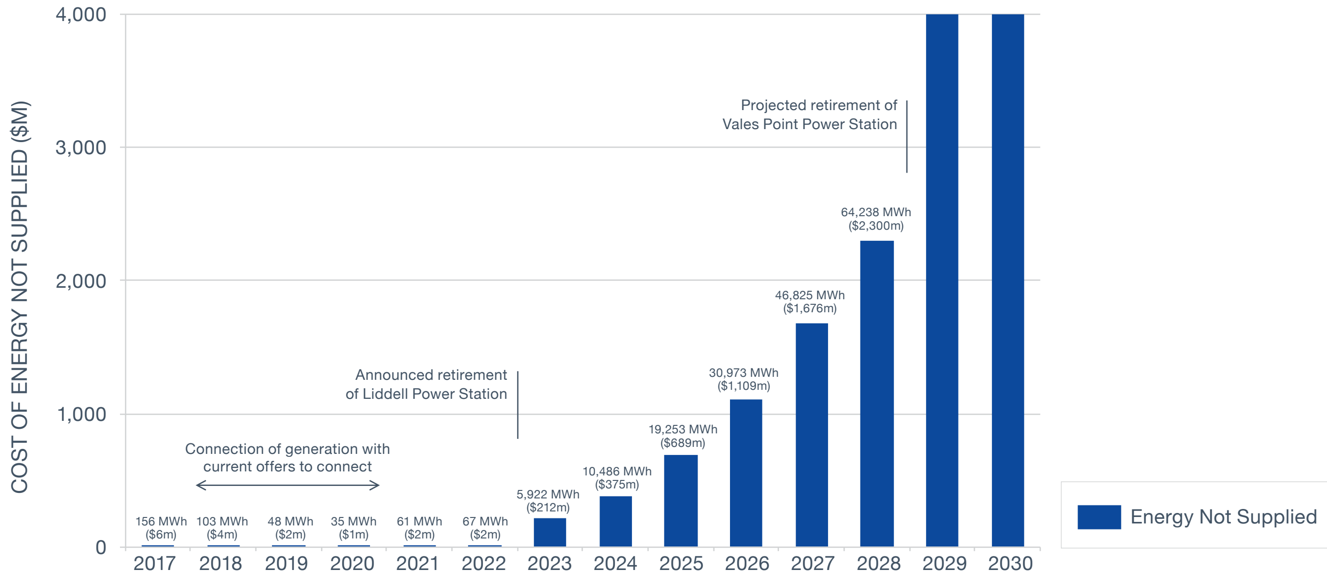


Figure 1.4 – Projected unserved energy and cost to consumers



4 The shortfall has been calculated as the 10% POE value based on a probabilistic assessment of actual generation capability and forecast demand. The actual generation capability takes into account historical coal-fired generation availability, gas generation availability and historical generation patterns of intermittent generation.

1.1.3 The best renewable resources are in areas with limited transmission capacity

The existing transmission networks in the eastern states of Australia were developed primarily to transport power from the Snowy Hydro Scheme and coalfields to major load centres. The design of the power system to locate power stations near their fuel sources and transport electricity was adopted as the least cost approach to the power system as a whole.

Australia has abundant high-quality natural resources for wind, solar and hydro generation.

- Wind resources are generally in coastal and eastern South Australia (SA), coastal and north-western Victoria (Vic) and the Southern Highlands, New England and Broken Hill areas in NSW.
- Solar resources are generally in northern SA, Queensland (Qld) and north-western NSW.
- Hydro resources are generally in the Snowy Mountains and Tasmania.

The wind and solar resources are mapped in Figure 1.5.

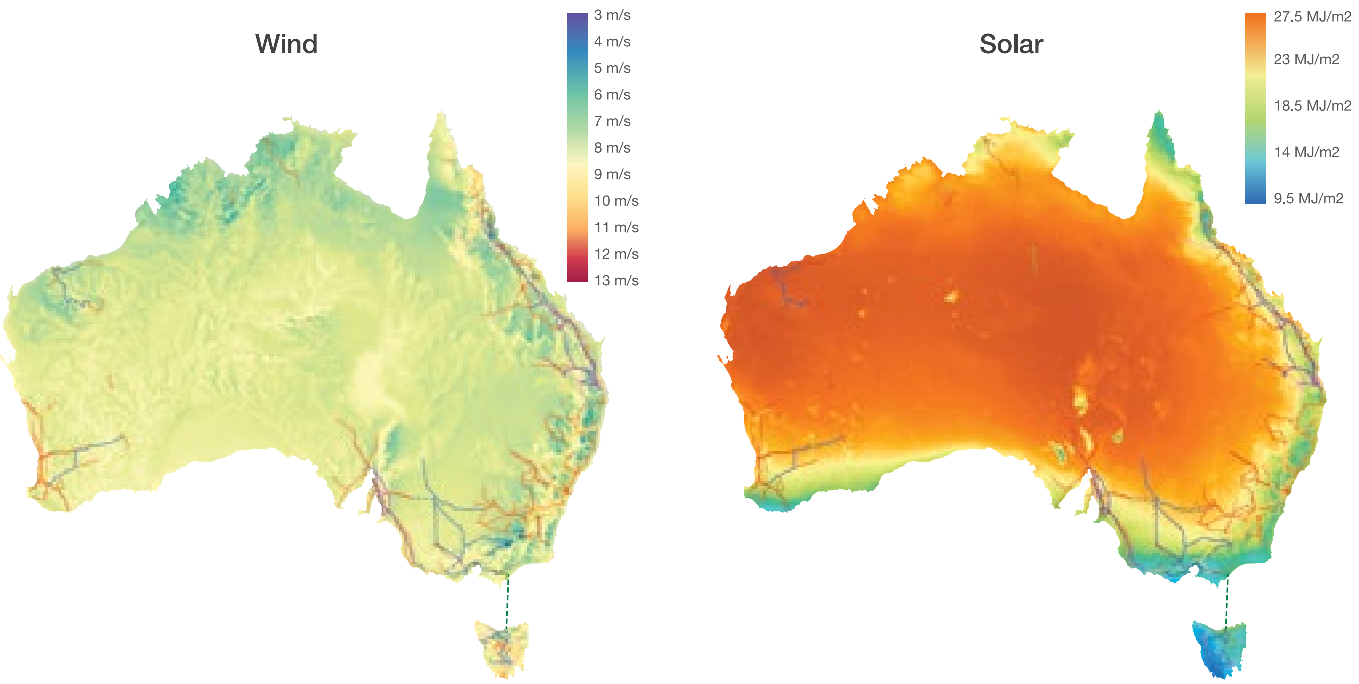
All current generation connection enquiries TransGrid has are for wind and solar generation. However, the best wind and solar resources are generally not near existing generation plant and are in areas with limited transmission capacity. The existing transmission network outside the Sydney – Wollongong – Newcastle – Hunter Valley area will reach its existing capacity to connect renewable generation by 2020.

To transition to the energy system of the future, we have identified ideal renewable energy precincts that:

- Provide commercially viable opportunities to establish renewable generation in high-quality resource areas
- Minimise the network extensions required to provide transmission capacity between the precincts and major load centres.

These precincts are set out in our plan to transition to the energy system of the future in Figure 1.7 (page 17).

Figure 1.5 – Wind and solar resources in Australia



1.1.4 The wholesale market price is unsustainably high and can be lowered through improved competition

Wholesale market prices across the NEM have increased significantly over the last five years. Since the retirement of Hazelwood Power Station in March 2017, wholesale prices have risen to a level significantly above the actual least-cost generation. The trend in wholesale market price is shown in Figure 1.6.

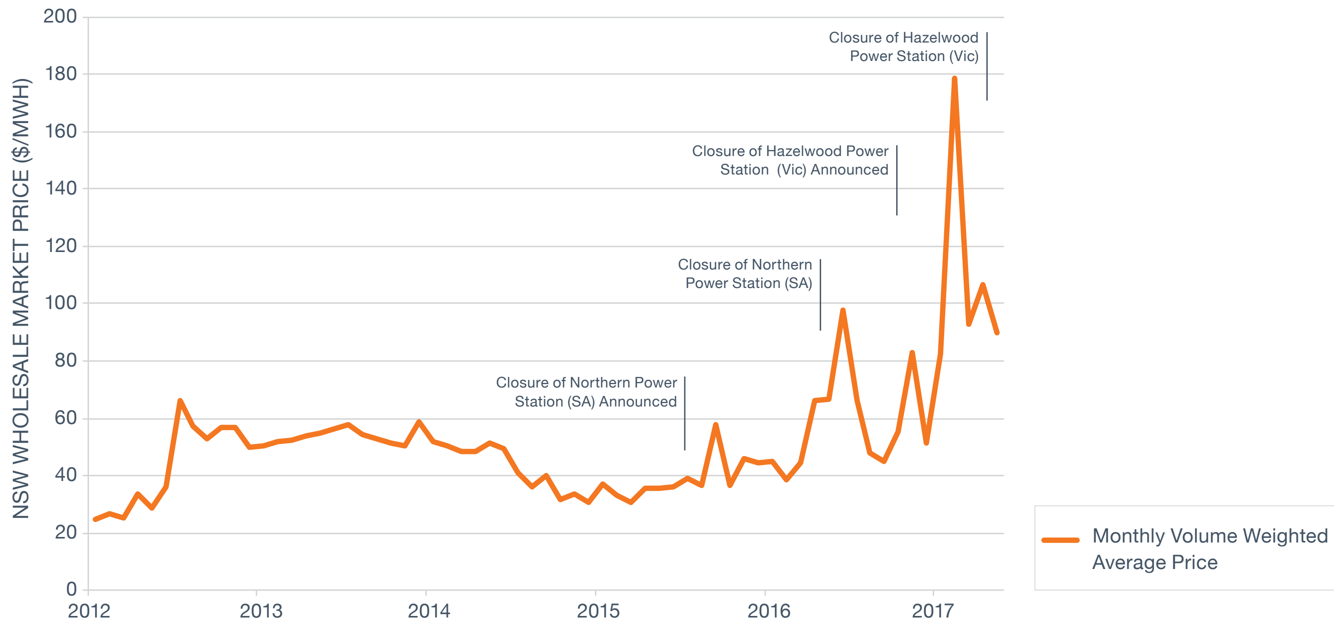
Like every market, a reduction in supply results in an increase in price.

Connection of new generation and greater interconnection will improve wholesale market competition and place downward pressure on generation costs. The connection of new generation will also place downward pressure on gas prices by reducing the amount of gas used for electricity generation.

Transmission networks form the platform on which the competitive wholesale market operates. When transmission capacity is sufficient, the least-cost generation is dispatched and sets the market price. When transmission capacity is insufficient, least-cost generation can be constrained and higher-cost generation used instead, resulting in a higher market price. This also reduces competition between generators, which results in higher prices.

There are opportunities to place downward pressure on wholesale market dispatch costs by developing transmission networks to connect new generation and provide greater interconnection.

Figure 1.6 – Wholesale market price



1.2 Plan to transition to the energy system of the future

We have developed a plan to transition to the energy system of the future and meet the objectives of energy security and reliability, affordability and reduced emissions.

The primary driver for the plan is to address the projected shortfall in generation to meet maximum demand and ensure sufficient reserve. The plan will open new renewable energy precincts, place downward pressure on the wholesale market price and maintain the resilience of the power system by sharing important ancillary services between all mainland states.

The plan comprises:

- New generation, which requires extension of the transmission network to renewable energy precincts
- Interconnection, which will share energy and ancillary services between states and place downward pressure on wholesale market prices
- Energy storage, which can be used to smooth the intermittency of variable renewable generation
- Demand management, which can shift energy use from peak times to other times.

The plan is shown in Figure 1.7.

The plan will cost around $15 per year on an average residential electricity bill, or around $3/MWh for large energy users. This is well below the recent excursion of wholesale market price above generation costs.

Early modelling indicates that the downward pressure on wholesale market price from improved competition in the wholesale market would outweigh the cost to deliver the plan.

The plan is consistent with the findings of AEMO's National Transmission Network Development Plan (NTNDP) 2016, that a combination of interconnector developments will deliver positive net benefits under a range of scenarios.

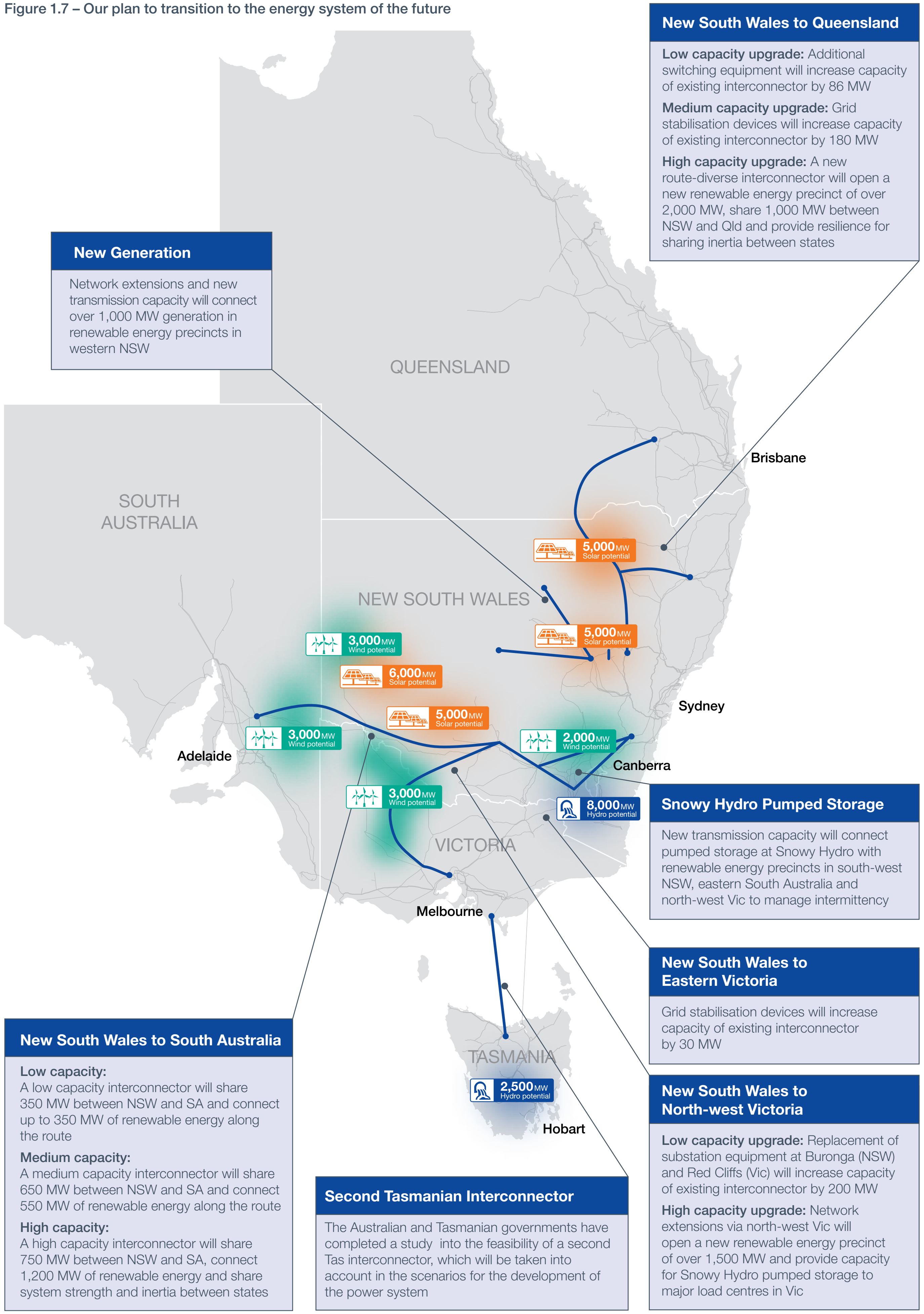
For major infrastructure projects, the lead time for planning and development approvals can take several years. Therefore, it is essential to initiate plans now to address the projected shortfall in generation in 2023.

The NSW to SA interconnector and NSW to north-west Vic network extension are options under consideration in regulatory consultations run by ElectraNet and AEMO respectively. We undertake joint planning with ElectraNet and AEMO and contribute to the regulatory consultations via submissions.

We will commence regulatory consultation in the second half of 2017 to determine the scope, staging and timing for the other developments that provide the least-cost development path for the plan across the power system as a whole.

This TAPR sets out transmission network developments to both maintain the performance of the existing network and underpin the transition to the energy system of the future.

Figure 1.7 – Our plan to transition to the energy system of the future

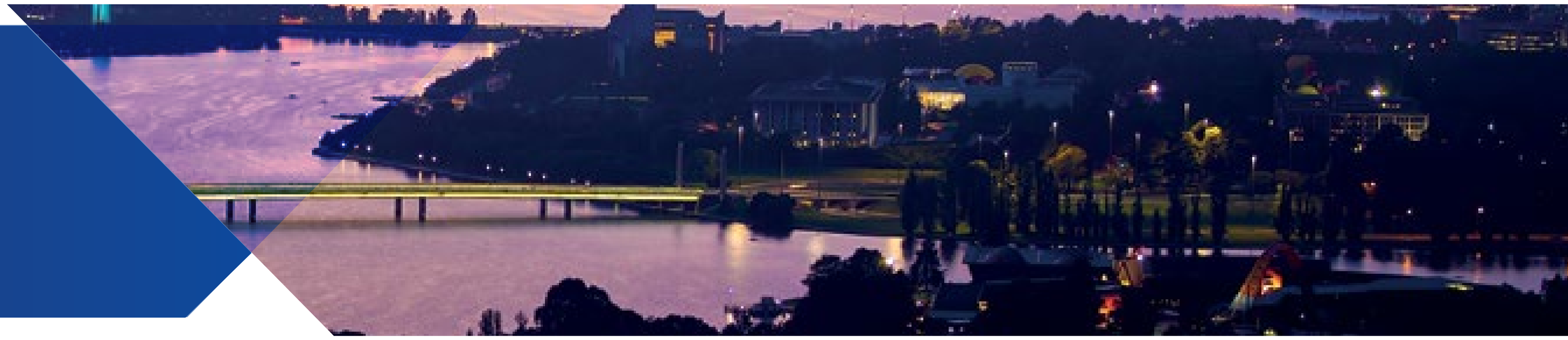


Chapter 2

Transmission network developments

- Our transmission network developments have been selected to transition to the energy system of the future, ensure network resilience and support emissions reduction targets at the least cost
- We have deferred network investment to supply Inner Sydney using demand management, following extensive consultation, in the largest deferral in the NEM to date
- We have outlined network developments to fulfil our reliability obligations in the ACT and at Molong, Mudgee and Broken Hill in NSW
- A portfolio of low-cost investments will provide connections to distribution networks to meet growing demand, improve network reliability and deliver economic benefits
- We plan to replace or refurbish transmission lines, substation assets and secondary systems to ensure network reliability.

2 Transmission network developments



Regulatory Investment Test for Transmission (RIT-T)

We recognise the importance of consulting with our stakeholders to plan, develop and maintain the network to ensure it meets expectations now and into the future. For significant augmentation investments, one of the avenues for consultation is the Regulatory Investment Test for Transmission (RIT-T). This process is designed to notify stakeholders of the investment need, network or non-network solutions, invite the public to submit delivery proposals and advise stakeholders of the selection process.

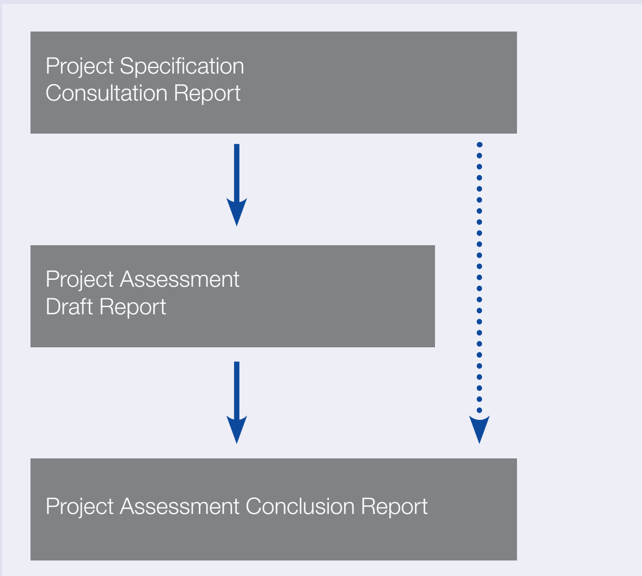
The RIT-T applies to transmission network investments where the cost of the most expensive credible option is greater than $6 million. It currently does not apply to investments relating to replacement, maintenance or urgent and unforeseen investments. Its application to replacement projects is currently the subject of a NER rule change, with a final determination expected shortly.

The RIT-T normally involves publication of three reports that highlight key milestones in the consultative process: the Project Specification Consultation Report (PSCR), the Project Assessment Draft Report (PADR) and the Project Assessment Conclusion Report (PACR). Minimum consultation periods following publication of the PSCR and PADR are specified and there is a requirement for the consideration of submissions received in response to these documents. The PADR can be omitted under certain circumstances provided for in the NER.

For the category of 'replacement transmission network asset' there is a requirement to disclose information in annual planning reports that includes a brief project description, commissioning date, other reasonable options considered, and the estimated cost.

No RIT-T consultations were completed since the publication of TAPR 2016. However, in October 2016 TransGrid and Ausgrid commenced consultation on the augmentations proposed for the Inner Sydney area. This consultation is known as Powering Sydney's Future and recommences a stakeholder engagement program which originally launched in 2014. A public forum was held in November 2016 to further engage with stakeholders, particularly those interested in providing non-network solutions.

Figure – RIT T consultation documents



2.1 Proposed major developments

There is significant development in generation in NSW and throughout the NEM. There are currently around 8,000 MW of new renewable generation connection proposals in NSW alone, with many seeking to connect to remote locations where the existing network capacity is limited. At the same time, large baseload generators are projected to retire, making the integration of new generation essential to maintain secure supply and provide sufficient competition in the wholesale market.

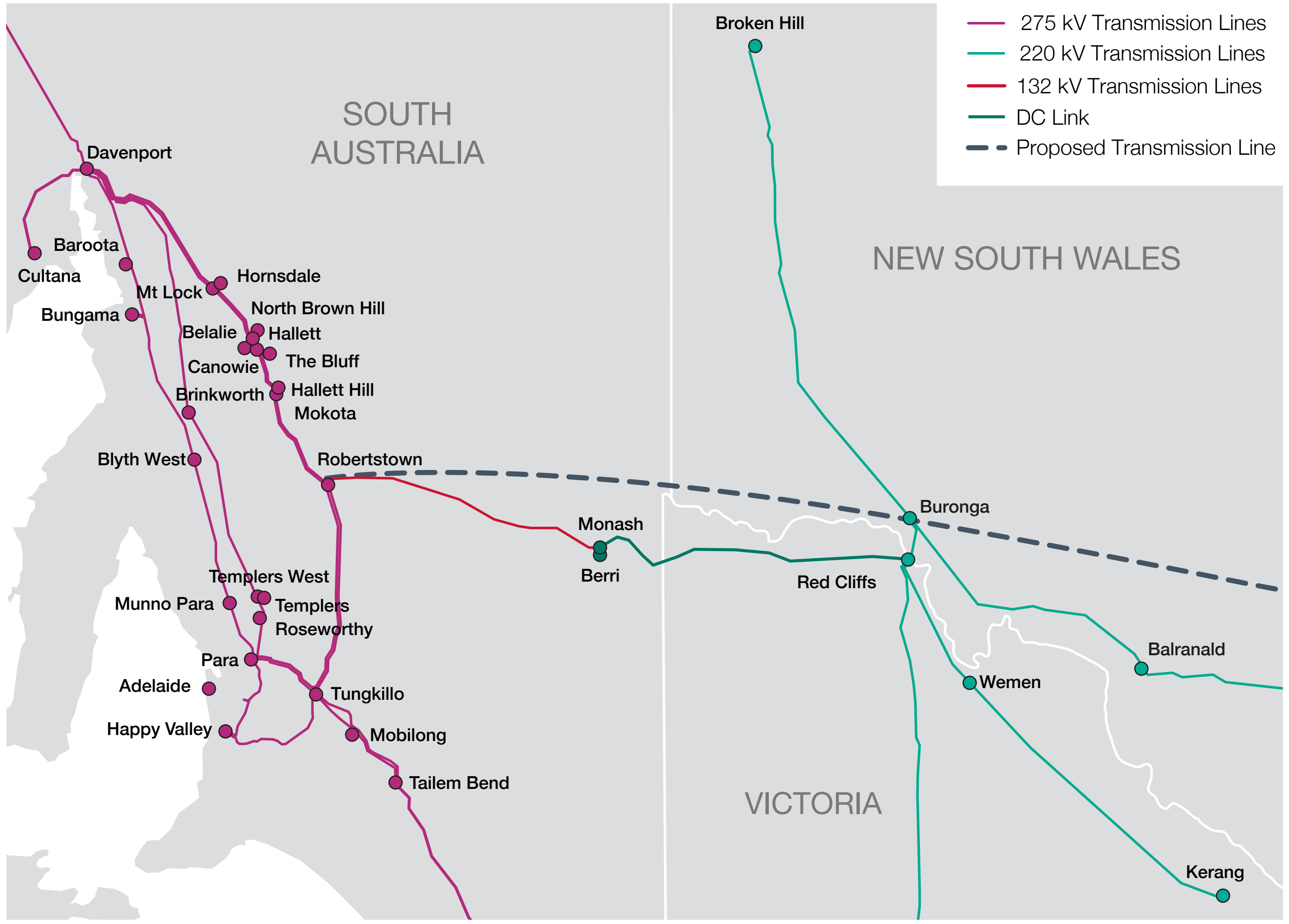
In our 2017 annual planning review, we identified possible network developments to address emerging constraints and support the connection of new renewable generation.

These projects include:

- Interconnection between NSW and SA
- Reinforcement of the Snowy to Sydney network
- Reinforcement of the southern NSW network
- Reinforcement of the central NSW network
- Reinforcement of the north-western NSW network (QNI upgrade).

2.1.1 NSW to SA Interconnector

Figure 2.1 – NSW to SA Interconnector possible option



South Australia has one of the highest penetrations of variable renewable generation in the world. This can lead to low reserve conditions and introduce challenges in managing system security.

Interconnection from NSW to SA, along with other options to address this risk, is being investigated in ElectraNet's South Australian Energy Transformation Project Specification and Consultation Report.[5]

This project is expected to support the export of renewable energy, address low reserve conditions and potential power system security issues in SA. There would be significant market benefits to the NEM through reduced energy cost by dispatch of lower cost generating plant, and increased competition of generators through reinforcing the south western NSW transmission network. This would establish a renewable generation precinct in NSW.

The interconnection options from NSW to SA include:

- New 275 kV or 330 kV AC transmission lines in single circuit, double circuit or staged configuration between Buronga 220 kV substation and Robertstown 275 kV substation, and potentially new or upgraded lines to Wagga 330 kV substation in NSW
- New HVDC link from Robertstown to Wagga Wagga or Mt Piper.

5 ElectraNet South Australian Energy Transformation Project Specification and Consultation Report, https://www.electranet.com.au/wp-content/uploads/resource/2016/11/20161107-Report-SouthAustralianEnergyTransformationPSCR-1.pdf, viewed on 17 May 2017

Construction is expected to take up to 24 months following planning approvals and property and easement acquisition.

A low capacity option can provide approximately 350 MW transfer capacity between NSW and SA by connecting Robertstown to Buronga with a single circuit 275 kV line and associated transformation at Buronga. This will provide the opportunity to connect up to 350 MW of new renewable energy along the route.

A medium capacity option can provide approximately 650 MW transfer capability, using a double circuit 275 kV connection between Robertstown and Buronga, combined with an upgrade of the existing X5 line between Buronga and Darlington Point and a new circuit in parallel with X5. This will provide the opportunity to connect approximately 550 MW renewable energy connections along the route.

A high capacity option can provide approximately 750 MW transfer capability, using a double circuit 330 kV connection between Robertstown and Darlington Point, and a new single circuit 330 kV line between Darlington Point and Wagga. This will provide the opportunity to connect approximately 1,200 MW renewable energy connections along the route.

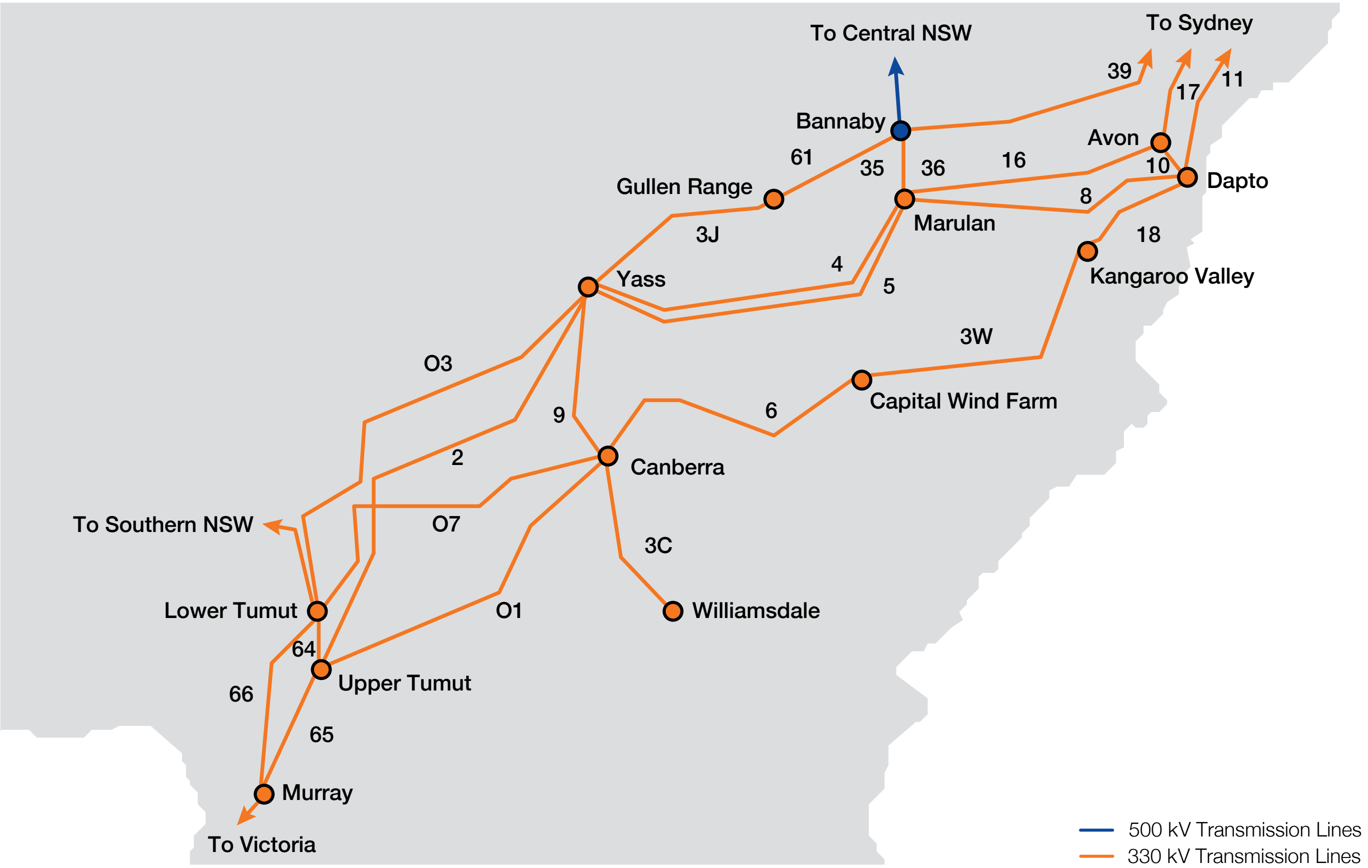
The NSW component is estimated to cost between $279 million and $1,084 million, depending on the preferred option.

Subject to the outcome of the South Australian Energy Transformation RIT-T, the project is expected to be delivered by November 2021.

2.1.2 Reinforcement of the Snowy to Sydney network

Figure 2.2 shows the existing network connections between Snowy and Sydney.

Figure 2.2 – Snowy to Sydney transmission network



There is an emerging risk of constraining northerly power flows from southern NSW. An upgrade to the southern network is proposed to facilitate:

- The connection of an additional 2,000 MW of generation resulting from an upgrade of the Snowy Hydro Scheme[6]
- The connection of over 350 MW of new renewable generation in the area
- An increase to the import capacity from Vic by more than 350 MW from expansion of southern interconnections.

Upgrading the southern network transfer capacity may include transmission line upgrades and generation runback (load curtailment) schemes, with low to high capacity options.

Upgrading 330 kV lines from Yass to Marulan (4 and 5), Canberra to Yass (9), Kangaroo Valley to Dapto (18), Sydney West to Bannaby (39), Gullen Range to Bannaby (61) and Yass to Gullen Range (3J) to meet a 120˚C design temperature is estimated to provide approximately 160 MW of increased transfer capacity.

6 Available at Snowy Hydro website http://www.snowyhydro.com.au/news/expanding-pumped-hydro-storage/, Viewed on 24 April 2017

Staged upgrades of 330 kV lines 39 and Canberra to Upper Tumut (O1) to a 120˚C design temperature, lines 4 and 5 to a design temperature of 100˚C, installing phase shifting transformers at Bannaby and Marulan substations, and construction of a new transmission line between Yass and Bannaby can provide an estimated 970 MW of increased transfer capacity.

Rebuilds of 330 kV lines 4, 5, 9, 18, 39, 61 and 3J to ratings between 1,300 MW and 2,100 MW can provide approximately 1,000 MW of additional transfer capacity.

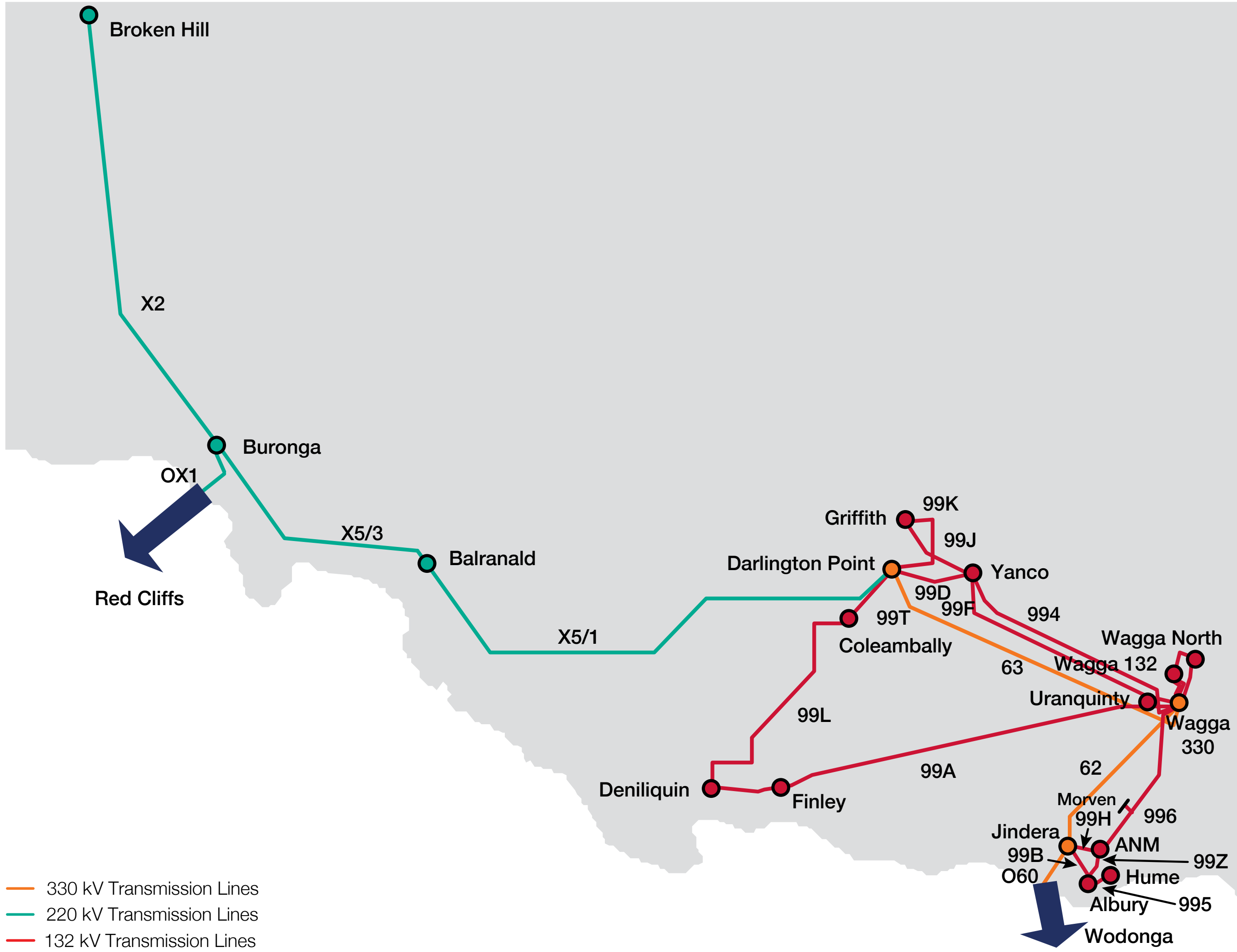
These upgrade options are estimated to deliver benefits through reduced generation costs and increased competition, with project options costing between $60 million and $397 million.

Subject to a decision to proceed with an expansion of the Snowy Hydro Scheme, this project is expected to be delivered by March 2022.

2.1.3 Reinforcement of the southern NSW network

Figure 2.3 shows the existing network in southern NSW west of the Snowy Mountains.

Figure 2.3 – South western NSW network



Southern NSW is a strong area of interest for the connection of new renewable generation. The southern NSW network was originally developed to service demand, and has limited capacity to integrate further generation in the area. Thermal capacity constraints between Broken Hill and Wagga in the 220 kV and 330 kV networks, and voltage control issues in the southern NSW network, can limit the connection of new generation or increases to imports from Vic.

We are investigating the most economic option that will facilitate an increased penetration of renewable generation in the south western NSW and north-western Vic networks. This will require greater transmission capacity in these areas, requiring network augmentations to relieve the constraints and realise market benefits.

A low capacity upgrade option could provide approximately 300 MVA of increased network capacity. This would involve uprating the 220 kV lines between Buronga and Darlington Point to single circuit 275 kV, uprating the Darlington Point to Wagga 330 kV conductor capacity, and installation of additional voltage support in the area.

