Annual Planning Report 2017

Version: 1.0

Date: 22 December 2017

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REVIEW DATE

This document may not be reviewed once published, but will be replaced with the 2018 version by 31 December 2018.

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Version Control

Version No.	Date	Description of Version
1.0	22 December 2017	Initial issue

Document Authorisation

Name:	Dennis Stanley	Stephen Devlin
Position:	Branch Manager Asset Strategy	General Manager Energy Networks
Date:	22 December 2017	22 December 2017

Statement of Purpose

ActewAGL aims to provide efficient, cost-effective transmission and distribution services to our customers, whilst meeting their current and future reliability and power quality expectations, ensuring public safety and minimising environmental impact.

The purpose of the Annual Planning Report is to inform Customers, Generators, Investors, and Government about the ActewAGL electricity transmission and distribution network's current capability, anticipated investments to maintain that capability, drivers of future development needs and options to meet them.

In doing so we aim to provide information in a clear, concise and accurate way that:

- Enables us to have informed dialog with Generators and Customers to contribute to our understanding of their development plans;
- Clearly identifies and promotes opportunities for Generators and Customers to participate in the development of our plans for the network; and
- Informs investment and connection decisions.

It is our priority to have a transparent and accessible approach to the way we plan our network. This will encourage meaningful stakeholder participation in the planning process and improve the planning of the investments necessary to deliver transmission and distribution services to the people of the ACT.

Achieving the above will also meet the obligations in the National Electricity Rules (NER) and the ACT Energy Utilities Technical Regulations (UTR).

ActewAGL welcomes feedback on this Annual Planning Report, especially from external stakeholders considering investments that could either defer or accelerate network development. For all enquiries and for making written submissions please contact:

ActewAGL Distribution
Branch Manager – Asset Strategy
GPO Box 366
Canberra ACT 2601
Email: dennis.stanley@actewagl.com.au

Executive Summary

ActewAGL is both a registered Distribution Network Service Provider and a Transmission Network Service Provider, and is required to produce a Distribution Annual Planning Report (DAPR) covering its distribution network and a Transmission Annual Planning Report (TAPR) for the transmission network. To align the publication of the DAPR and TAPR, the National Electricity Rules (NER) permits the publication of both documents in a combined Annual Planning Report.

ActewAGL publishes an Annual Planning Report to provide information about the electricity transmission and distribution networks in the ACT, to discuss current or emerging issues affecting the operation of these networks, proposed solutions to issues, and identify opportunities for external stakeholders to provide non-network solutions to these issues.

Energy is supplied to ActewAGL's network primarily from generation sources in neighbouring states. There is an increasing amount of embedded generation including the Royalla Solar Farm that generates up to 20 MW, the Mugga Lane Solar Park that generates up to 12.85 MW, the Williamsdale Solar Farm that generates up to 10 MW, and a large amount of domestic rooftop solar photovoltaic (PV) generation amounting to approximately 59.8 MW of installed capacity. Maximum system demand in the 2017 calendar year was 633 MW.

This Annual Planning Report presents the results of ActewAGL's annual planning review, including joint planning with TransGrid Limited, the provider of bulk transmission network services to ActewAGL.

The objective of this Annual Planning Report (APR) is to provide customers and external stakeholders with an opportunity to:

- Assess the capability of ActewAGL's transmission and distribution system to transfer electrical energy to and from its present and future customers in the ACT.
- Understand how the transmission and distribution system may affect their operations.
- Identify locations that would benefit from embedded generation or demand-side management initiatives.

The APR also provides an outline of ActewAGL's reliability centred maintenance program and summarises the results of recent reliability improvement initiatives.

1. Introduction

1.1. About ActewAGL

ActewAGL was established in October 2000 when the Australian Gas Light Company (AGL) and Icon Distribution Investments Limited (formerly ACTEW Corporation), an ACT Government owned corporation, entered into Australia's first multi-utility joint venture. Today ActewAGL is made up of two partnerships:

ActewAGL Retail is owned equally by Icon Retail Investments Limited and AGL ACT Retail Investments Pty Ltd.

ActewAGL Distribution is owned equally by Icon Distribution Investments Limited and Jemena Networks (ACT) Pty Ltd.

Although ActewAGL was established in October 2000, with our predecessors we've been supplying reliable essential services to the ACT since 1915.

ActewAGL Distribution is licensed under the ACT Utilities Act 2000 (12 May 2016) to provide electricity transmission, distribution and connection services. ActewAGL is registered with the Australian Energy Market Operator (AEMO) as both a Transmission Network Service Provider (TNSP) and a Distribution Network Service Provider (DNSP), and operates in the National Electricity Market (NEM) as a Registered Participant. The NEM operates on an interconnected power system that includes the power systems of Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania.

From 1 January 2018 ActewAGL Distribution will be known as **Evoenergy**. This change of name is required by the Australian Energy Regulator's (AER's) ring-fencing guidelines.

The *National Electricity Law (NEL)* and *National Electricity Rules (NER)* are enacted in the ACT by the *Electricity (National Scheme) Act 1997 ACT*.

The National Electricity Objective as stated in the National Electricity Law is:

"to promote efficient investment in and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:

a) price, quality, safety, reliability and security of supply of electricity; and
b) the reliability, safety and security of the national electricity system."

ActewAGL's mission is:

"To offer our customers the safe, reliable and sustainable energy solutions they want."

ActewAGL's revenue for the provision of transmission and distribution network services is regulated. We prepare and submit on a five-yearly basis, a Regulatory Revenue Proposal to the Australian Energy Regulator (AER). The AER reviews this proposal and sets the maximum allowable revenue that ActewAGL can collect from customers for each year of the five-year regulatory period. This determines the revenue that ActewAGL can recover from its customers and hence the funds that can be invested in the network in the form of Operational Expenditure (Opex) and Capital Expenditure (Capex).

Technical regulation is overseen by the ACT Utilities Technical Regulator (UTR) of the Australian Capital Territory Government.

1.2. ActewAGL's operating conditions

ActewAGL is regulated by statutory and legislative requirements, including occupational, health and safety, environmental, competition, industrial, consumer protection and information laws, the National Electricity Rules, the ACT Utilities Act 2000, and the ACT Utilities (Technical Regulation) Act 2014. ActewAGL manages compliance with these laws and regulations through its internal policies and procedures. Management of the physical and financial assets as well as employees is through delegated authorities, from the Board, to executives and staff. Physical infrastructure assets are managed through an Asset Management System that has been certified as being compliant with ISO 55001, to meet the requirements of the ACT Utilities (Technical Regulation) Act 2014.

ActewAGL's operating licence to provide Utility Services was granted on 29 June 2001 by the ACT Independent Competition and Regulatory Commission, a body corporate established under the Independent Competition and Regulatory Commission Act 1997 (ACT) ("ICRC") pursuant to the Utilities Act 2000 (ACT).

This licence confers on ActewAGL the right to provide Authorised Utility Services, including electricity transmission, distribution and connection services. ActewAGL may exercise the rights conferred on it in any part of the Territory.

ActewAGL's licence was varied on 1 July 2009 to provide gas distribution and connection services under the Utilities Act 2000 (ACT).

1.3. ActewAGL's function

ActewAGL provides electricity and gas services over an area of 2,358 square kilometres to 191,481 electricity and 146,863 gas customers, as at 30 June 2017, within the Australian Capital Territory.
ActewAGL is responsible for the operation, maintenance, planning and augmentation of the transmission and distribution system within the ACT. There are a small number of rural cross border high voltage lines feeding 89 rural customers within NSW. Because of the presence of the Brindabella Ranges the developed electricity network is mainly confined to the Canberra urban and surrounding rural areas on the north east side of the ACT.

We supply electricity and natural gas network services to customers in the ACT (and south-east NSW for natural gas). This includes:

- conducting all maintenance, upgrade, and extension work on the distribution networks;
- performing connection, alterations, disconnection and reconnection;
- providing emergency response;
- maintaining quality and reliability of supply; and
- maintaining meters (where these meters are owned by ActewAGL Distribution).

ActewAGL's company values form the basis for all works done by ActewAGL and are:

- Honesty
- Respect
- Health and Safety
- Teamwork
- Continuous Improvement
- Accountability

ActewAGL also owns and operates a telecommunications network that supports the operation of the electricity network.

1.4. Power of Choice

The Power of Choice (PoC) rule changes, driven by the Australian Energy Market Commission (AEMC), came into effect on 1 December 2017 and include a suite of reforms to the National Electricity Rules designed to encourage energy consumers to make more informed choices about how and when they use electricity.

These reforms also mean changes to roles and responsibilities. The metering services previously facilitated through non-contestable distribution services are now within the direct control of retailers. Retailers will be responsible for coordinating meter installations, including new connections, additions and alterations (such as new solar PV installations), management of meter faults and end-of-life meter replacement programs. All of these have traditionally been the responsibility of DNSP's. ActewAGL will engage with independent Metering Coordinator (MC) businesses who will help us to make all of this happen.

ActewAGL has updated its Electricity Service and Installation (S&I) Rules which are available on our website.

1.5. Purpose of this document

This Annual Planning Report (APR) has been prepared to comply with the National Electricity Rules (NER) clause 5.12.2 Transmission Annual Planning Report (TAPR) and clause 5.13.2 and Schedule 5.8 Distribution Annual Planning Report (DAPR).

The purpose of this report is to inform Registered Participants, stakeholders and interested parties, of the identified current and future network issues, and the committed and proposed solutions to these issues. It identifies potential opportunities for non-network solutions such as embedded generation and demand-side management.

The APR provides information about ActewAGL's assessment and planning of its transmission and distribution capacity and ActewAGL's plans for development of the transmission network to meet demand over the next ten years, and development of the distribution network to meet demand over the next five years.

This report also details how ActewAGL plans to meet predicted demand for electricity supplied through its transmission lines, zone substations and high voltage feeders and discusses the process to engage with non-network providers and customers to address network constraints and system limitations.

1.6. Audience

This APR provides information to existing customers, potential new load and generation customers, non-network solution providers, AEMO, the AER, and other interested parties.

It also provides information to all readers on the operation, development and planning of ActewAGL's network, and the drivers for network investment.

1.7. Planning horizon of the APR

ActewAGL has used a ten-year planning horizon to prepare the demand and energy forecasts for its distribution network contained in this APR. The load forecasts show a 0.1% per annum average decrease in demand during summer months and a 0.7% per annum average increase in demand during winter months over the planning period, due to steady growth in the residential and commercial sectors of the ACT. Energy demand remains at a constant level and is forecast to decrease slightly over the planning period due to the increasing proliferation of rooftop PV throughout the region, coupled with the increasing efficiency of electrical appliances, and the advent of new battery storage systems.

Network development projects have been identified and are discussed in this APR for the next five-year planning period.

1.8. What has changed since 2016

The major changes for ActewAGL since the publication of the 2016 Annual Planning Report include:

1. System maximum demand during the 2016 calendar year was 619 MW. Peak summer demand for the 2017 calendar year was 633 MW. This occurred on 10 February 2017 when ambient temperature reached 41^{o}C. This was considerably hotter than the previous 2016 summer. Peak winter demand for the 2017 calendar year was 624 MW. This occurred on 7 August 2017.
2. The requirement for a second 132/11 kV 30/55 MVA transformer and 11 kV switchboard at East Lake Zone Substation to meet load growth in the East Lake / Kingston / Airport / Pialligo / Fyshwick area has been confirmed.
3. The Second Point of Supply to the ACT project scope has been confirmed to proceed and will include a new TransGrid 330/132 kV bulk supply point substation at Stockdill Drive, West Belconnen, and a new 132 kV transmission line section to connect it to ActewAGL's Canberra–Woden 132 V line.
4. The requirement for the installation of additional reactive support in the northern part of the 11 kV network has been identified. This replaces the requirement for 132 kV reactive support.

5. Generation capacity of the Mount Majura Solar Farm has increased from 2.3 MW to 3.6 MW. Generation capacity of the Mugga Lane Waste Transfer Station bio-gas generator has increased from 3.0 MW to 4.0 MW.
6. A new 10.6 MW solar farm developed by Impact Investment Group (Williamsdale Solar Farm) has been commissioned and permanent connection has been made to the new Tennent 132/11 kV 15 MVA Zone Substation. The mobile substation installed at Angle Crossing was subsequently removed from service and is being retained as a system spare.
7. A proposal has been developed to decommission the Fyshwick Zone Substation 66 kV assets and convert it to an 11 kV switching station supplied from East Lake Zone Substation.
8. The requirement for a new zone substation at Strathnairn has been deferred from 2022 to 2025.
9. The requirement for a new zone substation at Mitchell has been deferred from 2023 to 2027.
10. The requirement for a third 132/11 kV 30/55 MVA transformer at Belconnen Zone Substation has been deferred from 2020 to 2025.
11. Under the Power of Choice legislation, ActewAGL Distribution ceased to be a metering services provider as from 1 December 2017.

Major customer-initiated developments currently underway or planned for construction over the next five-year period, include:

- Ginninderry Estate, West Belconnen – residential development.
- Ginninderra Estate, West Belconnen – residential development.
- CSIRO Ginninderra Estate, Belconnen – residential development.
- The Republic, Belconnen Town Centre – multiple high-rise residential and commercial developments.
- Throsby Estate, Gungahlin – residential development.
- Taylor Estate, Gungahlin – residential development.
- Gungahlin Town Centre East – residential and commercial development.
- Kingston Foreshore, Kingston – residential and commercial development.
- Denman Prospect Estate, Molonglo Valley – residential development.
- Whitlam Estate, Molonglo Valley – residential development.
- North Coombs, Molonglo Valley – residential development.
- North Wright, Molonglo Valley – residential development.
- South Quay, Tuggeranong Town Centre – multiple high-rise residential and commercial developments.
- Capital Metro Light Rail – construction of two 11 kV traction power stations and depot / control centre.
- Australian National University – replacement of 11 kV bulk supply point switching station and construction of second 11 kV bulk supply point switching station.
- Data Centre, Mitchell – commercial development.
- Data Centre, Fyshwick – commercial development.
- Canberra central business district – several residential and commercial developments.
- Electric bus charging station, Woden.
- Capital Recycling Solutions – proposed 15 MW waste to energy power station to be constructed at Fyshwick. Connection options being evaluated.
- Renew Energy – proposed 20 MW solar farm to be constructed at Harman. Connection options being evaluated.
- Photon Energy – proposed 14 MW solar farm to be constructed at Environa. Connection options being evaluated.
- 132 kV Transmission line relocations Molonglo Valley. Approximately 14 km of overhead 132 kV transmission lines that currently traverse the Molonglo Valley (sections of Canberra–Woden and Civic–Woden lines) are to be relocated and replaced with underground cables to provide space for a major residential development. Coupled with this proposed project, the site for the future Molonglo Zone Substation has been relocated.
- 132 kV Transmission line relocations East Lake Zone Substation to Causeway Switching Station. Approximately 5.5 km of overhead 132 kV transmission lines that currently traverse the Jerrabomberra Wetlands (sections of East Lake–Telopea Park and East Lake–Gilmore lines) are to be relocated and replaced with underground cables to provide space for a major residential development. Coupled with this proposed project, the Causeway 132 kV Switching Station will be decommissioned and removed.