A medium capacity upgrade option could provide approximately 820 MVA of increased network capacity. This would involve uprating the existing 220 kV lines between Buronga and Darlington Point to single circuit 275 kV, building a new 275 kV single circuit line between Buronga, Balranald and Darlington Point, building a new single circuit 330 kV line between Darlington Point and Wagga, and installation of additional voltage support in the area.

These works are estimated to cost between $89 million and $473 million and may be co-ordinated with the development of a NSW to SA interconnector.

High capacity network extensions in southern NSW and north western Vic would open a new renewable energy precinct of 2,000 MW across both states, and provide capacity for Snowy Hydro pumped storage to major load centres in Vic.

The NSW component is estimated to cost between $200 million and $300 million, depending on the capacity.

Subject to evaluation of economic benefits, a project is expected to be initiated with the timing determined by the economic evaluation. The project may be staged if required to maximise economic benefits.

Buronga upgrade

We have initiated a low-cost upgrade to increase the capacity of the Buronga to Red Cliffs 220 kV line from 265 MVA to 417 MVA by replacing wave traps at Buronga with higher rated units.

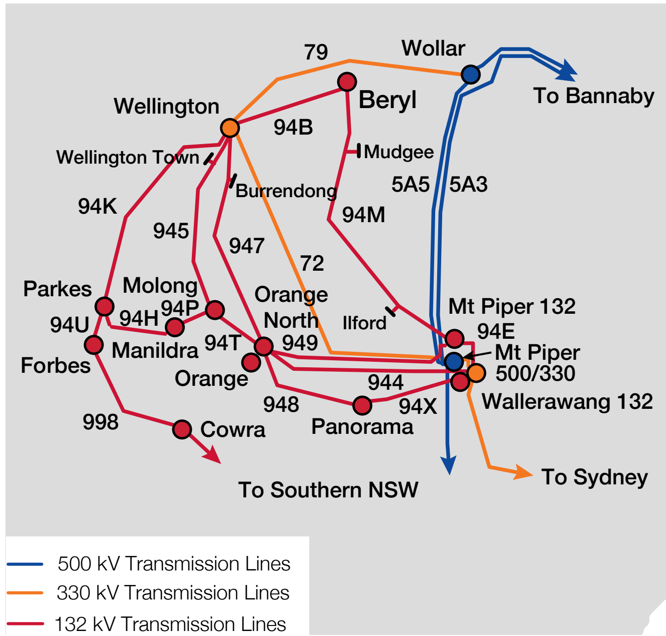
Increasing the line capacity avoids curtailment of renewable generation in the area, accommodates higher transfers between NSW to Vic and across Murraylink, and will assist in meeting Victorian summer maximum demand.

Equipment replacement at Red Cliffs is also required and we have initiated a project with AEMO and AusNet Services to perform these works.

2.1.4 Reinforcement of central NSW

Figure 2.4 shows the network in central NSW.

Figure 2.4 – Wellington to Mount Piper area network



The network in central NSW currently limits the connection of large loads or generation due to voltage and thermal limitations. Outages of elements in the network risk significantly limiting the capability to connect generation, mostly in the 132 kV network.

As there have been significant new generation connection interests in areas with abundant renewable energy resources, a coordinated augmentation in securing connections to the 132 kV network between Wellington and Mount Piper substations may deliver benefits. Currently, the existing rating of the 132 kV network between Wellington and Mount Piper is only 134 MVA, and upgrades of 94B Wellington to Beryl and 94M Beryl to Mount Piper 132 kV lines may be required to support higher levels of generation.

The following options to address emerging voltage stability issues have been considered:

- Establish a 330/132 kV substation in close proximity to the Beryl 132/66 kV substation by connecting into the Wellington to Wollar 330 kV line
- Upgrade 94M line by rebuilding as double circuit
- Upgrade 94B line by rebuilding as double circuit
- Install dynamic reactive support to mitigate voltage instability in the Beryl area.

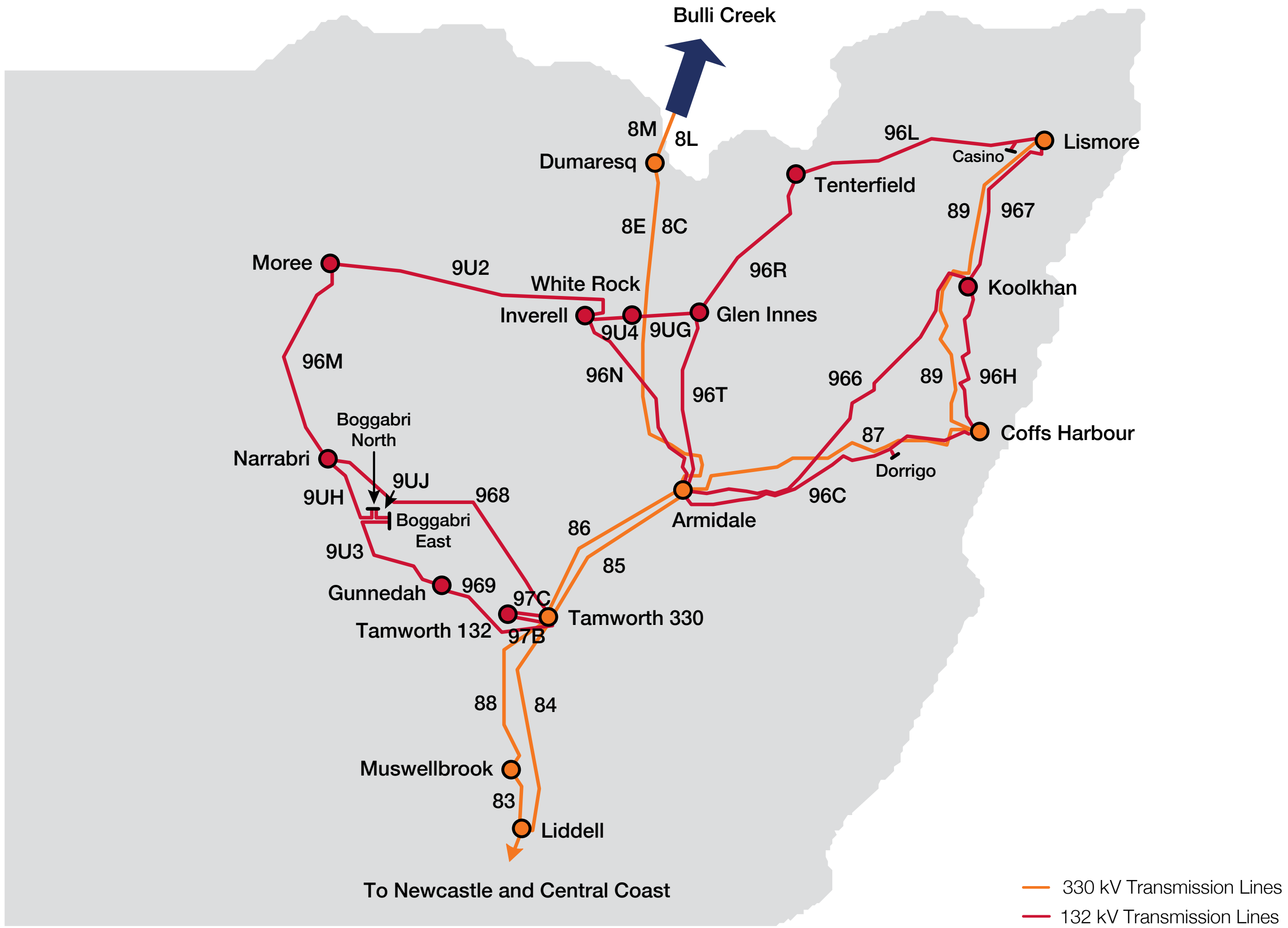
In addition, the substation and transmission line upgrade options will facilitate the connection of new renewable generation beyond the capacity of the existing network.

Subject to evaluation of economic benefits, a project is expected to be initiated with the timing determined by the economic evaluation. The project may be staged if required to maximise economic benefits.

2.1.5 Reinforcement of the north-western NSW network (QNI upgrade)

Figure 2.5 shows the transmission network in northern NSW.

Figure 2.5 – Northern NSW network



The connection of further new generation in northern NSW could be constrained due to transmission system limitations, particularly in the Liddell to Armidale corridor.

Increasing the transmission capacity north of Liddell and/or transfer capacity of QNI is expected to deliver generation cost savings and increased competition by allowing transmission of electricity from Qld and renewable energy from northern NSW.

A low capacity upgrade could be achieved by turning both transmission lines from Armidale to Dumaresq into a switching station mid-way between these substations, providing 20 MW additional transfer capacity. A further upgrade could be achieved by turning both transmission lines from Dumaresq to Bulli Creek (Qld) into a new switching station mid-way between these substations, with both upgrades together providing a total of 86 MW additional transfer capacity.

A medium capacity upgrade option that improves export from NSW to Qld by 300 MW and import by 50 MW can be achieved by installation of a second SVC at Armidale, along with upgrades to 330 kV lines between Liddell and Tamworth (83, 84 and 88) to 120°C design temperature.

Another medium capacity upgrade option that increases export from NSW to Qld by 460 MW and import by 190 MW can be achieved through installation of SVCs at Dumaresq and Tamworth, upgrades to 330 kV lines 83, 84 and 88 to 120°C design temperature, and installation of capacitor banks at Tamworth, Armidale and Dumaresq substations.

These medium capacity upgrade options are estimated to cost between $63 million and $142 million.

A high capacity upgrade via a new route diverse interconnector will open a new renewable energy precinct of over 2,000 MW, share 1,000 MW between NSW and Qld, and provide resilience for sharing inertia between the states.

Subject to evaluation of economic benefits, a project is expected to be initiated with the timing determined by the economic evaluation. The project may be staged if required to maximise economic benefits.

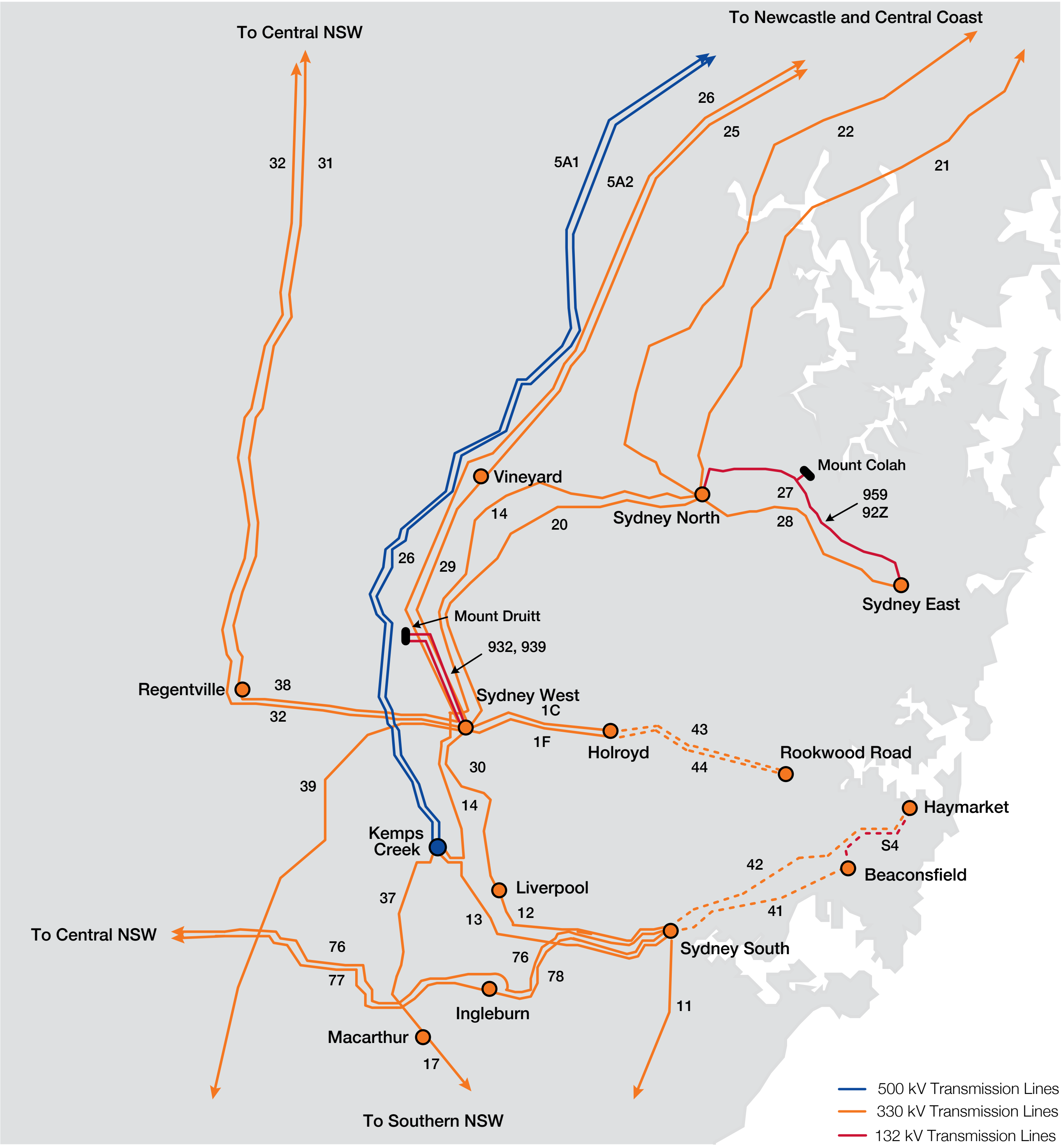
2.2 Subsystem developments

2.2.1 Greater Sydney

The Inner Sydney area includes the Central Business District (CBD) which is a hub for economic activity, major transport infrastructure, industry and tourism. Increasingly, it is also home to a growing number of people attracted to shorter commutes, harbour views and the many benefits that city living has to offer. The Inner Sydney area provides a base for a number of major infrastructure and transport networks including road tunnels, airports, ports, train networks and data centres. These entities require a high level of electricity reliability and security to maintain services required for Sydney to operate as a major international city with many of these entities having large development or expansion plans under construction or scheduled for the near term.

Figure 2.6 shows the Greater Sydney network, including transmission supplies to the area.

Figure 2.6 – Greater Sydney network



Powering Sydney's Future

Together with Ausgrid, we have assessed that the future value of expected unserved energy[7] and other costs to electricity consumers associated with oil-filled cables exceeds the cost of investment to avoid the expected unserved energy and other costs.

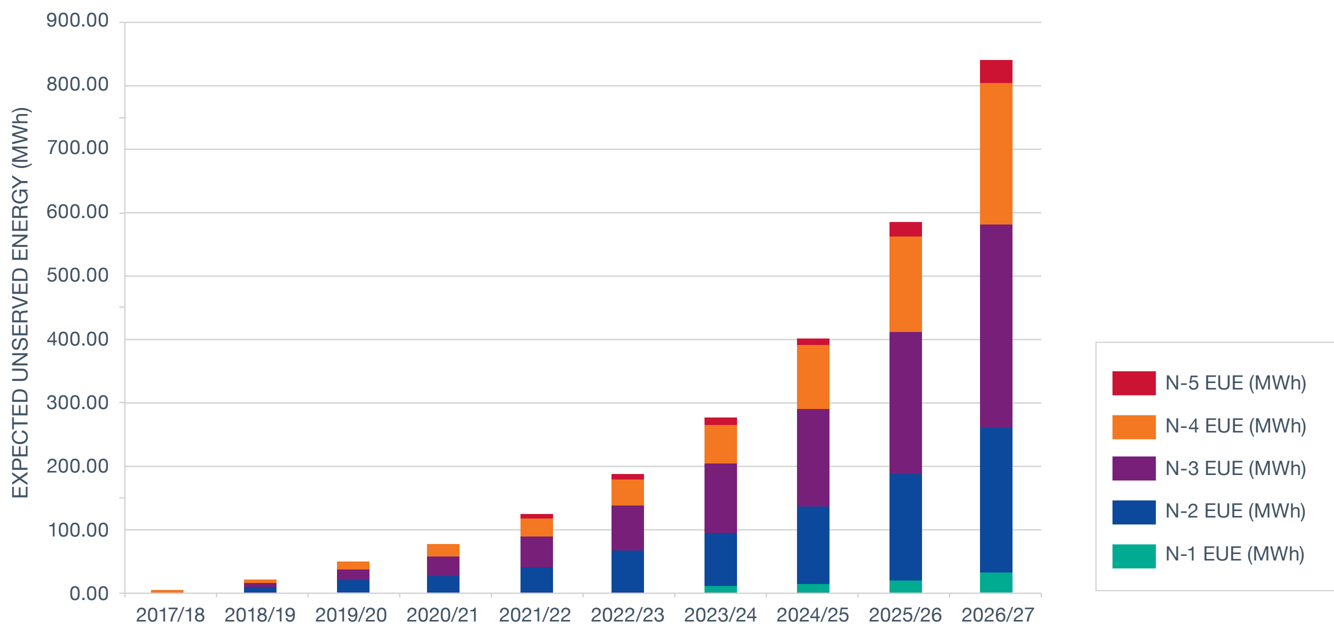
The expected date of this occurring is 2021/22. The following are expected to increase the amount of unserved energy in the future, as well as imposing a range of other costs on consumers:

- The deteriorating condition of ageing oil-filled cables in the existing network, the derating of our 330 kV cable 41 (in 2011 and 2016) and the derating of a number of 132 kV cables by Ausgrid (beginning in 2012)
- Ausgrid's planned retirement of three 132 kV oil-filled cables in Inner Sydney in the next two years
- The age-related deteriorating condition of a further eight 132 kV oil-filled Ausgrid cables in the Inner Sydney area
- Increases in customer demand due to renewed economic activity within Inner Sydney.

The ageing oil-filled cables are at a stage in their service life where they have an increasing likelihood of failure. The increased probability of failure and lengthy cable repair time increases the likelihood of multiple contingency events, which may result in unserved energy to consumers.

Working with Ausgrid, we have undertaken analysis as part of the RIT-T that shows an increasing risk to reliability for the Inner Sydney area (Figure 2.7) due to an increase in the probability of cable failure. In particular, if a forced outage of two or more significant transmission elements occurred, the impact of load curtailment would be significant.

Figure 2.7 – Forecast of expected unserved energy in Inner Sydney, 2017/18 to 2026/27



Further details of the identified need can be found in the Project Specification Consultation Report (PSCR).

The Project Assessment Draft Report (PADR) for the Powering Sydney's Future RIT-T[8] has identified demand management from 2018/29 to 2021/22, installation of two new 330 kV cables from Rookwood Road to Beaconsfield by 2022/23 and continued operation of cable 41 at 330 kV with a rating of 426 MVA as the preferred option to ad dress the increasing risk to reliability for Inner Sydney.

This option maximises the network transfer capability by utilising the remaining service life of cable 41 and minimises the impact to the local community by delivering two cables in one stage. The option will cost approximately $352 million and delivers positive net benefits.

In determining the preferred option, together with Ausgrid we considered various non-network solutions to address the risk of supply disruption. During the RIT-T process, we assessed eleven non-network proposals employing a range of technologies which included:

- Embedded generation – diesel generator and gas co/tri-generation
- Demand response
- Battery storage, which injects power into the grid when required
- Solar PV panels.

A summary of submissions received in response to the PSCR and an assessment of all credible network and non-network options were published in the PADR in May 2017. Discussions with potential providers of non-network solutions will advance in parallel with the third and final stage of the RIT-T process, the Project Assessment Conclusion Report (PACR), expected to be published in August 2017.

Continued analysis using updated forecasts has shown the expected unserved energy increasing beyond these identified levels; however, the proposed solutions will meet the need.

7 'Expected unserved energy' is defined in TransGrid's Electricity Transmission Reliability Standards as 'the expected amount of energy that cannot be supplied, taking into account the probability of supply outages attributable to credible contingency events, expected outage duration, and forecast load.'

8 TransGrid. Powering Sydney's Future Project Assessment Draft Report, Available at https://www.transgrid.com.au/what-we-do/projects/regulatory-investment-tests/Documents/Powering%20Sydney%27s%20Future%20-%20RIT-T%20PADR.pdf. Viewed on 17 May 2017.

Case study 2:

Powering Sydney's Future forum

Over the last five years, we have taken significant steps to improve our stakeholder engagement program and integrate stakeholder feedback into our planning cycles. In November 2016, we hosted a technical workshop with industry stakeholders and non-network proponents to discuss potential options to address an expected constraint to the Inner Sydney area.

The RIT-T process is designed to inform stakeholders of the energy supply need and proposed options (both network and non-network) to address it, test the market for alternative and more efficient solutions, and explain to stakeholders the basis on which the preferred option has been selected.

We received feedback that there is a perception that transmission networks don't actually pursue non-network alternatives and that the process of a RIT-T can be seen as a 'tick box' exercise.

In response, TransGrid hosted a technical workshop that invited stakeholders and non-network proponents to discuss potential options and ensure they had enough information to make an EOI submission to the RIT-T. Over 90 stakeholders attended the workshop, and more than 25 indicated that they would like to receive further information about submitting a non-network EOI.

The objectives of the workshop were to:

- Inform stakeholders about new information in relation to the context and drivers of the Powering Sydney's Future project
- Continue the conversation with stakeholders who were involved in earlier consultation on the future supply to Inner Sydney in 2014
- Seek initial views and discuss potential network and non-network solutions.

The full-day workshop included presentations given by senior TransGrid, Ausgrid and GHD representatives outlining the project background, Ausgrid drivers such as demand forecasting and ageing assets, TransGrid drivers such as the condition of cable 41 and reliability, the criteria measured against for the different route selections, and the possibility of non-network options such as batteries and standby generators.

Stakeholders were given an opportunity to raise their issues, concerns or comments about Powering Sydney's Future through four activities implemented at the workshop.

Dedicated time was allocated to a discussion on non-network solutions. This was an opportunity for all stakeholders to ask questions or share their views on possible non-network options. In particular, the discussion considered:

- Potential non-network ideas
- Challenges and barriers
- Incentives.

Overall, stakeholders were interested in non-network solutions such as embedded generation, energy power storage, voluntary curtailment of load, energy efficiency and solar options. There was an appetite for more information on non-network solutions that have had a credible impact elsewhere, more clarification of the target, incentives and schemes to be involved in.

Fast Frequency Response

As part of the PADR for Powering Sydney's Future, a large-scale battery at Beaconsfield was considered as one element of the demand management solution.

The feasibility of a battery up to 40 MWh for demand response for summer 2021/22 is being considered as part of the network support package for deferring the preferred network option by one year, if it proves to be technically and economically viable. A large-scale energy storage device is likely to readily support multiple value streams, including fast frequency response.

Initially, we propose to install a 5 MW, 5 MWh battery at Beaconsfield by December 2018 as a pilot for provision of fast frequency response. This will enable us to understand its performance during disturbances over a wide range of system conditions and validate its characteristic in system stability models. The estimated cost is $5.5 million. The battery can then be expanded to a 10 MW, 40 MWh battery for summer 2021/22 as required for Powering Sydney's Future.

The installation of a pilot for fast frequency response is consistent with the AEMC's recommendations in its System Security Market Frameworks Review Final Report. The report recommends an obligation on TNSPs to provide minimum levels of inertia, or alternative equivalent services, to allow the power system to be maintained in a secure operating state. We note that if a grid connected storage solution is shared with other value streams, we will need to subject the corresponding value streams to the appropriate RIT-T (for prescribed uses) and ring fencing guidelines (for non-prescribed uses) as required under the Rules.

Planned projects

We have planned several substation augmentation projects to address forecast load growth and connect new distribution zone substations. We have also identified low-cost investment opportunities that may deliver economic benefits or improve system security through:

- Improvements in power quality, eg voltage unbalance
- Reduction in load restoration times
- Improvements in network resilience during extreme weather events
- Improvements in operational efficiencies
- Improvements in our ability to respond during grid emergencies.

These projects are shown in Table 2.1.

Table 2.1 – Planned projects in Greater Sydney

Project description	Year planned	Total cost ($million June 18)	Purpose and possible other options	Project justification
Installation of one 66 kV switchbay at Macarthur 330/132/66 kV substation	Nov 2020	1.3	For connection of Endeavour Energy's planned Menangle Park Zone Substation to meet load growth in a new housing development at Menangle Park	Load driven
Installation of one 330/66 kV transformer at Macarthur 330/132/66 kV substation	Nov 2022	8.6	To address a capacity constraint in the Nepean area arising from 2018 Load transfers in the Endeavour Energy network will be enacted to defer the need date to after 2020 To defer the need, demand management in the Nepean area of 125 MW in the first year of the constraint, increasing by 12-13 MW each year would be necessary. This is not expected to be available at the required level Other options would be to increase the transfer capacity to TransGrid's Ingleburn 330/132 kV substation or increase the capacity of Endeavour Energy's Nepean substation. These options are not as economical for customers and have not be pursued	Load driven
Installation of one 66 kV switchbay at Macarthur 330/132/66 kV substation	Jun 2023	1.4	For connection of Endeavour Energy's planned Mt Gilead Zone Substation to meet load growth in a new housing development at Mt Gilead	Load driven
Installation of one 132 kV switchbay at Vineyard 330/132 kV substation	Jun 2023	1.6	For connection of Endeavour Energy's planned Box Hill Zone Substation, to supply a new urban development at Box Hill	Load driven
Construction of a new 132 kV switching station at TransGrid's Kemps Creek 500/330 kV substation	Jun 2024	10.5	A new Kemps Creek 132 kV busbar will initially be built at TransGrid's Kemps Creek substation as a switching station. It can be expanded to become a 330/132 kV bulk supply point in the future to support load growth in the region, including the new Western Sydney Airport and new residential and commercial precincts	Load driven
Load shedding scheme for mitigating risks of multiple 330 kV cable outages	By Jun 2023	0.2	This project implements a SCADA control scheme to selectively shed low-priority Inner Sydney loads following a contingent trip of both 330 kV cables 41 and 42, to reduce the amount of load at risk.[9]	Economic benefit
Eraring to Kemps Creek 500 kV smart grid controls	By Jun 2023	2.6	Installation of a special protection scheme to protect against trips of both of the 500 kV lines from Eraring to Kemps Creek For a double circuit trip, the scheme will run back generation and load to avoid cascading outages and further loss of load in the Greater Sydney area	Economic benefit
Sydney northwest 330 kV smart grid controls	By Jun 2023	3.0	Installation of a special protection scheme to protect against trips of two or more of the following 330 kV lines: Sydney North to Tuggerah (21), Sydney North to Vales Point (22), Vineyard to Eraring (25), Sydney West to Tuggerah (26) and Munmorah to Tuggerah (2M) For multiple circuit trips, the scheme will run back generation and load to avoid cascading outages and further loss of load in the network	Economic benefit
Sydney South 330 kV smart grid controls	By Jun 2023	1.8	Installation of a special protection scheme to protect against trips of two or more of the 330 kV lines from Sydney South substation For multiple circuit trips, the scheme will run back generation and load to avoid cascading outages and further loss of load in the network	Economic benefit
Bayswater to Sydney West 330 kV smart grid controls	By Jun 2023	2.8	Installation of a special protection scheme to protect against trips of two or more of the following 330 kV lines: Bayswater to Regentville (31), Bayswater to Sydney West (32) and Regentville to Sydney West (38) For multiple circuit trips, the scheme will run back generation and load to avoid cascading outages and further loss of load in the Greater Sydney area	Economic benefit

9 This project is not related to Powering Sydney's Future, and the two projects meet separate needs.

Ongoing projects

Beaconsfield 330/132 kV substation was rebuilt to address end-of-life condition issues and meet a requirement to connect additional 132 kV Ausgrid feeders into the site.

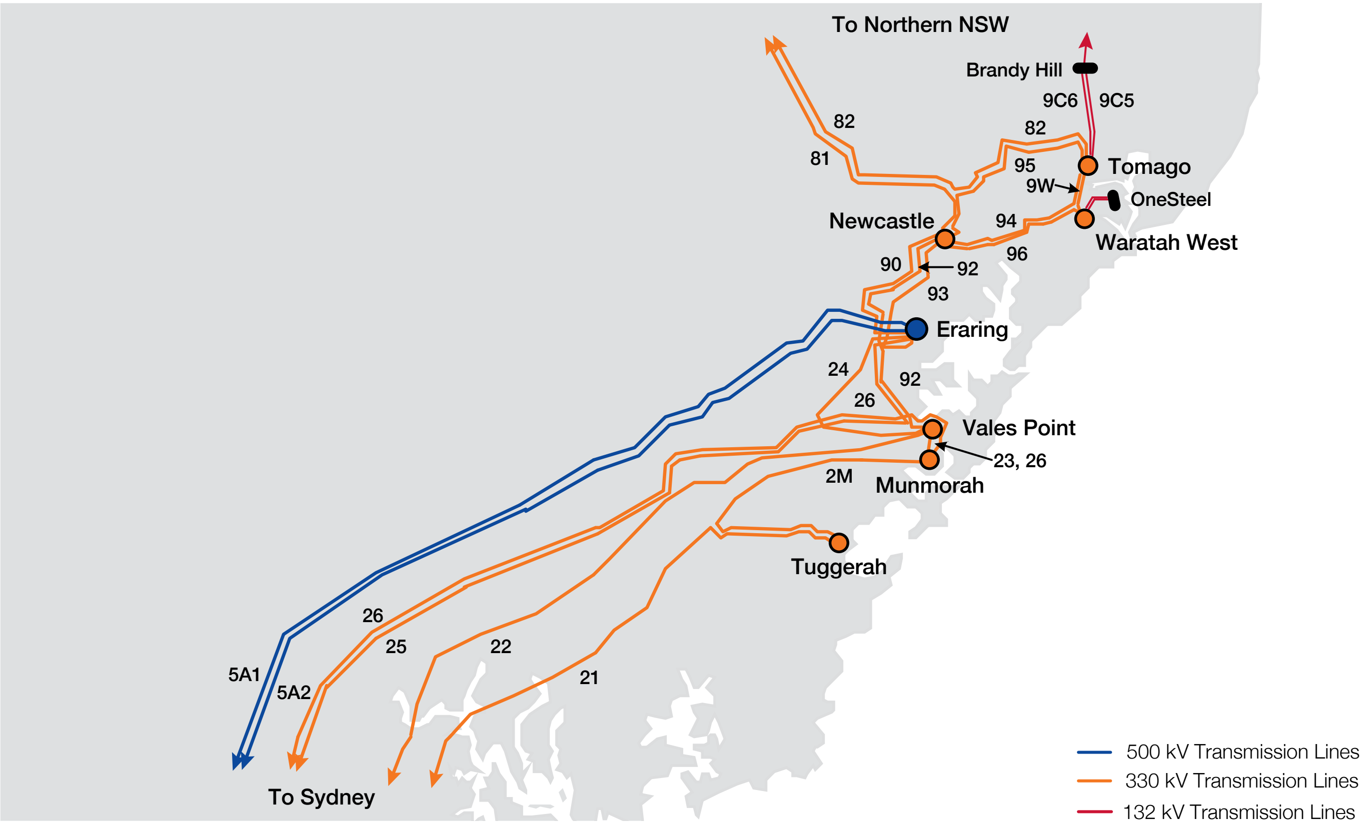
Due to space limitations, two new 132 kV GIS buildings either side of the existing substation site were built and the old site required decommissioning. The remaining works to cutover cables and decommission the end-of-life assets are expected to be completed by August 2018.

Completed projects

The replacement of Beaconsfield No.1 Reactor to provide voltage support to the Sydney network was completed in August 2016.

2.2.2 Newcastle and Central Coast

Figure 2.8 – Newcastle and Central Coast network



Planned projects

We have planned one substation augmentation project to improve the reliability of 330 kV supply at our Tomago 330/132 kV substation. This project is shown in Table 2.2.

Ongoing projects

Vales Point substation forms an integral part of the 330 kV transmission system on the Central Coast, connecting Vales Point Power Station and supplying Ausgrid's 132 kV network through two 200 MVA transformers.

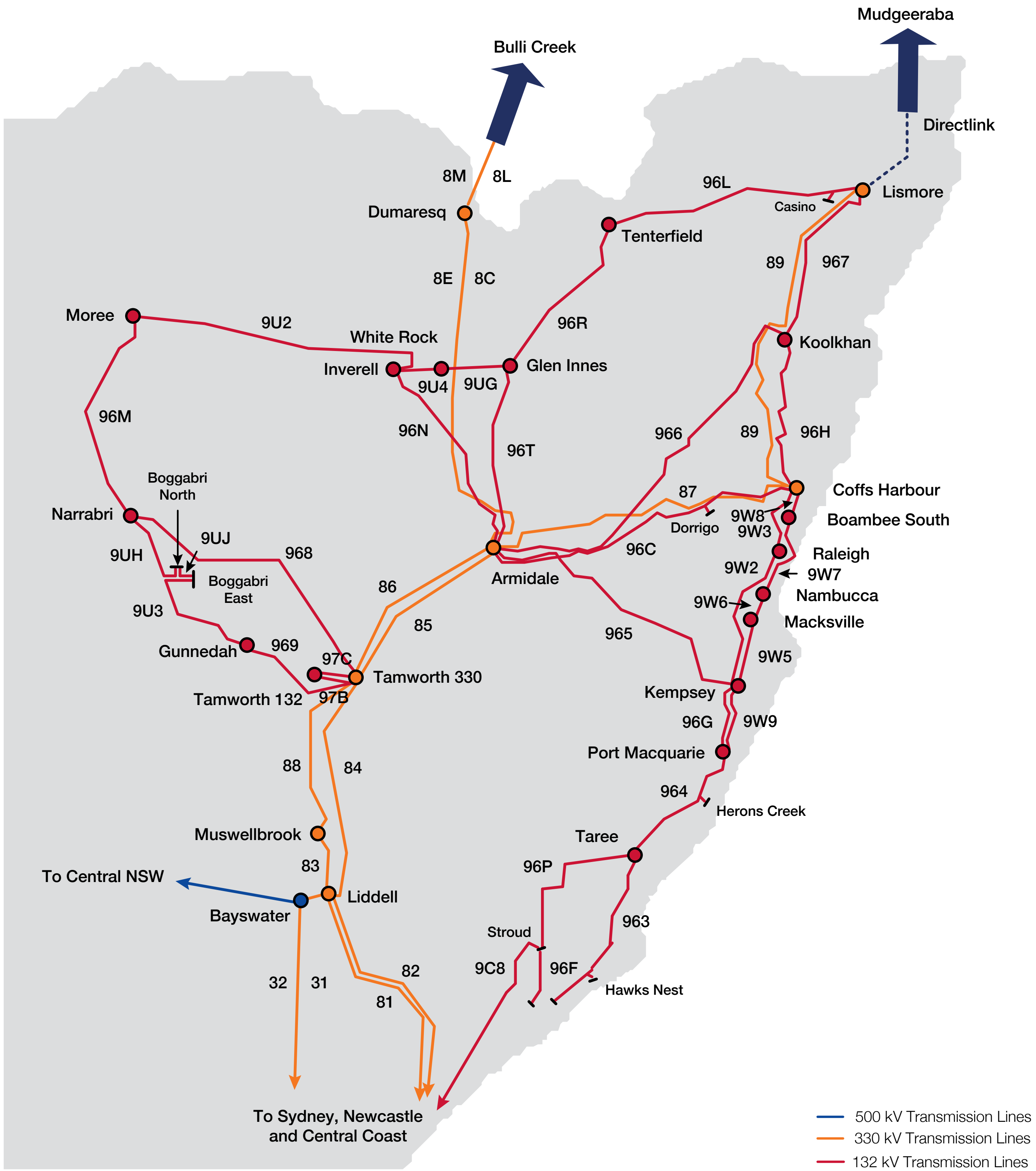
Ongoing asset replacement works at Vales Point substation are expected to be completed in 2018. These works address the risk of failure from assets that are reaching end-of-life condition.

Table 2.2 – Planned projects in Newcastle and the Central Coast

Project description	Planned date	Total cost ($million June 18)	Purpose and possible other options	Project justification
Upgrade of two single busbar connected power transformers to a double busbar connected arrangement	By Jun 2023	5.2	Improve reliability at Tomago 330/132 kV substation	Economic benefit

2.2.3 Northern NSW

Figure 2.9 – Northern NSW network



Planned projects

Voltage and thermal constraints may arise in the Narrabri and Gunnedah areas leading to an emerging risk to reliability if large mining or gas developments proceed in the area. These developments are shown in Table 2.3.

Other planned minor projects that improve security of supply to customers and provide economic benefits are also shown in Table 2.3 on page 32.

Table 2.3 – Planned projects in northern NSW

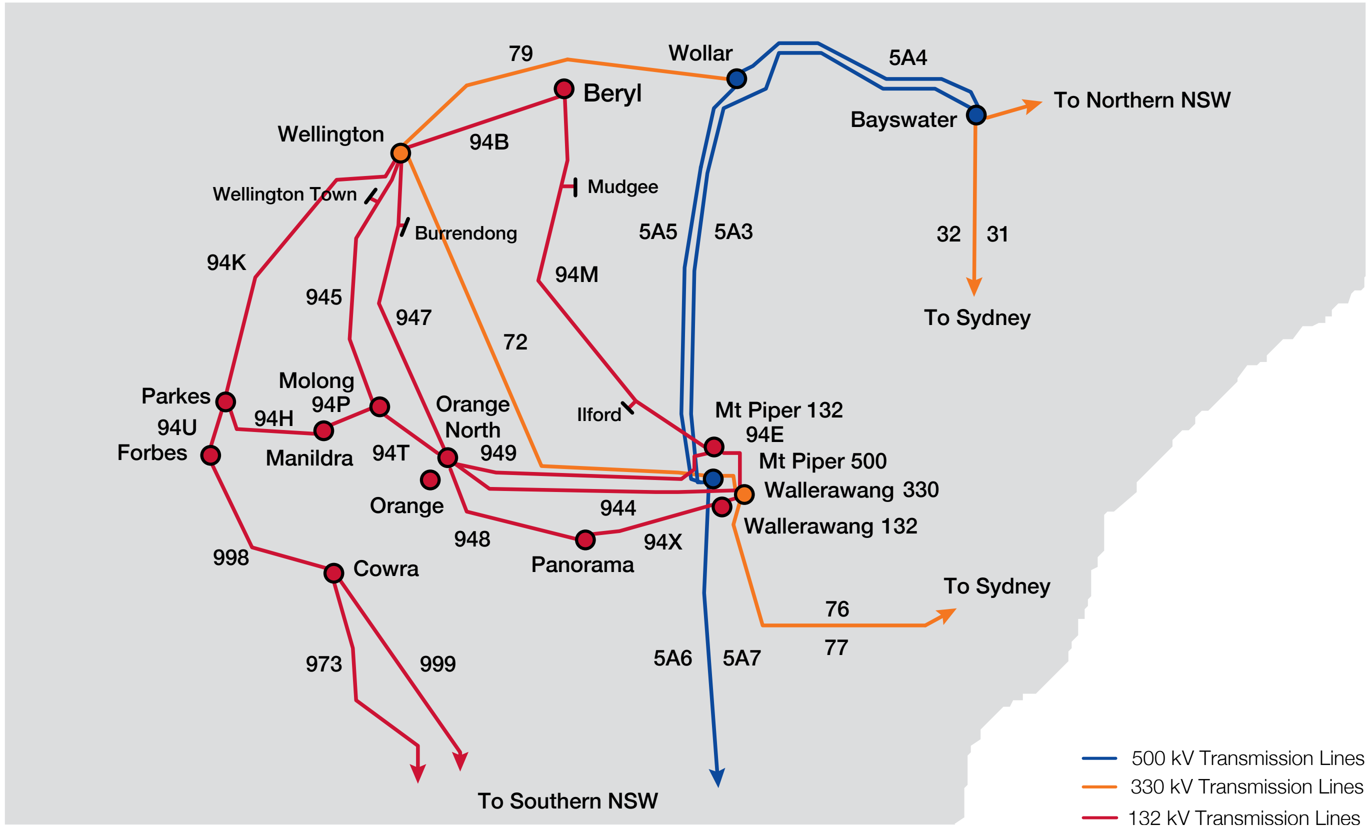
Project description	Planned date	Total cost ($million June 18)	Purpose	Project justification
Install capacitor banks at Narrabri substation	Nov 2020	4.9	Required to manage voltage constraints if large mining or gas developments proceed in the area	Load driven
Reconductor the Gunnedah to Tamworth 132 kV line (969)	Nov 2020	6.1	Required to manage a thermal constraint due to the rating of the 969 line if large mining or gas developments proceed in the area	Load driven
Transposition of 330 kV lines 87 (Coffs Harbour to Armidale) and 8C/8E (Armidale to Dumaresq)	By Jun 2023	1.2	These transpositions are to make the network more resilient to negative-sequence voltage levels greater than 0.5% within the northern NSW transmission network	Economic benefits
Provide auto-control of capacitor banks	By Jun 2023	0.1	Improve the voltage capability at various northern NSW substations to reduce the probability of under or over voltage load shedding	Economic benefits
Armidale North Coast Line Overload Load Shedding (LOLS) expansion	By Jun 2023	<0.1	Modification of the LOLS tripping scheme to include Essential Energy's Koolkhan to Maclean 66 kV feeder	Economic benefits
Northwest NSW 330 kV smart grid controls	By Jun 2023	3.6	Installation of a special protection scheme to protect against trips of two or more of the 330 kV lines between Armidale and Liddell For multiple circuit trips, the scheme will run back generation and load to avoid cascading outages and further loss of load in the network	Economic benefits
North-western transfer tripping scheme	By Jun 2023	0.1	The proposed tripping scheme is to avoid opening a 132 kV parallel between Tamworth and Armidale following an outage of one Tamworth to Armidale 330 kV line (line 85 or 86) to prevent potential thermal overloading and voltage stability issues. Instead, it will trip the line following a second outage (line 86 or 85). This will enable generation within the 132 kV subsystem to operate at full output during an outage of 330 kV line 85 or 86	Improve transfer capability
Taree 132 kV bus capacity augmentation	By Jun 2023	1.0	A trip of any 132 kV busbar section at Taree 132/66 kV substation will interrupt supply to the Taree area Installation of a new circuit breaker bay to allow two busbar protection zones at Taree substation will allow continued supply to customers in the Taree area during a bus section outage	Reduced unserved energy
Capacitor bank to increase NSW to Qld transfer limit	By Jun 2023	4.7	Installation of a 330 kV, 120 MVAr shunt capacitor bank at Armidale 330/132 kV substation to increase voltage stability limits on QNI	Improve transfer capability
Armidale capacitor transfer tripping scheme	By Jun 2023	0.2	Implementation of a transfer tripping scheme for the Armidale 132 kV capacitor bank to improve QNI transfer capability during an outage of an Armidale 330/132 kV transformer	Improve transfer capability

Completed projects

Tamworth 132/66 kV substation renewal was completed in December 2016 to address its end-of-life condition.

2.2.4 Central NSW

Figure 2.10 – Central NSW network



Planned projects

As a result of the implementation of the new reliability standard from 1 July 2018 (see section 4.4), we will be required to provide additional capability to supply Molong and Mudgee in order to reduce expected unserved energy.

Both of these projects are planned for completion early in the 2018/19 to 2022/23 regulatory period, as listed in Table 2.4.

Other planned minor projects that may provide economic benefits are also shown in Table 2.4.

Table 2.4 – Planned projects in central NSW

Project description	Planned date	Total cost ($million June 18)	Purpose	Project justification
Second Molong 132/66 kV transformer	Nov 2019	3.9	A second 132/66 kV transformer at Molong is proposed to comply with the new transmission reliability standard	Reliability compliance
Installation of a three-way switch on Beryl to Mount Piper 132 kV line (94M) to the tee connection to Mudgee	Nov 2019	7.5	Installation of a three-way switch at the Mudgee tee point on the 94M line is planned to comply with the new transmission reliability standard Other options considered include demand management, construction of a 132 kV busbar at Essential Energy's Mudgee substation, and automation of Essential Energy's existing manual Mudgee changeover scheme	Reliability compliance
Replace limiting high voltage plant on Mount Piper to Wallerawang 330 kV lines	By Jun 2023	3.3	Replace limiting HV plant and upgrade secondary plant on Mount Piper to Wallerawang 330 kV lines to improve summer 15-minute ratings and address an emerging risk to the integration of low-emissions generation in central NSW	Economic benefits
Two-way disconnector on Beryl to Mount Piper 132 kV line (94M) to the tee connection to Ilford substation	By Jun 2023	2.8	Installing a two-way disconnector on line 94M tee connection to Ilford substation to reduce duration of supply interruption to customers following trip of the line	Economic benefits

Ongoing projects

Works to address substation equipment reaching end-of-life condition are being carried out at Orange 132/66 kV substation. These works are expected to be completed by early 2019, They include:

- Removal of most of the 132 kV high voltage equipment
- Replacement of the 66 kV equipment and secondary systems
- Installation of an additional 66 kV capacitor bank to improve voltage support.

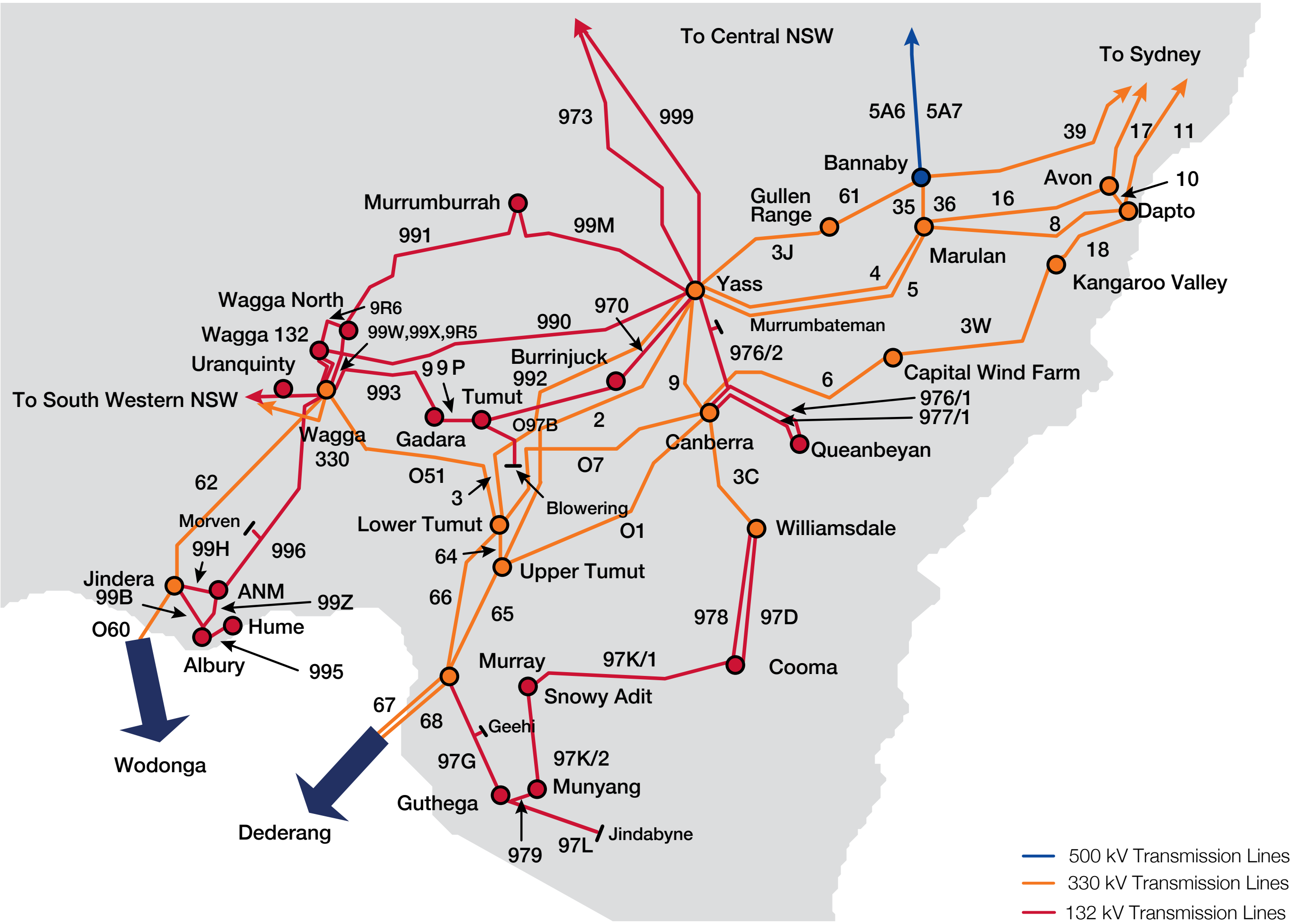
The out-of-service 94G cable will also be reconnected into Orange North 132 kV switching station as cable 9CG and energised as a backup for Essential Energy's 9MC cable. This is expected to be completed by November 2017.

Completed projects

The installation of an 18 MVAr capacitor bank at Beryl 132/66 kV substation was completed in January 2017 to provide additional reactive support and maintain reactive margin to meet NER requirements.

2.2.5 Southern NSW and the ACT

Figure 2.11 – Southern NSW and ACT network



Planned projects

Second supply to the Australian Capital Territory

We are required to provide two independent, geographically separate 330 kV supplies to the ACT as a condition of the ACT transmission licence. Canberra 330/132 kV substation provides the existing supply.

We are planning to establish a second geographically separate supply at Stockdill Drive by diverting 330 kV lines O1 and 3C into a new substation, with a 330/132 kV transformer providing 132 kV supply to ActewAGL. This provides an efficient solution to both comply with the ACT Electricity Transmission Supply Code and address the need to replace one of the existing 330/132 kV transformers at Canberra that has reached end-of-life condition. It is expected to be completed by December 2020 at an estimated cost of $37.4 million.

Other projects

Several precincts in Canberra are experiencing high localised load growth from new residential and commercial developments, and several low-cost investment opportunities that can improve reliability for consumers and deliver economic benefits have been identified. These are shown in Table 2.5.

Table 2.5 – Planned projects in southern NSW and the ACT

Project description	Planned date	Total cost ($million June 18)	Purpose	Project justification
Installation of one 132 kV switchbay at Canberra 330/132 kV substation	Nov 2020	1.7	For connection of ActewAGL's planned Strathnairn (formerly West Belconnen) Zone Substation, being built to meet the high peak load growth caused by a new housing development in Canberra	Load driven
Modification of Canberra to Woden 132 kV line to connect to TransGrid's planned Stockdill 330 kV substation	Nov 2021	3.6	For connection of ActewAGL's planned Molonglo Zone Substation in ACT, connecting to ActewAGL's Canberra to Woden 132 kV transmission line	Load driven
Transformer automatic voltage regulator (AVR) function changes	By Jun 2023	0.1	Will allow reverse power flow on various transformers with high levels of embedded renewable generation	Economic benefits
Yass 330 kV busbar capacity augmentation	By Jun 2023	5.1	Installation of new switchbays at Yass substation to reduce risk of multiple contingencies reducing the transfer capability from Snowy to NSW	Economic benefits
Yass area 330 kV smart grid controls	By Jun 2023	4.0	Installation of a special protection scheme to protect against trips of two or more of the following 330 kV lines: Yass to Gullen Range (3J), Yass to Marulan (4, 5), Bannaby to Gullen Range (61) For multiple circuit trips, the scheme will run back generation and load to avoid cascading outages and loss of further load in the network	Economic benefits
Snowy area 330 kV smart grid controls	By Jun 2023	3.3	Installation of a special protection scheme to protect against trips of both the Murray to Lower Tumut (66) and Murray to Upper Tumut (65) 330 kV lines For a double circuit trips, the scheme will run back generation and load to avoid cascading outages and further loss of load in the network	Economic benefits
Replace wave trap at Wagga 132 kV substation	By Jun 2023	0.6	Will increase the thermal rating of 132 kV line 99X between Wagga 330 and Wagga 132 kV substations	Economic benefits
Two-way disconnector on Wagga to ANM 132 kV line (996) to the tee connection to Morven substation	By Jun 2023	2.8	Reduces supply restoration time to Morven substation following outage of line 996. A two-way disconnector will allow disconnection of faulted section of line and restore supply via the unfaulted section	Economic benefits
Two-way disconnector on Yass to Canberra 132 kV line (976) to the tee connection to Murrumbateman substation	By Jun 2023	2.7	Reduces supply restoration time to Murrumbateman substation following outage of line 976. A two-way disconnector will allow disconnection of faulted section of line and restore supply via the unfaulted section	Economic benefits
SMART wires on Upper Tumut to Yass 330 kV line	By Jun 2023	5.6	Installation of SMART wires technology on the Upper Tumut to Yass 330 kV line can reduce its reactance and improve Snowy to Yass/Canberra transfer capability	Improve transfer capability
Transfer tripping scheme at Cooma	By Jun 2023	0.1	Implement a control system to trip Boco Rock Wind Farm following a coincident outage of both Williamsdale to Cooma 132 kV transmission lines (978 & 97D) The scheme will reduce constraints on the wind farm generation during a planned outage of one transmission line	Economic benefits
Albury area under-voltage load shedding (UVLS) scheme	By Jun 2023	0.2	Installation of UVLS scheme at Albury and ANM to enable the underlying 132 kV system to remain closed during outage of the Jindera 330/132 kV transformer and various transmission lines	Economic benefits
Transfer tripping scheme at Gadara, Tumut and Burrinjuck	By Jun 2023	0.4	Implement a control system to trip various 132 kV lines between Gadara and Burrinjuck to allow hydro generation at Burrinjuck and Blowering to continue during various outage conditions	Economic benefits

Table continues on page 36

Project description	Planned date	Total cost ($million June 18)	Purpose	Project justification
Increase rating of Wagga to Lower Tumut 330 kV line (O51)	By Jun 2023	0.3	Increases the rating of O51 line by replacing the wave traps at Lower Tumut and increasing the current transformer ratio at Wagga	Economic benefits
Capacitor bank installation to improve NSW to Vic transfer limit	By Jun 2023	5.5	Installation of a 330 kV 100 MVAr shunt capacitor bank at Canberra, Stockdill or Williamsdale substation to relieve voltage stability issues that cause constraints on export from NSW to Vic during high demand periods	Economic benefits

Ongoing projects

Canberra 330/132 kV substation equipment replacement works are expected to be completed in 2018. The replacement works are due to assets reaching end of serviceable lives and substation noise issues.

Burrinjuck 132/11 kV substation in-situ renewal is expected to be completed in 2018. The works address the end-of-life condition of assets in the substation.

Wagga 132/66 kV substation is being rebuilt in-situ due to end-of-life condition of assets. The works include replacement of substation equipment and secondary systems. Two new 132/66 kV 120 MVA transformers will replace the three existing 132/66 kV 60 MVA transformers. This work is expected to be completed in mid-2019.

Completed projects

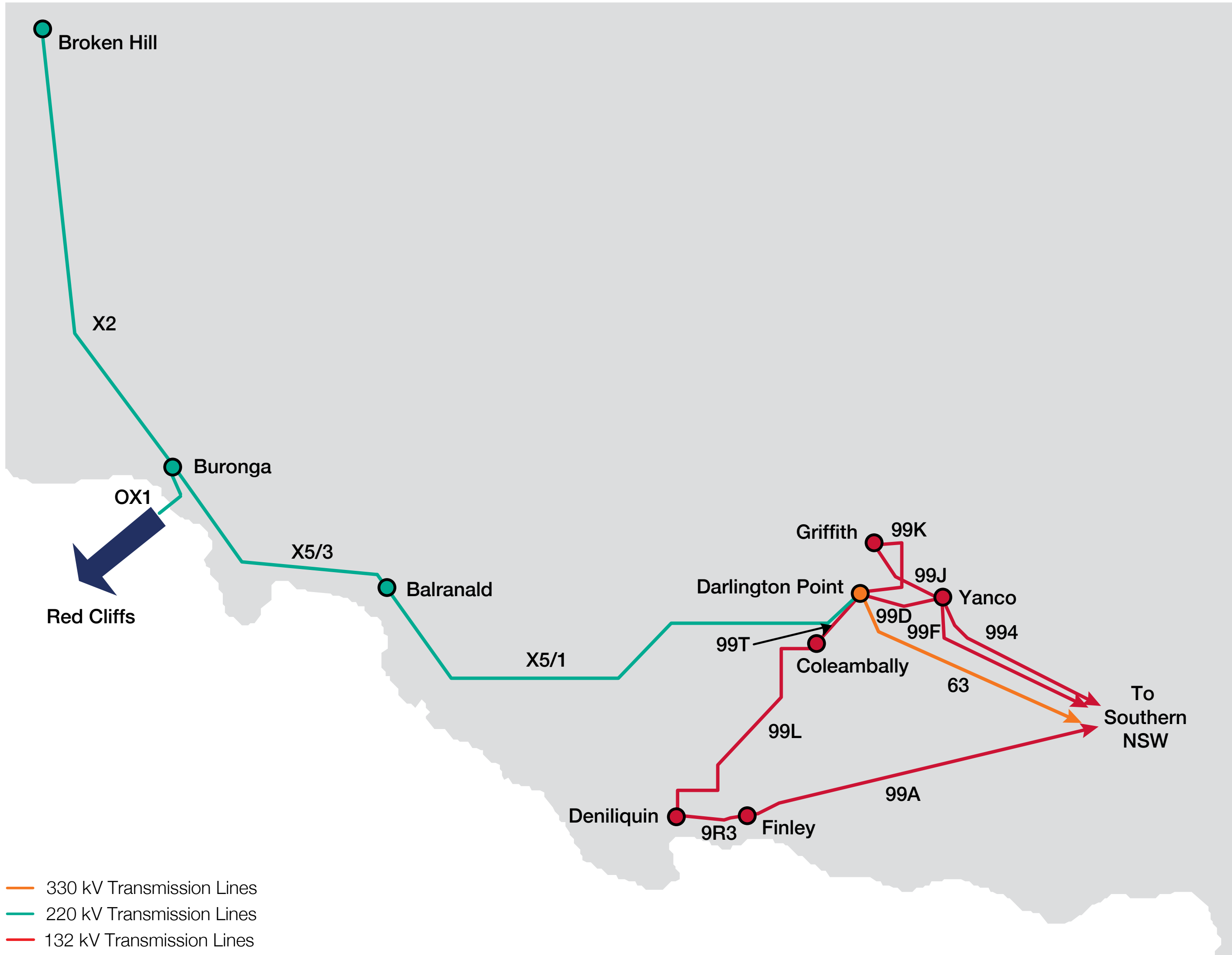
The secondary systems at Albury substation was successfully replaced in October 2016.

The Yass 330/132 kV No.3 transformer was replaced in April 2017.

A new 132 kV switchbay for Essential Energy was constructed at Williamsdale 330/132 kV substation in June 2017.

2.2.6 South western NSW

Figure 2.12 – South western NSW network



Planned projects

As a result of the implementation of the new reliability standard from 1 July 2018 (see section 4.4), we may be required to provide additional capacity to supply Broken Hill.

Broken Hill is part of the south western network and is supplied by a single transmission line from Buronga that is around 200 kilometres long. The existing gas turbines at Broken Hill have a start-up time of approximately 30 minutes, during which time the loads in the area would not be supplied.

Additional capacity will be required in the event that the total 220 kV and 22 kV load exceeds the capacity of the backup gas turbines owned by Essential Energy and the expected annual unserved energy exceeds the unserved energy allowance for Broken Hill of 10 minutes at average demand.

Further, the emergence of additional mining loads will require voltage support at Broken Hill and Buronga. These projects and other low-cost projects in south western NSW with economic benefits are shown in Table 2.6.

Table 2.6 – Planned projects in southwestern NSW

Project description	Planned date	Total cost ($million June 18)	Purpose	Project justification
Maintain supply reliability to Broken Hill	To be triggered if load exceeds capacity of backup gas turbines	To be determined	To provide additional capacity to supply Broken Hill, if the load exceeds the capacity of the backup gas turbines owned by Essential Energy and the expected unserved energy exceeds the unserved energy allowance for Broken Hill of 10 minutes at average demand Possible options include: › Establishing a battery storage solution to complement the existing 22 kV gas turbines › Installing additional gas turbine generation with a short start-up time › Procuring demand management from the loads in the area › Establishing a second duplicate 220 kV transmission line between Broken Hill and Buronga.	Reliability compliance
Dynamic reactive support installations at Broken Hill and Buronga	Nov 2020	26.8	Installation of reactors and SVCs at Broken Hill and Buronga to address voltage constraints should a large mining development proceed in the area	Load driven
Deniliquin full SCADA augmentation	By Jun 2023	0.7	SCADA capacity augmentation at Deniliquin 132/66 kV substation to reduce supply restoration time for an unplanned outage of 66 kV feeders or substation equipment	Economic benefits
Finley full SCADA augmentation	By Jun 2023	0.3	Full SCADA control and monitoring improvements at Finley to reduce supply restoration time for an unplanned outage of 66 kV feeders or substation equipment	Economic benefits
Dynamic rating system for Darlington Point 330/220 kV tie transformers	By Jun 2023	0.6	Develop and implement dynamic rating system for Darlington Point 330/220 kV transformers to increase their thermal rating	Economic benefits

2.2.7 Across NSW

NSCAS needs

We are contracted to provide 800 MVAr of absorbing reactive power services to meet a Network Support and Control Ancillary Services (NSCAS) gap until 30 June 2019. It is planned to continue providing these absorbing reactive power services as a prescribed service following expiry of the current contract. AEMO has supported this in the 2016 NTNDP, outlining that we are expected to include these reactors in the regulated asset base and continue to provide the required reactive voltage absorbing capability.[10]

The 2016 NTNDP did not identify any further NSCAS gaps in NSW.

NSCAS are ancillary services procured in order to maintain power system security. Under the NER, AEMO identifies NSCAS needs and we are required to procure NSCAS services to address needs in NSW. AEMO is the NSCAS Procurer of Last Resort if a TNSP is not able to procure NSCAS to meet their requirements.

10 Details are given in the 2016 NTNDP Section 7.6.2.

Planned projects

Significant growth in wind and solar generation is expected, driven initially by the Renewable Energy Target and later to meet the potential Clean Energy Target (or alternative mechanism) and projected shortfall in generation. Voltage control and stability issues due to the connection of this generation to weaker parts of the network will require dynamic reactive power support to allow stable system operation.

The following reactive power support technologies are being considered:

- SVCs
- Synchronous Condensers
- Static Compensators (STATCOMs)
- A combination of two or more of the above.

It is estimated that dynamic reactive power compensation will be required in at least two transmission locations where significant renewable generation is seeking to connect, most likely the south western and central parts of the network. The installation of dynamic reactive plant is likely to be required by 2020.

Other planned projects that improve security of supply for consumers and provide economic benefits are shown in Table 2.7.

Table 2.7 – Planned projects across NSW

Project description	Planned date	Total cost ($million June-18)	Purpose	Project justification
Improved fault location on various 132 kV transmission lines	By Jun 2023	2.5	Installation of travelling wave fault locators on 132 kV transmission lines to improve reliability	Economic benefit
Improve the Operational Telephone Network (OTN)	By Jun 2023	2.6	Reliable communication for use during supply disruptions	Economic benefit
Overvoltage control following underfrequency load shedding events	By Jun 2023	3.8	Implementation of overvoltage control schemes to automatically switch existing reactive plant quickly to maintain system security when the system frequency falls below a certain level	Economic benefit
Remote or self-reset of busbar protection	By Jun 2023	3.8	Installation of high definition Closed Circuit Television (CCTV) on busbars and facilities to reset busbar protections remotely at selected sites This will reduce restoration time and duration of supply interruptions following busbar faults	Economic benefit
Dynamic line rating monitoring	By Jun 2023	5.2	Increases the thermal capacity of various transmission lines (4% to 20% rating increase) under favourable weather conditions	Economic benefit
Remote relay interrogation	By Jun 2023	1.9	Installation of remote fault data interrogation system (FDIS) software at 73 substations to improve response to faults	Economic benefit

Ongoing projects

Dynamic line ratings

Existing static line ratings consider the probabilistic nature of weather and line loading conditions. The weather information used to determine these line ratings may not always reflect the weather conditions on critical spans of these transmission lines where conductor sag is the constraining issue, particularly for long transmission lines.

Real-time dynamic line rating (DLR) has the benefit of allowing maximum power transfer capability on the system based on actual weather conditions, where conductor thermal ratings are the determining factor.

Twenty-two transmission lines were identified where constraints are expected to impact future power flows, and DLR equipment was installed in late 2016. Dynamic rating algorithms have been created and full integration with market data systems is planned for late 2017.

Completed projects

Quality of supply monitoring

Quality of Supply (QoS) monitors were installed at twelve strategic customer connection sites in early 2017, enabling us to measure, record and analyse power quality aspects at these connection points.

2.3 Asset management projects

As our assets approach the end of their serviceable lives, it is important to plan for their orderly retirement. We have made significant improvements to the asset management strategies and policies that underpin our capital investment process. We constantly monitor the risk of asset failure and its impact on reliability, safety and communities through bushfire and other environmental damage. Using a risk value for each major asset, the need to take action is considered for high risk assets. We then evaluate options to mitigate the risk, including:

- Do nothing or increase maintenance interventions
- Defer the need for replacement, if viable non-network options are available
- Like for like replacement
- Replacement with an asset of different capacity based on forecast demand
- Reconfigure the network.

Economic analysis and comparison with our regulatory safety obligations is used to determine the appropriate course of action.

The projects described in the following sections have used this approach to determine the appropriate course of actions for the identified needs.

2.3.1 Transmission lines

Rebuild of 330 kV line 86

330 kV line 86 is a wood pole line between Armidale and Tamworth substations in northern NSW. The line forms part of the flow path for QNI.

We plan to rebuild this line to address emerging condition issues, replacing the existing composite wood pole structures with larger concrete pole structures and restringing with a larger conductor to improve the rating of the line. The project is estimated to cost $70.3 million and be delivered by June 2023.

The work is an expansion of the current wood pole replacement program that has been ongoing since 2011 to address prevalent wood rot throughout the line.

Concrete poles are proposed to be used as they have longer lifespan than wood poles and provide greater network security. We also considered using the existing conductor on new concrete poles.

Steel tower corrosion management

A refurbishment program that addresses steel tower corrosion issues is being undertaken on coastal tower transmission lines in the Newcastle, Central Coast, Sydney and Illawarra regions. The program includes refurbishment of rusted steel towers and the replacement of conductor fittings, earth wires and insulators at risk of failure.

In aggressive soil conditions, the buried steelwork of grillage foundations is expected to degrade over time and will require reinforcement in various locations. In non-aggressive soil conditions, installation or replacement of depleted cathodic protection systems is required to prevent any further steel loss.

These identified condition issues increase the probability of failure of a steel tower, conductor fittings, earth wires and insulators. Analysis has shown that risk costs can be offset by extending the lives of transmission lines through targeted refurbishment and replacement of specific components.

Further, asbestos impregnated paint has been identified on some steel tower transmission lines. The paint has been assessed as currently presenting a low risk to health. However, it is expected to deteriorate with time and will require removal.

The steel tower transmission line asset renewal projects are listed in Table 2.8.

Table 2.8 – Planned steel tower transmission line asset renewal projects

Transmission line location	Operational date required	Total estimated cost ($ million)
10 Avon – Dapto 330 kV line	Mar 2018	1.9
8 Dapto – Marulan 330 kV line	By Jun 2023	3.7
2M Munmorah – Tuggerah 330 kV line	By Jun 2023	2.9
5A1/5A2 Eraring – Kemps Creek 500 kV double circuit line	By Jun 2023	0.7
24 Eraring – Vales Point 330 kV line	By Jun 2023	2.9
14 Kemps Creek – Sydney North 330 kV line	By Jun 2023	1.1
13 Kemps Creek – Sydney South 330 kV line	By Jun 2023	0.5
20 Sydney West – Sydney North 330 kV line	By Jun 2023	0.3
25 & 26 Eraring – Vineyard 330 kV line and Munmorah – Sydney West 330 kV double circuit line	By Jun 2023	5.9
3W Capital Wind Farm – Kangaroo Valley 330 kV line	By Jun 2023	3.2
81 Liddell – Newcastle 330 kV line	By Jun 2023	2.2
21 Sydney North – Tuggerah 330 kV line	By Jun 2023	1.5

Table continues on page 40

Transmission line location	Operational date required	Total estimated cost ($ million)
16 Avon – Marulan 330 kV line	By Jun 2023	2.0
18 Dapto – Kangaroo Valley 330 kV line	By Jun 2023	1.6
Asbestos paint removal from various 330 kV steel tower transmission lines	By Jun 2023	40.1
11 Dapto – Sydney South 330 kV Line	By Jun 2023	21.2
31 Bayswater – Regentville 330 kV line	By Jun 2023	4.6
88 Muswellbrook – Tamworth 330 kV line	By Jun 2023	2.8
90 Eraring – Newcastle 330 kV line	By Jun 2023	1.3
23 Munmorah – Vales Point 330 kV line	By Jun 2023	1.0
12 Liverpool – Sydney South 330 kV line	By Jun 2023	0.6

Wood pole replacements

We are replacing wood pole structures in poor condition on some 132 kV transmission lines with concrete or steel poles to address deterioration from wood rot, decay and termite attack. The list of projects is shown in Table 2.9.

Table 2.9 – Wood pole replacement projects

Transmission line location	Operational date required	Total estimated cost ($ million)
970 Burrinjuck – Yass 132 kV line	Jul 2017	10.0
96H Coffs Harbour – Koolkhan 132 kV line	Dec 2017	18.7
944 Wallerawang – Orange North 132 kV line	Mar 2018	3.2

Optical fibre network installation

The existing assets servicing our medium bandwidth microwave communications backbone network are used to service protection and communication links throughout many parts of the network. High speed communications are increasingly required between sites to maintain the visibility and control of unmanned high voltage transmission sites within the network and to facilitate the remote interrogation and analysis of conditions and assets at all sites.

Additional operational benefits have been identified in the deployment of optical fibre links throughout the network to increase data capacity capabilities. These benefits include increased visibility and remote monitoring of assets, reduced maintenance requirements as monitoring can report imminent asset failure, remote analysis of failures before sending technicians to site and increased visibility of higher quality CCTV systems.

The installation of an interconnected fibre optic network addresses our long term vision of an intelligent network with real time asset management capabilities.

The following lines will have optical fibres installed on their routes to replace the existing microwave area network. This has been identified as the most efficient way to increase data capacity in the transmission network. This type of installation is typically achieved by replacing one of a transmission line's earthwires with an optical fibre cable encased in aluminium conductor known as Optical Ground Wire (OPGW).

This is part of the our 15 year strategy for rolling out OPGW across the transmission network, beginning with the formation of three new communications rings over the next 2 years. Works on the southern ring between Yass and Wagga substations, and the central west ring between Mount Piper to Orange, Wellington, Parkes and Forbes, will be complete by mid-2017. Works on the north coast ring between Newcastle and Lismore will be complete by mid-2018. The list of projects is shown in Table 2.10.

Table 2.10 – Fibre network projects

Transmission line location	Operational date required	Total estimated cost ($ million)
998 Cowra – Forbes 132 kV line	Sep 2017	5.6
94U Forbes – Parkes 132 kV line	Feb 2018	2.6
99F Uranquinty – Yanco 132 kV line*	Jun 2018	30.2
9W Waratah West to Tomago 330 kV line, 964 Port Macquarie – Taree, and 96P Taree – Stroud 132 kV lines	Jun 2018	16.8
992 Burrinjuck – Tumut 132 kV line*	Jun 2018	10.5
993 Gadara – Wagga 132 kV line*	Jun 2018	12.0
945 Wellington – Molong and 947 Wellington – Orange North 132 kV lines	Jun 2018	8.0
967 Lismore – Koolkhan and 96H Coffs Harbour – Koolkhan 132 kV lines	Jun 2018	7.2
9W2 Raleigh – Kempsey and 9W3 Coffs Harbour – Raleigh 132 kV lines	Jun 2018	10.0
99P Gadara – Tumut 132 kV line	Jun 2018	2.6
959 Sydney North – Sydney East 132 kV line*	By Jun 2023	2.5
17 Avon – Macarthur 330 kV line*	By Jun 2023	3.8
Various 500, 330 and 132 kV lines	By Jun 2023	35.2

* These projects also include wood pole and steel tower remediation works

Remediation of low spans

Transmission lines are designed and constructed to achieve standard electrical clearances of the conductor at specific operating conditions. The currently accepted industry standard is AS7000 for the Design of Overhead Lines, which specifies minimum electrical clearances that should be achieved when the conductor reaches its maximum operating temperature (also commonly referred to as the line design temperature).

We have conducted aerial laser surveys of its transmission lines to provide accurate measurement of span heights. Using this new technology that provides more accurate measurements than previous approaches, a number of transmission lines have been found to have spans violating AS7000 minimum clearances (low spans) at the maximum foreseeable operating temperature. These low spans pose a risk to public safety.

We have conducted a risk assessment on the identified low spans. The risk assessment method evaluates each low span violation in accordance with multiple risk criteria including magnitude (height and area), location and violation temperature. The spans have then been ranked accordingly, and categorised as presenting a higher risk and lower risk to public safety. The remediation options considered include:

- Remediate all low spans
- Remediate higher risk low spans only, with the lower risk spans addressed by means of administrative control measures.

The remediation of higher risk low spans is proposed to reduce the level of risk to public safety across the network. We are required to fulfil the requirements of AS5577 Electricity Network Safety Management Systems, and the public safety risk presented by the low spans must be reduced As Low As Reasonably Practical (ALARP). The proposed remediations are expected to mitigate the public safety risk to an acceptable level.

The list of low span remediation projects to meet statutory clearances is shown in Table 2.11.

Table 2.11 – Low Span Projects

Transmission line location	Operational date required	Total estimated cost ($ million)
4/5 Yass – Marulan double circuit 330 kV line	Dec 2017	1.7
97K Cooma – Munyang 132 kV line	Apr 2018	18.1
965 Armidale – Kempsey and 966 Armidale – Koolkhan 132 kV lines	Jun 2018	7.6
Various other wood pole lines	By Jun 2023	70.0
Various other steel tower lines	By Jun 2023	1.7

2.3.2 Substation plant

We continually monitor the condition of our substation assets to ensure safe and reliable operation. We have established asset replacement programs to cover the replacement of identified circuit breakers, instrument transformers, bushing and disconnectors with poor condition.

Our replacement programs comprise the most economic combination of replacement and refurbishment options for transmission equipment reaching a condition that reflects the end of its serviceable life. The condition based replacement programs help to ensure the continued safety of employees, contractors, and the public and to maintain a reliable electricity supply.

Table 2.12 shows substation projects planned until 2023.

Table 2.12 – Planned substation primary (HV) asset renewal/replacement projects

Project description and location	Area	Operational date required	Total estimated cost ($ million)
Sydney East 330 kV substation No.2 and No.3 transformer replacements	Sydney	By Jun 2023	15.5
Lismore 330 kV substation SVC replacement	Northern	By Jun 2023	10.5
Armidale 330 kV substation No.2 reactor renewal	Northern	By Jun 2023	3.6
Kemps Creek and Eraring 550 kV substations 33kV tertiary reactor renewals	Sydney to Central Coast	By Jun 2023	1.5
Forbes 132 kV substation transformer replacements	Central	By Jun 2023	8.7
Wellington 330 kV substation No.1 reactor replacement	Central	By Jun 2023	4.0
Sydney West 330 kV substation SVC replacement	Sydney	By Jun 2023	5.9
Marulan 330 kV substation No.4 transformer renewal	Southern	By Jun 2023	1.8

2.3.3 Secondary systems

We are currently deploying our first secondary system that uses IEC 61850.[11] It will achieve savings by significantly reducing the number of traditional copper-core cables and instead using optical fibre cables between substation switchyards and relay rooms.

The condition of various categories of automation assets such as protection relays, control systems, AC distribution, DC supply systems, and market meters creates a need for modernisation. This will deliver benefits such as reduced maintenance requirements, minimal reinvestment over the life of the assets, improved operational efficiencies, better utilisation of our high speed communications network, improved visibility of all assets using modern technologies and reduced reliance on routine maintenance and testing.

Several options were identified for each site and we commissioned an economic evaluation of risks and benefits to determine the most efficient solution. Options included running to failure, secondary system building installations, strategic replacements, and IEC 61850 deployments.

Works to address data capacity in the network are discussed in the optical fibre network installations in section 2.3.1.

The secondary system renewal and replacement projects are listed in Table 2.13.