- 132 kV Transmission line relocations Lawson. Approximately 1.6 km of overhead 132 kV transmission lines that currently run approximately 800 m northwest and southeast of Belconnen Zone Substation (sections of Latham–Belconnen and Belconnen–Bruce lines) are to be relocated and replaced with underground cables to provide space for a major residential development. A section of these 132 kV cables will be directional drilled beneath Lake Ginninderra.

1.9. Overview of this document

Chapter 1:	Introduces ActewAGL and the purpose of the Annual Planning Report, and summarises the main changes since ActewAGL's 2016 Annual Planning Report.
Chapter 2:	Explains the framework under which ActewAGL operates; the key aspects of network development and asset management strategies; and how customers and generators can participate in the planning process.
Chapter 3:	Describes ActewAGL's electricity network as it exists today and our planning philosophy for its future development.
Chapter 4:	Describes the current performance of ActewAGL's network against reliability targets, and summarises information about anticipated reliability performance, anticipated network augmentations, and asset management programs that impact system performance.
Chapter 5:	Describes the forecast electricity demand and energy requirements over the next ten years; discusses past and future trends; the impact of emerging technologies on forecasts; and assesses whether the existing generation supply can meet the forecast demand.
Chapter 6:	Describes ActewAGL's asset renewals program.
Chapter 7:	Describes those parts of ActewAGL's network forecast to require enhancement or development to meet forecast load demands or relieve constraints, and describes the options considered to achieve this. It also highlights any proposed augmentations that may be subject to the Regulatory Investment Tests for Transmission or Distribution.
Chapter 8:	Discusses strategies regarding demand-side management and why these are important to ActewAGL from a planning and investment perspective.
Chapter 9:	Discusses emerging technologies and why these are important to ActewAGL from a planning and investment perspective.
Appendices:	Provide additional and supporting data.

1.10. Feedback and enquiries

ActewAGL welcomes feedback on this Annual Planning Report. We welcome enquiries from interested parties to participate in non-network opportunities, demand-side management, and embedded generation, to assist ActewAGL manage its existing and forecast network issues.
Please address enquiries to:

ActewAGL Distribution
Branch Manager – Asset Strategy
GPO Box 366
Canberra ACT 2601
Email: dennis.stanley@actewagl.com.au

2. Planning Considerations

This chapter discusses relevant aspects of the legal framework that regulates how ActewAGL carries out network planning and augmentation activities in the ACT, and discusses key aspects of network planning and asset management strategies. It also discusses our engagement of stakeholders and customers in the network planning process.

2.1 The regulatory framework & operating environment

ActewAGL operates under the National Electricity Rules (NER) which are managed and updated by the Australian Energy Market Commission (AEMC).

ActewAGL is a Registered Participant in the National Electricity Market (NEM). This is the Australian wholesale electricity market and the associated electricity transmission grid. The NEM is operated by the Australian Energy Market Operator (AEMO) which controls the wholesale generation, dispatch and transmission of electricity in Queensland, New South Wales, South Australia, Victoria, the ACT and Tasmania. The NEM is not a physical thing but a set of procedures that AEMO manages in line with the National Electricity Law (NEL) and the National Electricity Rules. The market uses sophisticated systems to send signals to generators instructing them how much energy to produce each five minutes so that production is matched to consumer requirements, spare capacity is kept ready for emergencies, and the current energy price can be calculated. NEM infrastructure comprises both state and private assets managed by many participants.

ActewAGL is subject to the NEL and NER which regulate the NEM. ActewAGL operates in the NEM as both a Transmission Network Service Provider (TNSP) and a Distribution Network Service Provider (DNSP). The National Electricity Objective (NEO), as stated in the NEL is to:

"…promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:

(a) price, quality, safety, reliability and security of supply of electricity; and
(b) the reliability, safety and security of the national electricity system."

This objective requires Registered NEM participants to balance the costs and risks associated with electricity supply.

In addition, there are local territory requirements that ActewAGL must comply with under the terms of our license issued by the ACT Government. The ACT has a Utilities Technical Regulator (UTR) whose role is to ensure safe and reliable energy services to the community. In the ACT, the Chief Minister is responsible for technical regulation. The Director-General of the Environment and Planning Directorate is the Technical Regulator who administers technical regulation. The ACT's economic regulator is the Independent Competition and Regulatory Commission (ICRC).

Technical regulation ensures the safe and reliable delivery of energy to the ACT community. The Utilities (Technical Regulation) Act 2014 sets out technical requirements for energy utilities. The specifics of any requirements are set out in technical codes made under the Act.

2.1.1 National Electricity Rules

The NER Chapter 5 describes the planning, design and operating criteria that must be applied by Network Service Providers to their networks. These criteria specify certain electrical performance standards that must be met such as voltage levels, voltage unbalance, voltage fluctuations, harmonics levels, protection operating times, power quality and power system stability.

2.1.2 Electricity Distribution Supply Standards Code

The Electricity Distribution Supply Standards Code (August 2013), issued by the Technical Regulator sets out performance standards for ActewAGL's distribution network. ActewAGL is required to take all reasonable steps to ensure that its Electricity Network will have sufficient capacity to make an agreed level of supply available.

This local jurisdictional code specifies reliability standards that ActewAGL must endeavour to meet when planning, operating and maintaining the distribution network. It also specifies power quality parameters that must be met including limits on voltage flicker, voltage dips, switching transients, earth potential rise, voltage unbalance, harmonics and direct current content.

2.1.3 Electricity Transmission Supply Code

The Electricity Transmission Supply Code issued by the Utilities Technical Regulator (July 2016) sets out performance standards to be met by TransGrid's and ActewAGL's transmission networks in the ACT. Implications for meeting this code are described in Section 7.5.1 Second Point of Supply to the ACT project.

2.1.4 Regulatory Investment Test

Section 5.16 of the NER describes the Regulatory Investment Test for Transmission (RIT-T) and Section 5.17 describes the Regulatory Investment Test for Distribution (RIT-D). These tests must be carried out for any proposed investment where the augmentation or replacement cost of the most expensive credible option exceeds $5 million. The regulatory investment tests provide the opportunity for external parties to submit alternative proposals to the Network Service Provider, who is obliged to consider any credible proposal objectively.

2.1.5 Revenue Determination

The revenue ActewAGL earns from providing transmission and distribution services in the ACT is set by the AER. ActewAGL prepares and submits a revenue proposal to the AER on a five-yearly basis. The current Revenue Determination covers the period 1 July 2014 to 30 June 2019. This revenue amount determines how much ActewAGL is able to invest in capital projects and what it can spend on operational expenditure to maintain and operate the network in a secure and reliable state. ActewAGL is currently preparing its revenue proposal for the 2019-24 period. This will be submitted to the AER in January 2018.

2.1.6 Service Target Performance Incentive Scheme

For the regulatory period from 2014-19 and future regulatory periods ActewAGL is subject to the AER's Service Target Performance Incentive Scheme (STPIS).

For full details of the STPIS refer to the *AER Electricity Distribution Network Service Providers - Service Target Performance Incentive Scheme Guideline, November 2009 (STPIS Guidelines)*.

Reliability refers to the extent that customers have a continuous supply of electricity. The main objective of the STPIS is to provide TNSP's and DNS's with an incentive to maintain or improve reliability levels and consumer response without increasing costs. STPIS achieves this by rewarding network businesses that outperform their targets or by penalising network businesses that do not.

The ActewAGL STPIS scheme has two components:

- Reliability of Supply (unplanned SAIDI and SAIFI).
- Customer Service (telephone response time).

Both SAIDI and SAIFI are subdivided into Urban and Rural components. The definitions for the reliability of supply components are:

Unplanned SAIDI (System Average Interruption Duration Index)
The sum of the duration of each unplanned sustained customer interruption (in customer minutes) divided by the total number of distribution customers (urban or rural). Unplanned SAIDI excludes momentary interruptions (one minute or less).

Unplanned SAIFI (System Average Interruption Frequency Index)
The total number of unplanned sustained customer interruptions divided by the total number of distribution customers (urban or rural). Unplanned SAIFI excludes momentary interruptions (one minute or less). Key points:

- The parameters are separately applied to the two feeder types that ActewAGL has – urban and short rural.
- The performance targets are set at the start of each regulatory period and will remain the same for the full 5 year regulatory period.

The targets are generally set based on the average level recorded over the previous five years. For further detailed discussion on performance metrics, refer to Section 4.2.

2.1.7 Capital Expenditure Sharing Scheme

For the regulatory period from 2014-19 and probably future regulatory periods ActewAGL is subject to the AER's Capital Expenditure Sharing Scheme (CESS). Because the 2014-15 year was a transitional year the AER declared that the CESS would commence for ActewAGL on 1July 2015.

For full details of the CESS refer to the *AER Capital Expenditure Incentive Guideline for Electricity Network Service Providers, November 2013 (CESS Guidelines)*.

The main objective of the CESS is to provide DNSPs with an incentive to undertake efficient capital expenditure (capex) during a regulatory control period. It achieves this by rewarding DNSPs that outperform their capex allowance by making efficiency gains and spending less than forecast or by penalising DNSPs that spend more than their capex allowance because of a lack of efficiency gains.
ActewAGL's strategies to manage the CESS include:

1. Ensuring that the annual capex budget matches or is lower than the AER Approved Allowance for each regulatory year. This includes the annual reforecast budgets.
2. Ensuring that final actual capex in any regulatory year does not exceed budget and/or the AER Approved Allowance.
3. The development of internal capex benchmarking targets based on optimal industry performance.
4. Close co-ordination of the Asset Management Maintenance and Capital Programs with the Program of Works delivery to achieve a timely capex program.

2.1.8 Distribution Loss Factors

As electricity flows through the transmission and distribution networks, energy is lost due to electrical resistance and the heating of conductors. The losses are can be up to approximately 10% of the total electricity transported between power stations and end users (including up to 5% via the distribution network).

Energy losses on the network must be factored in at all stages of electricity production and transport, to ensure the delivery of adequate supply to meet prevailing demand and maintain the power system in balance. In practical terms, this means more electricity must be generated than indicated in simple demand forecasts to allow for this loss during transportation.

The impact of network losses on spot prices is mathematically represented as transmission and distribution loss factors. Loss factors are calculated and fixed annually to facilitate efficient scheduling and settlement processes in the NEM.

ActewAGL calculates and prepares a report annually of the distribution loss factors (DLFs) to comply with the AER's regulatory requirement. The DLF methodology can be found on ActewAGL's website[1], and ActewAGL's DLF for each network level can be found publicly at AEMO's website[2].

1 http://www.actewagl.com.au/~/media/ActewAGL/ActewAGL-Files/About-us/Publications/ACT-Distribution-loss-factor-methodology.ashx?la=en

2 https://www.aemo.com.au/media/Files/Electricity/NEM/Security_and_Reliability/Loss_Factors_and_Regional_Boundaries/2017/DLF_V1_2017_2018.pdf

2.2 ActewAGL integrated planning

2.2.1 Integrated planning strategies – Asset Management, Network Development & Network Reliability.

Significant organisational changes and investments have been made to date which will allow ActewAGL to respond to the regulatory and commercial challenges facing the business, and to optimise network performance through improved alignment of planning, asset management and regulatory compliance. Targeted activities to ensure alignment and improve network performance include:

- Achieve electricity Service Target Performance Incentive Scheme (STPIS) targets through proactive management of:
    - Timely response to network outages.
    - Delivering and implementing risk based defect management of assets.
    - Incorporating reliability performance requirements into network investment business cases.
    - Effective call centre performance management.
    - Targeted reliability improvements upgrading the most unreliable feeders.
    - Root cause analysis of network faults.
    - Expanded use of Failure Mode and Effects Analysis (FMEA).
- Determine and deliver opportunities for asset utilisation improvement, through:
    - Reviewing network supply security standards.
    - Incorporating asset utilisation into network investment business cases.
    - Proactive monitoring of network design practices.
    - Improved alignment of data flow and connection between asset management applications.
- Review our bushfire mitigation program prior to the commencement of the bushfire season and conduct an internal exercise to test bushfire emergency preparedness.
- Deliver a Program of Work (PoW) with particular focus on:
    - Achieving budget targets and efficiency of PoW delivery.
    - Improved PoW reporting which includes earned value metrics.

2.2.2. Asset Management Strategy

ActewAGL's Asset Management Strategy is intended to define the strategic objectives and approach to the management of its physical assets, in a manner that:

- Is optimised and sustainable in terms of whole-of-life, whole-system cost over the long-term;
- Assists in the delivery of ActewAGL's strategic plans and objectives;
- Appropriately considers how ActewAGL will supply current and future demand via the management of the condition and performance of the asset base, ensuring that asset management plans are coordinated with network development plans;
- Ensures that asset renewals are based on asset condition and risk of failure rather than purely on age;
- Meets the required level of service in the most cost-effective way through the efficient use and maintenance of existing assets and the prudent investment in new assets; and
- Appropriately considers the necessary current and future Asset Management capabilities of the organisation, in terms of people, processes, systems, equipment and data to achieve the identified outputs and objectives.

ActewAGL prepares technical specifications for the procurement of major primary assets which include requirements for an assessment of whole-of-life costs, including electrical losses. The method of assessing these costs is included in the specification and is taken into account when selecting the successful tenderer.

ActewAGL's Asset Management Strategy and Asset Management Objectives are directed at maintaining assets according to the principles of Risk Centred Maintenance (RCM). The governing factor in RCM analysis is the impact of a functional failure at the equipment level, and tasks are directed at a limited number of significant items - those whose failure might have safety, environmental or economic consequences. The continual assessment of assets follows the Plan – Do – Check – Act based approach.

ActewAGL's Asset Management Policy, Strategy and Objectives may be found published on ActewAGL's website.

The Asset Management Strategy has been updated since the previous publication of this report with a section on Aspirational Strategies. These have been developed because Energy Networks must conceptually transition from a Distribution Network Service Provider (DNSP) to a Distribution Systems Operator (DSO). That is, rather than simply receiving power from centralised generators and distributing it to customers, ActewAGL will oversee a system of intelligent networks with controllable Distributed Energy Resources (DERs) and loads. As a DSO, ActewAGL would still undertake the conventional role of a distribution network owner but would also make full use of smart techniques to create value for the wider electricity system. ActewAGL would be required to manage a complex and interactive energy system, driven by rapid technology development and changing consumer behaviour. There will be an increasing number of distributed points of variable production and consumption of electricity connected to the distribution network, unlike the traditional network that consists of a linear, one-way flow of energy from large-scale producers to consumers. The system is increasingly becoming a two-way network, enabling the exchange of energy and information, and increasing consumer choice.

Certification of Asset Management System to ISO 55001:

ISO 55001 was published in February 2014 (superseding the PAS 55 Standard) and states the requirements specification for an integrated, effective management system for asset management, the intent being to maximize value for money from assets.
ActewAGL has adopted ISO 55001 as the reference for measuring asset management continuous improvement and compliance.

In 2016 ActewAGL participated in an international benchmarking project, the Asset Management Customer Value Project. The results showed ActewAGL to be performing well against other international and national participants and provided a good base to commence the ISO 55001 compliance maturity assessment.

In July 2017 the JAS-ANZ accredited auditor Bureau Veritas assessed ActewAGL's Asset Management System in a Stage 1 audit and deemed it to meet the requirements the next stage (Stage 2) for ISO 55001 certification. ActewAGL successfully completed the Stage 2 audit by Bureau Veritas in November 2017 and has attained certification with the International Standards Organisation standard for Asset Management ISO 55001.

Certification to ISO 55001 ensures ActewAGL has the visibility, capability and control to satisfy increasing customer and Regulator expectations. Certification to ISO 55001 verifies compliance with the ACT Utilities Technical Regulator Electricity Network Asset Management Code August 2013.

2.2.3. Network Development Strategy

ActewAGL's network development strategy incorporates providing adequate supply to existing and new customers with prudent investment decision making, whilst applying risk management principles to achieve an appropriate balance between supply adequacy, security, reliability and safety at the lowest cost to our customers.

ActewAGL incorporates long term strategic planning with short term planning to ensure appropriate network developments meet the long term needs of our customers.

The nature of the transmission and distribution industry is changing rapidly with the emergence of new technologies (refer to Chapter 9) and the development of the network must be done so as to cater for these 'non-traditional' factors.

As assets near the end of their economic lives and require replacement, we consider whether a straight like-for-like replacement is the best solution or whether the network can be reconfigured in a way to minimise the costs of asset renewals.

ActewAGL plans and develops its transmission and distribution networks in an integrated way, for example the best way to resolve a transmission constraint could be to implement a distribution solution.

For all major investment projects we investigate non-network options and seek alternative proposals from external third parties.

2.2.4. Network Reliability Strategy

Transmission network reliability is measured in terms of the number of loss of supply events that occur in a year and the amount of unserved energy that results from such outages. ActewAGL's 132 kV transmission network is very secure in that all zone substations have at least two sources of 132 kV connection (i.e. N-1 security). In addition most zone substations have at least two power transformers and the 11 kV network is interconnected between zone substations allowing load transfer in the event of a contingency.

Distribution network reliability is measured in terms of the frequency and duration of unplanned interruptions to customers. Measurement factors include SAIDI, SAIFI and CAIDI (refer Section 4.2).

ActewAGL's strategy is to maintain or improve existing levels of reliability throughout the network through the deployment of devices such as auto-reclosers and remote controlled switches, and the use of our Advanced Distribution Management System (ADMS).

2.3. Customer Connections

Customers can connect to ActewAGL's system at either high voltage (11 kV) or low voltage (400/230 V) level, depending on their requirements. Customer connections can be either load or generation or a combination of the two. Most load and embedded generation connections (for example, rooftop PV) are connected to the low voltage system. Larger customer loads or embedded generators (such as solar farms) are generally connected to the high voltage system. Metering is measured at the high or low voltage point of connection accordingly.

Larger load connections such as a greenfield residential estate may require ActewAGL to augment the up-stream portion of the network (e.g. provide a new 11 kV feeder). Such augmentations form part of the shared network that is not funded by a specific customer.

Larger load or generation connections require a detailed technical study to be undertaken to determine the impact on the network to ensure adequacy of the proposed connection point with regards to capacity, safety and power quality.

Proposed customer connections are included in load forecasts which provide a key input to network planning.

2.4. Stakeholder Engagement

ActewAGL firmly believes in the principle of follow through as it applies to stakeholder engagement. After consultations have taken place, stakeholders are advised on how their suggestions have been taken on board, what risk or impact mitigation measures will be put in place to address their concerns, and how project impacts are being monitored. Furthermore, aside from project-affected groups, other stakeholders are consulted on issues that address their particular concerns, such as the environmental, social, economic, and governance performance of the business. This process offers a platform to report back on the process of stakeholder engagement itself, such as

- who has been consulted;
- on what topics; and
- with what results.

Keeping track of the commitments made to various stakeholder groups at various times, and communicating progress made against these commitments on a regular basis, requires appropriate systems and organisation. The following factors have been taken into account in determining ActewAGL's stakeholder engagement strategy: ActewAGL actively

- determines what information needs to be reported to which stakeholders, by what method and how frequently;
- updates its commitments register and discloses progress to affected and interested parties. In particular, ActewAGL publicises any material changes to commitments or implementation actions that vary from publicly disclosed documents;
- makes appropriate monitored results publicly available;

- reports on the process of stakeholder engagement as a whole, both to those stakeholders who are directly engaged, and to other interested parties; and
- provides information reported to stakeholders in non-technical and easily understandable formats.

Further information on ActewAGL's engagement with stakeholders, including media and the public can be found on ActewAGL's Consumer Engagement website[3].

3 http://www.actewagl.com.au/Networks/About-our-network/Initiatives/Consumer-engagement.aspx

3. The ActewAGL Network

3.1. Overview of the network

This chapter describes ActewAGL's transmission and distribution network in the ACT and how it fits in the supply chain between generating power stations and end use customers, and discusses issues affecting the National Transmission Flow Path (NTFP).

3.2. Characteristics of the ActewAGL network

The ActewAGL network consists of an interconnected 132 kV transmission network supplying twelve 132/11 kV zone substations and two 132 kV switching stations. There is also a single 66/11 kV zone substation. All 132 kV and 66 kV connections have N-1 transmission security with the exception of Tennent Zone Substation which is connected via a single circuit 132 kV tee-connection. There are three bulk supply points supplying the ActewAGL network, all owned and operated by TransGrid Limited as follows:

- Canberra 330/132 kV bulk supply substation.
- Williamsdale 330/132 kV bulk supply substation.
- Queanbeyan 132/66 kV bulk supply substation.

ActewAGL's assets include 132 kV transmission lines, 66 kV sub-transmission lines, 132/11 kV and 66/11 kV zone substations, 22 kV and 11 kV distribution feeders, 22/0.415 kV and 11/0.415 kV distribution substations, low voltage 400 V circuits and equipment such as distribution pillars and pits to provide connection points to customers. ActewAGL also owns a 132/11 kV 14 MVA mobile substation which can be deployed as required at short notice.

East Lake and Tennent zone substations are the two substations that have one power transformer only. All other zone substations have two or three power transformers, providing N-1 transformer security.

There are currently 247 x 11 kV feeders. Most of these are interconnected with other feeders (i.e. a meshed 11 kV network) and provide links between zone substations. There are also two 22 kV distribution feeders, supplied via 11/22 kV step-up transformers at Woden Zone Substation.

Approximately 53% of ActewAGL's distribution network is underground, although less than 2% of the transmission network is underground.

There are 25 customers directly connected at 11 kV, two customers directly connected at 22 kV, and no customers directly connected at either 66 kV or 132 kV. The remaining customers are connected to the low voltage network (400 V three phase or 230 V single phase). 11/0.415 kV distribution stations are ground-mounted, pole-mounted, or installed inside buildings such as chamber substations, and range in size from 25 kVA to 1500 kVA.

Customers are primarily commercial, light industrial or residential connections. There are no major industrial customers.

The majority of electricity consumed by customers in the ACT is generated outside the ACT. There are some small embedded generation facilities in the ACT, the largest being the Royalla Solar Farm at Royalla which has a peak output of 20 MW. Mount Majura Solar Farm at Majura with a maximum design output of 3.6 MW was commissioned in September 2016. Mugga Lane Solar Park at Mugga Lane, Hume with a maximum design output of 12.85 MW was commissioned in November 2016. Williamsdale Solar Farm at Williamsdale with a maximum design output of 10.6 MW was commissioned in December 2016. There are two bio-gas generators installed at Mugga Lane (4 MW) and Belconnen (3 MW) waste transfer stations, and one co-gen plant (1.2 MW) at the Harman defence facility.

There is approximately 59.8 MW of installed domestic rooftop photo-voltaic (PV) generation capacity consisting of 17,975 installations as at 30 June 2017. This represents approximately 9.4% of ActewAGL's customers. These are distributed all over the ACT. Their impact on zone substation summer peak demand is a reduction that ranges from 0.2% - 3.0% depending on the level of penetration in the area. Their impact on zone substation winter peak demand is negligible.

To date there are no battery storage systems connected directly to the ActewAGL distribution network and only a few domestic battery systems connected beyond-the-meter. There are three rapid-charge and five fast-charge electric vehicle charging stations connected to the low voltage network (refer Section 9.5).

System peak demand usually occurs in winter; however in 2017 it occurred in summer. In 2017 the winter peak demand was 624 MW and the summer peak demand was 633 MW.

ActewAGL owns, operates and maintains a telecommunications network that supports the operation of the electricity network. It provides bearers for control, protection and data signalling, telephone handsets and mobile radios for operations and maintenance activities. Telecommunications assets include optical fibres on transmission and distribution lines, digital microwave radios and associated repeater stations.

3.3. Transmission/Distribution system

Figure 3.1: ActewAGL Transmission System

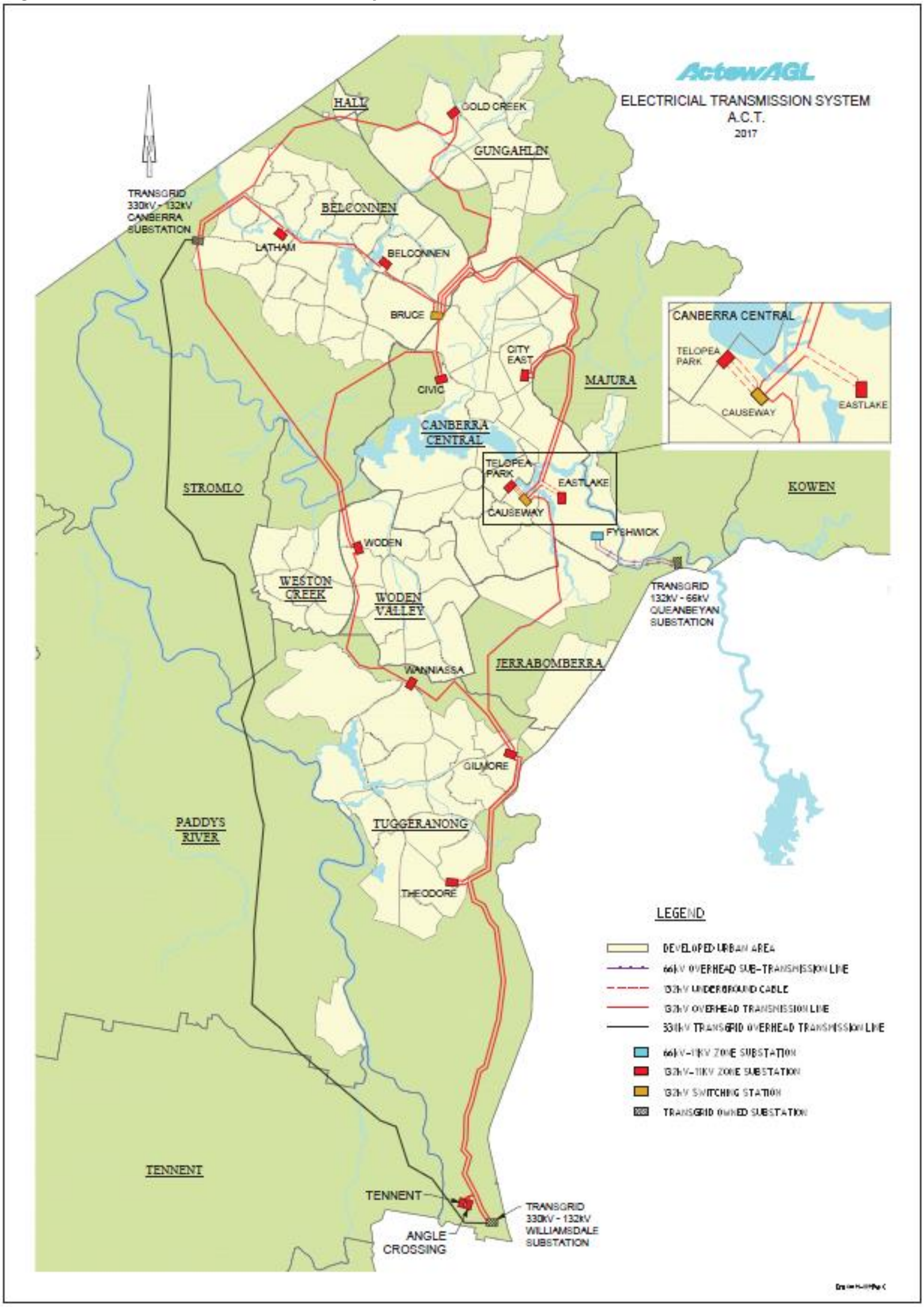


Figure 3.2 presents a schematic diagram of the ACT transmission network.