11 International Electrotechnical Commission (IEC) 61850 standard for Power Utility Automation, http://www.iec.ch/smartgrid/standards/

Table 2.13 – Planned substation secondary asset renewal and replacement projects

Project description and location	Area	Operational date required	Total estimated cost ($ million)
Munmorah 330 kV substation*	Newcastle and Central Coast	Mar 2018	10.7
Taree 132 kV substation*	Northern	Mar 2018	15.0
Sydney North 330 kV substation	Sydney	Apr 2018	37.0
Avon 330 kV switching station	Southern	May 2018	3.8
Wallerawang 330 kV substation	Central	By Jun 2023	4.7
Ingleburn 330 kV substation	Sydney	By Jun 2023	4.0
Broken Hill 220 kV substation	South western	By Jun 2023	12.3
Wagga 330 kV substation	Southern	By Jun 2023	6.0
Marulan 132 kV substation	Southern	By Jun 2023	4.6
Tamworth 330 kV substation	Northern	By Jun 2023	4.5
Muswellbrook 330 kV substation	Northern	By Jun 2023	4.3
Cowra 132 kV substation	Central	By Jun 2023	3.5
Liverpool 330 kV substation	Sydney	By Jun 2023	3.0
Lower Tumut 330 kV switching station	Southern	By Jun 2023	8.0
Darlington Point 330 kV substation	South western	By Jun 2023	4.1
Murrumburrah 132 kV substation	Southern	By Jun 2023	4.4
Tuggerah 330 kV substation	Newcastle and Central Coast	By Jun 2023	4.5
Deniliquin 132 kV substation	South western	By Jun 2023	10.4
Haymarket 330 kV substation	Sydney	By Jun 2023	8.1
Regentville 132 kV substation	Sydney	By Jun 2023	4.3
Panorama 132 kV substation	Central	By Jun 2023	4.3
Molong 132 kV substation	Central	By Jun 2023	3.6
Tenterfield 132 kV substation	Northern	By Jun 2023	3.4
Coleambally 132 kV substation	South western	By Jun 2023	1.7

* Project includes some HV asset removals or replacements

2.3.4 SCADA system

The Supervisory Control and Data Acquisition (SCADA) system is a vital tool that allows us to efficiently operate and maintain our network, providing real-time visibility of the network status and alerting abnormal conditions. We use the SCADA system to operate, control and monitor the high voltage network remotely from our central control centre. The current SCADA system is aging and will soon no longer be supported by the providers. Increasingly there is a requirement to update the system to ensure the ability to provide improved cyber security to meet new and emerging threats. The system is expected to be replaced by 2020.

Options to address the need included running to failure or replacement with a modern solution.

We consider that replacement is the only viable option. Replacement will ensure that the SCADA system uses the most current technology available, including security features and functionality that will enhance situational awareness and operability of the modern transmission network. This project will cost $15.7 million.

Chapter 3

Generation connection and network support opportunities

- We provide information on existing network capacity that is available for new generation in various areas of NSW
- The interest in new generation connection exceeds the existing network capacity in many areas of NSW
- We are proposing the development of renewable energy precincts to open up additional capacity for new low-emissions generation
- Energy storage and other network support may provide solutions to challenges arising from the transition to the energy system of the future
- Opportunities for non-network options may arise within five years in the Gunnedah/Narrabri and Broken Hill areas, depending on changes to load and generation in these areas.

3 Generation connection and network support opportunities

3.1 Generation connection opportunities

The approximate available network capacity for generation connections in various areas in NSW is presented in Table 3.1. It is based on the current maximum demand, with all committed network and customer projects, and allowing for N-1 contingencies. Generators that have committed to connect in NSW are discussed in section 4.1.

New generation at any of the identified locations will affect the utilisation of transmission network and the capacity at adjacent locations.

The 'generation connection interest' column in Table 3.1 includes proposed connections from proponents who have engaged us to complete network feasibility studies or have lodged a Development Approval to the Department of Planning and Environment as of 17 May 2017.

We continuously monitor and evaluate the network capacity at these locations.

Table 3.1 – Connection opportunities

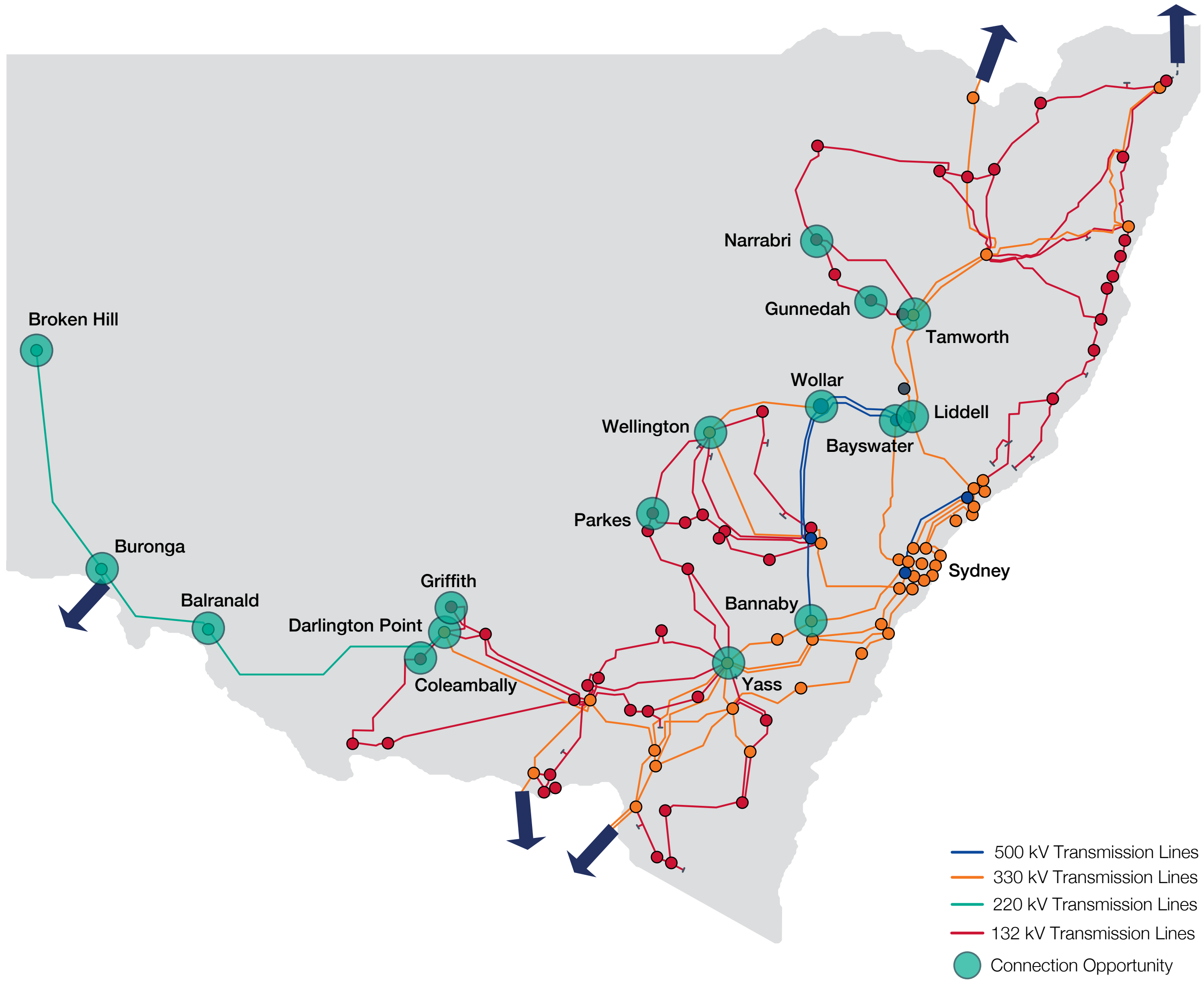
Connection sites	Voltage level	Available capacity (MW)	Generation connection interest (MW)
Broken Hill, Buronga, Balranald	220 kV	250	800
Darlington Point, Coleambally, Griffith	330 kV or 132 kV	470	550
Yass, Bannaby	330 kV	1,700[1]	1,750
Wollar, Wellington, Parkes	330 kV	900	1600
	132 kV	400[2]	700
Bayswater, Liddell	330 kV	500	Zero
Tamworth	330 kV	800	650
Narrabri, Gunnedah	132 kV	150[3]	200

Proposed future renewable energy precincts	Voltage level	Additional firm capacity provided[4]
South-western NSW	330 kV	1,200 (if high capacity NSW to SA Interconnector proceeds)
Southern NSW and north-western Vic	330 kV	2,000 (if network extension into north-western Vic proceeds)
North-western NSW	330 kV	2,000 (if route-diverse NSW to Qld Interconnector proceeds)

1 This figure was calculated at 15% POE flows on the Snowy to Yass/Canberra cut-set, as a credible scenario during times of maximum demand and high renewable generation
2 This figure is within the total available capacity at Wollar/Wellington, and not in addition to the 330 kV capacity
3 This figure is within the total available capacity at Tamworth, not in addition to the Tamworth 330 kV capacity
4 Subject to relevant projects proceeding as noted

Figure 3.1 shows these generation connection opportunities at selected NSW locations.

Figure 3.1 – Connection opportunities



As is evident in Table 3.1, the existing network is nearing capacity in some areas of NSW.

We are committed to transitioning to the energy system of the future and are working to identify solutions to the emerging network constraints. We have identified that additional generation capacity could be made available through the establishment of renewable energy precincts, as set out in Figure 1.7 and detailed in section 2.1. The additional capacity would deliver significant benefits in facilitating the connection of renewable generators in high interest areas with an abundance of renewable resources.

3.2 Opportunities for network support

The transition to a low emissions energy system will see a substantial change to the way electricity is generated. Traditional carbon intensive large-scale generation is expected to progressively retire, and replacement sources are likely to be a mix of large-scale variable renewable generation and distributed energy resources.

Operation of a secure and reliable power system will require the deployment of generation firming and ancillary services by alternative means. Energy storage is ideally placed to provide some of these ancillary services. Energy storage, in the form of pumped storage and batteries, can complement renewable generation by balancing energy produced from intermittent sources to ensure that it is available at the times it is required to meet demand.

Existing synchronous baseload generation provides inertia, helping to stabilise the power system following disturbances on the system. Batteries with appropriate inverter technology can provide fast frequency response, helping to stabilise the power system by slowing the rate of change of frequency as the level of system inertia is decreased. In addition to this fast frequency response, batteries are also able to provide Frequency Control Ancillary Services (FCAS).

A further value stream for batteries is the ability to deliver reactive support to the system, potentially lessening the need for dynamic reactive plant.

We propose to procure network support to defer capital investment to supply Inner Sydney as part of the Powering Sydney's Future project. This is described in section 2.2.1.

We have also identified the potential for network support in the Narrabri/Gunnedah and Broken Hill areas. The network constraints in these areas are discussed in section 2.2.3 and section 2.2.6 respectively. The intent to issue Requests for Proposals (RfP) is set out in section 3.3.

3.3 Requests for Proposals

NER Clause 5.12.2(c)(4) concerns constraints expected to arise in one, three and five years and requires that we indicate our intent to issue Requests for Proposals (RfP) with respect to those constraints.

3.3.1 Forecast constraint information

The required forecast constraint information is provided in Table 3.2.

Table 3.2: Forecast constraint information

Constraint or anticipated constraint	Reason for constraint	Bulk supply point(s) at which MW reduction would apply	MW at time that constraint is reached
Supply to the Gunnedah/ Narrabri area	Thermal overload and voltage stability	Gunnedah and/or Narrabri	Refer to section 2.2.3 The constraint is to meet potential load growth. The reduction will vary depending on the actual size of new load, when confirmed
Supply to Molong	Redundancy to meet new jurisdictional reliability standards from July 2018	Molong	Refer to section 2.2.4 The reduction is the full load at Molong, 5 MW
Supply to Mudgee	Response time to meet unserved energy allowance in jurisdictional reliability standards from July 2018	Mudgee	Refer to section 2.2.4 The reduction is the full load at Mudgee, 21 MW
Supply to the Broken Hill area	Supply/demand balance in the Broken Hill area if load exceeds local backup generation, and response time to meet unserved energy allowance in jurisdictional reliability standards from July 2018	Broken Hill	Refer to section 2.2.6 The constraint is to meet an unserved energy allowance in the event of potential changes to load or generation in the Broken Hill area. The reduction will vary depending on actual changes to load and/or generation, when confirmed

3.3.2 Intent to issue Request for Proposals

Table 3.3 indicates our intent to issue a RfP for non-network options.

Table 3.3: Anticipated issue of a RfP for non-network options

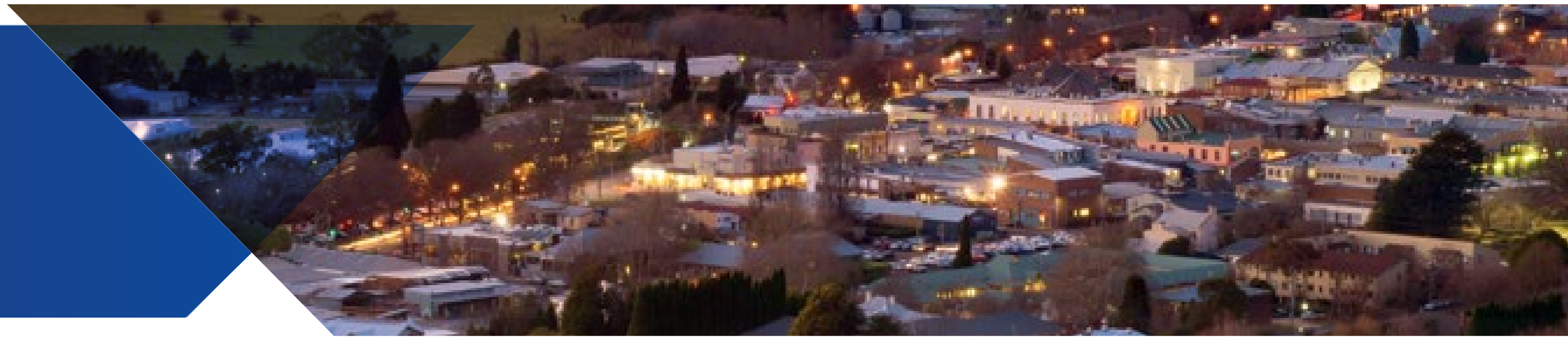
Constraint or anticipated constraint	Intent to issue RfP	Date
Supply to the Gunnedah/Narrabri area	To be assessed	To be assessed
Supply to the Broken Hill area	To be assessed	To be assessed

Chapter 4

Forecasts and planning assumptions

- Annual energy consumption in NSW and the ACT is forecast to grow at an average rate of 0.3% over the next ten years, due to strong economic growth and population growth in the region
- Under AEMO's neutral economic growth scenario 50% probability of exceedance (POE) conditions, summer maximum demand is expected to grow by around 0.3% and winter maximum demand by around 0.6% annually over the planning horizon. This is higher than last year's forecast and is driven by consumer appliance uptake and increasing cooling load from air conditioners
- Forecasts based on aggregated Bulk Supply Point (BSP) data project stronger summer and winter maximum demand growth, of 1.0% and 1.5% respectively
- 821 MW of new renewable generation has committed to connect at various locations in NSW. This is expected to grow further as advances in renewable generation technologies improve the cost competitiveness of new renewable generation
- We have undertaken an assessment of power system security against each of the criteria that contribute to the stability of the power system, and identified some stability services that may be required following further retirement of baseload generation and/or connection of new inverter-based generation
- New transmission reliability standards were approved in December 2016 to commence from 1 July 2018. We have identified works at three BSPs that will be required to comply with the standards, for which projects have been included in Chapter 2
- Our network development plans address the security of supply issues identified by AEMO in the 2016 ESOO and align with the 2016 NTNDP.

4 Forecasts and planning assumptions



4.1 Key highlights

4.1.1 Generation

Since the publication of TAPR 2016, the following levels of generation have signed connection agreements and are incorporated in our planning review as committed generation:

- 736 MW of wind generation capacity
- 85 MW of solar generation capacity.

We expect further generation to sign connection agreements over the next 12 months as proponents advance through the connection process. This will be taken into account in the annual planning review in 2018.

4.1.2 Load forecasts

The 2017 energy and maximum demand forecasts for the NSW Region show that energy consumption is forecast to grow at an annual average rate of 0.3% in the immediate ten-year forecast horizon (2017/18 to 2026/27).

Summer maximum demand is forecast to grow at an annual average rate of 0.3% during the forecast period and winter maximum demand is forecast to grow at an annual average rate of 0.6% between 2017 and 2026.

A summary of the NSW region forecasts is shown in Table 4.1.

Table 4.1 NSW region energy and demand forecasts (average annual percentage changes)

	Actual/Estimated 2007-08 to 2016-17	Projected 2017-18 to 2026-27
Energy Sent Out	-1.1%	0.3%
	Actual 2007-08 to 2016-17	Projected 50% POE 2017-18 to 2026-27
Summer Maximum Demand	1.3%	0.3%
	Actual 2007 to 2016	Projected 50% POE 2017 to 2026
Winter Maximum Demand	-0.8%	0.6%

4.2 Load forecasts

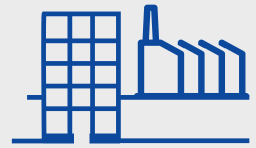
Changes in consumer consumption behaviour will affect load forecasts (the demand for electricity). The change in loads can be categorised into two broad types. Organic changes are the overall result of many small changes, either increases or decreases, across an area. Spot loads are localised, often larger changes associated with new developments or, in the case of load reductions, closure of a facility. The closure of the Kurri Kurri smelter in 2012 is an example of spot load reduction.

In recent years, larger spot load increases have primarily been due to increased housing and infrastructure related activities in north west and south west growth areas of Sydney and also due to new or expanded mining activities in regional areas of NSW.

To understand the likely changes in loads, we look at forecast annual energy use for the NSW region and forecast maximum demands for the NSW region (including the ACT), as well as individual bulk supply points. The NSW region forecasts are provided by AEMO and those for bulk supply points are provided by DNSPs and customers directly connected at those locations.

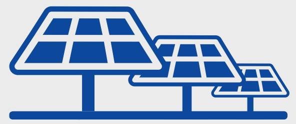
4.2.1 Forecast energy consumption

Energy consumption measures total energy throughput over a period of time in kilowatt hours (kWh), typically described in gigawatt hours (GWh) at the transmission level. We are required to plan our network to be able to meet forecast maximum demand, not energy. However, energy forecasts can usefully reflect broader drivers that may impact the future use of the network. Those drivers include:



- Economic conditions
  - Increasing levels of economic activity may create spot loads

- Government policies
  - The Federal Government's Renewable Energy Target (RET) and energy efficiency programs



- Emerging technologies
  - The ability for customers to self-generate electricity by using solar panels or store it using battery systems.

We reproduce AEMO's NSW regional energy forecast contained in its 2017 Electricity Forecasting Insights. The Electricity Forecasting Insights considers three economic scenarios: strong, neutral and weak. AEMO does not propose likelihoods for each of the scenarios. However, the neutral scenario is usually considered to be the central scenario as overall, it has lesser deviations from present trends in macro-economic variables than the strong and weak scenarios. The strong and weak economic scenarios have been derived as sensitivities to the neutral scenario.

Table 4.2 and Figure 4.1 show the native annual energy usage forecasts for the NSW region for each of AEMO's three scenarios. Details of the scenarios are given on AEMO's website.[12]

The key inputs to AEMO's strong, neutral and weak economic scenarios are assumptions on economic growth, population increase, future changes in electricity prices and energy efficiency uptake in the NSW region. Assumptions regarding these inputs drive the differences between the three economic scenarios.

The strong economic scenario assumes high economic growth, high population growth, higher electricity prices and higher uptake of energy efficiency measures. The weak economic scenario, on the other hand, assumes lower economic growth, lower population increase, lower electricity prices and lower uptake of energy efficiency measures.

The assumption of future growth rates for the variables…

Economic growth

Population

Electricity price

Energy efficiency uptake

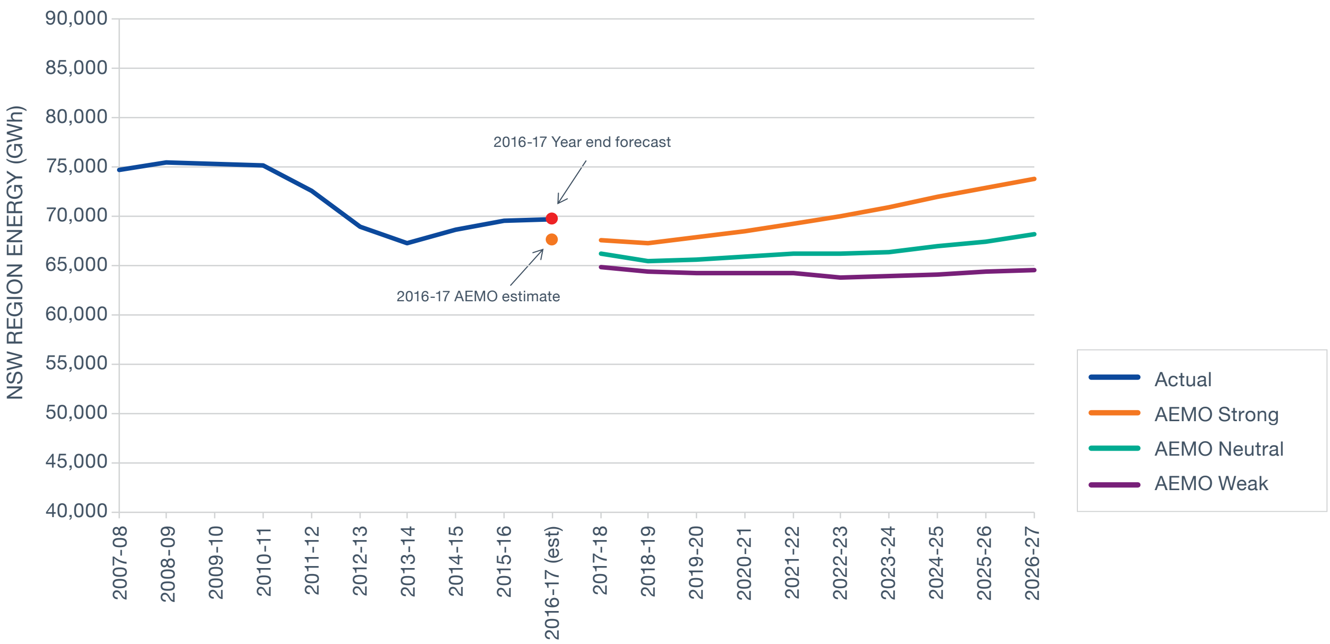
for the neutral economic scenario lie between the strong and weak economic scenarios.

12 http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Electricity-Forecasting-Insights

Table 4.2 – NSW region annual energy forecasts (GWh)

	Actual	AEMO strong	AEMO neutral	AEMO weak
2007-08	74,819			
2008-09	75,506			
2009-10	75,427			
2010-11	75,199			
2011-12	72,576			
2012-13	69,006			
2013-14	67,334			
2014-15	68,652			
2015-16	69,623			
2016-17 (est)	67,629			
2017-18		67,641	66,336	64,915
2018-19		67,394	65,582	64,510
2019-20		67,882	65,667	64,359
2020-21		68,532	65,919	64,286
2021-22		69,292	66,246	64,318
2022-23		70,086	66,349	63,783
2023-24		71,021	66,488	63,965
2024-25		72,022	67,004	64,201
2025-26		72,921	67,521	64,388
2026-27		73,902	68,217	64,616
Annual Average Growth Rate 2017/18 – 2026/27		1.0%	0.3%	-0.1%

Figure 4.1 – NSW region energy forecasts



The decline in NSW region energy consumption in the years following the global financial crisis (GFC) in 2008/09 was due to several factors:

- Moderation in average economic growth in Australia and NSW in the aftermath of the GFC
- Closure of certain large industrial units in sectors such as aluminium, oil refining, paper, cement and steel due to a fall in external demand and the persistence of a high exchange rate of the Australian dollar vis a vis the US currency
- High electricity prices depressing energy consumption
- Adverse consumer sentiments and the 'risk averse' nature of the consumer as reflected in high household savings ratio, indicating the unwillingness of consumers to make discretionary expenditures
- Growth in the uptake of energy efficiency measures leading to lowering of electricity consumption from the grid.

The effects of economic factors on historical maximum demands are less pronounced, as maximum demand is largely dependent on weather parameters. However, the closure of industrial plants resulted in a step decrease in overall maximum demand in the years following the GFC. The biggest decline in load was from the closure of the Kurri Kurri aluminium smelter in late 2012, resulting in a decrease of approximately 340 MW. In total, it is estimated that around 425 MW of load may have decreased in the NSW region due to closure of small and large industrials as a result of unfavourable business conditions.

This trend appears to have reversed, as energy consumption has been on an upward trend since 2014/15.

AEMO has forecast energy consumption in 2016/17 to be lower than that of 2015/16 due to recent increases in wholesale prices, increases in rooftop PV and uptake of energy efficiency.

However, actual energy consumption in 2016/17 is expected to be higher than that of 2015/16.

Consequently, the starting point for AEMO's energy forecasts is likely to be under stated, leading to energy consumption being underforecast.

4.2.2 Forecast maximum demand

Maximum demand is the highest total demand at a single point in time.[13] It is measured in watts, typically described in megawatts (MW) at the transmission level. The forecasts we use for planning our network are based upon:

- The NSW region summer and winter maximum demand forecasts published by AEMO in its 2017 Electricity Forecasting Insights[14]
- The bulk supply point forecasts provided by the four NSW and ACT DNSPs and our directly connected customers.

4.2.2.1 AEMO region forecast

Maximum demand is expected to remain relatively flat up to 2024 and then increase through to the end of the forecast period.

Compared to the 2016 National Electricity Forecasting Report forecasts, this year's summer and winter maximum demand forecasts (50% POE) start slightly higher and follow a slightly steeper trajectory for the ten-year forecast horizon.

Increases in maximum demand are attributed to appliance uptake, increasing cooling load, population growth, and a decline in retail prices (towards the end of the forecast period). In the short term, increases in maximum demand are forecast to be offset by increases in the installed capacity of rooftop PV.

Table 4.3 shows the historical summer maximum demands (not weather-corrected) and forecasts for 10%, 50% and 90% probability of exceedance (POE) maximum demands over the next 10 years for each of the three AEMO scenarios. Table 4.4 shows the corresponding data for winter.

13 For electricity networks, maximum demand is the highest average demand over a half hour period.
14 The responsibility for NSW region electricity forecasts was transferred from TransGrid to AEMO in 2012.

Table 4.3 – NSW region summer maximum demand forecasts (MW)

	Actual	AEMO strong			AEMO neutral			AEMO weak		
		10% POE	50% POE	90% POE	10% POE	50% POE	90% POE	10% POE	50% POE	90% POE
2007-08	12,411									
2008-09	13,644									
2009-10	13,513									
2010-11	14,412									
2011-12	11,673									
2012-13	13,414									
2013-14	11,740									
2014-15	11,737									
2015-16	13,216									
2016-17	13,899									
2017-18		14,181	13,283	12,532	14,036	13,218	12,256	13,741	13,009	12,113
2018-19		14,404	13,416	12,443	14,029	13,047	12,175	13,912	12,988	12,030
2019-20		14,431	13,430	12,452	14,032	13,051	12,085	13,858	12,868	11,899
2020-21		14,547	13,441	12,509	14,159	13,008	12,189	13,816	12,836	11,979
2021-22		14,858	13,670	12,759	14,161	13,152	12,200	13,793	12,876	12,066
2022-23		14,788	13,614	12,862	14,193	13,066	12,268	13,824	12,681	11,910
2023-24		14,994	13,958	13,088	14,196	13,160	12,339	13,746	12,893	12,073
2024-25		15,324	14,138	13,075	14,428	13,336	12,260	13,882	12,790	11,960
2025-26		15,517	14,147	13,278	14,671	13,258	12,380	14,055	12,739	11,900
2026-27		15,777	14,476	13,402	14,884	13,601	12,557	14,307	13,017	12,090
Annual Average Growth Rate 2017/18 – 2026/27		1.2%	1.0%	0.7%	0.7%	0.3%	0.3%	0.4%	0.0%	0.0%

* Note: Maximum demands in Table 4.3 are in 'Native sent out' measures. The 'Native as generated' summer maximum demand in 2016-17 was 14,317 MW according to AEMO. The native as generated figures include contribution from power station auxiliary loads and as such are higher than sent out figures.

Table 4.4 – NSW region winter maximum demand forecasts (MW)

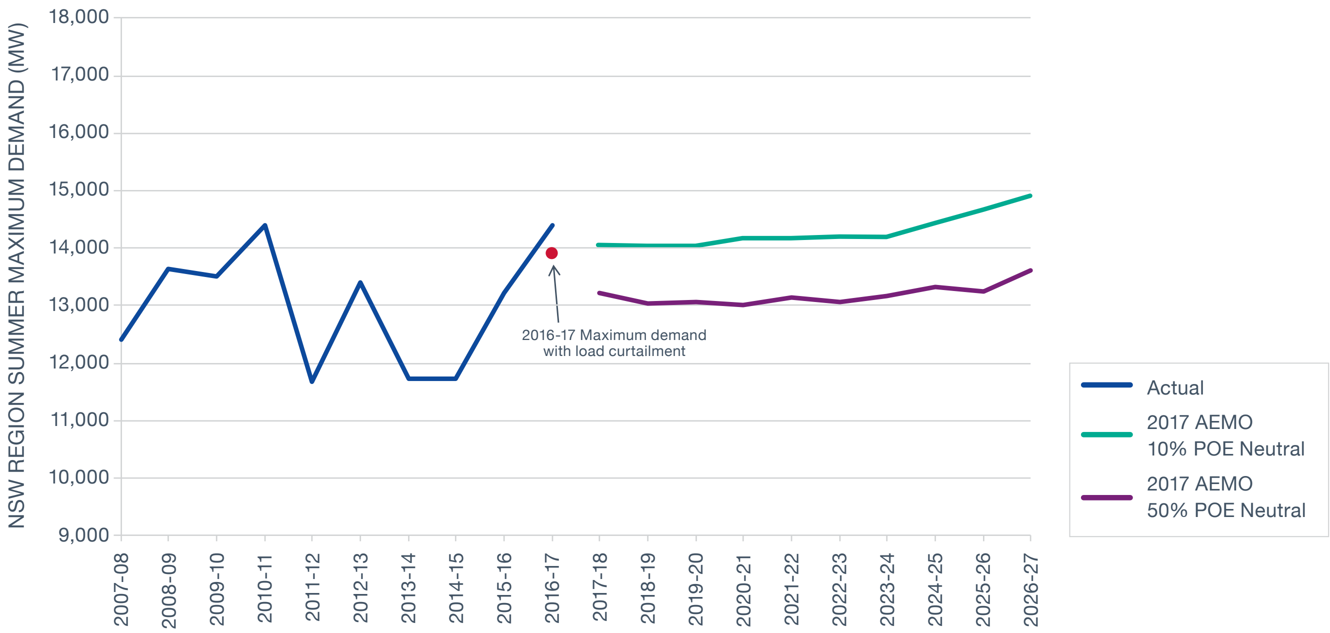
	Actual	AEMO strong			AEMO neutral			AEMO weak		
		10% POE	50% POE	90% POE	10% POE	50% POE	90% POE	10% POE	50% POE	90% POE
2007	13,407									
2008	13,785									
2009	12,661									
2010	13,038									
2011	12,538									
2012	11,818									
2013	11,300									
2014	11,248									
2015	11,876									
2016	12,441									
2017		13,288	12,844	12,474	13,263	12,801	12,483	13,345	12,844	12,493
2018		13,305	12,890	12,553	13,071	12,657	12,317	12,755	12,406	12,068
2019		13,322	12,883	12,562	12,992	12,587	12,222	12,792	12,411	12,078
2020		13,539	13,042	12,707	13,187	12,700	12,322	12,917	12,438	12,108
2021		13,735	13,206	12,906	13,301	12,810	12,451	13,019	12,542	12,185
2022		13,969	13,492	13,128	13,418	12,972	12,610	13,068	12,618	12,270
2023		14,285	13,745	13,390	13,588	13,110	12,773	13,130	12,650	12,257
2024		14,381	13,984	13,628	13,594	13,191	12,842	13,183	12,755	12,371
2025		14,812	14,251	13,866	13,862	13,409	12,990	13,404	12,912	12,524
2026		15,020	14,499	14,131	14,128	13,565	13,194	13,544	13,060	12,627
Annual Average Growth Rate 2017 – 2026		1.4%	1.4%	1.4%	0.7%	0.6%	0.6%	0.2%	0.2%	0.1%

Figure 4.2 shows the historical electricity maximum demand in summer to 2016/17 and the AEMO 10% and 50% POE demand forecasts. Figure 4.3 shows the corresponding data for winter.

AEMO's native summer and winter demand forecasts for the NSW region are shown on a 'sent out' basis.[15]

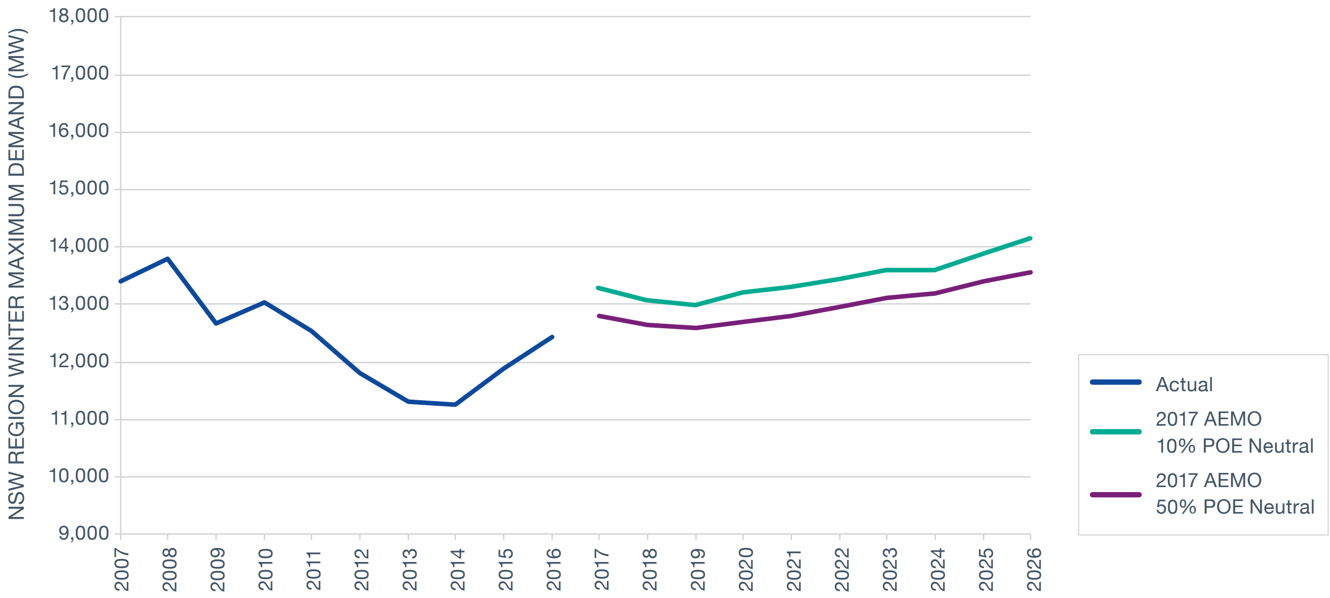
Figure 4.4 and Figure 4.5 show AEMO's forecasts produced in 2016 and 2017 for summer and winter maximum demands, respectively, together with actual (not weather and day-type corrected) maximum demands.

Figure 4.2 – NSW region 2017 summer maximum demand forecasts and actual demands



Note: Maximum demands shown in Figure 4.2 are in 'Native sent out' measures. The 'Native as generated' summer maximum demand in 2016-17 was 14,317 MW (AEMO data) which occurred on 10 Feb 2017. The native as generated figure includes contribution from power station auxiliary loads and as such higher than the sent out maximum demand figure. Since 10 February was an unusually hot day, there were load curtailment arrangements in place. The 2016-17 red dot in Figure 4.2 show the native sent out maximum demand with load curtailment. Had there been no load curtailment on 10 February, the native as generated maximum demand would have been around the 14,800 MW mark approximately.

Figure 4.3 – NSW region 2016 winter maximum demand forecasts and actual demands



15 'Sent out' maximum demand is measured at the point of entry to the transmission network and does not include power station auxiliary loads. In 2015 AEMO's summer and winter maximum demands (as published in TAPR 2015) were on a 'as generated basis' which were measured at power stations and included power station auxiliary loads.

AEMO's 2017 summer forecasts are on average 2% higher than the 2016 forecasts, and 2017 winter forecasts are on average 5% higher than the 2016 forecasts. This indicates that recent forecasts have been underforecast. Both the summer and winter forecasts show growth in forecast load in the ten-year forecast horizon.

In terms of network loadings, summer conditions are likely to be more onerous due to higher forecast loads, lower equipment ratings and generally worse power factors in summer.

Details of AEMO's forecasts and the methodologies it uses are available from AEMO's website.[16] Note that the Electricity Forecasting Insights gives forecasts for 'operational'[17] quantities, which differ slightly from the 'native' values given here. The correlation between the two sets of values is given in the spreadsheet associated with the Electricity Forecasting Insights on the AEMO website.