Figure 3.2: ACT Existing Transmission Network Schematic Diagram

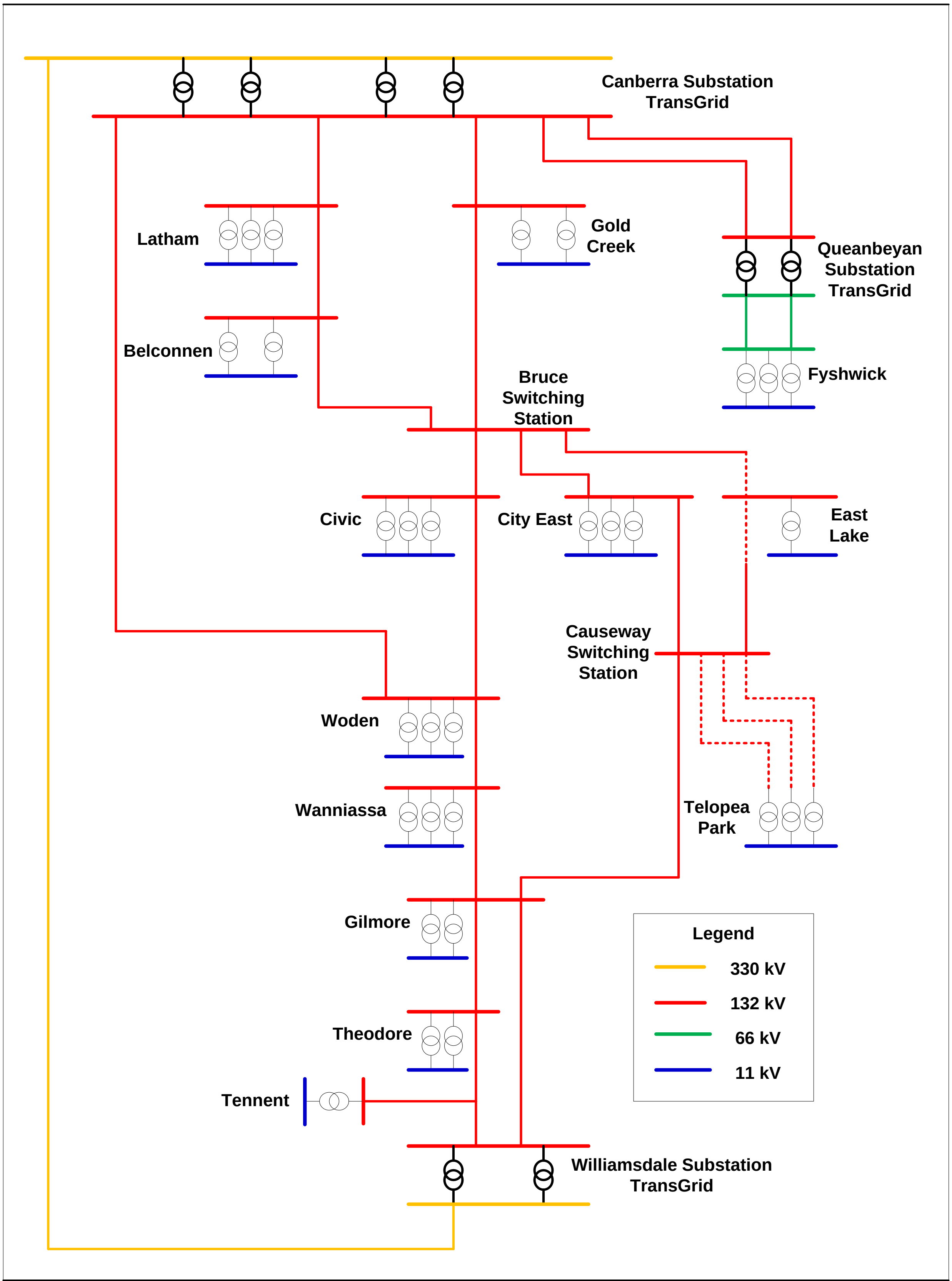
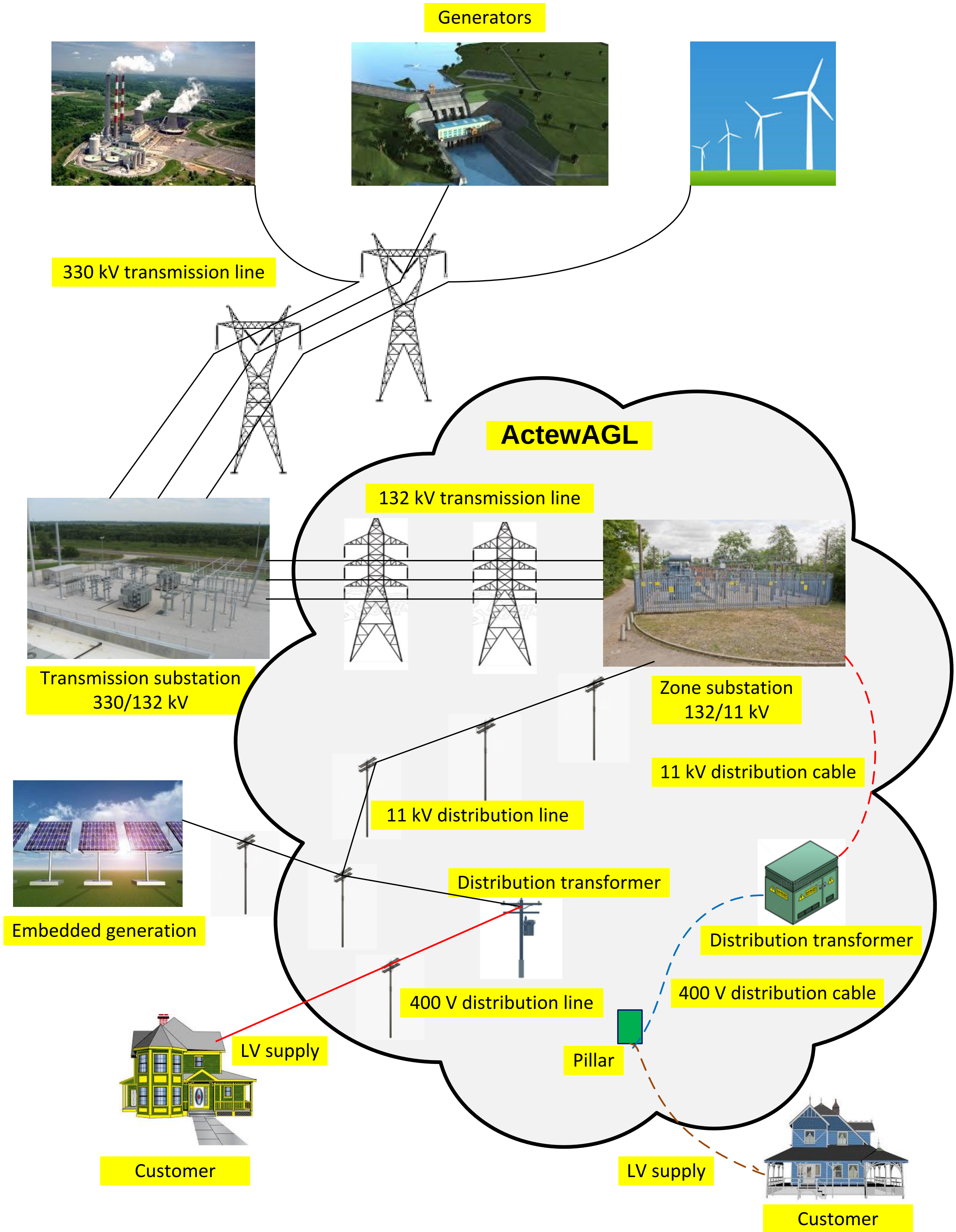


Figure 3.3 illustrates where ActewAGL fits in the supply chain.

Figure 3.3: Electricity Supply Chain



A summary of ActewAGL's major network assets is shown Table 3.1.

Table 3.1: ActewAGL Network Assets

Asset Type	Nominal Voltage	Quantity
Bulk Supply Points	330/132 kV	2
	132/66 kV	1
Transmission Lines	132 kV	189 km Overhead
	132 kV	6 km Underground
Sub-transmission Lines	66 kV	7 km overhead
Switching Stations	132 kV	2
Zone Substations	132/11 kV	12 (+ 1 mobile substation)
	66/11kV	1
Power transformers	132/11 kV	28
	66/11 kV	3
Feeders	22 kV	2
	11 kV	248
22/0.415 kV Substations	22 kV & 400 V	18
11/0.415 kV Substations	11 kV & 400 V	5,079
Number of transmission towers and pole structures	132 kV	917
	66 kV	52
Number of poles	22 kV, 11 kV and 400 V	50,685
Circuit km of distribution overhead lines	22 kV, 11 kV and 400 V	2,365 km
Circuit km of distribution underground cables	11 kV and 400 V	2,946 km
Number of customer connections	22 kV	2
	11 kV	25
	400 V / 230 V	191,454
Coverage area		2,358 km^2
System maximum demand		633 MW
Telecommunications network		Fibre optic and radio

Table 3.2 lists ActewAGL's zone substations, their year of commissioning and their installed power total capacity and firm capacity (N-1 rating).

Table 3.2: ActewAGL's Zone Substations

Zone Substation	Year commissioned	Voltage	Total capacity	Firm capacity	No of transformers
Belconnen	1977	132/11 kV	110 MVA	55 MVA	2
City East	1979	132/11 kV	171 MVA	114 MVA	3
Civic	1967	132/11 kV	165 MVA	110 MVA	3
East Lake	2013	132/11 kV	55 MVA	0 MVA	1
Fyshwick	1982	66/11 kV	75 MVA	50 MVA	3
Gilmore	1987	132/11 kV	90 MVA	45 MVA	2
Gold Creek	1994	132/11 kV	114 MVA	57 MVA	2
Latham	1971	132/11 kV	150 MVA	100 MVA	3
Telopea Park	1986	132/11 kV	150 MVA	100 MVA	3
Tennent	2017	132/11 kV	15 MVA	0 MVA	1
Theodore	1990	132/11 kV	90 MVA	45 MVA	2
Wanniassa	1975	132/11 kV	150 MVA	100 MVA	3
Woden	1967	132/11 kV	150 MVA	100 MVA	3

3.4. Planning Philosophy

The planning and development process for both transmission and distribution networks, is carried out in accordance with the National Electricity Rules (NER) Chapter 5 Part B Network Planning and Expansion. Planning for the transmission network is carried out in accordance with the NER Section 5.12 Transmission annual planning process and for the distribution network in accordance with the NER Section 5.13 Distribution annual planning process.

The primary objective of planning is to ensure that customers are able to receive a sufficient and reliable supply of electricity now and into the future. ActewAGL's planning standards are set to ensure that peak demand can be met with an appropriate level of backup should a credible contingency event occur. A credible contingency event is the loss of a single network element, which occurs sufficiently frequently, and has such consequences, as to justify the NSP to take prudent precautions to mitigate. This is commonly referred to as an N-1 event. Typically there is a high level of redundancy applied to electricity networks. This reflects the implications of network service failures, noting that communities and businesses have a low tolerance to electricity supply interruptions.

ActewAGL's planning standards are determined on an economic basis but expressed deterministically. ActewAGL uses probabilistic planning techniques when carrying out economic analysis. When assessing the economic benefits of a proposed solution to an issue, we calculate the probability of an event occurring that would result in an interruption of supply to customers. This probability is used as part of the economic analysis to determine whether the benefits of the proposed solution exceed the costs. For example if the supply demand to a part of the network could not be met fully in the event of a contingency, existing assets may be upgraded or new assets may be installed if justified economically. Changes to system losses are included in the economic evaluation of a project.

The early identification, consultation and monitoring of emerging network limitations and prospective network developments is aimed at providing proponents of non-network solutions adequate time to prepare proposals.

ActewAGL's planning approach to addressing load growth or network constraint issues, is to use probabilistic analysis techniques coupled with fully exploring non-network solutions such as demand-side management, before investing in network augmentation. This approach takes into account the combination of demand forecasts, asset ratings and asset failure rates to identify the severity of constraints and the required timing of solutions.

ActewAGL runs a load flow model of the network using a computer software program known as ADMS (Advanced Distribution Management System). This system is linked to our Supervisory Control and Data Acquisition (SCADA) system and obtains and analyses data such as the status of network assets (e.g. positions of circuit breakers), current flows and voltage levels throughout the network, in real time. This system is used to identify issues such as power flow constraints or voltage level issues on the network, and is used to model what-if scenarios such as the effect of a new load or generation connection. Using this tool, ActewAGL is able to identify existing and emerging constraints which form the basis of our asset management and network development plans.

ActewAGL's planning process is an annual process and covers a minimum forward planning period of ten years. The process commences with a comprehensive analysis of all indicators and trends to forecast the future load on the network. A detailed analysis of the network is then carried out to identify performance and capability shortcomings, i.e. constraints.

ActewAGL uses a two hour emergency cyclic rating for all its zone substation power transformers. ActewAGL has adopted the use of two hour emergency ratings and normal cyclic ratings, and uses the ADMS system to regularly record and reassess the cyclic loading capability of zone substation equipment, based on equipment manufacturer's recommendations and relevant Australian and international standards. ActewAGL maintains a high level of zone substation power transformer utilisation by using the two hour emergency cyclic rating, and effective load balancing between zone substations wherever possible. Load balancing is an integral initial solution to network augmentation planning.

Chapter 7 describes the outcomes of our annual planning process. If the augmentation or replacement cost of a proposal exceeds $5 million, we undertake a Regulatory Investment Test in line with the requirements of the NER (section 5.16 for transmission RIT-T and section 5.17 for distribution RIT-D). The purpose of the Regulatory Investment Test is to identify the credible option that maximises the present value of net economic benefit to all those who produce, consume and transport electricity in the market. A preferred option may have a negative net economic benefit (that is, a net economic cost) where the identified need is for reliability corrective action.

ActewAGL ensures the following prior to committing to any large investment:

- Investments are cost effective and consider whole-of-life costs associated with a new asset.
- Timing of the new investment is such to meet the requirement of the need when it reaches the point that the need cannot otherwise be met.
- Appropriate investment procedures are followed, including business case and Board approval, and execution of RIT-T or RIT-D if required.
- Works are timed to ensure smooth capital and replacement cash flows, and availability of resources.
- Works are coordinated as required with other utilities and/or network service providers, and to meet customer needs.

3.4.1 Deterministic versus probabilistic planning approaches

Planning requirements are generally set as "deterministic" requirements, where rules or standards require investment to meet N (or N-0), N-1 and N-2 contingency criteria, where "N" is a single infrastructure element such as a transformer, transmission line or cable. These criteria basically define the level of reliability and security to which a network is designed. These requirements are intended to ensure that the network can withstand periods of plant outage, without leading to load shedding. The strict use of deterministic planning criteria that consider only supply side options, however, may preclude demand side management options.

Under the "deterministic" planning approach, the timing of augmentations is determined on the basis of peak demand exceeding the planning criteria. If the deterministic planning approach is applied strictly, network investment to augment capacity would be required prior to the year when peak demand exceeds capacity. Deterministic criteria like N-1 and N-2 also assume that network investment occurs in discrete units, with known levels of reliability. It therefore effectively assumes that investment in infrastructure is used to meet planning criteria. This can be a barrier to demand management as demand management projects are not always available in discrete blocks to balance against network investments in infrastructure such as transformers and line upgrades.

The "probabilistic" planning approach is an extension of the deterministic planning approach in the sense that it provides a method of assessing the economic value of network reliability to customers. This can be used as a way to prioritise competing projects. In doing this, probabilistic planning also provides scope for non-network demand management alternatives to reduce load by introducing the economic value of supply for customers, which is the basis for all demand management projects.

Customers will offer demand response capabilities when the reward for demand response is greater than the value they place on that supply. This can include accepting some degree of direct load control or capacity limitation. Deterministic planning criteria, strictly applied, do not facilitate NSPs offering this type of optimisation decision to customers, as it focuses entirely on the level of reliability and security of supply, not the value of that supply to customers. A probabilistic planning framework therefore may offer a different range of opportunities for demand management.

Figure 3.4 illustrates ActewAGL's network planning process.