Figure 4.4 – AEMO's 2017 and 2016 summer maximum demand forecasts

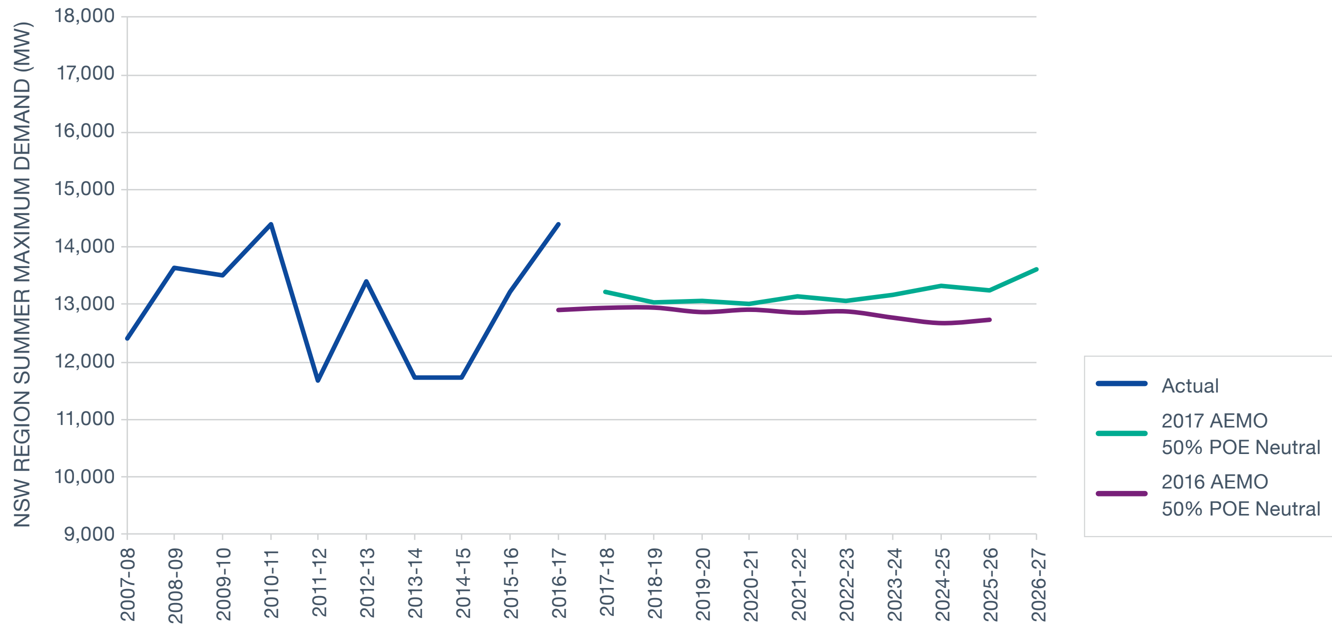
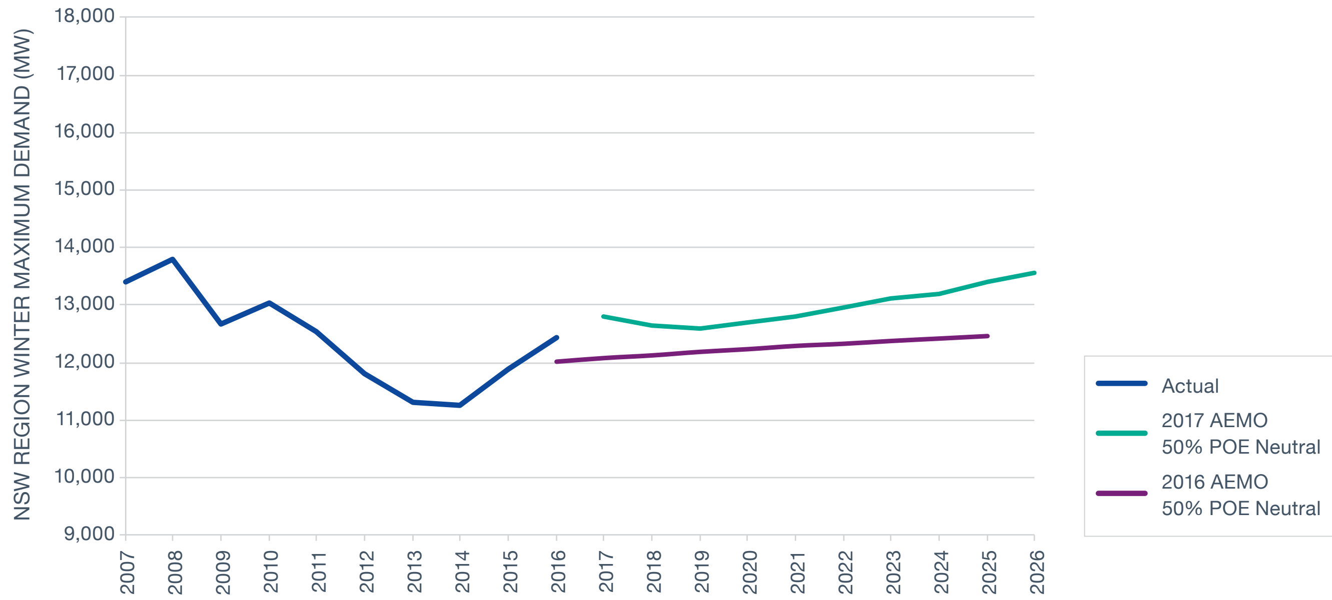


Figure 4.5 – AEMO's 2017 and 2016 winter maximum demand forecasts



16 http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Electricity-Forecasting-Insights

17 'Operational' quantities: Operational consumption includes residential, commercial and large industrial consumption. It includes contributions from scheduled and semi-scheduled generation plus that from significant intermittent non-scheduled generators. It does not include contributions from small non-scheduled generation. 'Native' quantities include all of the above.

4.2.2.2 Bulk supply point forecasts

Generally, the load changes at bulk supply points (BSPs) are organic. However, where there are spot loads,[18] they will be included in the relevant forecasts. The BSP forecasts incorporate the local knowledge of the distributors and directly connected customers.

Macroeconomic data are generally not available at a BSP level. Consequently, it is generally not possible to develop macroeconomic models for individual BSPs and to produce forecasts for different economic scenarios. In practice, the BSP forecasts are produced in a variety of ways, reflecting the amount of data available and the nature of the loads.

Figure 4.6 shows the 2017 NSW Network Aggregate DNSP Summer Maximum Demand Forecasts. Over the next ten years (2017-18 to 2026-27), aggregate DNSP summer maximum demand POE50 forecasts are expected to grow at an annual average rate of 1%.

Figure 4.6 – Aggregate BSP forecasts

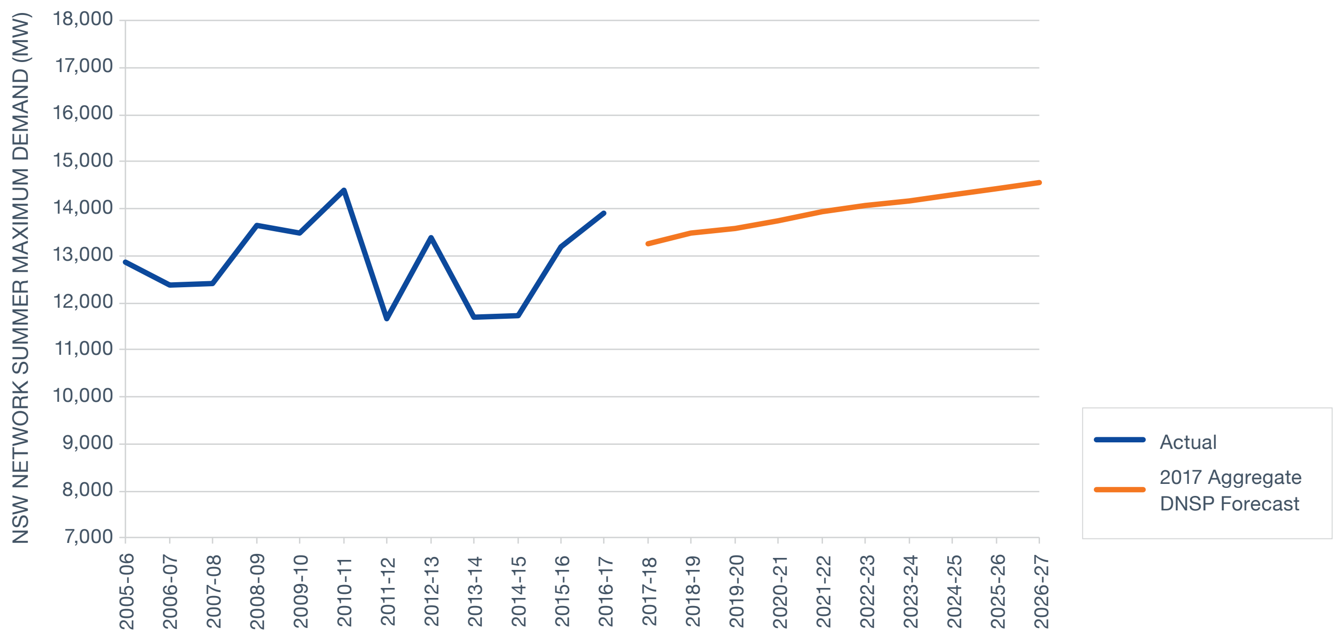
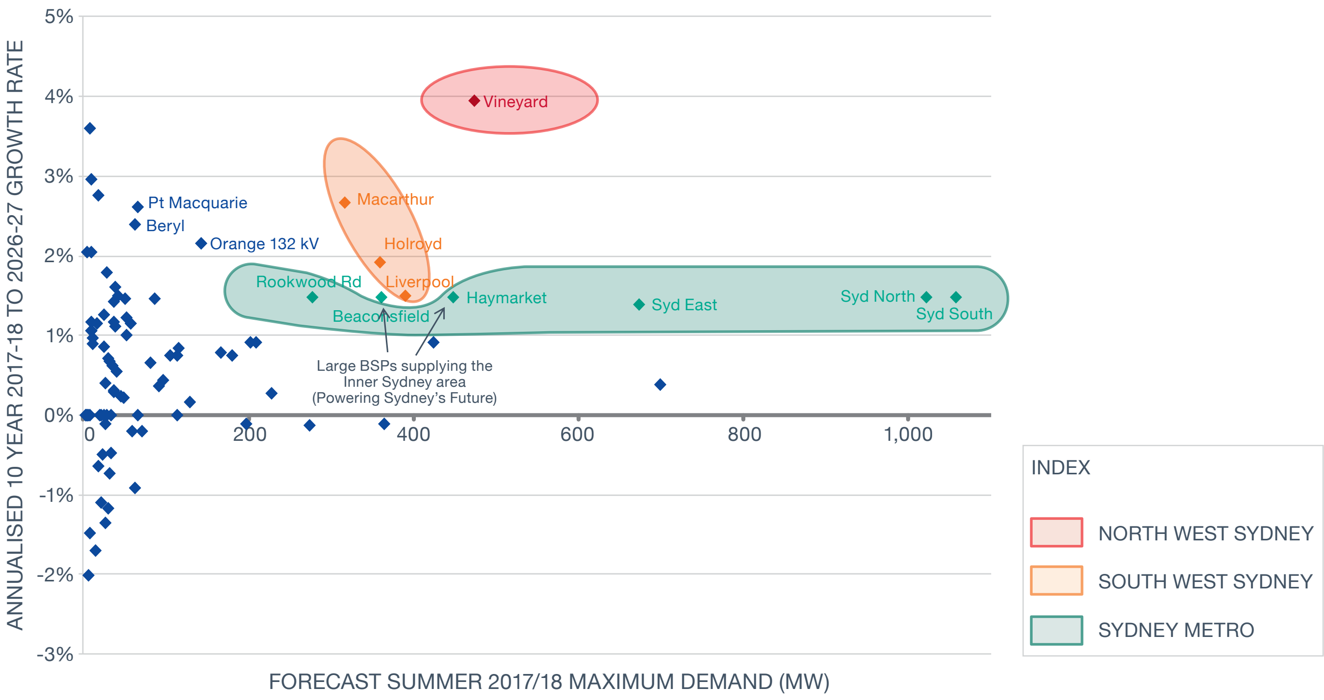


Figure 4.7 – BSP summer forecast growth rates



18 Spot loads are step (one-shot) increases in load for a BSP due to new housing developments or large industrial customers. There could be spot load decreases in cases where there are withdrawals of large load customers from the grid.

Figure 4.7 shows the forecast growth rates for BSPs serving the DNSPs in summer, with annualised growth rates. The detailed year-on-year forecasts of summer and winter maximum demands at the individual BSP level are set out in Appendix 1.

The BSPs with the highest growth rates are those serving the following areas.

South-west Sydney

This area is predominantly within the South West Sector Land Release and Broader Western Sydney Employment area where a large number of residential lot releases are planned. There are also some applications for industrial loads and plans for a Liverpool CBD development over a longer period of time (over 10 years).

North-west Sydney

The development of North West Rail infrastructure and associated activity (medium/high density residential), commercial and industrial areas will drive load growth in this area.

Sydney Inner Metropolitan area

This area continues to grow at a higher rate than the overall NSW region average. Real income and population growth is forecast to result in higher load growth.

Major real estate and developmental activities are occurring at Barangaroo, Central Park, Green Square, Harold Park and the Southern Employment Lands.[19] Beaconsfield and Haymarket BSPs are two of our largest exit points which supply the Sydney Inner Metropolitan area.

4.2.2.3 Comparing the AEMO and BSP maximum demand forecasts

The BSP forecasts are not produced on the same basis as the overall NSW forecasts produced by AEMO. For example:

- The underlying economic conditions may not be the same as those used by AEMO
- They may have been based on historical data with a timeframe different to that used by AEMO
- They indicate the likely maximum demand at that location, whenever it may occur, rather than the contribution to the overall NSW maximum demand
- They generally assume that only scheduled embedded generation is operating at the time of maximum demand.

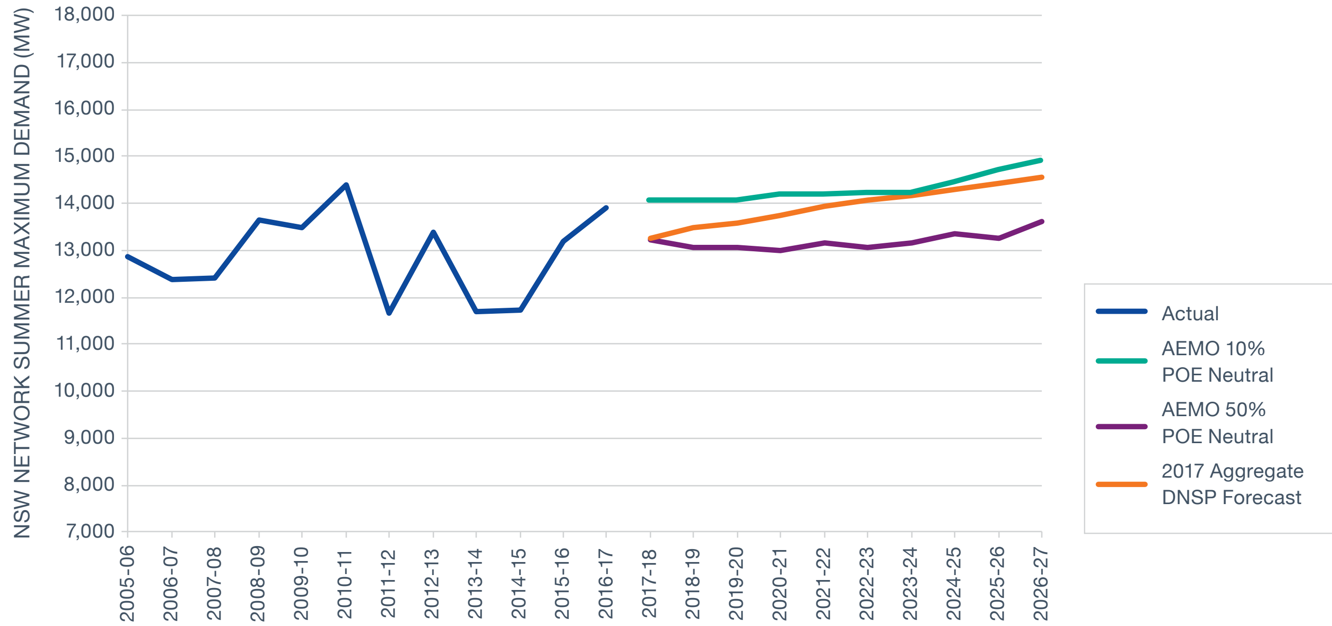
Unlike the AEMO forecasts, none of the BSP loads, by definition, include transmission losses or power used by generator auxiliaries. Despite this difference, the individual BSP forecasts for each season can be aggregated to provide a useful comparison with the overall NSW demand forecasts.

We attempt to account for some of the aforementioned limitations by:

- Using 50% POE forecasts where they are available, and where they are not available, by assuming that individual bulk supply point forecasts are likely to have been based on enough historical data to converge towards an approximate 50% POE forecast
- 'Diversifying' individual bulk supply point forecasts to allow for the time diversity observed between historical local seasonal maximum demand and NSW maximum demand
- Adding forecast aggregate industrial loads not included in the BSP forecasts
- Incorporating loss factors, which are also derived from historical observations, into the aggregate BSP forecasts.

Figure 4.8 shows the comparison between the aggregated DNSP forecasts and AEMO's 10% POE and 50% POE neutral scenario maximum demand forecasts for summer. Figure 4.9 shows the equivalent data for winter.

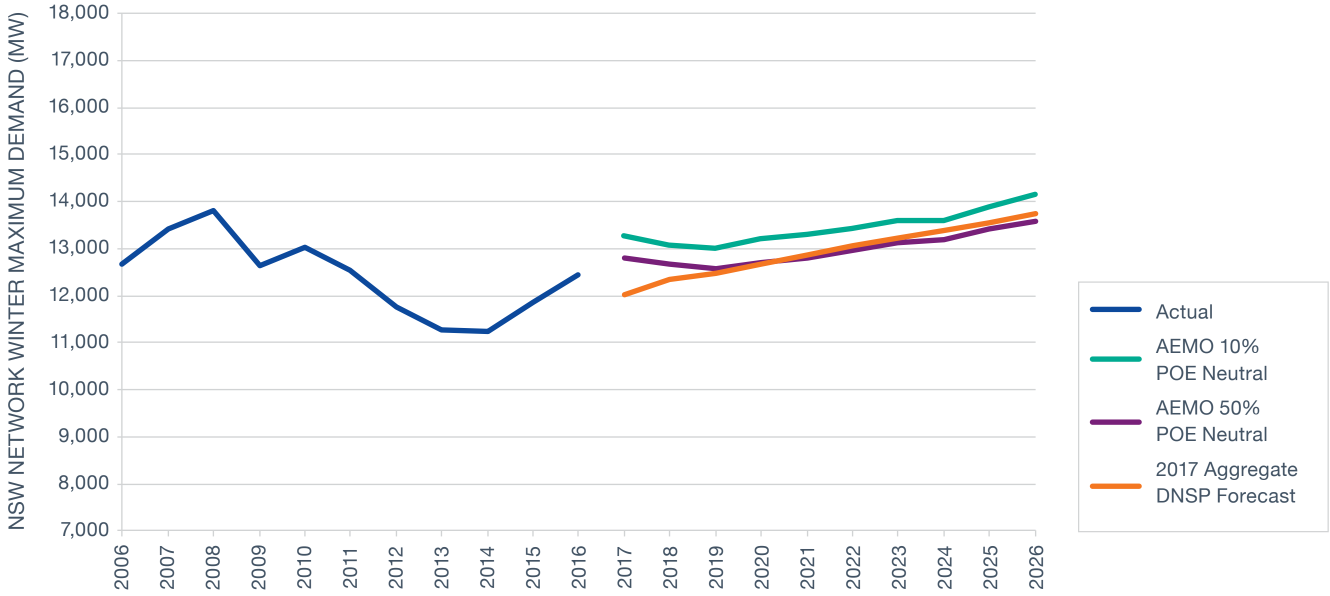
Figure 4.8 – AEMO and aggregate DNSP forecasts of NSW summer maximum demand[20]



19 City of Sydney Southern Employment Lands project website, http://www.cityofsydney.nsw.gov.au/vision/better-infrastructure/major-projects/southern-employment-lands. Viewed on 31 May 2017.

20 Actuals and AEMO forecasts are on a 'sent out' basis. DNSP forecasts are on an 'as delivered' basis adjusted for transmission network losses and other factors.

Figure 4.9 – AEMO and aggregate DNSP forecasts of NSW winter maximum demand



The aggregate BSP forecasts and AEMO forecasts differ in terms of their 10 year average growth rates, as expected for forecasts developed on different bases. Although the comparisons do not indicate which forecast is more accurate, they allow a high-level comparison to be made.

There is some alignment between the summer forecasts (0.3% AEMO and 1.0% aggregate BSP) but the growth rate for the aggregate DNSP-BSP forecasts for winter is higher than AEMO's forecasts (0.6% AEMO and 1.5% aggregate BSP). The forecast trajectories of both the winter forecasts align well in the later years of the ten-year forecast horizon.

4.3 Assessment of power system security

The transmission network provides the platform to transport energy from large-scale generation to major load centres. It also provides the platform for power system stability by sharing ancillary services provided by generators and some network assets.

We have undertaken an assessment of power system security against each of the criteria that contribute to the stability of the power system. The criteria are shown in Table 4.5.

Table 4.5: Key considerations when developing the transmission network

Criteria	Description
Maximum demand	Demand is the amount of electricity being used at an instant in time. Maximum demand is the highest amount of electricity that has been used (or is expected to be used) at any instant in a period of time.
Energy	The total amount of electricity used over a period of time.
Voltage control	The ability to maintain voltages throughout the power system within stable and safe limits.
System strength	The ability of the power system to temporarily provide high energy to manage disturbances while maintaining voltage control. System strength is provided by synchronous rotating generators. Inverter-based generators such as wind and solar generators require system strength to operate correctly but do not produce it.
Frequency control	The ability to maintain the frequency of the power system within stable limits. Traditional frequency control acts quickly for small changes in frequency under normal conditions, but slowly for large changes in frequency during disturbances. Therefore, it is complemented by inertia to ensure the power system can 'ride through' disturbances without significant frequency variation while it responds. Fast frequency response (FFR) is a newer approach enabled by high speed power electronics. Battery storage devices and solar generators use these electronics in their inverters. FFR has the potential to act quickly during disturbances, but the resilience of power electronics during disturbances has yet to be verified in practice.
Inertia	The ability of the power system to 'ride through' disturbances without significant frequency variation. Inertia (shorthand for 'synchronous inertia') measures the physical capability of synchronous rotating generators to continue without slowing down significantly during a disturbance. Unlike synchronous generators, wind generators do not always turn at the same speed as the power system frequency. Therefore, they connect to the power system using power electronics that converts their output to the power system frequency. Although wind turbines have some inertia, it can only be provided to the power system by configuring the power electronics to shape their output to simulate inertia during a disturbance. Similarly, solar generation could operate at less than full capacity to have capacity to simulate inertia. This is known as 'synthetic inertia' and has different characteristics to synchronous inertia.
Reserve	Extra generation that is readily available by increasing the output of generators already generating in the power system. The power system is normally operated with enough reserve to cover the loss of the largest generator unit.
Power system data communications	High speed data communications to provide visibility, monitoring and control of the power system. This includes dispatching generation and operating networks.

Maximum demand and energy

Maximum demand and energy consumption in NSW have both grown consistently in the last three years. Growth has been driven by population growth, hotter summer temperatures and a reduction in electricity prices.

There is a projected shortfall in generation to meet maximum demand following the retirement of Liddell Power Station in 2022. A shortfall in generation to meet demand will result in unserved energy. When the shortfall is limited to a small number of high-demand days, the unserved energy can be small. However, as the level of shortfall increases, the unserved energy increases significantly.

The shortfall can be met by additional new generation, greater interconnection, storage and demand management. This is discussed in Chapter 1.

Voltage control

Voltage control is provided by generators and network assets such as transformer tapchangers, capacitor banks, reactors and Static VAr Compensators (SVCs).

There is sufficient voltage control capability in the NSW transmission network over the next ten years.

There are opportunities to make small increases to interconnector export capacity to Qld and Vic through the installation of additional network assets for voltage control. Projects to install capacitor banks in northern and southern NSW to increase export capacity have been included in sections 2.1.2, 2.1.5, 2.2.3 and 2.2.5.

System strength

System strength is provided by synchronous rotating generators, and can also be provided by network assets such as synchronous condensers. SVCs can contribute to system strength by providing dynamic voltage control, but not fault currents.

There is sufficient system strength in the NSW transmission network at present.

Wind, solar and other inverter-based generators require system strength to operate correctly. As the penetration of inverter-based generators increases, there will be a need to install network assets to provide additional system strength. Projects to install synchronous condensers or SVCs have been included in sections 2.1.2, 2.2.6 and 2.2.7.

Frequency control

Frequency control is provided throughout the NEM. There is sufficient frequency control capability in the NEM over the next ten years.

Fast frequency response (FFR) has the potential to act quickly during disturbances, but the resilience of power electronics during disturbances has yet to be verified in practice. A project to install a large-scale battery that provides FFR has been included in section 2.2.1. This will enable its application in practice to be understood and validated in system stability models.

Inertia

We have reviewed the adequacy of inertia in NSW to limit the rate of change of frequency (RoCoF) following a disturbance. An acceptable RoCoF of up to 3Hz/s was allowed, as the level at which automatic under-frequency load shedding (AUFLS) can manage system frequency. The review found that:

- The current inertia in NSW is adequate to limit the RoCoF to below 3Hz/s with up to 5 baseload generators out of service at all times
- The inertia in NSW after the retirement of Liddell Power Station will be adequate to limit the RoCoF to below 3Hz/s with up to 1 generator out of service at all times
- The inertia in NSW after the retirement of Liddell Power Station and Vales Point Power Station will be insufficient to limit the RoCoF to below 3Hz/s at all times. There is a small proportion of time (0.06%) when there will be a risk of a RoCoF greater than 3Hz/s.

Even after the retirement of Liddell Power Station and Vales Point Power Station, sufficient inertia is expected to remain across the NEM as a whole. Therefore, resilient interconnection to adjacent states can be used to manage the risk of insufficient inertia in NSW. If required, additional inertia can be provided by new synchronous condensers, conversion of retiring generators to synchronous condensers and 'synthetic inertia' from inverter-based generators (subject to successful trial). The emergence of FFR devices is likely to allow the power system to operate securely at a RoCoF greater than 3Hz/s, reducing the level of inertia required in the future.

Reserve

In NSW, the power system is operated with a reserve level of 700 MW.

There will be a lack of reserve when there is a shortfall of generation to meet demand, or when the available generation is less than 700 MW above demand.

There is a projected shortfall in reserve under certain conditions over the period of this report. The shortfall can be met by additional new generation, greater interconnection, storage and demand management. This is discussed in Chapter 1.

Power system data communications

High speed data communications contributes to power system security by providing visibility, monitoring and control of the power system.

We are extending our high speed data communications optical fibre network as set out in section 2.3.1. We are also working to develop least-cost communications solutions to areas of NSW with the best renewable resources to support the connection of new generation and establishment of renewable energy precincts.

4.4 Service standards

New reliability standards

New transmission reliability standards for NSW were published by IPART in December 2016. They comprise two components for each bulk supply point (BSP).

A level of redundancy is specified for each BSP (or group of BSPs). This specifies the number of backup arrangements (0, 1 or 2) that must be in place to support the continued supply of electricity in the event that part of the transmission network fails.

An unserved energy allowance is a new addition to the standards. It specifies the expected time that energy will not be supplied per year. The recommended unserved energy allowances range from 0.6 minutes per year in Inner Sydney to 115 minutes in one area in NSW's west.

The standards are planning standards, rather than performance standards. This means that the network needs to be planned to meet the standards over the life-cycle of the assets on average, rather than be met in every year.

TransGrid may require investment to ensure that the reliability standards are met. Typically there would be lower unserved energy when the assets are newer and higher unserved energy when the assets are closer to the end of their serviceable lives.

The standard provides flexibility to promote the most efficient network or non-network solution to meet the unserved energy allowance, which may include the transmission network, distribution network, network support arrangements, backup supply capability, or a combination of these.

This report includes network developments to meet the new reliability standards in sections 2.2.4 and 2.2.6.

Our network planning approach will remain compliant with the Transmission Network Design and Reliability Standard for NSW 2010 until the new standards come into effect on 1 July 2018.

ACT reliability standard

We are also subject to the Electricity Transmission Supply Code July 2016 under the transmission licence we hold in the ACT.

The Code includes the requirement for the provision of two or more geographically separate points of supply at 132 kV or above. It also requires that there be a continuous electricity supply at maximum demand to the ACT network at all times, including following a single credible contingency event.

We currently supply the ACT load via the Canberra and Williamsdale substations. However, Williamsdale substation is supplied through Canberra substation. The construction of a new substation located at Stockdill Drive will meet the requirement for a second, fully independent supply point. More detailed information about this project is available in section 2.2.5.

4.5 Alignment with ESOO and NTNDP

AEMO's 2016 ESOO projected that 0.0031% of energy consumption in NSW is at risk from 2025-26 under the neutral economic scenario and 0.0095% is at risk from 2022-23 under the strong economic scenario.

We agree with AEMO's supply adequacy assessment and have developed an updated assessment that takes into account the increasing summer maximum demand and actual generator capabilities. This is set out in Chapter 1.

Our plan to transition to the energy system of the future aligns with AEMO's 2016 NTNDP[21] as it:

- Will open new renewable energy precincts that will facilitate connection of clean energy generation from resource-rich areas through extension and upgrade of the current network capability. Our strategy addresses the transmission limitations noted in the NTNDP that may hinder renewable generation, including:
  - limitations on the 330 kV lines between Yass/Canberra and Sydney during high Vic to NSW export and high wind and solar generation in the Canberra area
  - limitations on the 330 kV lines between Dumaresq and Liddell during high import from Qld and high wind/PV generation
  - 220 kV line between Broken Hill and Buronga during high wind and solar generation from Broken Hill; and
  - 132 kV network around Wellington (eg Dubbo, Nyngan, Parkes etc) during high PV penetration connected to 132 kV network
- Improves sharing of energy and ancillary services through increased interconnection, delivering cost-efficient generation and lower wholesale market prices. The 2016 NTNDP states that there is likely to be benefits from fuel cost and capital deferral savings from augmenting the NSW to Qld and NSW to Vic interconnectors, and further benefits could be realised from establishing an interconnector to SA to export renewable generation from SA
- Manages low system strength and risk of insufficient reserve and inertia in NSW by providing resilient interconnection to adjacent states
- Supports use of new technologies such as large-scale energy storage to address challenges posed by variable renewable generation by providing smoothing capability and frequency response.
- Encourages demand side management.

We are also currently addressing the supply limitation to Sydney CBD raised in the NTNDP through our Powering Sydney's Future RIT-T.

21 Australian Energy Market Operator's 2016 National Transmission Network Development Plan. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan. Viewed on 17 May 2017.

Appendix 1

Individual bulk supply point forecasts

Appendix 1

Individual bulk supply point forecasts

This appendix provides the maximum demand forecasts supplied by our customers for individual bulk supply points, based on local knowledge and the availability of historical data.

A1 Individual bulk supply point forecasts

Our customers have provided maximum demand forecasts, in terms of both megawatts (MW) and megavolt ampere reactive (MVAr), for individual bulk supply points between the NSW transmission network and the relevant customer's network. These forecasts are produced using methodologies that are likely to have been tailored to the circumstances relating to the load(s) at particular bulk supply point(s) such as the degree of local knowledge and the availability of historical data. The forecasts are given in the tables below.

Some large and relatively stable industrial loads that we isolate for modelling purposes have been removed from the bulk supply point forecasts and aggregated. The removal of this data affects the forecasts shown for Broken Hill. Other industrial loads are included in bulk supply point forecasts provided by distributors. Aggregate forecasts for all identified major industrial loads (excluding those that are also in the bulk supply point forecasts) at the time of maximum NSW region demand are given in Tables A1.11 and A1.12.

Tables A1.1 to A1.12 provide forecasts of maximum demand occurring during a particular season at a particular bulk supply point (or group of bulk supply points) on the NSW transmission network. They do not represent forecasts of demand contributions at these bulk supply points to the overall NSW region maximum demand.

Information on forecast diversity factors for each bulk supply point with respect to the network (NER Schedule 5.7) have not been provided because:

- The NER definition of 'network' is very broad, making it unclear what combination of other load or loads are to be assumed when calculating the diversities. The absence of this information could lead to an impossibly large number of diversity combinations,[22] many of which are unlikely to be of use
- In an interconnected network, the loading on a particular substation can reflect the configuration of the underlying network as well as generation patterns within the national electricity market. Consequently, there can be considerable variation in diversity factors at a particular location from year to year.

When undertaking the comparison between the AEMO NSW region forecasts and the aggregated distribution network service provider forecasts, we use diversity factors of 4% in both summer and winter.[23]

Information on particular diversity factors is available from TransGrid, notwithstanding the above difficulties. Contact details are provided on the back cover of this document.

22 For example, in a ten-node network, there are over 500 diversity figures for each node, covering the ways in which its diversity can be calculated with respect to the various combinations of one or more of the other nine nodes. For larger networks such as TransGrid's, the number of possible diversity figures is immense.

23 These diversity factors apply at the NSW region level. They represent the difference between the undiversified regional maximum demand (the summated maximum demands of the individual bulk supply points) and the diversified regional maximum demand (the maximum of the summated bulk supply point loads). This regional approach was adopted as it is not possible to estimate a typical diversity factor for individual bulk supply point loads with respect to the NSW regional load due to the year to year variability of those individual diversity factors.

TABLE A1.1 – Ausgrid bulk supply point summer maximum demand[24]

	2017/18		2018/19		2019/20		2020/21		2021/22		2022/23		2023/24		2024/25		2025/26		2026/27	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Beaconsfield West 132 kV	361	1	413	7	413	13	415	19	423	25	589	97	597	123	608	143	613	158	627	174
Rookwood Rd 132 kV	277	-54	325	-48	325	-42	327	-57	331	-72	205	52	210	69	211	71	214	71	220	72
Haymarket 132 kV	448	71	512	94	517	116	518	142	533	168	609	180	617	208	619	173	620	188	637	203
Liddell 33 kV	25	12	25	12	25	12	25	12	25	12	25	12	25	12	25	12	25	12	25	12
Munmorah 132 kV and 33 kV	105	21	105	21	106	22	107	23	107	23	109	22	109	23	110	23	111	24	111	25
Muswellbrook 132 kV	228	136	227	136	228	137	229	138	230	139	231	139	232	140	232	140	233	141	233	141
Newcastle 132 kV	424	122	425	109	429	110	433	109	440	130	442	115	445	117	446	118	449	119	451	120
Sydney East 132 kV	673	84	676	80	684	77	692	83	706	90	717	114	729	133	737	109	754	130	762	151
Sydney North 132 kV	1022	87	878	160	810	232	821	220	841	207	734	280	742	282	752	344	763	342	772	340
Sydney South 132 kV	1058	99	1137	128	1187	156	1213	161	1257	166	1290	135	1308	147	1319	173	1349	179	1357	184
Tomago 132 kV	209	44	210	44	211	40	214	41	217	47	218	44	220	45	221	45	223	46	225	47
Tuggerah 132 kV	181	26	180	23	182	23	184	23	185	21	189	31	190	32	191	32	193	33	194	33
Vales Point 132 kV	113	32	113	31	115	37	116	36	117	37	117	33	118	34	119	40	120	41	122	46
Waratah West 132 kV	202	61	204	62	213	83	216	85	220	72	224	91	227	93	228	93	229	94	230	94

TABLE A1.2 – Ausgrid bulk supply point winter maximum demand[24]

	2017		2018		2019		2020		2021		2022		2023		2024		2025		2026	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Beaconsfield West 132 kV	322	-7	367	2	362	4	377	5	380	12	383	6	548	98	560	127	563	124	574	121
Rookwood Rd 132 kV	237	-98	279	-91	282	-87	289	-83	292	-86	299	-75	179	16	185	14	188	25	194	36
Haymarket 132 kV	394	0	453	42	459	44	467	46	471	60	475	53	551	99	562	128	565	125	576	122
Liddell 33 kV	24	11	24	11	24	11	24	11	24	11	24	11	24	11	24	11	24	11	24	11
Munmorah 132 kV and 33 kV	99	20	99	21	101	22	102	23	104	24	104	25	105	27	106	28	107	29	108	27
Muswellbrook 132 kV	204	129	218	139	219	139	219	140	220	142	222	143	223	144	224	144	224	145	225	146
Newcastle 132 kV	353	72	358	75	362	62	368	67	377	96	380	77	388	106	393	108	396	110	401	112
Sydney East 132 kV	699	55	732	67	738	69	752	72	765	90	776	105	797	113	815	98	827	110	844	122
Sydney North 132 kV	882	-97	753	54	735	71	702	88	715	97	737	109	630	116	640	92	652	136	665	181
Sydney South 132 kV	925	48	1026	22	1058	59	1103	97	1134	121	1189	183	1226	156	1240	162	1270	195	1293	228
Tomago 132 kV	160	21	162	21	164	18	167	19	168	8	173	23	174	11	177	13	179	14	182	15
Tuggerah 132 kV	185	23	186	20	188	22	191	24	194	25	196	22	199	26	201	28	204	29	207	38
Vales Point 132 kV	104	27	105	29	107	33	108	34	110	35	110	31	111	34	112	34	113	35	114	34
Waratah West 132 kV	176	43	183	49	190	69	197	74	199	63	207	81	208	69	212	71	213	72	215	73

24 Zone substation forecasts aggregated to TransGrid bulk supply points using agreed load flow models.

TABLE A1.3 – Endeavour Energy bulk supply point summer maximum demand[25]

	2017		2018		2019		2020		2021		2022		2023		2024		2025		2026	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Dapto 132 kV	699	55	709	56	709	56	708	56	708	56	708	56	709	56	719	57	721	57	724	57
Holroyd 132 kV	360	41	363	41	405	46	407	46	410	47	413	47	416	47	419	48	423	48	427	49
Ilford 132 kV	5	1	15	4	15	4	15	4	22	6	22	5	22	5	22	5	22	5	22	5
Ingleburn 66 kV	129	31	129	31	129	31	129	31	130	31	130	31	130	31	130	31	131	32	131	32
Liverpool 132 kV	391	76	393	76	400	77	409	79	418	81	425	82	430	83	436	84	441	85	446	86
Macarthur 132 kV and 66 kV	318	57	336	61	346	62	358	65	369	67	379	68	386	70	391	71	397	72	403	73
Marulan 132 kV	71	26	70	26	70	25	70	25	70	25	70	25	69	25	69	25	69	25	69	25
Mount Piper 66 kV	28	12	28	12	28	12	28	12	28	12	28	12	28	12	28	12	28	12	28	12
Regentville 132 kV	273	72	275	72	274	72	273	72	272	72	271	71	270	71	270	71	270	71	270	71
Sydney North 132 kV	33	3	33	3	33	3	33	3	33	3	32	3	32	3	32	3	32	3	32	3
Sydney West 132 kV	1171	215	1182	217	1189	218	1196	219	1201	220	1203	221	1203	221	1202	221	1205	221	1208	222
Vineyard 132 kV	475	123	511	133	524	136	542	141	563	146	586	152	609	158	630	164	651	169	672	175
Wallerawang 132 kV and 66 kV	60	13	60	13	59	13	59	12	59	12	59	12	59	12	59	12	59	12	59	12

TABLE A1.4 – Endeavour Energy bulk supply point winter maximum demand[26]

	2017		2018		2019		2020		2021		2022		2023		2024		2025		2026	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Dapto 132 kV	705	79	717	81	726	82	726	82	728	82	728	82	728	82	730	82	738	83	743	84
Holroyd 132 kV	285	77	293	80	297	81	335	91	337	91	341	92	344	93	348	94	351	95	357	97
Ilford 132 kV	5	1	6	1	16	4	16	4	23	6	23	6	23	6	23	6	23	6	23	6
Ingleburn 66 kV	117	13	117	13	117	13	117	13	117	13	117	13	118	13	118	13	118	13	119	13
Liverpool 132 kV	276	38	284	39	287	39	293	40	297	41	302	41	307	42	311	43	315	43	322	44
Macarthur 132 kV and 66 kV	275	53	291	57	311	62	326	65	340	68	354	71	366	74	375	76	383	78	393	80
Marulan 132 kV	84	29	85	29	85	29	85	29	85	29	84	29	84	29	84	29	84	29	85	29
Mount Piper 66 kV	31	11	31	11	31	11	31	11	31	11	31	11	31	11	31	11	31	11	31	11
Regentville 132 kV	212	56	217	57	218	58	218	57	218	57	217	57	217	57	217	57	217	57	219	58
Sydney North 132 kV	27	3	28	3	27	3	27	3	27	3	27	3	27	3	27	3	27	3	28	3
Sydney West 132 kV	857	135	889	140	905	143	923	145	936	147	949	150	960	151	967	152	974	153	985	155
Vineyard 132 kV	322	62	383	74	407	79	427	82	454	88	482	93	510	98	537	104	562	108	587	113
Wallerawang 132 kV and 66 kV	83	22	84	22	83	22	83	22	83	22	83	22	83	22	83	22	83	22	84	22

25 Marulan 132 kV: Both Endeavour Energy and Essential Energy take supply from Marulan. This forecast is for the Endeavour Energy component. Diversity factors of 3% in summer should be applied to obtain the forecast total summer load at Marulan.

26 Marulan 132 kV: Both Endeavour Energy and Essential Energy take supply from Marulan. This forecast is for the Endeavour Energy component. Diversity factors of 2% in winter should be applied to obtain the forecast total winter load at Marulan.

TABLE A1.5 – Essential Energy (North) bulk supply point summer maximum demand

	2017/18		2018/19		2019/20		2020/21		2021/22		2022/23		2023/24		2024/25		2025/26		2026/27	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Armidale 66 kV	25	4	26	4	26	4	26	4	26	4	27	4	27	4	27	4	28	4	28	4
Boambee South 132 kV	17	2	17	2	18	2	18	2	19	2	19	2	20	2	20	2	20	2	21	3
Casino 132 kV	29	8	31	8	31	8	32	9	32	9	32	9	33	9	33	9	33	9	34	9
Coffs Harbour 66 kV	57	8	58	8	58	8	58	8	59	8	59	8	59	8	60	8	60	8	61	9
Dorrigo 132 kV	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
Dunoon 132 kV	6	-1	6	-1	6	-1	6	-1	6	-1	6	-1	6	-1	6	-1	6	-1	6	-1
Glen Innes 66 kV	8	-1	8	-1	8	-1	8	-1	8	-1	8	-1	8	-1	8	-1	8	-1	7	-1
Gunnedah 66 kV	25	-2	26	-2	26	-2	26	-2	26	-2	26	-2	26	-2	27	-2	27	-2	27	-2
Hawks Nest 132 kV	10	1	10	1	10	1	10	1	10	1	10	1	10	1	11	1	11	1	11	1
Herons Creek 132 kV	10	3	10	3	10	3	11	3	11	3	11	3	11	3	11	3	11	3	12	3
Inverell 66 kV	30	-3	31	-3	31	-3	31	-3	31	-3	31	-3	31	-3	31	-3	31	-3	31	-3
Kempsey 33 kV	26	6	25	6	25	6	25	6	25	6	24	6	24	6	24	6	23	6	23	6
Koolkhan 66 kV	53	8	53	8	54	8	54	8	55	8	55	8	56	8	57	8	57	8	58	8
Lismore 132 kV	91	17	92	17	92	17	92	17	92	17	93	17	93	17	93	17	93	17	94	17
Macksville 132 kV	9	1	9	1	9	1	9	1	9	1	9	1	9	1	10	2	10	2	10	2
Moree 66 kV	23	1	23	1	23	1	23	1	22	1	22	1	22	1	22	1	22	1	22	1
Mullumbimby 132 kV	37	-5	37	-5	37	-5	37	-5	37	-5	37	-5	37	-5	37	-5	38	-5	38	-5
Nambucca 66 kV	6	1	6	1	6	1	6	1	5	1	5	1	5	1	5	1	5	1	5	1
Narrabri 66 kV	52	2	53	2	53	2	54	2	55	2	55	2	56	2	57	2	58	2	58	2
Port Macquarie 33 kV	65	1	66	1	68	1	70	1	72	2	74	2	76	2	78	2	80	2	82	2
Raleigh 132 kV	10	1	11	1	11	1	11	1	11	1	12	1	12	1	12	1	12	1	13	1
Stroud 132 kV	36	-2	36	-2	37	-2	37	-2	38	-2	38	-2	38	-2	39	-2	39	-2	40	-2
Tamworth 66 kV	115	24	116	24	117	24	118	24	119	24	120	25	121	25	122	25	123	25	124	25
Taree 33 kV	30	2	30	2	30	2	31	2	31	2	31	2	31	2	32	2	32	2	32	2
Taree 66 kV	50	9	50	9	51	9	52	9	53	9	54	9	55	9	56	10	57	10	57	10
Tenterfield 22 kV	5	1	5	1	5	1	5	1	5	1	5	1	5	1	5	1	6	1	6	1
Terranora 110 kV	82	22	83	22	85	23	86	23	87	23	87	23	87	23	87	23	87	23	87	23

TABLE A1.6 – Essential Energy (North) bulk supply point winter maximum demand

	2017		2018		2019		2020		2021		2022		2023		2024		2025		2026	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Armidale 66 kV	38	5	38	5	38	5	38	5	39	5	39	5	39	5	39	5	39	5	39	5
Boambee South 132 kV	17	1	18	1	18	1	18	1	18	1	19	1	19	1	19	1	19	1	20	1
Casino 132 kV	24	3	24	3	24	3	24	3	24	3	24	3	23	3	23	3	23	3	23	3
Coffs Harbour 66 kV	53	0	53	0	52	0	51	0	50	0	50	0	49	0	48	0	47	0	47	0
Dorrigo 132 kV	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1
Dunoon 132 kV	6	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	8	0	8	0
Glen Innes 66 kV	13	-1	13	-1	13	-1	13	-1	13	-1	13	-1	13	-1	13	-1	13	-1	13	-1
Gunnedah 66 kV	23	3	23	3	23	3	23	3	23	3	23	3	23	3	23	3	23	3	23	3
Hawks Nest 132 kV	8	0	8	0	8	0	8	0	8	0	9	0	9	0	9	0	9	0	9	0
Herons Creek 132 kV	11	2	11	2	11	2	11	2	11	2	11	2	11	2	11	2	11	2	11	2
Inverell 66 kV	29	-8	29	-8	29	-8	29	-8	28	-8	28	-8	28	-8	28	-8	28	-8	28	-8
Kempsey 33 kV	30	2	30	2	30	2	31	2	31	2	31	2	32	3	32	3	32	3	32	3
Koolkhan 66 kV	45	-1	45	-1	45	-1	45	-1	44	-1	44	-1	44	-1	44	-1	44	-1	43	-1
Lismore 132 kV	80	2	82	2	84	2	86	2	88	2	90	2	92	3	95	3	97	3	99	3
Macksville 132 kV	10	1	10	1	10	1	11	2	11	2	11	2	12	2	12	2	12	2	13	2
Moree 66 kV	37	3	37	3	37	3	37	3	38	3	38	3	38	3	38	3	38	3	38	3
Mullumbimby 132 kV	52	-1	53	-1	53	-1	54	-1	54	-1	54	-1	55	-1	55	-1	55	-1	56	-1
Nambucca 66 kV	8	1	9	1	9	1	9	1	9	1	9	1	10	1	10	1	10	1	10	1
Narrabri 66 kV	48	-1	49	-1	50	-1	51	-1	52	-1	53	-1	54	-1	55	-1	56	-1	57	-1
Port Macquarie 33 kV	72	11	73	11	75	12	76	12	77	12	79	12	80	12	82	13	83	13	85	13
Raleigh 132 kV	10	2	11	2	11	2	11	2	11	2	12	2	12	2	12	2	12	2	13	2
Stroud 132 kV	31	-3	31	-3	32	-3	32	-3	33	-3	33	-3	34	-3	34	-3	35	-4	36	-4
Tamworth 66 kV	102	14	103	14	105	14	106	14	108	15	109	15	111	15	113	15	114	15	116	16
Taree 33 kV	24	2	25	2	25	2	25	2	25	2	26	3	26	3	26	3	26	3	27	3
Taree 66 kV	53	5	54	6	55	6	56	6	57	6	58	6	59	6	60	6	61	6	62	6
Tenterfield 22 kV	5	1	5	1	5	1	5	1	5	1	5	1	5	1	5	1	5	1	5	1
Terranora 110 kV	83	13	85	14	86	14	87	14	88	14	88	14	88	14	88	14	88	14	88	14

TABLE A1.7 – Essential Energy (Central) bulk supply point summer maximum demand

	2017/18		2018/19		2019/20		2020/21		2021/22		2022/23		2023/24		2024/25		2025/26		2026/27	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Beryl 66 kV	63	15	66	15	70	16	73	17	74	17	75	17	76	18	76	18	77	18	78	18
Cowra 66 kV	31	3	31	3	31	3	30	3	30	3	30	3	30	3	30	3	30	3	29	3
Forbes 66 kV	33	1	33	1	33	1	33	1	33	1	33	1	33	1	33	1	33	1	33	1
Manildra 132 kV	10	4	10	4	10	4	11	4	11	4	11	4	11	4	11	4	11	4	11	4
Molong 66 kV	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0
Mudgee 132 kV	21	0	21	0	21	0	21	0	21	0	21	0	21	0	21	0	21	0	21	0
Orange 66 kV	49	16	49	16	49	16	49	16	50	16	50	16	50	16	50	16	50	16	50	16
Orange 132 kV	142	38	145	39	148	40	151	40	155	41	158	42	162	43	165	44	169	45	172	46
Panorama 66 kV	65	16	65	16	65	16	65	16	65	16	65	16	65	16	65	16	65	16	65	16
Parkes 66 kV	27	-2	27	-2	27	-2	27	-2	28	-2	28	-2	28	-2	28	-2	28	-2	28	-2
Parkes 132 kV	32	15	32	15	32	15	32	15	33	15	33	15	33	15	34	15	34	15	34	15
Wallerawang 66 kV	4	0	4	0	4	0	4	0	4	0	4	0	4	0	4	0	4	0	4	0
Wallerawang 132 kV	21	13	21	13	21	13	20	12	20	12	20	12	19	12	19	12	19	12	19	12
Wellington Town 132 kV	10	1	10	1	10	1	11	1	11	1	11	1	11	1	11	1	11	1	11	1
Wellington 132 kV	166	5	167	5	168	5	170	5	171	5	173	5	174	5	176	5	177	5	178	5

TABLE A1.8 – Essential Energy (Central) bulk supply point winter maximum demand

	2017		2018		2019		2020		2021		2022		2023		2024		2025		2026	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Beryl 66 kV	65	7	68	7	72	7	76	8	77	8	78	8	80	8	81	8	83	9	84	9
Cowra 66 kV	24	0	24	0	23	0	23	0	23	0	23	0	23	0	23	0	23	0	23	0
Forbes 66 kV	24	-6	23	-6	23	-6	23	-6	23	-6	22	-5	22	-5	22	-5	21	-5	21	-5
Manildra 132 kV	10	3	10	3	10	3	10	3	11	4	11	4	11	4	11	4	11	4	11	4
Molong 66 kV	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	6	0
Mudgee 132 kV	22	0	23	0	23	0	23	0	23	0	23	0	23	0	24	0	24	0	24	0
Orange 66 kV	60	14	60	14	59	14	59	14	58	13	58	13	58	13	57	13	57	13	57	13
Orange 132 kV	139	39	141	39	143	40	144	40	146	41	148	41	150	42	152	43	154	43	156	44
Panorama 66 kV	67	7	67	7	66	7	66	7	65	7	65	7	64	7	64	7	64	7	63	7
Parkes 66 kV	24	-2	25	-2	25	-2	26	-2	26	-2	27	-2	27	-2	28	-2	28	-2	29	-2
Parkes 132 kV	32	12	32	12	32	12	33	12	33	12	33	12	34	13	34	13	34	13	35	13
Wallerawang 66 kV	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0
Wallerawang 132 kV	21	13	20	12	20	12	20	12	19	11	19	11	19	11	19	11	18	11	18	11
Wellington Town 132 kV	8	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1
Wellington 132 kV	145	-4	145	-4	145	-4	145	-4	145	-4	145	-4	145	-4	145	-4	145	-4	145	-4

TABLE A1.9 – Essential Energy (South and Far West) and ActewAGL bulk supply point summer maximum demand[27]

	2017/18		2018/19		2019/20		2020/21		2021/22		2022/23		2023/24		2024/25		2025/26		2026/27	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Albury 132 kV	113	10	113	10	113	10	114	10	113	10	113	10	113	11	113	11	113	11	113	11
Balranald 22 kV	4	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1
Broken Hill 22 kV	37	11	37	11	38	12	38	12	39	12	39	12	40	12	41	13	41	13	42	13
Canberra 132 kV	365	150	362	149	363	149	361	148	360	148	359	147	354	145	356	146	352	144	353	145
Coleambally 132 kV	11	5	11	5	11	5	11	5	11	5	11	5	12	5	12	5	12	5	12	5
Cooma 66 kV	14	6	14	6	14	6	13	5	13	5	13	5	12	5	12	5	12	5	12	5
Cooma 132 kV	36	-7	36	-7	36	-7	36	-7	36	-7	37	-7	37	-7	37	-7	37	-7	37	-7
Darlington Pt 132 kV	18	-9	19	-10	19	-10	20	-10	20	-10	21	-11	21	-11	22	-11	22	-11	23	-12
Deniliquin 66 kV	46	3	46	3	46	3	47	4	47	4	47	4	47	4	47	4	47	4	47	4
Finley 66 kV	18	5	18	5	18	5	18	5	18	5	18	5	17	5	17	5	17	5	17	5
Griffith 33 kV	86	10	88	10	89	10	90	11	92	11	93	11	94	11	96	11	97	11	98	11
Marulan 132 kV	42	0	43	0	43	0	44	0	45	0	45	0	46	0	46	0	47	0	48	0
Morven 132 kV	7	1	7	1	7	1	7	1	7	1	7	1	7	1	7	1	7	1	7	1
Munyang 33 kV	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
Murrumbateman 132 kV	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0
Murrumburrah 66 kV	38	12	39	13	39	13	39	13	40	13	40	13	41	13	41	13	41	13	42	14
Queanbeyan 66 kV	62	9	64	9	67	9	69	9	70	9	71	9	71	9	72	9	73	9	75	9
Queanbeyan 132 kV	8	0	9	0	10	0	11	-1	11	-1	11	-1	11	-1	11	-1	11	-1	11	-1
Snowy Adit 132 kV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tumut 66 kV	35	23	35	23	35	23	35	23	36	24	36	24	36	24	36	24	37	25	37	25
Wagga 66 kV	97	32	98	32	98	32	99	33	99	33	100	33	100	33	101	33	101	33	102	34
Wagga North 132 kV	63	0	62	0	62	0	61	0	61	0	60	0	59	0	59	0	58	0	58	0
Wagga North 66 kV	19	3	19	3	19	3	19	3	19	3	19	3	19	3	19	3	19	3	19	3
Williamsdale 132 kV	197	40	196	40	196	40	195	40	195	40	194	40	191	39	192	39	190	39	191	39
Yanco 33 kV	39	14	39	14	40	15	41	15	41	15	42	15	43	16	43	16	44	16	45	17
Yass 66 kV	12	-1	12	-1	12	-1	12	-1	12	-1	12	-1	12	-1	12	-1	13	-1	13	-1

27 Marulan 132 kV: Both Endeavour Energy and Essential Energy take supply from Marulan. This forecast is for the Essential Energy component. Diversity factors of 3% in summer should be applied to obtain the forecast total summer load at Marulan.

TABLE A1.10 – Essential Energy (South and Far West) and ActewAGL bulk supply point winter maximum demand[28]

	2017		2018		2019		2020		2021		2022		2023		2024		2025		2026	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Albury 132 kV	83	9	82	9	82	9	81	9	80	9	79	8	79	8	79	9	78	8	77	8
Balranald 22 kV	2	0	2	0	2	0	2	0	2	0	3	0	3	0	3	0	3	0	3	0
Broken Hill 22 kV	34	4	33	4	33	4	33	4	33	4	33	4	33	4	33	4	33	4	32	3
Canberra 132 kV	443	117	444	117	448	118	449	118	450	119	453	119	453	119	455	120	457	120	460	121
Coleambally 132 kV	5	1	5	1	5	1	5	1	5	1	5	1	4	1	4	1	4	1	4	1
Cooma 66 kV	32	2	31	2	31	2	30	2	30	2	29	2	29	2	28	2	28	2	27	2
Cooma 132 kV	42	1	42	1	42	1	41	1	41	1	41	1	41	1	41	1	40	1	40	1
Darlington Pt 132 kV	19	-12	19	-12	20	-13	21	-13	21	-13	22	-14	23	-15	23	-15	24	-15	25	-16
Deniliquin 66 kV	30	-4	30	-4	30	-4	30	-4	31	-4	31	-4	31	-4	31	-4	31	-4	31	-4
Finley 66 kV	15	0	15	0	15	0	15	0	14	0	14	0	14	0	14	0	14	0	14	0
Griffith 33 kV	48	14	48	14	49	14	49	14	49	14	50	15	50	15	50	15	51	15	51	15
Marulan 132 kV	50	6	50	6	50	6	51	6	51	6	51	6	52	6	52	6	52	6	53	6
Morven 132 kV	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0
Munyang 33 kV	29	10	29	10	29	10	29	10	29	10	29	10	29	10	29	10	29	10	29	10
Murrumbateman 132 kV	6	0	6	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0
Murrumburrah 66 kV	35	12	36	12	37	12	38	12	39	13	40	13	41	13	42	14	43	14	44	14
Queanbeyan 66 kV	69	9	70	9	72	10	73	10	74	11	76	11	76	11	77	11	77	11	78	12
Queanbeyan 132 kV	7	-1	8	-1	9	-1	10	-1	10	-1	10	-1	10	-1	10	-1	10	-1	10	-1
Snowy Adit 132 kV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tumut 66 kV	31	14	30	13	30	13	30	13	30	13	30	13	30	13	29	13	29	13	29	13
Wagga 66 kV	70	23	70	23	69	23	69	23	69	23	68	22	68	22	68	22	67	22	67	22
Wagga North 132 kV	57	0	56	0	56	0	56	0	56	0	56	0	55	0	55	0	55	0	55	0
Wagga North 66 kV	17	2	17	2	17	2	17	2	17	2	17	2	17	2	17	2	16	2	16	2
Williamsdale 132 kV	201	43	202	43	203	43	204	43	204	43	205	44	205	44	206	44	207	44	209	44
Yanco 33 kV	30	6	31	6	31	6	31	6	32	7	32	7	32	7	33	7	33	7	33	7
Yass 66 kV	13	-2	13	-2	13	-2	13	-2	13	-2	13	-2	13	-2	13	-2	13	-2	13	-2

TABLE A1.11 – Major industrial customers – Sum of individual summer maximum demands

	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
Industrial Loads	1027	1019	1021	1025	1027	1027	1027	1027	1027	1027

TABLE A1.12 – Major industrial customers – Sum of individual winter maximum demands

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
Industrial Loads	1052	1039	1031	1034	1039	1040	1040	1040	1040	1040

28 Marulan 132 kV: Both Endeavour Energy and Essential Energy take supply from Marulan. This forecast is for the Essential Energy component. Diversity factors of 2% in winter should be applied to obtain the forecast total winter load at Marulan.

Appendix 2

How we plan

Appendix 2

How we plan

Our network investment process is designed to respond to the changing needs of stakeholders and ensure the efficient delivery of our capital program.

The process includes:

- Early engagement with stakeholders throughout the planning cycle, involving end-users and impacted communities
- An integrated, whole-of-business approach to capital program management
- Optimisation of investments, and operating and maintenance costs, while meeting augmentation and asset management requirements
- Early resolution of key risk areas such as environmental approvals, property acquisition and scope definition in the project delivery process
- Documented options evaluations and project scoping to enhance transparency.

The key processes and steps, including where and how we engage with stakeholders, are set out in Figure A2.1.

Figure A2.1 Planning Methodology

		TransGrid planning process	Stakeholder involvement
STAGE 1	Identify need	Look at demand forecasts, expected generation patterns and the condition of existing assets. Will there be a shortfall in supply if we do nothing?	Sense-check forecasts with • Distributors • Directly connected customers • AEMO Seek feedback from end users and their representatives on need assessment.
STAGE 2	Review options	Identify possible network and non-network options to fulfil the need, including: • Demand management • Local or distributed generation • Network infrastructure optimised to expected requirements • Improved operational and maintenance regimes	Input from large users, service providers and experts on potential for non-network options. Communicate with local community that may be impacted by network infrastructure.
STAGE 3	Plan in detail	Request proposals and undertake investment analysis on most viable options.	Encourage proposals from market participants for non-network options. Engage impacted communities in network corridor selection, if relevant. Involve end users and their representatives in final investment decision.
STAGE 4	Implement solution	Enter into contracts for network or non-network solutions. Build or renew network infrastructure, if required.	Work with impacted community to support best local outcomes. Report progress in meeting identified need to end users and their representatives.

Planning approach

As a TNSP, we are obliged to meet the requirements of the National Electricity Rules (NER). In particular, we are obliged to meet the requirements of clause S5.1.2.1:

'Network Service Providers must plan, design, maintain and operate their transmission networks and distribution networks to allow the transfer of power from generating units to Customers with all facilities or equipment associated with the power system in service and may be required by a Registered Participant under a connection agreement to continue to allow the transfer of power with certain facilities or plant associated with the power system out of service, whether or not accompanied by the occurrence of certain faults (called 'credible contingency events').'

The NER sets out the required processes for developing networks as well as minimum performance requirements of the network and connections to the network. It requires us to consult with Registered Participants and interested parties and to apply the Australian Energy Regulator's (AER's) Regulatory Investment Test for Transmission (RIT-T) as appropriate to development proposals.

Our planning obligations are interlinked with the reliability obligations placed on DNSPs in NSW. We must ensure that its system is adequately planned to enable these licence requirements to be met.

We plan the network to achieve supply at least cost to the community, without being constrained by state borders or ownership considerations.

Our approach to network planning includes consideration of non-network options, including demand side response and demand management and/or embedded generation, as an integral part of the planning process. Joint planning with DNSPs, directly supplied industrial customers, generators and interstate TNSPs is carried out to ensure that the most economic options, whether network options or non-network options, consistent with customer and community requirements are identified and implemented.

Jurisdictional planning requirements

In addition to meeting requirements imposed by the NER, environmental legislation and other statutory instruments, we are required to comply with the Transmission Network Design and Reliability Standard set by the NSW Government. The current standard generally requires us to plan and develop our transmission network in NSW on an N–1 basis. That is, unless specifically agreed otherwise with the affected distribution network owner or major directly connected end-use customer, there will be no inadvertent loss of load (other than load which is interruptible or dispatchable) following an outage of a single circuit (a line or a cable) or transformer, during periods of forecast high load.

In fulfilling our obligations, we must recognise specific customer requirements as well as the Australian Energy Market Operator's (AEMO) role as system operator for the National Electricity Market (NEM). To accommodate this, the standard N–1 approach can be modified in the following circumstances:

- Where agreed with a distribution network owner or major directly connected end-use customer, agreed levels of supply interruption can be accepted for particular single outages, before augmentation of the network is undertaken (for example the situation with radial supplies)
- Where requested by a distribution network owner or major directly connected end-use customer and agreed with us, there will be no inadvertent loss of load (other than load which is interruptible or dispatchable) following events more onerous than N–1 such as concurrent outages of two network elements
- The main transmission network, which is operated by AEMO, should have sufficient capacity to accommodate AEMO's operating practices without inadvertent loss of load (other than load which is interruptible or dispatchable) or uneconomic constraints on the energy market. AEMO's operational practices include the re-dispatch of generation and ancillary services following a first contingency, such that within 30 minutes the system will again be 'secure' in anticipation of the next critical credible contingency.

These jurisdictional requirements and other obligations require the following to be observed in planning:

- At all times when the system is either in its normal state with all elements in service or following a credible contingency:
  - Electrical and thermal ratings of equipment will not be exceeded
  - Stable control of the interconnected system will be maintained, with system voltages maintained within acceptable levels
- A quality of electricity supply at least to NER requirements is to be provided
- A standard of connection to individual customers as specified by Connection Agreements is to be provided
- As far as possible connection of a customer is to have no adverse effect on other connected customers
- Environmental and social objectives are to be satisfied
- Acceptable safety standards are to be maintained
- The power system in NSW is to be developed at the lowest cost possible whilst meeting the constraints imposed by the above factors.

Consistent with a responsible approach to the environment, it is also aimed to reduce system energy losses where economic.

A further consideration is the provision of sufficient capability in the system to allow components to be maintained in accordance with our asset management strategies.

The NSW Government requested that the Independent Pricing and Regulatory Tribunal (IPART) develop reliability standards for electricity transmission in NSW to apply from the next regulatory period which starts on 1 July 2018. The new standards are discussed in section 4.4.

National planning requirements

AEMO has the role of the national transmission planner and is required to produce a National Transmission Network Development Plan (NTNDP). The NTNDP has regard to jurisdictional planning and regulatory documents (such as Transmission Annual Planning Reports) and, in turn, the jurisdictional planning bodies need to have regard to the NTNDP in formulating their plans. Our plans are consistent with AEMO's plans set out in the NTNDP.

The network planning process

The network planning process is undertaken at three levels:

1. Connection planning

Connection planning is concerned with the local network directly related to the connection of loads and generators. Connection planning typically includes connection enquiries and the formulation of draft connection agreements leading to a preliminary review of the capability of connections. Further discussions are held with specific customers where there is a need for augmentation or for provision of new connection points.

2. Network planning within the NSW region

The main 500 kV, 330 kV and 220 kV transmission system is developed in response to overall load growth and generation developments and may be influenced by interstate power transfers through interconnection. Any developments include liaison with affected NSW and interstate parties.

The assessment of the adequacy of 132 kV systems requires joint planning with DNSPs. This ensures that development proposals are optimal with respect to both transmission and distribution requirements leading to the lowest possible cost of transmission to the end customer. This is particularly important where the DNSP's network operates in parallel with the transmission network, forming a meshed system.

3. Inter-regional planning

The development of interconnectors between regions and of augmentations within regions that have a material effect on inter-regional power transfer capability are coordinated with network owners in other states in accordance with the NER. Inter-regional developments are planned consistent with the NTNDP.

Consideration of non-network alternatives

Our planning process includes consideration and adoption, where economic, of non-network alternatives which can address the emerging constraint(s) under consideration and may defer or cancel the need for network augmentations.

Compliance with NER requirements

Our approach to the development of the network since the commencement of the NEM is in accordance with the NER, other rules and guidelines published by the AER and the Australian Energy Market Commission (AEMC).

Planning horizons and reporting

Transmission planning is carried out over a short-term time frame of one to seven years, medium-term time frames of seven to 15 years and long-term time frames of 15 to 50 years. The short-term planning supports commitments to network developments with relatively short lead-times. The medium-term planning looks at currently emerging technologies and their impact on the power system. The long-term planning considers options for future major developments and provides a framework for the orderly and economic development of the transmission network and the strategic acquisition of critical line and substation sites.

In this TAPR, the constraints that appear over long-term time frames are considered to be indicative. The timing and capital cost of possible network options to relieve them may change significantly as system conditions evolve. We have published outline plans including data for possible long-term developments.

Identifying network constraints and assessing possible solutions

An emerging constraint is identified during various planning activities covering the planning horizon. It may be identified through:

- Our planning activities
- Joint planning with other NSPs
- The impact of prospective generation developments
- The occurrence of constraints affecting generation dispatch in the NEM
- The impact of network developments undertaken by other TNSPs
- As a result of a major load development.

During the initial planning phase, a number of options for addressing the constraint are developed. In accordance with NER requirements, consultation with interested parties is carried out to determine a range of options including network, demand management and local generation options and/or to refine existing options.

A cost effectiveness or cost-benefit analysis is carried out in which the costs and benefits of each option are compared in accordance with the RIT-T consultation process. In applying the applicable test the cost and benefit factors may include:

- Avoiding unserved energy caused by either a generation shortfall or inadequate transmission capability or reliability
- Reduction in greenhouse gas emissions or increased capability to apply low emissions plant
- Loss reductions
- Alleviating constraints affecting generation dispatch
- Avoiding the need for generation developments
- More efficient generation and fuel type alternatives
- Improvement in marginal loss factors
- Deferral of related transmission works
- Reduction in operation and maintenance costs.

Options with similar net present value would be assessed with respect to factors that may not be able to be quantified and/or included in the RIT-T, but nonetheless may be important from environmental or operational viewpoints. These factors include (but are not limited to):

- Improvement in quality of supply above minimum requirements
- Improvement in operational flexibility.

Application of power system controls and technology

We seek to take advantage of the latest proven technologies in network control systems and electrical plant where these are found to be economic. For example, the application of SVCs has had a considerable impact on the power transfer capabilities of parts of the main grid, and has deferred or removed the need for higher cost transmission line developments in the past.

System protection schemes have been applied in several areas of the NSW system to reduce the impact of network limitations on the operation of the NEM, and to facilitate the removal of circuits for maintenance.

The broad approach to planning and consideration of these technologies, together with related issues of protection facilities, transmission line design, substation switching arrangements and power system control and communication, is set out in the following sections. This approach is in line with international practice and provides a cost effective means of maintaining a safe, reliable, secure and economic supply system consistent with maintaining a responsible approach to environmental and community impacts.

A2.1 Planning criteria

The NER specifies the minimum and general technical requirements in a range of areas including:

- A definition of the minimum level of credible contingency events to be considered
- The power transfer capability during the most critical single element outage. This can range from zero in the case of a single element supply to a portion of the normal power transfer capability
- Frequency variations
- Magnitude of power frequency voltages
- Voltage fluctuations
- Voltage harmonics
- Voltage unbalance
- Voltage stability
- Synchronous stability
- Damping of power system oscillations
- Fault clearance times
- The need for two independent high speed protection systems
- Rating of transmission lines and equipment.

In addition to adherence to NER and regulatory requirements, our transmission planning approach has been developed taking into account the historical performance of the components of the NSW system, the sensitivity of loads to supply interruption, and state-of-the-art asset maintenance procedures. It has also been recognised that there is a need for an orderly development of the system taking into account the requirement to meet future load and generation developments.

A set of criteria, detailed below, are applied as a point of first review, from which point a detailed assessment of each individual case is made.

Main transmission network

The NSW main transmission system is the transmission system connecting the major power stations and load centres and providing the interconnections from NSW to Qld and Vic. It includes the majority of the transmission system operating at 500 kV, 330 kV and 220 kV.

Power flows on the main transmission network are subject to overall State load patterns and the dispatch of generation within the NEM, including interstate export and import of power. AEMO operates the interconnected power system and applies operational constraints on generator dispatch to maintain power flows within the capability of the NSW and other regional networks. These constraints are based on the ability of the networks to sustain credible contingency events that are defined in the NER. These events mainly cover forced outages of single generation or transmission elements, but also provide for multiple outages to be redefined as credible from time to time. Constraints are often based on short-duration loadings on network elements, on the basis that generation can be re-dispatched to relieve the line loading within 15 minutes.

The rationale for this approach is that, if operated beyond a defined power transfer level, credible contingency disturbances could potentially lead to system-wide loss of load with severe social and economic impact.

Following any transmission outage, for example during maintenance or following a forced line outage for which line reclosure has not been possible, AEMO applies more severe constraints within a short adjustment period, in anticipation of the impact of a further contingency event. This may require:

- The re-dispatch of generation and dispatchable loads
- The redistribution of ancillary services
- Where there is no other alternative, the shedding (interruption) of load.

AEMO may direct the shedding of customer load, rather than operate for a sustained period in a manner where overall security would be at risk for a further contingency. The risk is, however, accepted over a period of up to 30 minutes. We consider AEMO's imperative to operate the network in a secure manner.

Our planning for the main network concentrates on the security of supply to load connection points under sustained outage conditions, consistent with the overall principle that supply to load connection points must be satisfactory after any single contingency.

The main 500 kV, 330 kV and 220 kV transmission system is augmented in response to the overall load growth and generation requirements and may be influenced by interstate interconnection power transfers. Any developments include negotiation with affected NSW and interstate parties including AEMO to maintain power flows within the capability of the NSW and other regional networks.

The reliability of the main system components and the ability to withstand a disturbance to the system are critically important in maintaining the security of supply to NSW customers. A high level of reliability implies the need for a robust transmission system. The capital cost of this system is balanced by:

- Avoiding the large cost to the community of widespread shortages of supply
- Providing flexibility in the choice of economical generating patterns
- Allowing reduced maintenance costs through easier access to equipment
- Minimising electrical losses which also provides benefit to the environment.

The planning of the main system must take into account the risk of forced outages of a transmission element coinciding with adverse conditions of load and generation dispatch. Two levels of load forecast (summer and winter) are considered, as follows.

Loads at or exceeding a one in two year probability of occurrence (50% POE)

The system will be able to withstand a single contingency under all reasonably probable patterns of generation dispatch or interconnection power flow. In this context, a single contingency is defined as the forced outage of a single transmission circuit, generating unit, transformer, reactive plant or a busbar section.

Provision will be made for a prior outage (following failure) of a single item of reactive plant.

Further, the system will be able to be secured by re-dispatching generation (AEMO action), without the need for pre-emptive shedding (interruption) of load, so as to withstand the impact of a second contingency.

Loads at or exceeding a one in ten year probability of occurrence (10% POE)

The system will be able to withstand a single contingency under a limited set of patterns of generation dispatch or interconnection power flow.

Further, the system will be able to be secured by re-dispatching generation (AEMO action), without the need for pre-emptive load shedding, so as to withstand the impact of a second contingency.

These criteria do not apply to radial sections of the main system.

The patterns of generation applied to the 50% POE load level cover patterns that are expected to have a relatively high probability of occurrence, based on the historical performance of the NEM and modelling of the NEM generation sources into the future. The limited set of patterns of generation applied to the 10% probability of exceedance load level cover two major power flow characteristics that occur in NSW. The first power flow characteristic involves high output from baseload generation sources throughout NSW and high import to NSW from Qld. The second power flow characteristic involves high import to NSW from Vic and southern NSW generation coupled with high output from the NSW baseload generators.

Under all conditions there is a need to achieve adequate voltage control capability. We have traditionally assumed that all online generators can provide reactive power support within their rated capability. However, in the future, we intend to align with other utilities in relying only on the reactive capability given by performance standards. Reactive support beyond the performance standards may need to be procured under network support arrangements.

A further consideration is the provision of sufficient capability in the system to allow components to be maintained in accordance with our asset management strategies.

Supply in NSW is heavily dependent on base load coal fired generation in the Hunter Valley, the western area and Central Coast. These areas are interconnected with the load centres via numerous single and double circuit lines. In planning the NSW system, taking into account AEMO's operational approach to the system, there is a need to consider the risk and impact of overlapping outages of circuits under high probability patterns of load and generation.

The analysis of network adequacy must take into account the probable load patterns, typical dispatch of generators and loads, the availability characteristics of generators (as influenced by maintenance and forced outages), energy limitations and other factors relevant to each case.

Options to address an emerging inability to meet all connection point loads would be considered with allowance for the lead time for a network augmentation solution.

Before this time, consideration may be given to the costs involved in re-dispatch in the energy and ancillary services markets to manage single contingencies. In-situations where these costs appear to exceed the costs of a network augmentation, this will be brought to the attention of network load customers for consideration. We may then initiate the development of a network or non-network solution through a consultation process.

Relationship with inter-regional planning

We monitor the occurrence of constraints in the main transmission system that affects generator dispatch. Our planning therefore also considers the scope for network augmentations to reduce constraints that may satisfy the RIT-T.

Under the provisions of the NER, a region may be created where constraints to generator dispatch are predicted to occur with reasonable frequency when the network is operated in the 'system normal' (all significant elements in service) condition. The creation of a region does not consider the consequences to load connection points if there should be a network contingency.

The capacity of interconnectors that is applied in the market dispatch is the short-time capacity determined by the ability to maintain secure operation in the system normal state in anticipation of a single contingency. The operation of the interconnector at this capacity must be supported by appropriate ancillary services. AEMO does not operate on the basis that the contingency may be sustained but we must consider the impact of a prolonged plant outage.

As a consequence, it is probable that for parts of the network that are critical to the supply to loads, we would initiate augmentation to meet an N–1 criterion before the creation of a new region.

The development of interconnectors between regions will be undertaken where the augmentation satisfies the RIT-T. The planning of interconnections will be undertaken in consultation with the jurisdictional planning bodies of the other states.

It is not planned to maintain the capability of an interconnector where relevant network developments would not satisfy the RIT-T.

Networks supplied from the main transmission network

Some parts of our network are primarily concerned with supply to local loads and are not significantly impacted by the dispatch of generation (although they may contain embedded generators). The loss of a transmission element within these networks does not have to be considered by AEMO in determining network constraints, although ancillary services may need to be provided to cover load rejection in the event of a single contingency.

Supply to major load areas and sensitive loads

The NSW system contains six major load areas: Northern; Newcastle and Central Coast; Greater Sydney; Central; Southern; and South Western NSW.

Some of these load areas, including individual smelters, are supplied by a limited number of circuits, some of which may share double circuit line sections. It is strategically necessary to ensure that significant individual loads and load areas are not exposed to loss of supply in the event of multiple circuit failures. As a consequence, it is necessary to assess the impact of contingency levels that exceed N–1.

Outages of network elements for planned maintenance must also be considered. Generally this will require 75% of the peak load to be supplied during the outage. While every effort would be made to secure supplies in the event of a further outage, this may not be always possible. In this case attention would be directed to minimising the duration of the plant outage.

Urban and suburban areas

Generally, urban and suburban networks are characterised by a high load density served by high capacity underground cables and relatively short transmission lines. The connection points to our network are usually the low voltage (132 kV) busbars of 330 kV substations. There may be multiple connection points and significant capability on the part of the DNSP to transfer load between connection points, either permanently or to relieve short-time loadings on network elements after a contingency.

The focus of joint planning with DNSPs is the capability of the meshed 330/132 kV system and the capability of the existing connection points to meet expected maximum loadings. Joint planning addresses the need for augmentation to the meshed 330/132 kV system and our connection point capacity or to provide a new connection point where this is the most economic overall solution.

Consistent with good international practice, supply to high-density urban and central business districts is given special consideration. For example, the inner Sydney metropolitan network serves a large and important part of the State load. Supply to this area is largely via a 330 kV and 132 kV underground cable network. The 330 kV cables are part of our network and the 132 kV cable system is part of Ausgrid's network. The existing reliability standard for the area specified by the NSW Government in the Transmission Network Design and Reliability Standard is that the system will be capable of meeting the peak load under the following contingencies:

1. The simultaneous outage of a single 330 kV cable and any 132 kV feeder or 330/132 kV transformer; or
2. An outage of any section of 132 kV busbar.

The requirement for a reliability criterion for the overall network that is more onerous than N–1 reflects:

- The importance and sensitivity of the Sydney area load to supply interruptions
- The high cost of applying a strict N–2 criterion to the 330 kV cable network
- The large number of elements in the 132 kV network
- The past performance of the cable system
- The long time to repair cables should they fail.

The criterion applied to the Inner Sydney area is consistent with that applied in the electricity supply to major cities throughout the world. Most countries use an N–2 criterion. Some countries apply an N–1 criterion with some selected N–2 contingencies that commonly include two cables sharing the one trench or a double circuit line.