Figure 3.4: ActewAGL's network planning process

Planning Inputs and Drivers:

Demand forecasts	Equipment ratings	Load transfer capacity
Security standards	Reliability standards	National Electricity Rules
ACT technical regulations	Quality of supply	Network performance targets
Demand side management criteria	System constraints	Customer load connections
Embedded generation connections	Equipment condition reports	Capital approval process
RIT-T and RIT-D processes	Network augmentation criteria	Design manual
Company policies & standards	Stakeholder obligations	Health & Safety
Financial objectives	Strategic benefits	Legal & Statutory obligations

Planning Process:

Load flow studies	Fault level studies	Network capacity analysis
Identify emerging constraints	Identify credible network options	Identify credible non-network options
Identify power quality improvements	Identify security improvements	Identify network reliability improvements
Joint planning with TransGrid	Options analysis	Carry out RIT-T or RIT-D
Prepare Development Applications	Select preferred options	Prepare business case and project approval
Economic analysis – NPV studies	Risks analysis	Model/simulate network
Load forecasting	Capital approval governance	Customer consultation
Strategic alignment	Security of supply	Financial analysis (NPV)

Planning Outputs:

Programme of Works	RIT-T or RIT-D consultation reports	Annual Planning Report
Zone Substation development reports	Project technical specifications	Capital investment approval
Uprate existing assets	Land access & easement agreements	Demand-side management contracts
Asset renewals & replacements	Tender or contract for procurement	Tender of contract for design & construction
Meet security & reliability standards	Five-yearly regulatory proposal	Build new network infrastructure if required
Regulatory Information Notice	Network modelling	Network augmentation projects
Development Application submissions	Non-network solutions	Customer connections

4. Network Performance

4.1. Introduction

This chapter discusses the performance of the ActewAGL electricity network. There are a number of factors that contribute to network performance and these include the following:

- Network reliability which is measured in terms of the number and duration of customer outages.
- Network security which measures the power system's capacity to continue operating within defined technical limits even if a major power system element such as a transmission line or zone substation transformer, fails. Such failures are known as 'credible contingency events'.
- Constraints that restrict access to the network for maintenance purposes without the need to disrupt supply to customers.
- Major system incidents that may have been as a result of structural or geographic weaknesses.
- The level of photovoltaic generation penetration and the ability of the network to cope.
- The condition of the assets making up the network.
- Network fault levels and the ability of the network to cope.
- The quality of the power supply in terms of voltage stability, harmonic content, freedom from flicker, and security from shocks and stray voltages.
- The level of network losses.
- The level of network information systems penetration.
- Any network innovations such as automatic fault isolation and restoration.

4.2. System reliability and performance metrics

ActewAGL's service standards obligations arise mainly from the application of the ACT Utilities (Technical Regulation) Act 2014 (the Act). The Act requires ActewAGL to comply with all relevant industry and technical codes, any directions by the Independent Competition and Regulatory Commission (ICRC) or the ACT Technical Regulator. Relevant codes include the Consumer Protection Code, the Electricity Distribution Supply Standards Code (2013) and the Electricity Transmission Supply Code (2016).

The network reliability measures and standards are adopted from the Supply Standards Code and the referred Australian Standards therein which set out parameters for electricity supply through the ActewAGL network.

The minimum distribution supply reliability standards are detailed in the Supply Standards Code, Schedule 2. Section 6.1 of the Code also specifies that ActewAGL must publish supply reliability targets annually for the following year, which include:

- **SAIDI**: System Average Interruption Duration Index. The ratio of total customer minutes interrupted to total customers served. This is a performance measure of network reliability, indicating the total minutes, on average, that customers are without electricity during the relevant period.
- **SAIFI**: System Average Interruption Frequency Index. The ratio of total customer interruptions to total customers served. This is a performance measure of network reliability, indicating the average number of occasions each customer is interrupted during the relevant period.
- **CAIDI**: Customer Average Interruption Duration Index. The ratio of total customer time interrupted to total customer interruptions. Measured in minutes and indicates the average duration an affected customer is without power. CAIDI = SAIDI/SAIFI.

The reliability targets specified in the Electricity Distribution Supply Standards Code (2013) are shown in Table 4.1.

Table 4.1: Electricity Distribution Supply Standards Code Annual Reliability Targets

Parameter	Target	Units
Average outage duration pa (SAIDI)	91.0	Minutes
Average outage frequency pa (SAIFI)	1.2	Number
Average outage time pa (CAIDI)	74.6	Minutes

ActewAGL has set internal business targets of 32.1 minutes for unplanned SAIDI and 0.62 for unplanned SAIFI within the overall externally set SAIDI target of 91 minutes and SAIFI target of 1.2 in the Electricity Distribution Supply Standards Code.

As previously discussed in Section 2.1.5, the AER introduced on 1 July 2015 a Service Target Performance Incentive Scheme (STPIS) as part of the 2014-19 Regulatory Determination period. The STPIS reliability targets set by the AER for the 2015-19 period for unplanned outages are shown in Table 4.2.

Table 4.2: AER STPIS Reliability Performance Targets for Unplanned Outages:

Year	2015-16	2016-17	2017-18	2018-19
Unplanned SAIDI				
Urban feeder	30.32	30.32	30.32	30.32
Short rural feeder	46.86	46.86	46.86	46.86
Unplanned SAIFI				
Urban feeder	0.585	0.585	0.585	0.585
Short rural feeder	0.895	0.895	0.895	0.895

Table 4.3 shows ActewAGL's actual performance indicator figures for the 2016-17 financial year, for both planned and unplanned outages. Figures for the previous 5 years are included for comparison purposes. Approximately 88.5% of ActewAGL's 11 kV feeders are classified as *urban* with the remaining 11.5% classified as *short rural*.

Table 4.3: ActewAGL Reliability Performance

Key Performance Indicators Distribution Network		Feeder category			Supply Code Overall target
		Urban	Rural Short	Overall network	
SAIDI					
2010-14 average	Overall actual	78.32	88.27	79.40	91.0
	Planned actual	47.47	40.77	46.74	
	Unplanned actual	30.85	47.50	32.66	
2014-15	Overall actual	81.14	85.48	82.56	91.0
	Planned actual	47.33	54.56	49.69	
	Unplanned actual	33.81	30.92	32.87	
2015-16	Overall actual	76.22	56.61	74.01	91.0
	Planned actual	40.49	26.36	38.89	
	Unplanned actual	35.73	30.25	35.12	
2016-17	Overall actual	83.91	82.44	83.74	91.0
	Planned actual	44.80	39.70	44.21	
	Unplanned actual	39.11	42.74	39.53	
	STPIS Unplanned Target for 2015-19	30.32	46.86		
SAIFI					
2010-14 average	Overall actual	0.801	1.079	0.831	1.2
	Planned actual	0.213	0.188	0.210	
	Unplanned actual	0.588	0.890	0.621	
2014-15	Overall actual	0.853	0.762	0.823	1.2
	Planned actual	0.212	0.230	0.218	
	Unplanned actual	0.640	0.532	0.605	
2015-16	Overall actual	0.876	0.725	0.860	1.2
	Planned actual	0.104	0.109	0.185	
	Unplanned actual	0.682	0.616	0.675	
2016-17	Overall actual	0.883	1.042	0.902	1.2
	Planned actual	0.215	0.190	0.212	
	Unplanned actual	0.669	0.852	0.690	
	STPIS Unplanned Target for 2015-19	0.585	0.895		
CAIDI					
2010-14 average	Overall actual	97.82	81.84	95.57	74.6
	Planned actual	223.36	216.30	222.67	
	Unplanned actual	52.46	53.36	52.60	
2014-15	Overall actual	95.20	112.20	100.30	74.6
	Planned actual	223.10	237.20	227.90	
	Unplanned actual	52.80	58.10	54.30	
2015-16	Overall actual	86.97	78.12	86.10	74.6
	Planned actual	208.44	242.43	210.76	
	Unplanned actual	52.38	49.11	52.03	
2016-17	Overall actual	267.12	259.28	265.99	74.6
	Planned actual	208.63	209.10	208.68	
	Unplanned actual	58.49	50.18	57.31	
	No STPIS CAIDI target				

The number of loss of supply events (multi-premise) for the 2016-17 financial year was 635. System minutes off transmission supply for the 2016-17 financial year was 0.

The reliability of supply component of the STPIS scheme will apply financial rewards for each year within the regulatory control period to ActewAGL on the basis of performance relative to targets. The maximum annual revenue at risk for the reliability of supply component is between +5% (upper limit) and –5% (lower limit).

Both SAIDI and SAIFI components exclude major event days such as extreme weather or bushfire conditions.

ActewAGL has various programs underway aimed at improving system reliability. Several of these are associated with asset replacements, for example ground-mounted manually operated oil-insulated switchgear that has reached the end of its economic life is being replaced with remote controlled vacuum-insulated switchgear, and pole-mounted manually operated air-break switches are being replaced with gas-insulated remote controlled switches. The 11 kV network is being developed to reduce the number of radial feeders by installing ties to adjacent feeders. This will improve back-up supply capability and reduce the number of customers affected by a planned or unplanned outage.

Other initiatives to improve reliability such as self-healing networks are being considered with the aid of ActewAGL's Advanced Distribution Management System (ADMS).

4.3. System constraints and security

A system constraint is a situation where the power flow through a part of the transmission or distribution network must be restricted in order to avoid exceeding a known technical limit. Examples of technical limits include the thermal rating of conductors or other equipment such as transformers, operating voltage levels, and equipment protection settings. Some constraints can exist under normal operating conditions; however they are most likely to occur when an element (such as a transmission line or distribution feeder) is out of service.

ActewAGL has a meshed 132 kV network in that all 132/11 kV zone substations are connected to two or more 132 kV lines, ie they have N-1 transmission security (refer Figure 3.2). The exception is Tennent Zone Substation which is connected radially via a 132 kV tee-off. However the load at Tennent is small and a backup 11 kV feeder supply is provided to it from Wanniassa Zone Substation. ActewAGL's sole 66/11 kV zone substation, Fyshwick, is supplied via two single circuit 66 kV lines from TransGrid's Queanbeyan Substation so also has N-1 transmission security.

All 132 kV lines have sufficient capacity to supply full capacity to each zone substation without constraint in the event of an outage of a 132 kV transmission line (refer Appendix D).

The 132 kV network is supplied from two TransGrid 330/132 kV bulk supply substations (Canberra and Williamsdale). As Williamsdale Substation is supplied radially from Canberra Substation at 330 kV, a constraint has been identified jointly by TransGrid and ActewAGL whereby in the event of a total outage of Canberra Substation, supply to ActewAGL's 132 kV network would be interrupted. This issue is to be addressed in the current planning period (refer section 7.5.1).

All zone substations with the exception of East Lake and Tennent zone substations have two or more power transformers (i.e. N-1 transformer security). East Lake Zone Substation has one only 132/11 kV transformer but a second is proposed to be installed in 2019 towards the end of the current regulatory period (refer section 7.5.2). In the interim, in the event of a transformer contingency, supply can be restored via 11 kV feeder ties to Telopea Park and Fyshwick zone substations.

The majority of the 11 kV distribution network is meshed with links between feeders and between zone substations. ActewAGL constantly monitors loads on all feeders and analyses the impact of proposed new connections. Such analysis is done using the Advanced Distribution Management System (ADMS). Transfer capability between zone substations via the 11 kV network is carefully monitored and managed, with open points between feeders changed to cater for load growth whilst avoiding constraints such as thermal loading of conductors.

As the majority of generation and bulk transmission is located externally to the ACT, system frequency is not able to be controlled by ActewAGL. However in the event of a major system event such as a large generator or 330 kV transmission line contingency, frequency could drop below the normal operating frequency excursion band. Under clause 4.2.6 (c) of the NER, in such an event all affected TNSPs and DNSPs must be able to shed load quickly until frequency is restored to avoid the problem escalating. NER clause 4.3.1 (k) specifies that a DNSP must be able to shed up to 60% of its total load during an under-frequency event to allow for prompt restoration or recovery of the power system. ActewAGL is in the process of installing under frequency load shedding (UFLS) relays at all of its zone substations, to trip feeders according to a set hierarchy (i.e. feeders supplying critical loads such as hospitals would be the last to be tripped).

ActewAGL's network operations control centre is located at Fyshwick. ActewAGL has a disaster recovery facility (DRF) at Civic Zone Substation. The DRF is basically a backup control centre with full SCADA and remote control facilities. Should a failure of the main control centre occur, the system could continue to be operated fully and securely from the DRF.

4.4. Significant system events

A significant event on ActewAGL's network is classified as an unplanned outage that results in more than two SAIDI minutes (equivalent to all of our customers, on average, having their power supply interrupted for two minutes or longer). Such events are usually the result of major equipment failure, major weather events, or major bushfire events. Four significant systems events occurred during the 2016-17 financial year as follows:

- 12 July 2016 – 7.93 SAIDI minutes
- 13 July 2016 – 3.08 SAIDI minutes
- 13 January 2017 – 16.92 SAIDI minutes
- 10 February 2017 – 2.17 SAIDI minutes

4.5. Photovoltaic penetration

Domestic rooftop photovoltaic (PV) generation systems are currently installed on approximately 9.4% of homes in the ACT. These vary in size from 1 kW – 10 kW capacity. The level of penetration is increasing steadily due to a number of reasons that include:

- Cost of PV systems is decreasing as more units are produced (i.e. reduced manufacturing costs) and more suppliers are competing for this market.
- Some developments (notably Denman Prospect Estate and Ginninderry Estate) have mandated that PV systems must be installed on all new detached dwellings to be constructed.
- Modern homes are being built with a PV system incorporated into the original design which avoids the costs associated with retrofitting later.
- The climate in the ACT is conducive to PV with long sunshine hours annually.
- The ACT Government is promoting its 100% renewable energy target and encouraging the installation of PV systems.
- Increased awareness of the public to climate change issues and the benefits of renewable energy.

There has also been an increase in small scale rooftop PV systems being installed on commercial and community buildings over the last year. These systems range in size from 30 kW – 200 kW.

Photovoltaic penetration in the ACT is widespread as shown in Table 4.4 and Appendix E.

Table 4.4: Photovoltaic penetration by zone substation (excluding network level PV) as at 30 June 2017

Zone Substation	Number of PV installations	Total capacity installed (W)
Belconnen	1,548	5,136,864
City East	1,183	3,999,826
Civic	839	2,597,159
East Lake	21	332,600
Fyshwick	30	508,026
Gilmore	965	3,367,458
Gold Creek	2,605	8,366,736
Latham	3,015	9,542,336
Telopea Park	673	2,560,647
Tennent	0	0
Theodore	1,510	4,839,455
Wanniassa	3,127	9,941,471
Woden	2,458	8,591,276
TOTAL	**17,975**	**59,783,854**

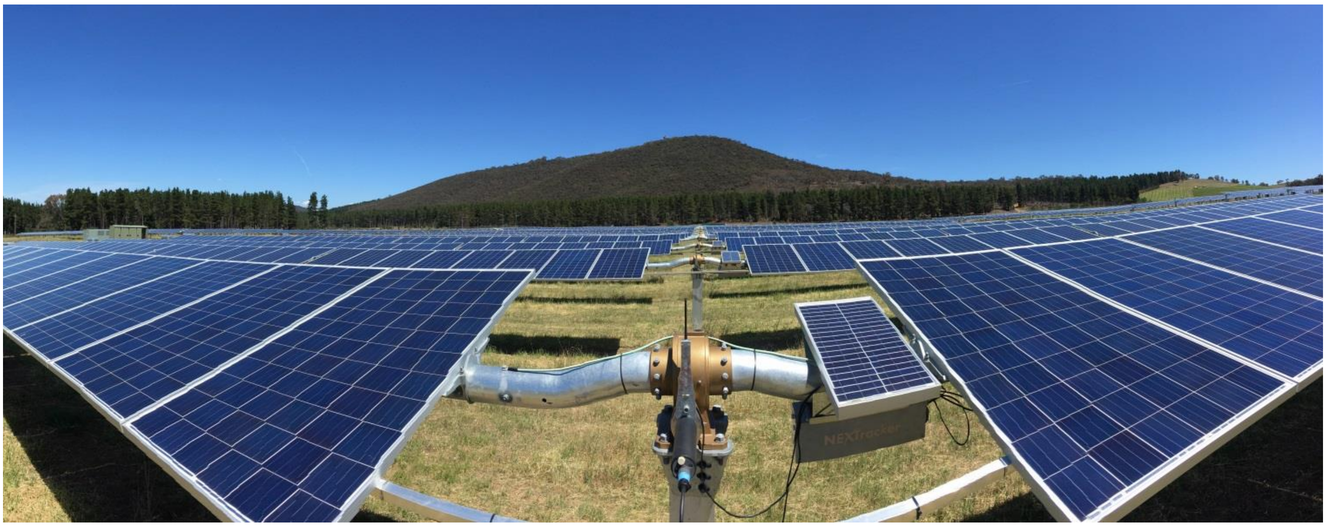
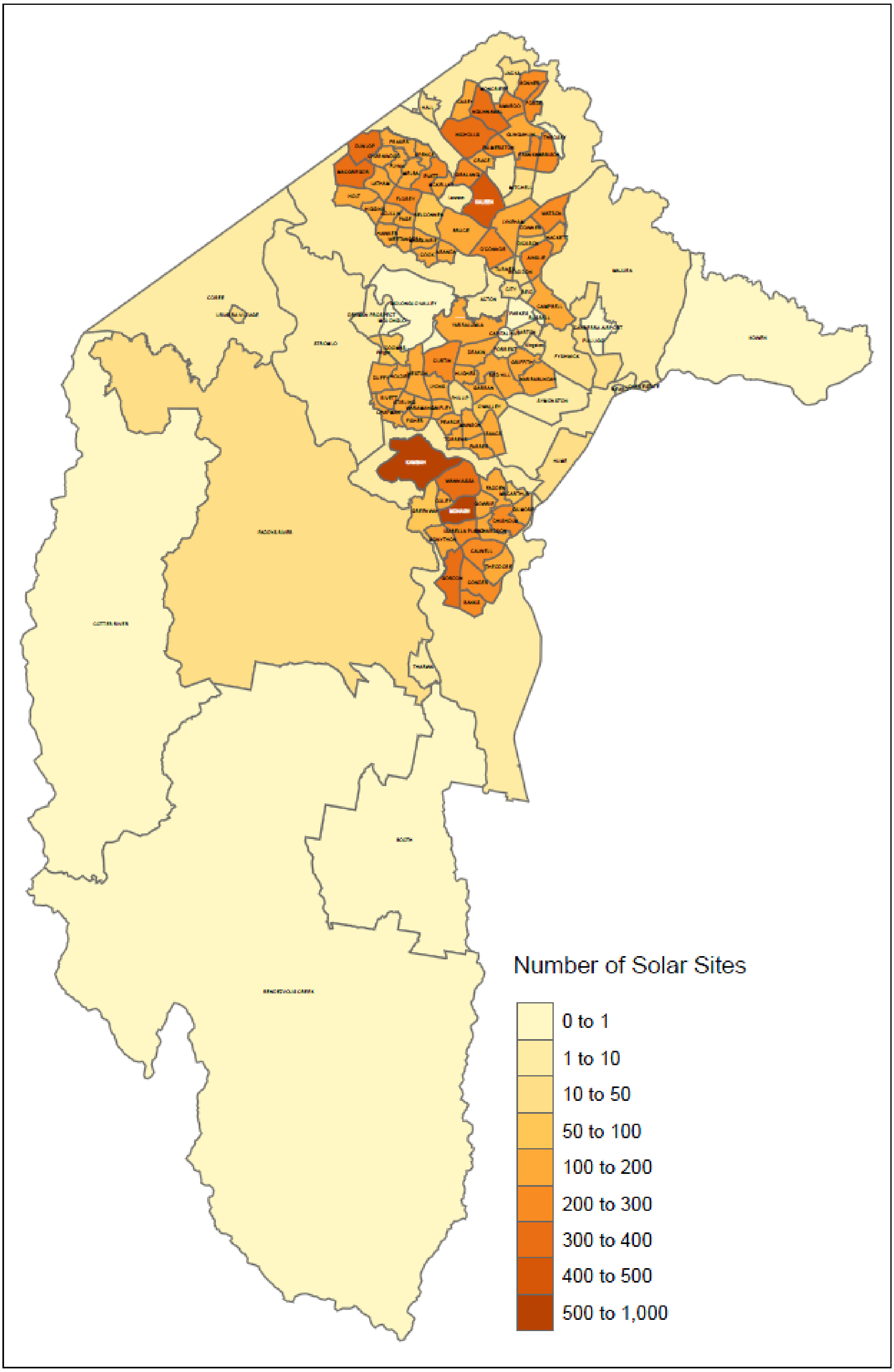


Figure 4.1 shows the distribution of domestic rooftop solar PV installations throughout the ACT.

Figure 4.1: Number of Rooftop Solar PV Installations per Suburb



4.6. Ageing assets

Electricity transmission and distribution networks are constructed of a range of asset types that all have their own maintenance, refurbishment and replacement life cycles.

Primary assets, those with the purpose of transmitting and distributing energy, such as poles, conductors and transformers, generally have an asset standard design life of around 45 – 60 years before requiring replacement.

Secondary assets, those with the purpose of measuring, monitoring, controlling, communicating and providing protection for primary assets, generally have an asset standard design life of around 15 – 20 years.

ActewAGL has prepared Asset Specific Plans for each class of asset, and from these plans has developed maintenance programs for each asset for its whole life cycle, including condition monitoring, periodic maintenance, renewal and leading to its ultimate replacement (refer Chapter 6).

Before replacing an asset such as a distribution substation, ActewAGL reviews its network plan for that location. In some cases, load growth (or reduction) may deem it more appropriate to replace with a larger or smaller distribution substation rather than simply a like-for-like replacement. In this way ActewAGL integrates its planning to coordinate asset management spending with network development spending to provide the most appropriate and cost effective solutions.

Assets are replaced as the result of a condition assessment, i.e. an asset is not just replaced because it has reached its 'retirement age'. It is replaced because its future maintenance costs exceed its replacement plus net present value costs.

ActewAGL's network comprises long life assets. It is essential that we invest in growth, replacement and maintenance works to ensure we continue to deliver a highly reliable and safe network for our customers and the community.

ActewAGL has made significant investments to improve supply quality and reliability but also to ensure the most cost-effective asset management strategy is adopted. The vast majority of expenditure directed to the replacement of ageing assets is for electricity network assets. Typical of these works is the replacement of aged 132 kV SF_6 gas-insulated circuit breakers with modern models which require a lower volume of SF_6 gas.

The ActewAGL network includes approximately 52,000 poles, the majority of which are wooden and subject to gradual rotting and subsequent loss of strength. All poles are inspected and assessed on a rotating annual program. Pole reinforcements are carried out to prolong the life of wooden poles. Low voltage poles are replaced with two-part fibreglass poles in locations that are difficult to access (typically urban residential property back yards), while high voltage and transmission poles are generally replaced with pre-stressed spun concrete poles.

The 66 kV switchgear at Fyshwick Zone Substation has been assessed as being at end of life and cannot continue to operate reliably. This switchgear has exceeded its design life, is experiencing increasing operational defects and declining performing. This switchgear is no longer supported by the manufacturer and spare parts are not available which has resulted in un-repairable defects affecting operational performance. It is recommended this switchgear is de-commissioned, and this is the preferred option for network augmentation project "Decommission Fyshwick Zone Substation" (refer section 7.5.4).

The following diagrams show the age distribution of ActewAGL's assets as follows:

Figure 4.2 Poles
Figure 4.3 11 kV Switchboards
Figure 4.4 Underground Cables
Figure 4.5 Transformers
Figure 4.6 Overhead conductors
Figure 4.7 SCADA, control and protection equipment