The above criterion is applied in the following manner in planning analysis:

1. Under system normal conditions, all elements must be loaded within their 'recurrent cyclic' rating
2. System loadings under first contingency outages will remain within equipment recurrent cyclic ratings without corrective switching other than for automatic switching or 'auto-change-over'
3. Cyclic load shedding (in areas other than the Sydney CBD) may be required in the short term following a simultaneous outage of a single 330 kV cable, and any 132 kV transmission feeder or 330/132 kV transformer in the inner metropolitan area, until corrective switching is carried out on the 330 kV or 132 kV systems
4. The system should be designed to remove the impact of a busbar section outage at existing transmission substations. New transmission substations should be designed to cater for busbar section outages
5. The load forecast to be considered is based on '50% probability of exceedance'
6. Loading is regarded as unsatisfactory when 330/132 kV transformers and 330 kV or 132 kV cables are loaded beyond their recurrent cyclic rating
7. Fault interruption duty must be contained to within equipment ratings at all times.

Outages of network elements for planned maintenance must also be considered. Generally this will require 75% of the peak load to be supplied during an outage. While every effort would be made to secure supplies in the event of a further outage, this may not be always possible. In this case attention would be directed to minimising the duration of the outage.

From 1 July 2018, we must incorporate an allowable unserved energy at connection points when planning the network.

Non-urban areas

Generally, these areas are characterised by lower load densities and, generally, lower reliability requirements than urban systems.

The areas are sometimes supplied by relatively long, often radial, transmission systems. Connection points are either on 132 kV lines or on the low voltage busbars of 132 kV substations. Although there may be multiple connection points to a DNSP, they are often far apart and there will be little capacity for power transfer between them. Frequently supply limitations will apply to the combined capacity of several supply points together.

The focus of joint planning with DNSPs will usually relate to:

- Augmentation of connection point capacity
- Duplication of radial supplies
- Extension of the 132 kV system to reinforce or replace existing lower voltage systems and to reduce losses
- Development of a higher voltage system to provide a major augmentation and to reduce network losses.

Supply to one or more connection points would be considered for augmentation when the forecast maximum demand at the end of the planning horizon exceeds the load firm N–1 capacity of our network. However, consistent with the lower level of reliability that may be appropriate in a non-urban area, an agreed level of risk of loss of supply may be accepted. Thus augmentations may actually be undertaken:

- When the forecast load exceeds the firm capacity by an agreed amount
- Where the period that some load is at risk exceeds an agreed proportion of the time
- An agreed amount of energy (or proportion of annual energy supplied is at risk.

As a result of the application of the criteria, some radial parts of the 330 kV and 220 kV network are not able to withstand the forced outage of a single circuit line at time of maximum demand, and in these cases provision has been made for under-voltage load shedding.

Provision is also required for the maintenance of the network. Additional redundancy in the network is required where maintenance cannot be scheduled without causing load restrictions or an unacceptable level of risk to the security of supply.

Transformer augmentation

In considering the augmentation of transformers, appropriate allowance is made for the transformer cyclic rating[29] and the practicality of load transfers between connection points.

The outage of a single transformer (or single-phase unit) or a transmission line that supports the load carried by the transformer is allowed for.

Provision is also required for the maintenance of transformers. This has become a critical issue at a number of sites in NSW where there are multiple transformers in service. To enable maintenance to be carried out, additional transformer capacity or a means of transferring load to other supply points via the underlying lower voltage network may be required.

Consideration of low probability events

Although there is a low probability that loads will need to be shed (interrupted) as a result of system disturbances, no power system can be guaranteed to deliver a firm capability 100% of the time, particularly when subjected to disturbances that are severe or widespread. It is also possible that extreme loads, above the level allowed for in planning, can occur, usually under extreme weather conditions.

The NSW network contains numerous lines of double circuit construction and, whilst the probability of overlapping outages of both circuits of a line is very low, the consequences could be widespread supply disturbances.

Thus there is a potential for low probability events to cause localised or widespread disruption to the power system. These events can include:

- Loss of several transmission lines within a single corridor, as may occur during bushfires
- Loss of a number of cables sharing a common trench
- Loss of more than one section of busbar within a substation, possibly following a major plant failure
- Loss of a number of generating units
- Occurrence of three-phase faults,[30] or faults with delayed clearing.

In our network, appropriate facilities and mechanisms are put in place to minimise the probability of such events and to lessen their impact. The decision process considers the underlying economics of facilities or corrective actions, taking account of the low probability of the occurrence of extreme events.

We will take measures, where practicable, to minimise the impact of disturbances to the power system by implementing power system control systems at minimal cost in accordance with the NER.

29 Transformer nominal ratings are based on them carrying a constant load. However, loads are often cyclic (they vary throughout the day). In these cases transformers may be able to carry more than their nominal rating for a short period around the time of the maximum load as they are loaded less heavily before and after that period. A cyclic loading takes this into account.

30 Alternating current power systems generally have three phases. Faults on those systems can involve one, two or all three of those phases. Faults involving three phases are generally the most onerous.

A2.2 Protection requirements

Basic protection requirements are included in the NER. The NER requires that protection systems be installed so that any fault can be detected by at least two fully independent protection systems. Backup protection is provided against circuit breaker failure. Provision is also made for detecting high resistance earth faults.

Required protection clearance times are specified by the NER and determined by stability considerations as well as the characteristics of modern power system equipment. Where special protection facilities or equipment are required for high-speed fault clearance, they are justified on either NER compliance or a benefit/cost basis.

All modern distance protection systems on the main network include the facility for power swing blocking (PSB). PSB is utilised to control the impact of a disturbance that can cause synchronous instability. At the moment PSB is not enabled, except at locations where demonstrated advantages apply. This feature will become increasingly more important as the interconnected system is developed and extended.

A2.3 Transient stability

In accordance with the NER, transient stability is assessed on the basis of the angular swings following a solid fault on one circuit at the most critical location that is cleared by the faster of the two protections (with intertrips assumed in service where installed). At the main system level a two phase-to-ground fault is applied and on 132 kV systems, which are to be augmented, a three-phase fault is applied.

Recognition of the potential impact of a three-phase fault at the main system level is made by instituting maintenance and operating precautions to minimise the risk of such a fault.

The determination of the transient stability capability of the main grid is undertaken using software that has been calibrated against commercially available system dynamic analysis software.

Where transient stability is a factor in the development of the main network, preference is given to the application of advanced control of the power system or high-speed protection systems, before consideration is given to the installation of high capital cost plant.

A2.4 Steady state stability

The requirements for the control of steady state stability are included in the NER. For planning purposes, steady state stability (or system damping) is considered adequate under any given operating condition if, after the most critical credible contingency, simulations indicate that the halving time of the least damped electromechanical mode of oscillation is not more than five seconds.

The determination of the steady state stability performance of the system is undertaken using software that has been calibrated against commercially available software and from data derived from the monitoring of system behaviour.

In planning the network, maximum use is made of existing plant, through the optimum adjustment of plant control system settings, before consideration is given to the installation of high capital cost plant.

A2.5 Line and equipment thermal ratings

Line thermal ratings have often traditionally been based on a fixed continuous rating and a fixed short-time rating. We apply probabilistic-based line ratings, which are dependent on the likelihood of coincident adverse weather conditions and unfavourable loading levels. This approach has been applied to selected lines whose design temperature is about 100°C or less. For these lines, a contingency rating and a short-time emergency rating have been developed. Typically, the short-time rating is based on a load duration of 15 minutes, although the duration can be adjusted to suit the particular load pattern to which the line is expected to be exposed. The duration and level of loading must take into account any requirements for re-dispatch of generation or load control.

We have installed ambient condition monitors on a number of transmission lines to enable the application of real-time line conductor ratings in the generation dispatch systems.

Transformers are rated according to their specification. Provision is also made for use of the short-time capability of the transformers during the outage of a parallel transformer or transmission line.

We own 330 kV cables and these are rated according to the manufacturer's recommendations that have been checked against an appropriate thermal model of the cable.

The rating of line terminal equipment is based on the manufacturers' advice.

A2.6 Reactive support and voltage stability

It is necessary to maintain voltage stability, with voltages within acceptable levels, following the loss of a single element in the power system at times of peak system loading. The single element includes a generator, a single transmission circuit, a cable and single items of reactive support plant.

To cover fluctuations in system operating conditions, uncertainties of load levels, measurement errors and errors in the setting of control operating points, it is necessary to maintain a margin from operating points that may result in a loss of voltage control. A reactive power margin is maintained over the point of voltage instability or alternatively a margin is maintained with respect to the power transfer compared to the maximum feasible power transfer.

The system voltage profile is set to standard levels during generator dispatch to minimise the need for post-contingency reactive power support.

Reactive power plant generally has a low cost relative to major transmission lines, and the incremental cost of providing additional capacity in a shunt capacitor bank can be very low. Such plant can also have a very high benefit/cost ratio and therefore the timing of reactive plant installations is generally less sensitive to changes in load growth, than the timing of other network augmentations. Even so, we aim to make maximum use of existing reactive sources before new installations are considered.

We have traditionally assumed that all online generators can provide reactive power support within their rated capability, but in the future intend to align with other utilities in relying only on the reactive capability given by performance standards. Reactive support beyond the performance standards may need to be procured under network support arrangements.

Reactive power plant is installed to support planned power flows up to the capability defined by limit equations, and is often the critical factor determining network capability. On the main network, allowance is made for the unavailability of a single major source of reactive power support in the critical area affected at times of high load, but not at the maximum load level.

It is also necessary to maintain control of the supply voltage to the connected loads under minimum load conditions.

The factors that determine the need for reactive plant installations are:

- In general it has proven prudent and economic to limit the voltage change between the pre- and post-contingency operating conditions
- It has also proven prudent, in general, and economic to ensure that the post-contingency operating voltage at major 330 kV busbars lies above a lower limit
- The reactive margin from the point of voltage collapse is maintained to be greater than a minimum acceptable level
- A margin between the power transmitted and the maximum feasible power transmission is maintained
- At times of light system load, it is essential to ensure that voltages can be maintained within the system highest voltage limits of equipment.

Following forced outages, relatively large voltage changes are accepted at some locations on the main network, and agreed with customers, providing voltage stability is not placed at risk. These voltage changes can approach, and in certain cases, exceed 10% of maximum demand.

On some sections of the network, the possibility of loss of load due to depressed voltages following a contingency is also accepted. However, there is a preference to install load shedding initiated by under-voltage so that the disconnection of load occurs in a controlled manner.

When determining the allowable rating of switched reactive plant, the requirements of the NER are observed.

A2.7 Transmission line voltage and conductor sizes determined by economic considerations

Consideration is given to the selection of line design voltages within the standard nominal 132 kV, 220 kV, 275 kV, 330 kV and 500 kV range, taking due account of transformation costs.

Minimum conductor sizes are governed by losses, radio interference and field strength considerations.

We strive to reduce the overall cost of energy and network services by the economic selection of line conductor size. The actual losses that occur are governed by generation dispatch in the market.

For a line whose design is governed by economic loading limits, the conductor size is determined by a rigorous consideration of capital cost versus loss costs. Hence the impact of the development on generator and load marginal loss factors in the market is considered. For other lines, the rating requirements will determine the conductor requirements.

Double circuit lines are built in place of two single circuit lines where this is considered to be both economic and to provide adequate reliability. Consideration would be given to the impact of a double circuit line failure, both over relatively short terms and for extended durations. This means that supply to a relatively large load may require single rather than double circuit transmission line construction where environmentally acceptable.

In areas prone to bushfire, any parallel single circuit lines would preferably be routed well apart.

A2.8 Short-circuit rating requirements

Substation high voltage equipment is designed to withstand the maximum expected short circuit duty[31] in accordance with the applicable Australian Standard.

Operating constraints are enforced to ensure equipment is not exposed to fault duties beyond the plant rating.

In general, the short circuit capability of all of the plant at a site would be designed to match or exceed the maximum short circuit duty at the relevant busbar. In order to achieve cost efficiencies when augmenting an existing substation, the maximum possible short circuit duty on individual substation components may be calculated and applied in order to establish the adequacy of the equipment.

Short circuit duty calculations are based on the following assumptions:

- All main network generators that are capable of operating, as set out in connection agreements, are assumed to be in service
- All generating units that are embedded in distribution networks are assumed to be in service
- The maximum fault contribution from interstate interconnections is assumed
- The worst-case pre-fault power flow conditions are assumed
- Normally open connections are treated as open
- Networks are modelled in full
- Motor load contributions are not modelled at load substations
- Generators are modelled as a constant voltage behind sub-transient reactance.

At power station switchyards, allowance is made for the contribution of the motor component of loads. We are further analysing the impact of the motor component of loads and is assessing the need to include such contributions when assessing the adequacy of the rating of load substation equipment.

A2.9 Substation configurations

Substation configurations are adopted that provide acceptable reliability at minimum cost, consistent with the overall reliability of the transmission network. In determining a switching arrangement, consideration is also given to:

- Site constraints
- Reliability expectations with respect to connected loads and generators
- The physical location of 'incoming' and 'outgoing' circuits
- Maintenance requirements
- Operating requirements
- Transformer arrangements.

We have applied the following configurations in the past:

- Single busbar
- Double busbar
- Multiple element mesh
- Breaker-and-a-half.

In general, at main system locations, a mesh or breaker-and-a-half arrangement is now usually adopted.

Where necessary, the expected reliability performance of potential substation configurations can be compared using equipment reliability parameters derived from local and international data.

The forced outage of a single busbar zone is generally provided for. Under this condition, the main network is planned to have adequate capability although loss of load may eventuate. In general, the forced outage of a single busbar zone should not result in the outage of any baseload generating unit.

Where appropriate, a 330 kV bus section breaker would ordinarily be provided to segregate 'incoming' lines when a second 'incoming' 330 kV line is connected to the substation.

A 132 kV bus section circuit breaker would generally be considered necessary when the peak load supplied via that busbar exceeds 120 MW. A bus section breaker is generally provided on the low voltage busbar of 132 kV substations when supply to a particular location or area is taken over more than two low voltage feeders.

A2.10 Autoreclosure

As most line faults are of a transient nature, all of our overhead transmission lines are equipped with autoreclose facilities.

Slow speed three-pole reclosure is applied to most overhead circuits. On the remaining overhead circuits, under special circumstances, high-speed single-pole autoreclosing may be applied.

For public safety reasons, reclosure is not applied to underground cables.

Autoreclose is inhibited following the operation of breaker-fail protection.

31 The maximum fault current that the equipment may be subjected to.

A2.11 Power system control and communication

In the design of the network and its operation to designed power transfer levels, reliance is generally placed on the provision of some of the following control facilities:

- Automatic excitation control on generators
- Power system stabilisers on generators and SVCs
- Load drop compensation on generators and transformers
- Supervisory control over main network circuit breakers
- Under-frequency load shedding
- Under-voltage load shedding
- Under and over-voltage initiation of reactive plant switching
- High speed transformer tap changing
- Network connection control
- Check and voltage block synchronisation
- Control of reactive output from SVCs
- System Protection Schemes (SPS).

The following communication, monitoring and indication facilities are also provided where appropriate:

- Network wide SCADA and Energy Management System (EMS)
- Telecommunications and data links
- Mobile radio
- Fault locators and disturbance monitors
- Protection signalling
- Load monitors.

Protection signalling and communication is provided over a range of media including pilot wire, power line carrier, microwave links and, increasingly, optical fibres in overhead earthwires.

A2.12 Scenario planning

Scenario planning assesses network capacity, based on the factors described above, for a number of NEM load and generation scenarios. The process entails:

1. Identification of possible future load growth scenarios. These are developed based on AEMO's forecasts to be used in the next NTNDP. We use the key data for each scenario to prepare load forecasts for NSW. These are published in the TAPR and by AEMO in the National Forecasting Insights. The forecast can also incorporate specific possible local developments such as the establishment of new loads or the expansion or closure of existing industrial loads.
2. Development of a number of generation scenarios for each load growth scenario. These generation scenarios relate to the development of new generators and utilisation (including retirement) of existing generators. This is generally undertaken by a specialist electricity market modelling consultant, using their knowledge of relevant factors, including:
   - Generation costs
   - Impacts of government policies
   - Impacts of energy related developments such as gas pipeline projects.
3. Modelling of the NEM for load and generation scenarios to quantify factors which affect network performance, including:
   - Generation from individual power stations
   - Interconnector flows.
4. Modelling of network performance for the load and generation scenarios utilising the data from market modelling.

The resulting set of scenarios is then assessed over the planning horizon to establish the adequacy of the system and to assess network and non-network augmentation options.

The planning scenarios developed by TransGrid take into account AEMO's scenarios used in the NTNDP.

Appendix 3

Line utilisation report

Appendix 3

Line utilisation report

This report sets out our transmission line utilisation for the period from 1 April 2016 to 31 March 2017.

Line utilisation report

The line loading information from 1 April 2016 to 31 March 2017 was obtained from AEMO's Operation Planning and Data Management System (OPDMS). This system produces half hourly system load flow models (snapshots) of the NEM.

For each half-hour period, the utilisation (loading) of each line was calculated as a proportion of the relevant rating. The highest values of these proportions are reported here.

The utilisation of each line was calculated based on two conditions:

1. With all network elements in service, referred to as the 'N utilisation'. These utilisation figures are based on normal line ratings
2. With the most critical credible contingency (usually an outage of another line in the area), referred to as the 'N–1 utilisation'. These utilisation figures are based on the line contingency ratings.

The N utilisation and N–1 utilisation of the transmission lines in the NSW transmission network are shown in Figures A3.2 to A3.9. For each line, the utilisations are shown in the box placed adjacent to the line. The box shows:

A. The transmission line number

B. The maximum N utilisation of the transmission line

C. The maximum N–1 utilisation of the transmission line

D. The number of the line that creates the critical contingency in the event of an outage.

The box layout is shown in Figure A3.1.

FIGURE A3.1 – Key to interpreting the information shown in Figures A3.2 to A3.9

A – Line number: B – Maximum N Utilisation %
C – Maximum N–1 Utilisation % [D – Line number out for N–1]

In some situations, the N–1 utilisation has been estimated to be more than 100%. These situations could be because of:

- A higher level of line loading being allowed, considering the operational line overloading control schemes, runback schemes available for managing the line loadings, and generation re-dispatch capability by AEMO
- The predicted dispatch conditions that change over the five-minute dispatch period, causing the line loadings to increase above the predicted values.

FIGURE A3.2 – TransGrid N and N–1 line utilisations – Sydney and Newcastle

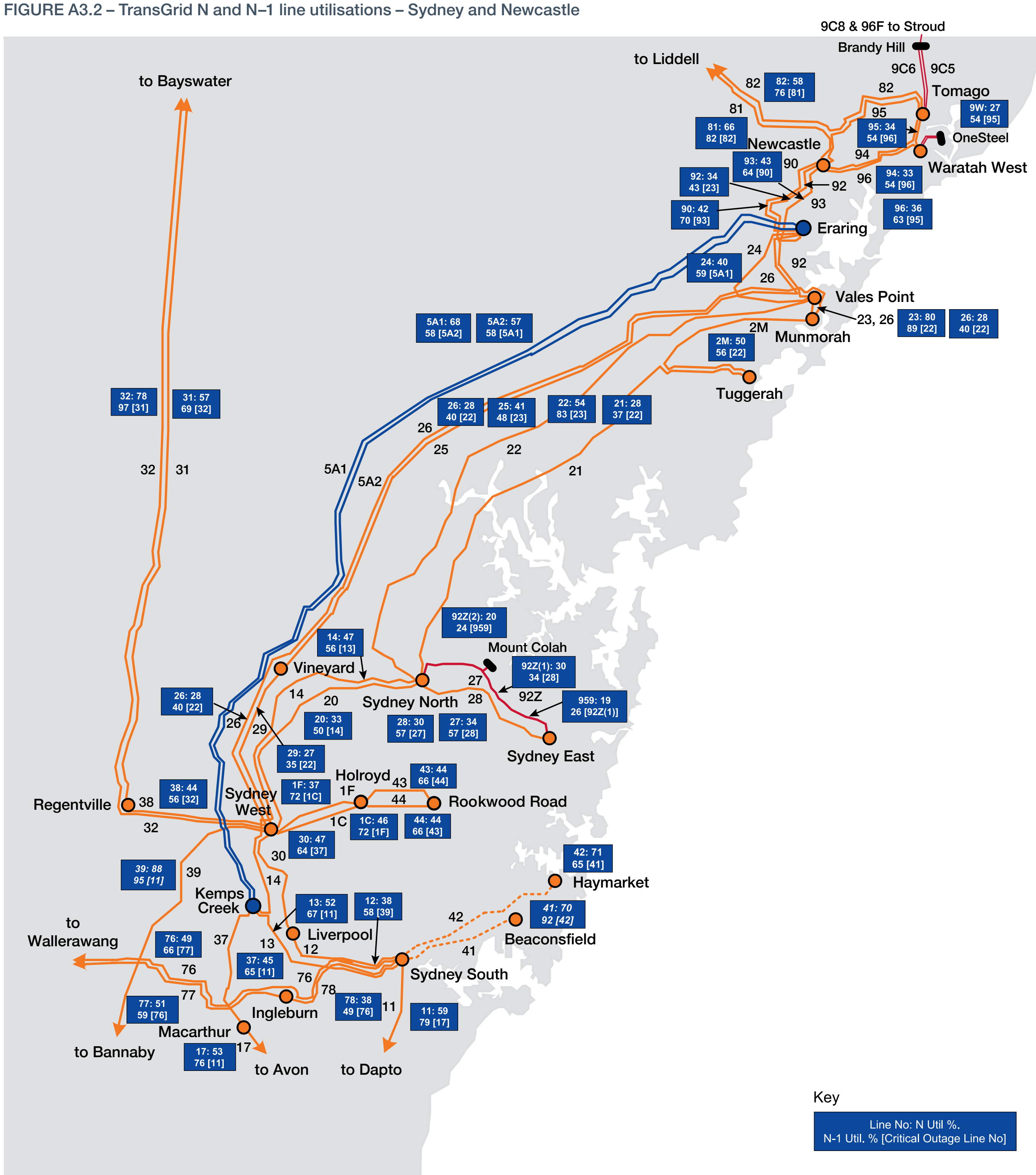


FIGURE A3.3 – TransGrid N and N–1 line utilisations – North East NSW and Hunter Valley

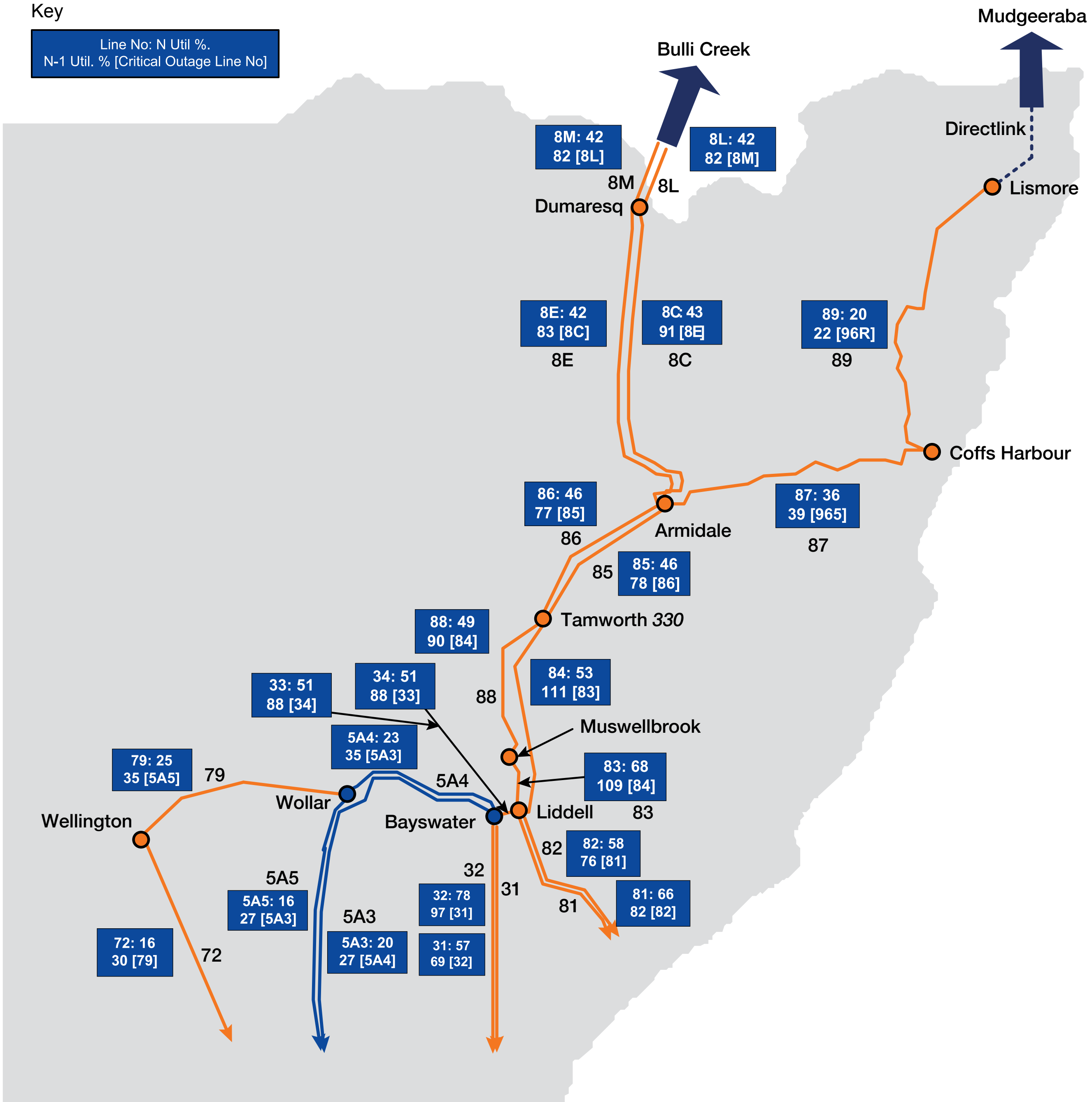


FIGURE A3.4 – TransGrid N and N–1 line utilisations – South and South East

FIGURE A3.5 – TransGrid N and N–1 line utilisations – Far West

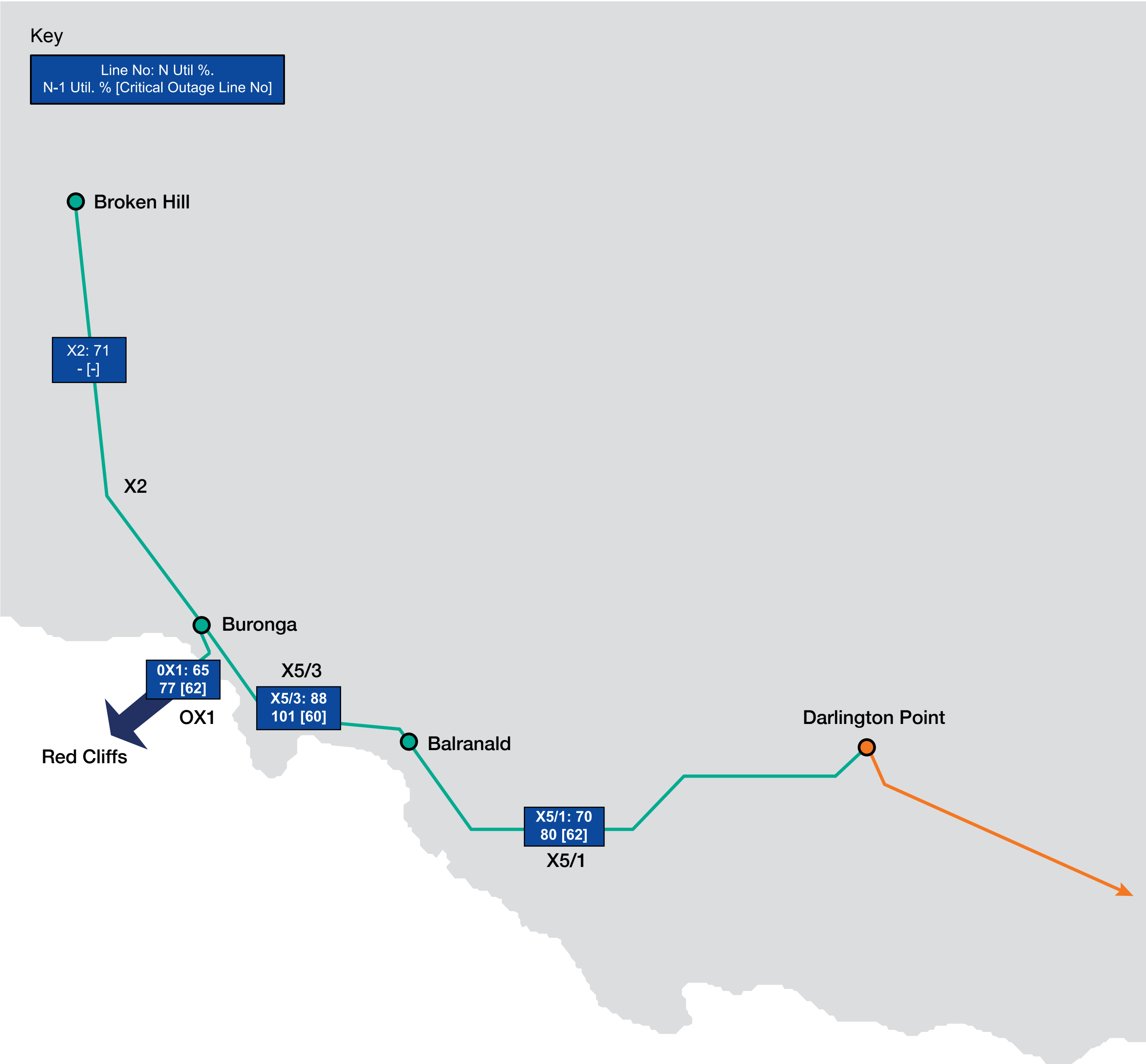


FIGURE A3.6 – TransGrid N and N–1 line utilisations – North Coast and North West 132 kV System

FIGURE A3.7 – TransGrid N and N–1 line utilisations – Central West

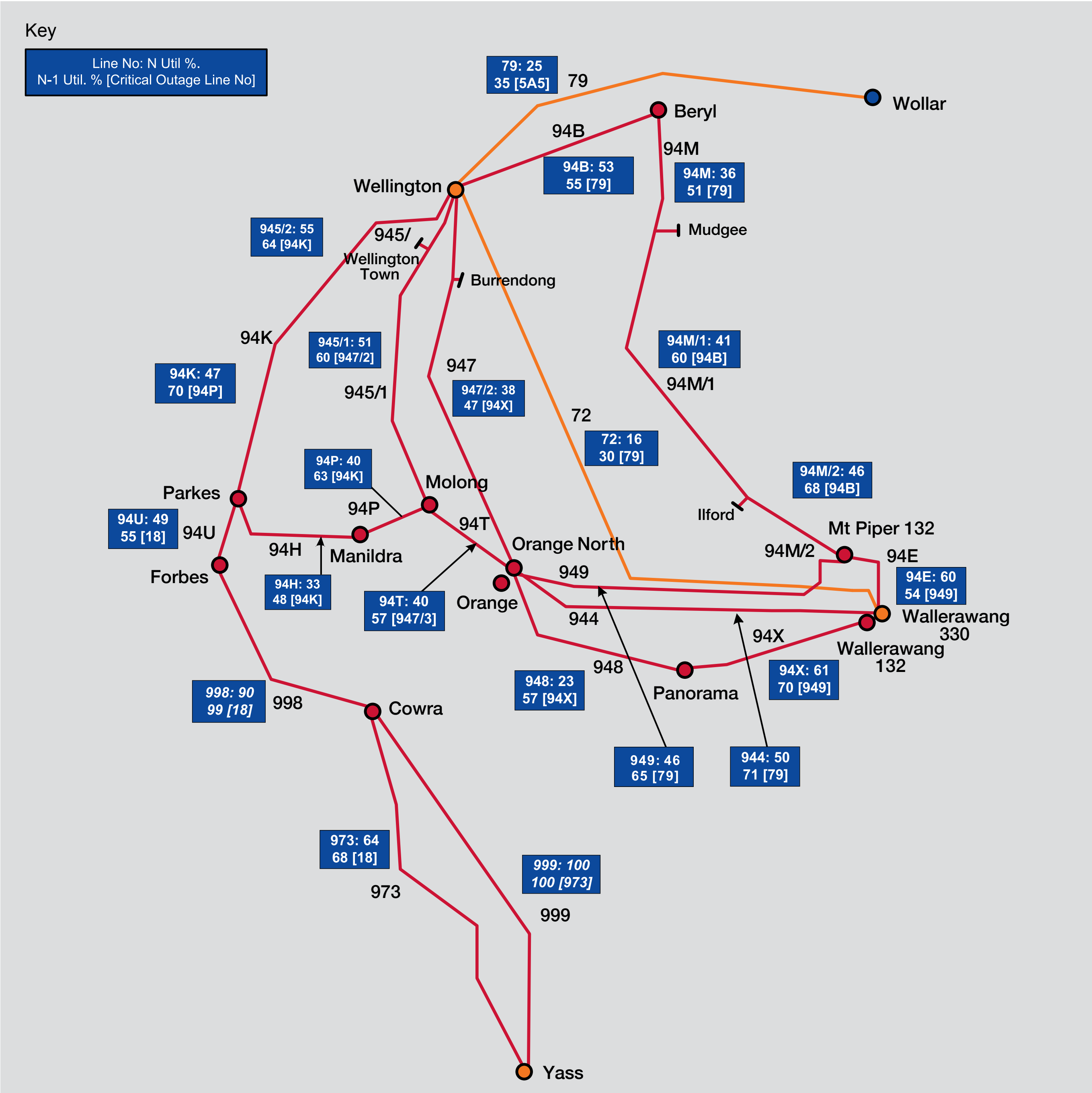


FIGURE A3.8 – TransGrid N and N–1 line utilisations – South and Snowy

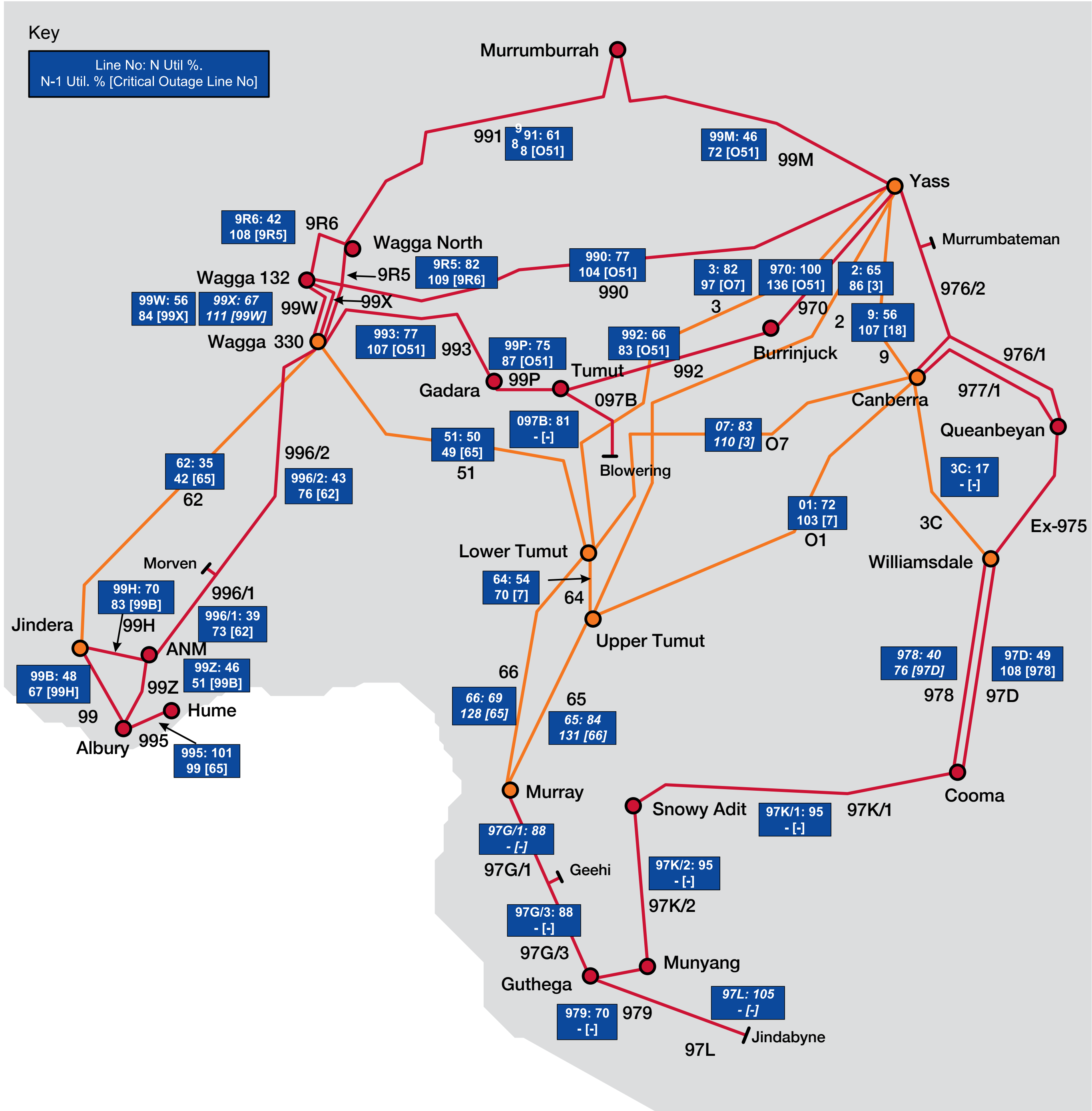
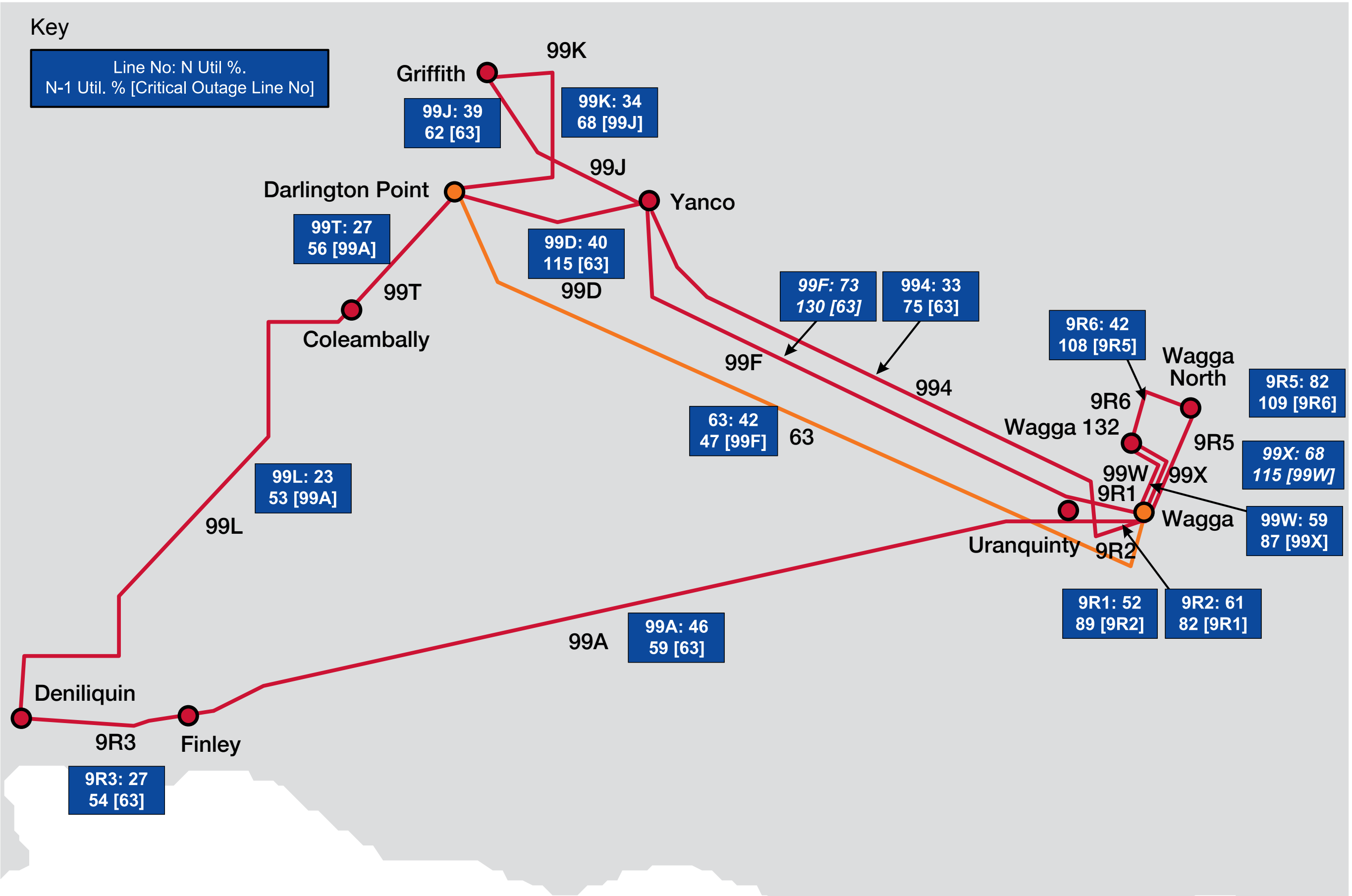


FIGURE A3.9 – TransGrid N and N–1 line utilisations – South West



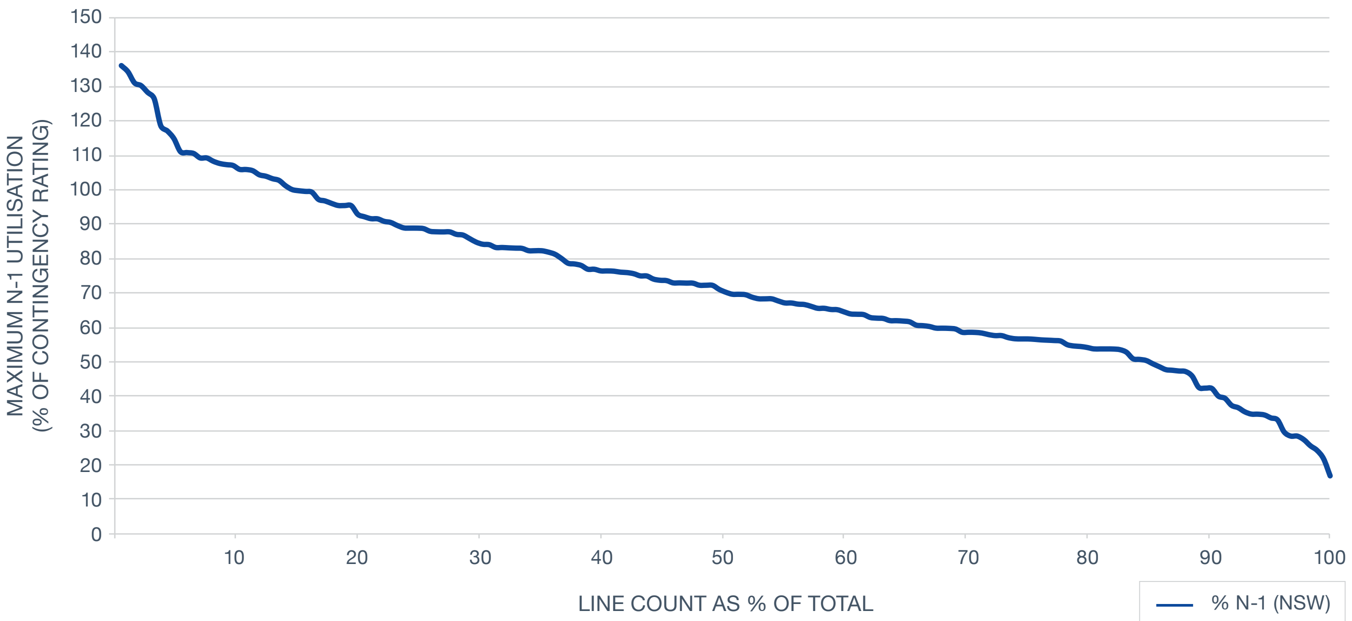
Summary of the N–1 utilisation of the transmission lines in the TransGrid's network

The distribution of the utilisation of the transmission lines across our network is shown in Figure A3.10.