Figure 4.2: Poles – Quantity currently in service by age and material

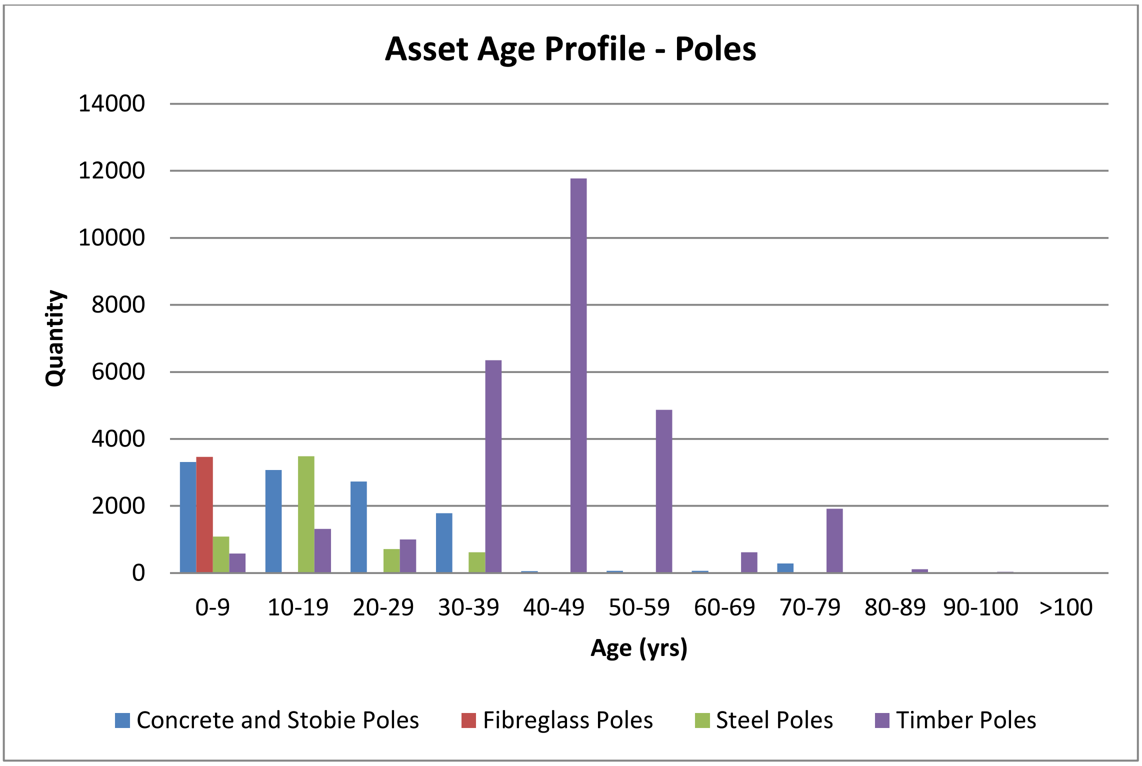


Figure 4.3: Switchgear – Quantity currently in service by age and type

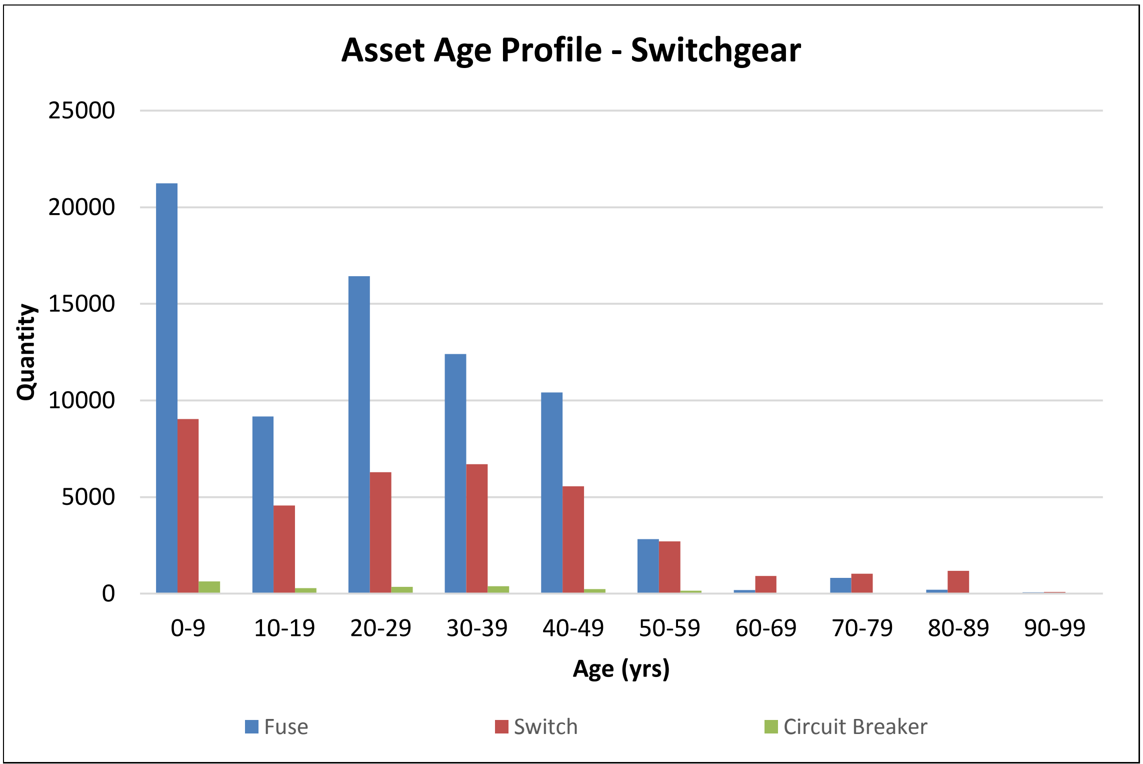


Figure 4.4: 11 kV Cables – Quantity currently in service by age and type

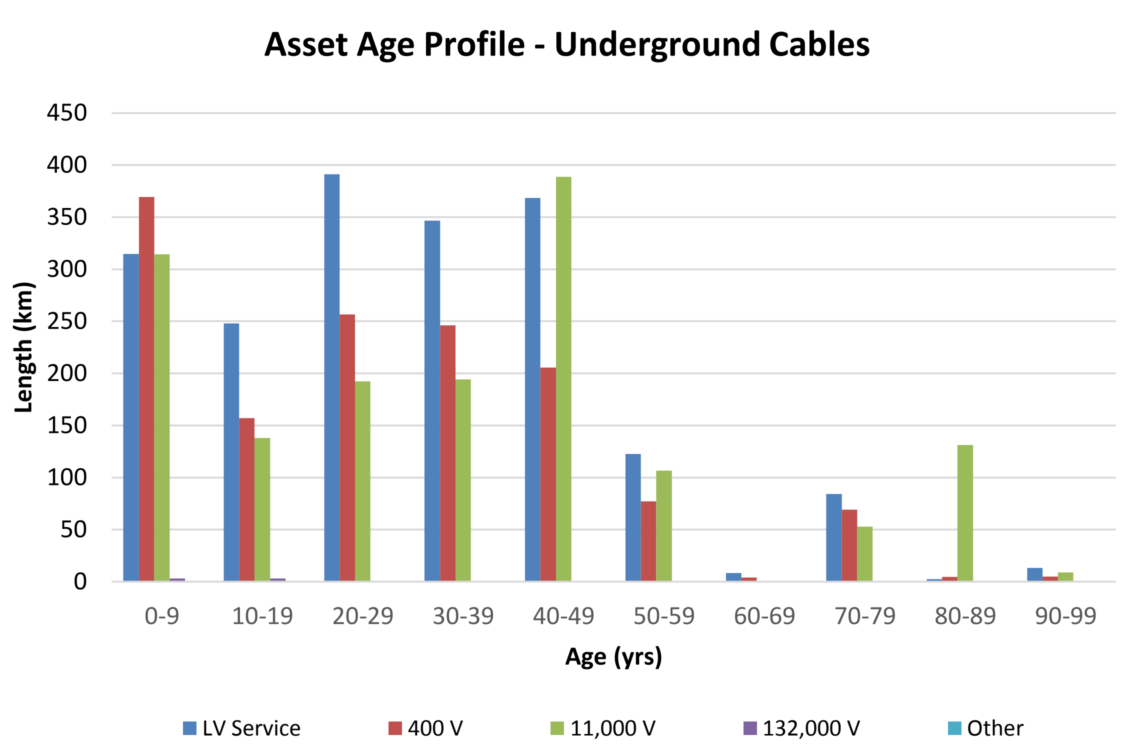


Figure 4.5: Transformers – Quantity currently in service by age and type

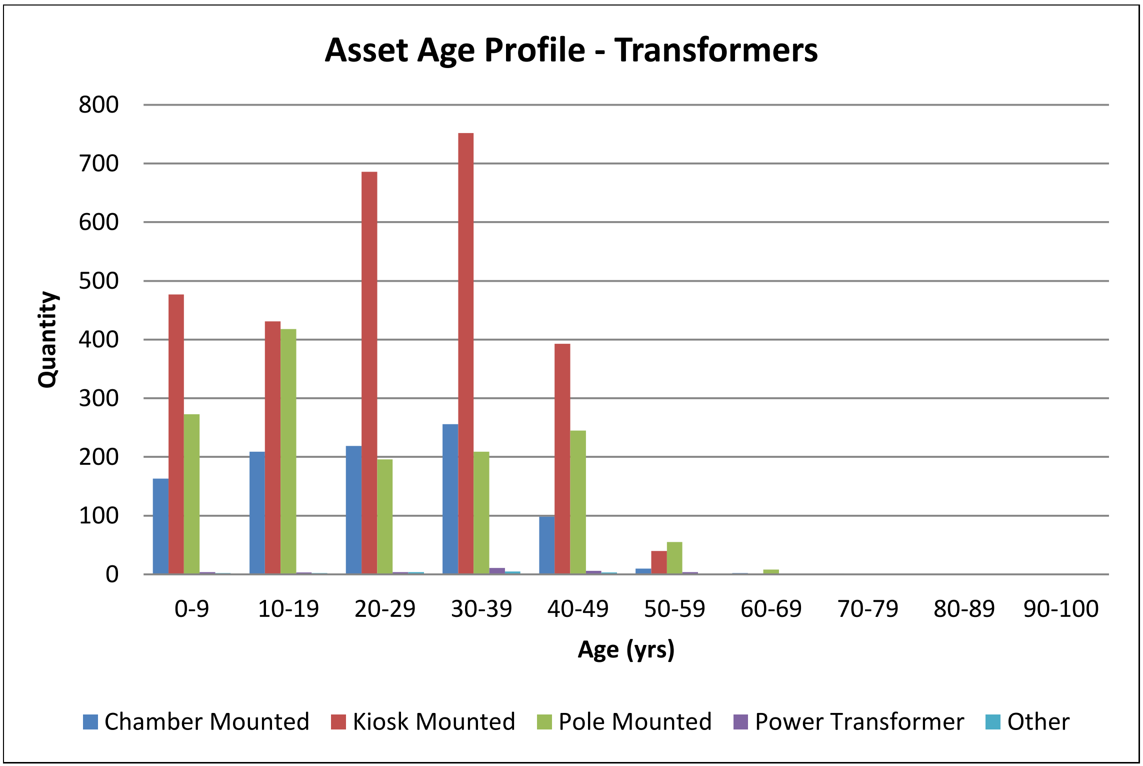


Figure 4.6: Overhead Conductors – Quantity currently in service by age and type

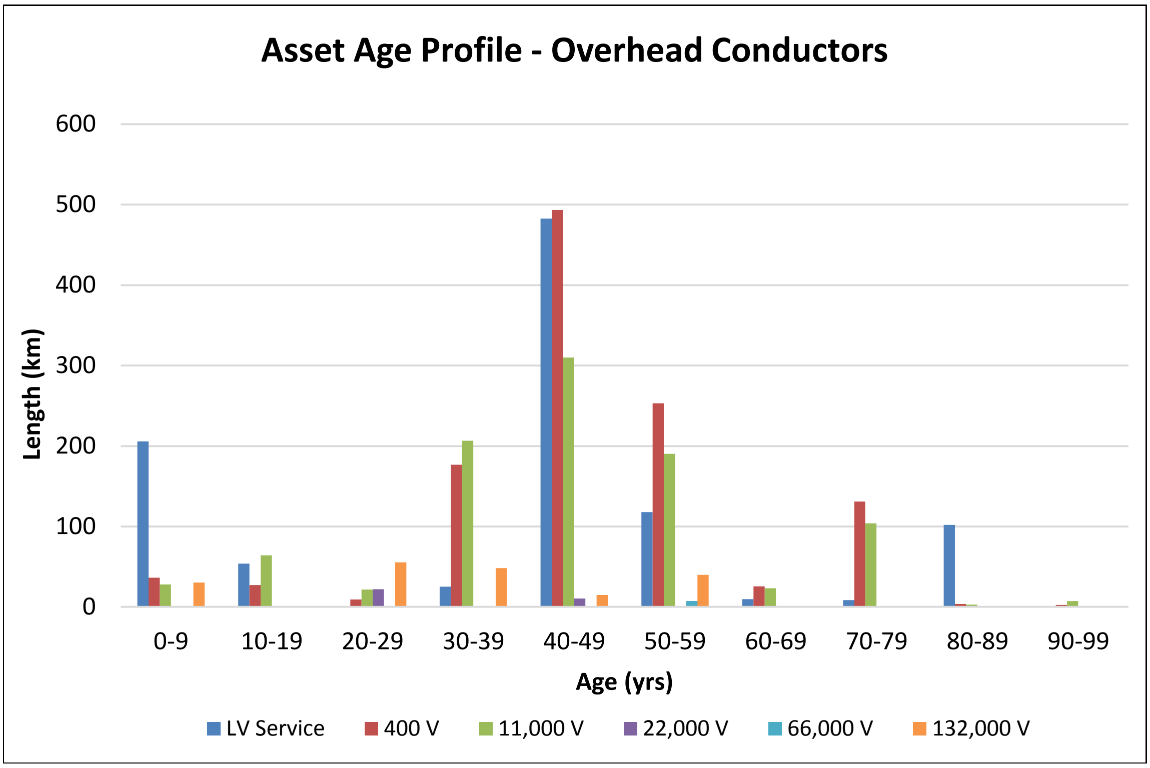
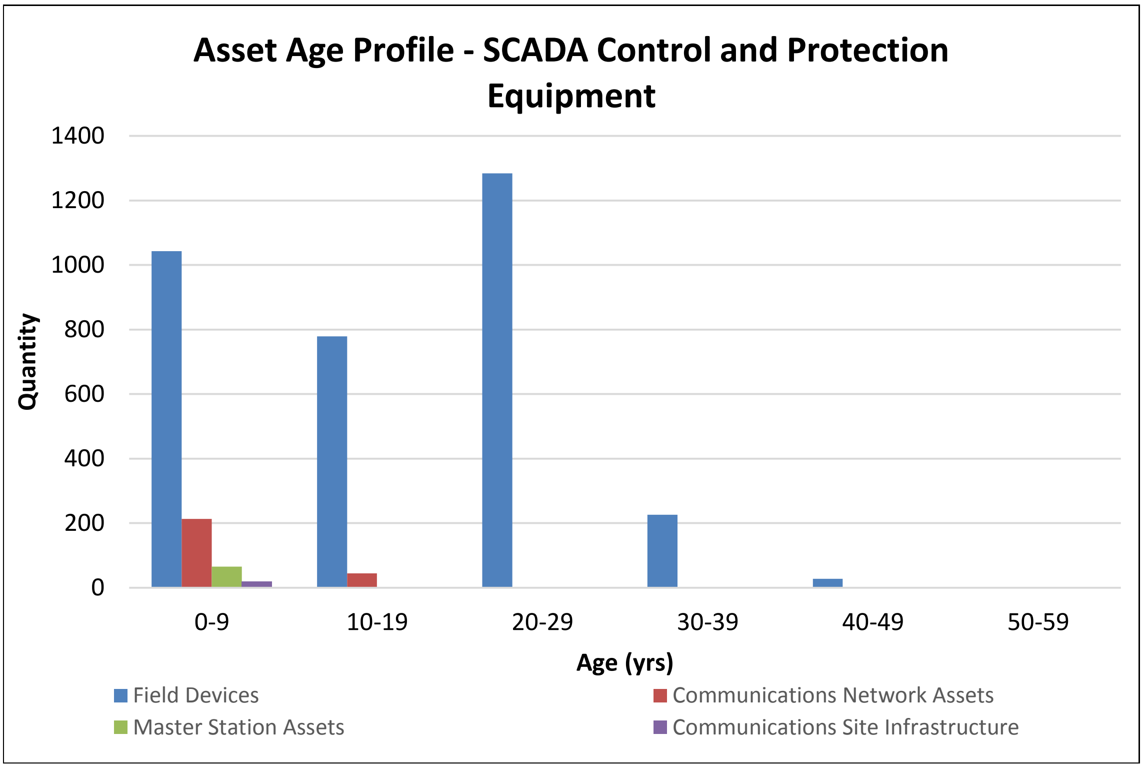


Figure 4.7: SCADA, Control and Protection Equipment – Quantity currently in service by age and type



The ActewAGL network has a large number of wooden poles, overhead conductors and underground cables that have been in service for 40 years or more. These assets will be monitored over coming years regarding their condition and risk of failure. Annual replacement programs may need to be increased as more assets reach the end of their economic service lives. All wooden poles are tested with an acoustic device. Any pole that fails the acoustic test is then tested with a gamma ray device (that measures wood density) and an ultrasonic device, to determine the remaining life of the pole.

The majority of secondary protection and SCADA equipment has an effective life of approximately 15–20 years.

ActewAGL uses the Risk Centred Maintenance approach (as outlined in the Asset Management Objectives), to plan and carry out the replacement of aged assets.

4.7. Fault level

Fault level is defined in terms of current (kA). The fault current is the maximum current that would flow at that point in the network should a short circuit fault occur. Major equipment elements such as circuit breakers, switchgear, cables and busbars are specified to withstand the maximum possible fault level. Fault level is also an indication of a power system's "strength". Higher fault current levels are typically found in a strong power system, while lower fault current levels indicate a weaker power system. A strong power system exhibits better voltage control in response to a system disturbance, whereas a weak power system is more susceptible to voltage instability or collapse.

High voltage overhead lines that are insufficiently fault rated may cause the conductors to clash, sag below minimum ground clearance, or even break when subjected to a fault current. Such situations can occur when network augmentations such as the construction of a new zone substation increase the fault levels in the distribution network.

Conversely increasing amounts of power electronic converter generation (e.g. PV generation) connected to the network, replacing synchronous generation, serves to reduce fault levels and consequently reduce system strength.

ActewAGL specifies new 11 kV equipment to be capable of withstanding 25 kA three-phase short circuit fault current. Maximum 11 kV fault level on the network has been calculated at approximately 12.2 kA. ActewAGL's 11 kV network is non-effectively earthed via the neutral earthing transformers at zone substations. This keeps the fault level generally less than 3 kA and increases the longevity of 11 kV equipment.

ActewAGL specifies new 132 kV equipment to be capable of withstanding 31.5 kA three-phase short circuit fault current. Maximum 132 kV fault level on the network has been calculated at approximately 24.0 kA.

The high voltage system supplied by the 132 kV transmission network is not effectively earthed employing a neutral earthing transformer to limit 11 kV earth fault current to 3 kA. The wide use of earthing transformers to limit feeder earth (zero sequence) fault levels at zone substations is a unique characteristic of ActewAGL's network. Note that 3 kA is not used for earthing design as there is always some circuit impedance and/or fault impedance.

Electricity network earthing and protection systems are designed, installed, operated and maintained with care to avoid injury to persons or damage to property or the environment.

4.8 Power quality

Power quality refers to the network's ability to provide customers with a stable sinusoidal waveform free of distortion, within voltage and frequency tolerances.

Power quality issues manifest themselves in voltage, current or frequency deviation, which result in premature failure, reduced service life or incorrect operation of customer equipment.

The NER Schedules 5.1a, 5.1 and 5.3 detail the applicable power quality design and operating criteria that must be met by ActewAGL. The ACT Utilities (electricity Distribution Supply Standards Code) Determination 2013 provides details of power quality standards to be met by ActewAGL. ActewAGL's Service and Installation Rules describe the applicable power quality design and operating criteria that must be met by our customers.

Electricity customers have ever-increasing expectations and are becoming less tolerant of power quality and reliability issues. Some modern appliances are not suited to events that occur on distribution networks due to their sensitivity and design.

At all voltages in ActewAGL's network, the quality of supply is maintained to provide a safe and secure source of electricity to our customers.

Power quality is measured by the installation of mobile power quality analysers in various locations on the distribution network. Measurements are taken on both a proactive and reactive basis.

Optimisation of network power quality enhances asset lifetimes due to reductions in operating stresses (e.g. lower transformer iron losses and resultant heating from harmonic voltage distortion).

ActewAGL has a proactive program to survey power quality across the distribution network. This program features the following:

- 70 randomly selected survey sites per year.
- For each site, measurements are taken at the customer's point of supply.
- This provides ActewAGL with a network-wide picture of power quality through a structured randomised program.

This program is compliant with AS.61000.4.30 - Testing and measurement techniques - Power quality measurement methods.

During the 2016-17 financial year, in addition to routine pro-active power quality monitoring, ActewAGL investigated and resolved 51 power quality enquiries from customers including:

- 37 high voltage levels (all associated with solar PV installations).
- 1 low voltage level complaint.
- 1 advice regarding EMF levels.
- 9 low voltage distribution network supply faults.
- 3 fluctuating voltage complaints (all associated with flickering lights).

Power quality enquiries have been increasing in frequency over the past seven years. This is largely due the increase in solar PV systems connecting to the ActewAGL network.