The distribution shows that approximately 15% of the transmission lines in the network are utilised up to their installed maximum capacity and over half of the lines are utilised at more than 70% of their installed capacity.

The distribution of the N–1 line utilisations reflects at least 40 years of planning history of the transmission network. It is considered to be typical of a well-planned network where various parts of the network are well-established, while other parts have had recent step augmentations that will be further utilised in future years.

FIGURE A3.10 – Distribution of TransGrid line N–1 utilisations (1 April 2016-31 March 2017)



Appendix 4

Transmission constraints

Appendix 4
Transmission constraints

This appendix provides an analysis of the power flows in our network that have reached or come close to the network limits, and the assets affected.

Introduction

This appendix describes an analysis of how close the flows in our network are to its capacity limits. It identifies the transmission elements where flows have been at, or close to, the limits.

Capacity could be limited due to the power flows reaching:

- The maximum rating of a single transmission element, such as a transmission line or a transformer
- The combined capacity of a group of transmission elements, such as several parallel transmission lines constituting inter regional links
- The limits set by system wide considerations such as voltage, transient or oscillatory stability.

We provide the capability of our transmission network to AEMO. AEMO manages the power flows in the transmission network to be within the capability of the declared limits of the individual assets or the capability of the transmission system. AEMO does so by automatically adjusting the quantity of generation dispatched, so that the transmission flows will be maintained under the prevailing operating conditions, including the flows to be expected under credible unplanned outages.

The optimal generation dispatch, the dispatch which minimises total cost while ensuring the capability limits of the transmission system are not violated, is determined using the National Electricity Market Dispatch Engine (NEMDE). The capability limits are included within NEMDE as mathematical equations, which are known as the 'Constraint Equations'. Each constraint equation has a unique identifier, and contains information including the capability limit and the factors which describe or determine the limiting power flows, such as power flow in a transmission line or generator power outputs, which contribute to the limiting power flow.

The constraints reported here cover the transmission system capability limitation experienced during the period 1 March 2016 to 28 February 2017.

Transmission system performance – Binding duration

Table A4.1 summarises the top 20 constraints where higher cost generation may have been dispatched because some transmission elements or parts of the transmission network have reached their maximum capability. The table shows the constraint identifier, its description, type of limitation addressed by the constraint equation, and length of the time period where the transmission element, or the part of the transmission system, was operated at its maximum capability for the 12 month period from March 2016 – March 2017.

TABLE A4.1 – Constraints operating at the capability limit

Rank	Constraint ID	Total duration (hh:mm)	Type	Impact	Reason
1	V::N_NIL_V2	590:45	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
2	N^^Q_NIL_B1	479:10	Voltage Stability	Qld Generation + Interconnectors	Avoid voltage collapse for loss of Kogan Creek generator
3	V>>N-NIL_HA	357:55	Thermal	NSW Generation + Interconnectors	Avoid overloading Murray to Upper Tumut (65) 330 kV line on trip of Murray-Lower Tumut (66) 330 kV line
4	V::N_NIL_SD	193:20	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
5	V::N_NIL_V4	161:05	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
6	V::N_NIL_S2	153:20	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
7	N^^V_NIL_1	141:30	Voltage Stability	Vic - NSW Interconnector + Generators	Avoid voltage collapse for loss of the largest Vic generating unit or Basslink
8	N>LSDU_LSDU	112:15	Thermal	Terranora Interconnector	Avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6)
9	V::N_NIL_V	97:10	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
10	Q:N_NIL_ AR_2L-G	65:10	Transient Stability	NSW - Qld (QNI) Interconnector	Avoid transient instability for fault at Armidale and trip of 330 kV line 8C or 8E from Dumaresq to Armidale
11	N^Q_NIL_A	55:05	Voltage Stability	NSW - Qld (QNI) Interconnector + Directlink	Avoid voltage collapse for trip of Liddell to Muswellbrook (83) line
12	V::N_NIL_V1	52:15	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
13	N>>N-NIL__3_ OPENED	29:05	Thermal	NSW Generation + Interconnectors	Avoid overload Liddell to Muswellbrook (83) line on trip of Liddell to Tamworth (84) 330 kV line
14	N>N-NIL_LSDU	19:20	Thermal	Terranora Interconnector	Avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6)
15	V::N_NIL_S1	7:45	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
16	N>>N- NIL__B_15M	5:15	Thermal	Vic - NSW Interconnector + Generators	Avoid overloading Upper Tumut to Canberra (01) line on trip of Lower Tumut to Canberra (07) line
17	N>>N-NIL__3_ CLOSED	4:05	Thermal	NSW Generation + Interconnectors	Avoid overloading Liddell to Muswellbrook (83) line on trip of Liddell to Tamworth (84) line
18	N>>N-NIL_01N	3:45	Thermal	NSW Generation + Interconnectors	Avoid overloading Canberra to Yass (9) line on trip of Kangaroo Valley to Dapto (18) line
19	N::Q_NIL_KC	3:15	Transient Stability	NSW - Qld (QNI) Interconnector + Terranora	Prevent transient instability for trip of a Kogan Creek generator
20	V::N_NIL_V3	3:10	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic

Transmission system performance – Market impact

Table A4.2 summarises the constraints with the 20 highest market impacts, measured by the marginal value. The table shows the constraint identifier, its description, type of limitation addressed by the constraint equation, the sum of the marginal values of the constraint binding and length of the time period where the transmission element, or the part of the transmission system, was operated at its maximum capability for the 12 month period from March 2016 to March 2017.

TABLE A4.2 – Marginal value of binding constraints

Rank	Constraint ID	Sum of marginal values	Total duration (hh:mm)	Type	Impact	Reason
1	N>>N-NIL__3_ OPENED	$827,452.88	29:05	Thermal	NSW Generation + Interconnectors	Avoid overload Liddell to Muswellbrook (83) line on trip of Liddell to Tamworth (84) 330 kV line
2	N^^Q_NIL_B1	$732,194.60	479:10	Voltage Stability	Qld Generation + Interconnectors	Avoid voltage collapse for loss of Kogan Creek generator
3	N>>N-NIL__B_15M	$262,686.50	5:15	Thermal	Vic - NSW Interconnector + Generators	Avoid overloading Upper Tumut to Canberra (01) line on trip of Lower Tumut to Canberra (07) line
4	N>>N-NIL_01N	$241,480.54	3:45	Thermal	NSW Generation + Interconnectors	Avoid overloading Canberra to Yass (9) line on trip of Kangaroo Valley to Dapto (18) line
5	N^Q_NIL_A	$191,112.41	55:05	Voltage Stability	NSW - Qld (QNI) Interconnector + Directlink	Avoid voltage collapse for trip of Liddell to Muswellbrook (83) line
6	V::N_NIL_V2	$162,789.48	590:45	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
7	Q:N_NIL_ AR_2L-G	$156,633.21	65:10	Transient Stability	NSW - Qld (QNI) Interconnector	Avoid transient instability for a fault at Armidale and trip of 330 kV line 8C or 8E from Dumaresq to Armidale
8	V>>N-NIL_HA	$99,662.06	357:55	Thermal	NSW Generation + Interconnectors	Avoid overloading Murray to Upper Tumut (65) 330 kV line on trip of Murray-Lower Tumut (66) 330 kV line
9	V::N_NIL_SD	$63,568.78	193:20	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
10	N^^V_NIL_1	$59,832.36	141:30	Voltage Stability	Vic - NSW Interconnector + Generators	Avoid voltage collapse for loss of the largest Vic generating unit or Basslink
11	V::N_NIL_S2	$44,726.01	153:20	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
12	N>LSDU_LSDU	$42,218.61	112:15	Thermal	Terranora Interconnector	Avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6)
13	N>>N-NIL__H_15M	$34,443.72	0:20	Thermal	Vic - NSW Interconnector + Generators	Avoid overloading Upper Tumut to Canberra (01) line on trip of Lower Tumut to Canberra (07)
14	V::N_NIL_V4	$31,834.87	161:05	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
15	N>N-NIL_LSDU	$23,602.16	19:20	Thermal	Terranora Interconnector	Avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6)
16	V::N_NIL_V	$22,665.94	97:10	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in Vic
17	V::N_NIL_V1	$13,736.55	52:15	Transient Stability	Vic Generation + Interconnectors	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line in VIC
18	N>>N-NIL__S	$13,123.98	0:35	Thermal	NSW Generation + Interconnectors	Avoid overloading Mount Piper to Wallerawang (70) line on tip of Mount Piper to Wallerawang (71) line
19	N>>N-NIL_64	$7,425.98	0:20	Thermal	NSW Generation + Interconnectors	Avoid overloading Bannaby to Sydney West (39) line on trip of Dapto to Sydney South (11) line
20	N>>N-NIL__3_ CLOSED	$3,286.25	4:05	Thermal	NSW Generation + Interconnectors	Avoid overloading Liddell to Muswellbrook (83) line on trip of Liddell to Tamworth (84) line

Possible future transmission system performance

The maximum demand event for each of NSW, Qld and Vic were analysed for the constraints that were binding (or violating) and the 10 constraints that were closest to binding at the time of the maximum demand in the March 2016 to March 2017 period. The constraints that were not binding but close to binding were assessed to identify possible future transmission system limitations.

Region	Max demand (MW)	Date and time
NSW	14,108.41	10/02/2017 16:30
QLD	9,476.57	18/01/2017 17:00
VIC	9,253.71	8/03/2016 16:20

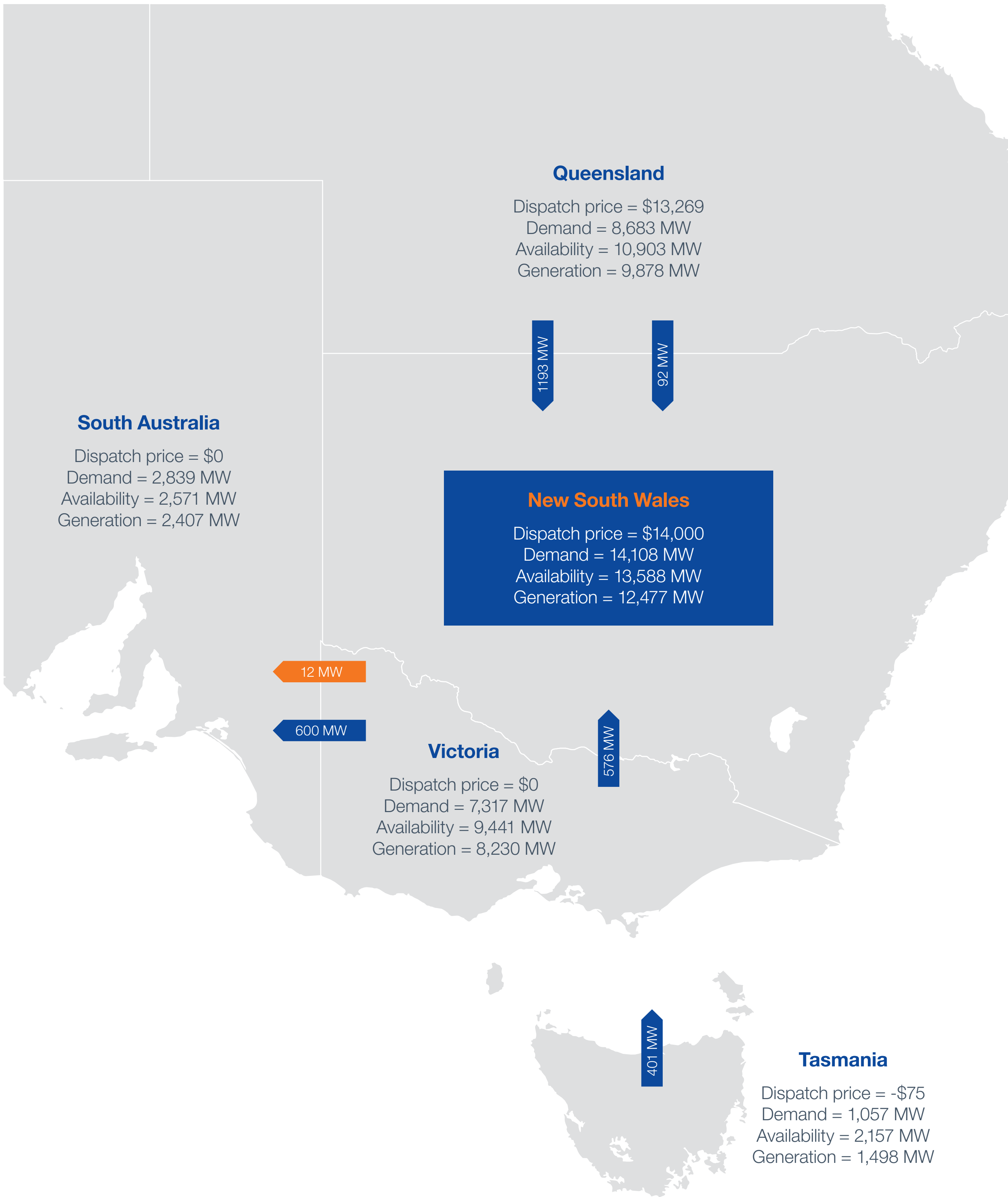


TABLE A4.3 – NSW binding or violating constraints on 10 February 2017 at 16:30

Constraint ID	Type	Impact	Reason
Q:N_NIL_AR_2L-G	Transient Stability	NSW – QLD Interconnector	Avoid transient instability for a fault at Armidale and trip of 330 kV line 8C or 8E from Dumaresq to Armidale
Q:N_NIL_BI_POT	Transient Stability	NSW – QLD Interconnector	Avoid transient instability on trip of a Boyne Island potline
N>>N-NIL__S	Thermal	NSW Generation + Interconnectors	Avoid overloading Mount Piper to Wallerawang (70) line on trip of Mount Piper to Wallerawang (71) line
N>>N-NIL__H_15M	Thermal	Vic - NSW Interconnector + Generators	Avoid overload Lower Tumut to Canberra (07) using 15 mins rating on trip of Lower Tumut to Yass (3) line

TABLE A4.4 – NSW constraints that were close to binding on 10 February 2017 at 16:30

Rank	Constraint ID	Headroom (MW)	Type	Impact	Reason
1	Q:N_NIL_OSC	7	Oscillatory Stability	NSW - Qld (QNI) Interconnector	Avoid QNI oscillatory instability
2	N>>N-NIL_01N	28	Thermal	NSW Generation + Interconnectors	Avoid overloading Canberra to Yass (9) line on trip of Kangaroo Valley to Dapto (18) line
3	N>N-NIL_MBDU	124	Thermal	Terranora Interconnector	Avoid overloading Mullumbimby to Dunoon line (9U6 or 9U7) on trip of the other Mullumbimby to Dunoon line (9U7 or 9U6)
4	N>>N-NIL__C_15M	128	Thermal	Vic - NSW Interconnector + Generators	Avoid overloading Lower Tumut to Yass (3) on trip of Lower Tumut to Canberra (07) line
5	N>N-NIL_LSDU	134	Thermal	Terranora Interconnector	Avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6)
6	N_NIL_TE_B	138	Other	Terranora Interconnector	Avoid reaching lower limit on Directlink
7	N>N-NIL_8C_8E	168	Thermal	NSW - Qld (QNI) Interconnector	Avoid overload of Dumaresq to Armidale (8C) line on trip of Dumaresq to Armidale (8E) line
8	Q>N-NIL_8L_8M	200	Thermal	NSW - Qld (QNI) Interconnector	Avoid overload of Bulli Creek to Dumaresq (8L) line on trip of Bulli Creek to Dumaresq (8M) line
9	N>>N-NIL_48	214	Thermal	Vic - NSW Interconnector + Generators	Avoid overload of Kangaroo Valley to Dapto (18) line on trip of Yass to Marulan (4) line
10	N>>N-NIL_1G	216	Thermal	NSW Generation + Interconnectors	Avoid overload of Vales Point to Munmorah (23) on trip of Vales Point to Sydney North (22) line

Maximum demand event in Qld

FIGURE A4.2 – NEM overview map on 18 January 2017 at 17:00

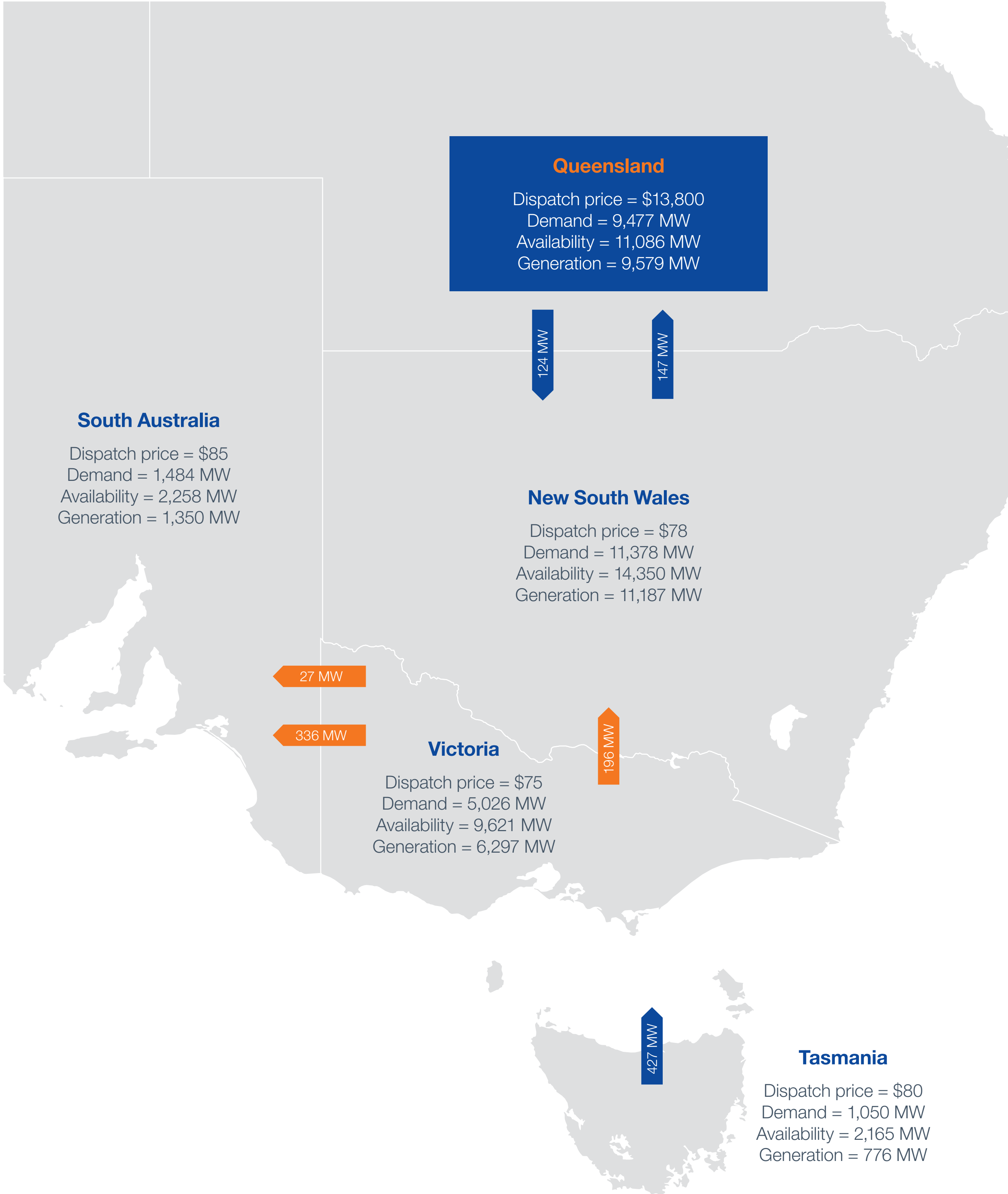


TABLE A4.5 – NSW binding constraints on 18 January 2017 at 17:00

Constraint ID	Type	Impact	Reason
N>>N-NIL__3_OPENED	Thermal	NSW Generation + Interconnectors	Avoid overloading Liddell to Muswellbrook (83) on trip of Liddell to Tamworth (84) line

TABLE A4.6 – NSW constraints that were close to binding on 18 January 2017 at 17:00

Rank	Constraint ID	Headroom (MW)	Type	Impact	Reason
1	N>>N-NIL__2_OPENED	5	Thermal	NSW Generation + Interconnectors	Avoid O/L Liddell to Tamworth (84) on trip of Liddell to Muswellbrook (83) line
2	N^^Q_NIL_B1	54	Voltage Stability	Qld Generation + Interconnectors	Avoid voltage collapse on loss of Kogan Creek generator
3	N^Q_NIL_A	64	Voltage Stability	NSW - Qld (QNI) Interconnector + Directlink	Avoid voltage collapse on loss of Liddell to Muswellbrook (83) line
4	N>N-NIL_TE_LOAD	80	Thermal	Terranora Interconnector	Limit Directlink flow south if Terranora load was >= 85 MW
5	N_NIL_TE_B	120	Other	Terranora Interconnector	Avoid reaching lower limit on Directlink
6	N>N-NIL_MBDU	126	Thermal	Terranora Interconnector	Avoid overloading Mullumbimby to Dunoon line (9U6 or 9U7) on trip of the other Mullumbimby to Dunoon line (9U7 or 9U6)
7	N>N-NIL_LSDU	131	Thermal	Terranora Interconnector	Avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6)
8	N>N-NIL_TE_D2	214	Thermal	Terranora Interconnector	Avoid overloading Lismore 330 to Lismore 132 (9U) on trip of Lismore 330 to Lismore 132 (9U8) line
9	N>N-NIL__4_15M	232	Thermal	NSW Generation + Interconnectors	Avoid overloading Muswellbrook to Tamworth (88) on trip of Liddell to Tamworth (84) line
10	N_NIL_TE_A	240	Other	Terranora Interconnector	Avoid reaching upper limit on Directlink

Maximum demand event in Victoria

FIGURE A4.3 – NEM overview map on 8 March 2016 at 16:20

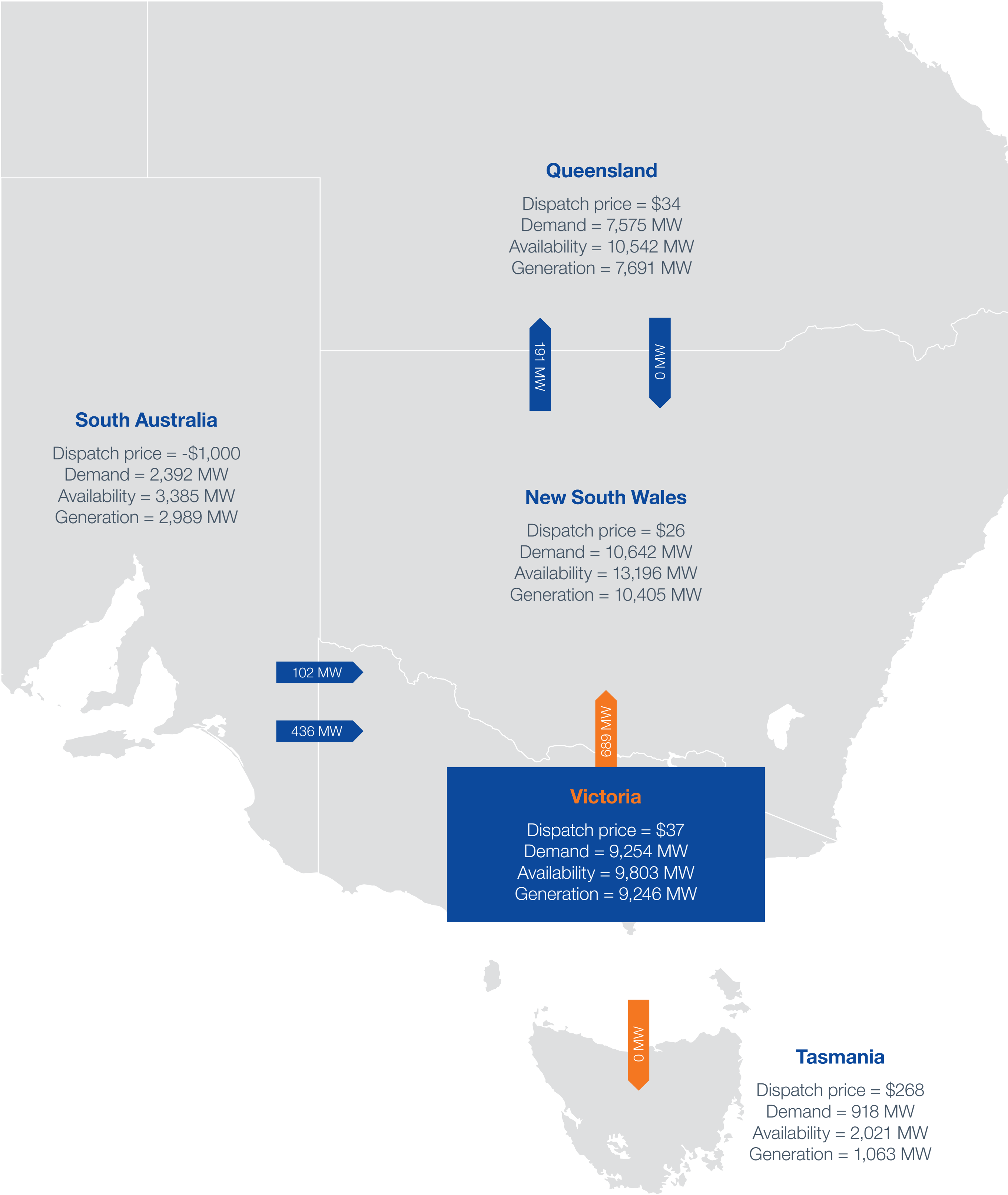


TABLE A4.7 – NSW binding constraints on 8 March 2016 at 16:20

Constraint ID	Type	Impact	Reason
N^^Q_NIL_B1	Voltage Stability	Qld Generation + Interconnectors	Avoid voltage collapse on loss of Kogan Creek

TABLE A4.8 – NSW constraints that were close to binding on 8 March 2016 at 16:20

Rank	Constraint ID	Headroom (MW)	Type	Impact	Reason
1	N>N-NIL_LSDU	33	Thermal	Terranora Interconnector	Avoid overloading Lismore to Dunoon line (9U6 or 9U7) on trip of the other Lismore to Dunoon line (9U7 or 9U6)
2	N^Q_NIL_A	38	Voltage Stability	NSW - Qld (QNI) Interconnector + Directlink	Avoid voltage collapse on loss of Liddell to Muswellbrook (83) line
3	N_NIL_TE_A	120	Other	Terranora Interconnector	Avoid reaching upper limit on Directlink
4	N>N-NIL_TE_D2	143	Thermal	Terranora Interconnector	Avoid overloading Lismore 330 to Lismore 132 (9U) on trip of Lismore 330 to Lismore 132 (9U8) line
5	N::Q_NIL_KC	203	Transient Stability	NSW - Qld (QNI) Interconnector + Terranora	Prevent transient instability for trip of Kogan Creek generator
6	N>>N-NIL__3_OPENED	209	Thermal	NSW Generation + Interconnectors	Avoid overloading Liddell to Muswellbrook (83) on trip of Liddell to Tamworth (84) line
7	N>>N-NIL__2_OPENED	219	Thermal	NSW Generation + Interconnectors	Avoid overloading Liddell to Tamworth (84) on trip of Liddell to Muswellbrook (83) line
8	N^^Q_NIL_B5	226	Voltage Stability	Qld Generation + Interconnectors	Avoid voltage collapse on loss of Callide C3 generator
9	N^^Q_NIL_B6	226	Voltage Stability	Qld Generation + Interconnectors	Avoid voltage collapse on loss of Callide C4 generator
10	N>N-NIL_MBDU	226	Thermal	Terranora Interconnector	Avoid overloading Mullumbimby to Dunoon line (9U6 or 9U7) on trip of the other Mullumbimby to Dunoon line (9U7 or 9U6)

Appendix 5

Glossary

Appendix 5

Glossary

Term	Explanation/Comments
AEMC	The Australian Energy Market Commission
AEMO	The Australian Energy Market Operator. Responsible for management of the NEM and has the role of Victorian JPB
AER ('the regulator')	The Australian Energy Regulator
Assets	TransGrid's 'poles and wires', all the substations and electricity transmission lines that make up the network
Augmentation	Expansion of the existing transmission system or an increase in its capacity to transmit electricity
Bulk supply point (BSP)	A point of supply of electricity from a transmission system to a distribution system
Connection point	The agreed point of supply established between the network service provider and another registered participant or customer
Constraint (limitation)	An inability of a transmission system or distribution system to supply a required amount of electricity to a required standard.
Consumers	Any end user of electricity including large users, such as paper mills, and small users, such as households
Demand	The total amount of electrical power that is drawn from the network by consumers. This is talked about in terms of 'maximum demand' (the maximum amount of power drawn throughout a given period) and 'total energy consumed' (the total amount of energy drawn across a period)
Demand management (DM)	A set of initiatives that are put in place at the point of end-use to reduce the total and/or maximum consumption of electricity
Direct customers	TransGrid's customers are those directly connected to our network. They are either Distribution Network Service Providers, directly connected generators, large industrial customers, customers connected through inter-regional connections or potential new customers
Distribution Network Service Provider, DNSP (Distributor)	An organisation that owns, controls or operates a distribution system in the National Electricity Market. Distribution systems operate at a lower voltage than transmission systems and deliver power from the transmission network to households and businesses
Easement	A designated area in which TransGrid has the right to construct, access and maintain our assets, while ownership of the property remains with the original land owner
Electricity Statement of Opportunities (ESOO)	A document produced by AEMO that focuses on electricity supply demand balance in the NEM
Embedded generation	A generating unit connected to the distribution network, or connected to a distribution network customer. (Not a transmission connected generator)
Generator	An organisation that produces electricity. Power can be generated from various sources, e.g. coal fired power plants, gas-fired power plants, wind farms
Interconnection	The points on an electricity transmission network that cross jurisdictional/state boundaries
Jurisdictional Planning Body (JPB)	The organisation nominated by a relevant minister as having transmission system planning responsibility in a jurisdiction of the NEM
Load	The amount of electrical power that is drawn from the network
Local generation	A generation or cogeneration facility that is located on the load side of a transmission constraint
LRET	Large Scale Renewable Energy Target
'N – 1' reliability	The system is planned for no loss of load on the outage of a single element such as a line, cable or transformer
National Electricity Law	Common laws across the states which comprise the NEM, which make the NER enforceable
National Electricity Market (NEM)	The National Electricity Market, covering Queensland, New South Wales, Victoria, South Australia and Tasmania

Term	Explanation/Comments
National Electricity Rules (NER or 'the Rules')	The rules that govern the NEM. The Rules are administered by the AEMC
Native energy (demand)	Energy (demand) that is inclusive of Scheduled, Semi-Scheduled and Non-Scheduled generation
Non-network options	Alternatives to network augmentation which address a potential shortage in electricity supply in a region, e.g. demand response or local generation
NSCAS	Network Support and Ancillary Services. Services used by AEMO that are essential for managing power system security, facilitating orderly trading, and ensuring electricity supplies are of an acceptable quality.
NTFP	National Transmission Flow Path
NTNDP	National Transmission Network Development Plan
Outage	An outage is when part of the network is switched off. This can be either planned (i.e. when work needs to be done on the line) or unplanned
POE	Probability of Exceedence. This is the probability a forecast would be met or exceeded, e.g. a 50% POE demand implies there is a 50% probability of the forecast being met or exceeded
PV	Photovoltaic
Reliability	Reliability is a measure of a power system's capacity to continue to supply sufficient power to satisfy customer demand, allowing for the loss of generation capacity
RET	Renewable Energy Target
Secondary system	Equipment used to control, automate and monitor the network
Substation	A set of electrical equipment used to step high voltage electricity down to a lower voltage. Lower voltages are used to deliver power safely to small businesses and residential consumers
SVC	Static VAr Compensator. An electrical device installed on the high voltage transmission system to provide fast acting voltage control to regulate and stabilise the system
Transmission Annual Planning Report (TAPR)	This document that sets out issues and provides information to the market that is relevant to transmission planning in NSW.
Transmission line	A high voltage power line running at 500 kV, 330 kV, 220 kV or 132 kV. The high voltage allows delivery of bulk power over long distances with minimal power loss
Transmission Network Service Provider, TNSP	A body that owns controls and operates a transmission system in the NEM

The following table gives some of the common electricity measurements used:

Property	Unit
Voltage	Volts (V) and kilovolts (kV). 1 kV = 1000 V
Power	Watts (W), usually expressed in kilowatts (kW) and megawatts (MW).
1 MW = 1000 kW = 1 million W	The amount of energy consumed in an hour is usually expressed as kilowatt-hours (kWh) or megawatt-hours (MWh). 1 MWh = 1000 kWh
Energy consumption	The amount of energy consumed in an hour is usually expressed as kilowatt-hours (kWh) or megawatt-hours (MWh). 1 MWh = 1000 kWh
Maximum power that a transformer can deliver	Usually expressed in megavolt-ampere (MVA)
Reactive power	Usually expressed in megavolt-ampere reactive (MVAr)

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