The ActewAGL quality of supply strategy is currently being redrafted to identify the future challenges the network faces and initiatives that will be implemented to support the quality of supply ActewAGL provides to its customers.

4.8.1 Steady State Voltage

Voltage levels at customers' premises must be supplied and maintained within regulation limits to ensure correct operation of appliances and safety to equipment and personnel.

Voltage levels on the 132 kV bus at Canberra and Williamsdale bulk supply substations, is controlled by TransGrid via its 330/132 kV interconnecting transformers' on-load tap changers (OLTCs) and 132 kV capacitor banks. Similarly the 66 kV bus voltage at Queanbeyan bulk supply substation is controlled by TransGrid.

The 11kV bus voltage at each zone substation is maintained by the voltage-regulating relay which controls the tap position of the 132/11kV transformers. In order to maintain the voltage within limits along the 11 kV feeders, the bus voltage is varied according to network conditions (loading, incoming voltage, feeder voltage drops etc.).

ActewAGL has installed TNSP metering on the 11 kV group circuit breakers at all 132/11 kV zone substations. In addition to providing metering functions, these meters provide accurate voltage measurements and other power quality information to the ADMS in real time.

ActewAGL monitors steady state voltage levels and responds to customer complaints where required. ActewAGL shall use the implementation of the ADMS and the application of smart metering technology to further ensure compliance of steady state voltage levels.

Steady state phase-neutral low voltage at the customer's point of supply is maintained at 230 V +10% / -6% in accordance with Australian Standards AS/NZS 60038 and AS 61000.3.100.

4.8.2 Rapid Fluctuations in Voltage (Flicker)

Voltage fluctuations are defined as repetitive or random variations in the magnitude of the supply voltage. The magnitudes of these variations do not usually exceed 10 per cent of the nominal supply voltage, however small magnitude changes occurring at certain frequencies can give rise to an effect known as flicker. Voltage fluctuations may cause spurious tripping of relays, interference with communications equipment, and may trip electronic equipment.

Flicker is usually customer-generated due to the following:

- Frequent starting of induction motors – mainly the direct on line starting of induction motors.
- Electric welders.
- Arc furnaces.

ActewAGL responds to a customer report of flicker by installing a mobile power quality analyser. ActewAGL advises the customer if the flicker is due to its operations, or rectifies if caused by ActewAGL's equipment.

Maximum permissible voltage flicker levels are specified in TR IEC 61000.3.7:2012.

4.8.3 Voltage Dips

Voltage dips are typically caused by events such as lightning or faults on adjacent feeders, or are generated by equipment located within customers' premises (e.g. induction motor starting).

Dips caused by faults on adjacent feeders can propagate throughout the network, affecting customers' supply voltage on all feeders at the zone substation. Although only customers on the faulted feeder experience an interruption, many experience the reflected voltage sags generated by the fault.

ActewAGL monitors voltage dips as part of its proactive power quality monitoring program. ActewAGL uses its SCADA system and protection records to analyse events and uses its mobile power quality analysers to assist in the analysis and rectification of voltage dips. ActewAGL shall use the implementation of numerical protection devices and the ADMS to further reduce the overall number of voltage dips on the network. ActewAGL proposes to review fault switching and investigate the use of auto-reclosers, sectionalisers and fault passage indication devices to reduce fault switching.

4.8.4 Switching Voltage Transients

Switching transients are primarily associated with the operation of circuit breakers and are typically the consequence of the switched current being extinguished prior to the natural current zero value of the sinusoidal current waveform. This characteristic is termed as current chopping.

The chopping of the current results in transient voltages being generated which enter and travel through the interconnected network. Switching transients can also be generated by the switching of lumped capacitances (e.g. capacitor banks).

Switching transients are typically high frequency, short duration voltage conditions (mainly overvoltage conditions) which can result in damage to sensitive equipment.

ActewAGL shall manage switching transient voltages through switchgear procurement standards (i.e. utilising switching equipment that has small chopping current characteristics) and asset specific maintenance regimes, and routine maintenance programs designed to avoid excessive switch contact arcing.

4.8.5 Voltage Difference Neutral to Earth

Voltage differences between neutral and earth can present the risk of damage to electrical equipment at customers' premises as well as a risk of electric shock and fire. Typically voltage differences can be caused by such things as:

- Inadequate earthing (high earth resistance or open circuit earth) at substations.
- Inadequate bonding of earth and neutral in Multiple Earth Neutral (MEN) systems.

ActewAGL adheres to the relevant distribution substation earthing requirements and advises customers of correct earthing practices. ActewAGL includes neutral to earth monitoring as part of its power quality monitoring program to assist with classifying neutral to earth voltage non-compliance.

Target voltage difference between neutral and earth is < 10 V steady state (5 minute average) at the point of supply.

4.8.6 Earth Potential Rise

Earth potential rise refers to the localised increase in the voltage of an object that should remain at earth potential, and is typically caused by a fault current passing through an earth connection that is inadequate for the magnitude of the fault current. This can be due to:

- Inadequate sizing of the earth conductor relative to the maximum fault current.
- High impedance between the earth conductor and the mass of earth (true earth).

Under such conditions the passage of the fault current through the inadequate earth connection will result in a voltage increase on the earth connection for the duration of the fault. This condition can present risk of electric shock to a person who may be standing on "true earth" but is in contact with the inadequately earthed device. It can also result in damage to sensitive equipment.

ActewAGL complies with earth potential rise requirements by basing its network designs on reference publications[4]. ActewAGL's system is designed to ensure that step and touch voltages arising from earth potential rise are within the allowable limits of Australian Standard AS/NZS 7000. ActewAGL inspects the earth connections on its system on a five-yearly program.

4.8.7 Voltage Unbalance

Voltage unbalance typically results from:

- Unbalanced phase impedances.
- Unbalanced phase loadings.
- Interaction between phases (induced voltages) on overhead lines.

Unbalanced voltages can result in high neutral currents which introduce the potential for high neutral to earth voltage difference, and the generation of negative sequence voltages that can damage three-phase induction motors.

ActewAGL manages voltage unbalance within the required limits through appropriate design practices and transformer procurement specifications. ActewAGL uses its mobile power quality analysers and quality of supply survey procedures to identify and rectify voltage unbalance. This is supported through the use of ADMS calculations to ensure compliance.

[4] ENA EG-O Power System Earthing Guide
ENA EG-1 Substation Earthing Guide
AS 3835 – EPR – Protection of Telecommunication Network
AS/NZS 4853 – Electrical Hazards on Metallic Pipelines

4.8.8 Direct Current (DC) Component

A high DC component of the neutral voltage can cause damage to electronic devices and impact on the correct operation of protective devices. It can also lead to an increase in losses and result in heating within electrical and electronic equipment.

ActewAGL ensures that customer's inverters connected to the network adhere to the relevant standards and regulatory requirements.

ActewAGL publishes on its website the "Requirements for Connection of Embedded Generators up to 5 MW to the ActewAGL Distribution Network "document. This includes the requirement that inverters must comply with the requirements of the Clean Energy Council (CEC) and Australian Standard AS/NZS 4777 (Grid connection of energy systems via inverters).

4.8.9 Harmonics

Harmonics are usually customer-generated. Non-linear loads such as industrial equipment (e.g. arc welders), variable speed drives, uninterruptible power supplies, and office equipment, are all sources of harmonic currents. Harmonic currents flowing in transformers cause an increase in the copper (resistive) losses and iron (magnetising) losses. Harmonic distortion can cause the supply voltage waveform to depart from sinusoidal in a repetitive manner. This can affect the operation of computer equipment, create noise on radio and television receivers, and cause vibration in induction motors.

ActewAGL responds to customer requests to measure and analyse harmonic levels. ActewAGL uses its mobile power quality analysers and undertakes harmonic monitoring as part of its power quality surveys. ActewAGL is currently investigating the use of the ADMS to identify areas of the network where harmonic levels are outside regulation limits and explore the potential of real-time harmonic monitoring at zone substations.

Customers must ensure that harmonic distortion caused by their equipment does not exceed the limits prescribed in Australian Standard AS/NZS 61000 parts 3.2, 3.4, 3.12 and TR IEC 61000.3.6.2012.

4.8.10 Electromagnetic Fields (EMF)

Electromagnetic fields are a key design consideration for bare electrical conductors such as overhead lines and bus-work, particularly those which operate at high voltage. For conductors with an earth shield, such as underground cables, the fields are encapsulated within the cable and do not present external hazards.

Electromagnetic fields incorporate both electric fields resulting from the voltage on conductors and also the magnetic fields generated by the current flowing in the conductors. Both phenomena result in a "grading" of the respective fields from the conductor to the nearest earth location. In terms of voltage there will be a voltage "gradient" between the conductor and earth. In terms of current there will be a grading of the magnetic field (flux density) from the conductor to the earth.

Depending on the strength of these fields minute currents can be induced in the bodies of animals and humans. Research is inconclusive at present but there are concerns as to the health implications of exposure to electromagnetic fields. As such there are strict guidelines for the management of electromagnetic fields incorporated into the design of overhead lines and high current equipment.

The Energy Networks Australia (ENA) Association has published an EMF Management Handbook (January 2016)[5] which describes EMF's in detail and methods to mitigate magnetic fields. ActewAGL follows these guidelines where practicable and complies with the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Guidelines in the design of its network with respect to electromagnetic fields.

[5] http://www.ena.asn.au/sites/default/files/emf_handbook_2016

4.8.11 Inductive Interference

Inductive interference refers to the ability of the magnetic fields generated by current flowing in typically overhead line conductors, to cause interference with other electromagnetic radiation such as radio, television and communication signals.

ActewAGL shall continue to undertake routine maintenance programs to ensure all equipment is in good working condition, in particular all HV and LV overhead lines, to ensure that inductive interference is within the limits specified in Australian Standard AS 2344:2016 (limits of electromagnetic interference from overhead AC power lines and high voltage equipment).

4.8.12 Power Factor

Power factor relates to the relationship between real and reactive power. In an alternating current (AC) system the in-phase portions of voltage and current waveforms produce “active” or real power which is the capacity of the electricity system to perform work. The out of phase portions of voltage and current waveforms produce “reactive” power. The combination of active and reactive power is termed apparent power. A low or poor power factor will result in inefficiency due to high apparent power loading with a low real power delivery.

ActewAGL monitors power factor as part of its programmed proactive and reactive monitoring of the network. ActewAGL uses the ADMS to identify areas of the network that may be experiencing power factor issues. Metering data is also used to identify installations with power factor outside acceptable limits.

Customers can gain significant benefits by improving the power factor at their premises. These benefits include reduced electricity costs, increased plant load capacity and utilisation, and better voltage regulation. Improvement of power factor is usually achieved by the installation of capacitors.

ActewAGL requires that the power factor at the point of common coupling between ActewAGL’s network and the customer’s installation shall be between 0.9 lagging and unity. Leading power factor is unacceptable. Details can be found in ActewAGL’s Service & Installation Rules for Connection to the Electricity Distribution Network which can be found on our external website.

4.8.13 Automatic Under Frequency Load Shedding

The National Electricity Rules S5.1 requires network operators to have a proportion of their load available for shedding by under-frequency relays. This is required to arrest the collapse of the national grid in the event of a major contingency that results in a sudden large deficiency of generation, such as could occur due to tripping of several generating units or tripping of transmission interconnectors. ActewAGL applies under-frequency protection at the 11 kV level within its zone substations.
Currently there are four zone substations with under frequency systems installed. Two further under frequency systems are planned to be installed in 2018.

4.8.14 Summary of Power Quality Standards, Codes and Guidelines

A summary of the power quality standards, codes and guidelines applicable to the ACT is as follows:

NER Schedule 5.1a – System Standards.
NER Schedule 5.1 – Network Performance Requirements to be provided or co-ordinated by Network Service Providers.
NER Schedule 5.3 – Conditions for Connection of Customers.
AS 2344:2016 – Limits of electromagnetic interference from overhead a.c. powerlines and high voltage equipment installations in the frequency range 0.15 MHz to 3000 MHz.
AS/NZS 3000:2007 – Australian/New Zealand Wiring Rules.
AS/NZS 7000:2016 – Overhead Line Design.
TR IEC 61000.3.6:2012 – Electromagnetic compatibility (EMC) Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems.
AS/NZS 61000 – Electromagnetic Compatibility (various sub-standards).
AS/NZS 60038:2012 – Standard Voltages.

HB 264:2003 – Power quality handbook.
AS/NZS 4777 Grid connection of energy systems via inverters.
ActewAGL Service & Installation Rules for Connection to the Electricity Distribution Network.
ActewAGL Requirements for Connection of Embedded Generators up to 5 MW to the ActewAGL Distribution Network.

4.9 System Losses

As power flows through the transmission and distribution networks, a portion is lost due to the electrical resistance and heating of the conductors and transformers. Across the network these losses may be up to 3%–5% of the total energy transported. These losses are allowed for throughout the transmission and distribution networks to ensure that supply meets demand and the power system remains secure, ie more electricity is generated than is consumed by customers.

Distribution Loss Factors (DLFs) represent the average energy loss between the distribution network connection point and the transmission network connection point to which it is assigned.

ActewAGL periodically reviews open points on the network, to enable the network to be reconfigured to reduce losses. This includes load balancing between zone substation transformers.

The cost of electrical losses is factored into the assessment of tenders for new distribution and zone substation power transformers. The life cycle cost assessment ensures that the capital cost is not the dominant factor in the assessment of transformer tenders. The methodology takes into account the estimated losses over the life of the transformer ensuring better energy efficiency and environmental outcomes.

Electrical losses in the network are proportional to the square of the current. Having a higher power factor results in a lower current, for the same amount of useful energy, and therefore reduces network losses. Maximum demand and capacity charges, if they are effective in reducing peak load on the network, will also result in reduced currents and therefore reduced network losses.

Under the NER section 3.6.3, ActewAGL is required to calculate and publish the distribution loss factors on its network. Publishing of the loss factors improves transparency of the network loss performance to retailers and customers. ActewAGL has engaged GHD Hill Michael Consultants to calculate distribution loss factors for both site specific customers (embedded generators with output greater than 10 MW and load customers with maximum demand greater than 10 MW) and average DLFs for non-site specific customers. The entire population of high voltage distribution feeders was analysed for these calculations. ActewAGL's Advanced Distribution Management System (ADMS) was used to calculate the DLFs. This system allows for the entire distribution network from zone substation transformers to distribution transformers to be modelled. All network elements have known loss characteristics including copper and iron losses for both zone and distribution transformers and impedance and length of all conductors. Losses on the 132 kV transmission network are calculated using a PSS Sincal transmission network model.

The effects and costs of distribution losses are included in the system planning analysis and investment strategy as inputs to determining any augmentation required to the system capacity to maintain the supply-demand balance.

4.10 Information Technology

ActewAGL utilises eight core Information Technology (IT) applications (asset information systems) to manage the Electricity Network. Our focus has been on consolidating and leveraging these asset information systems to support the business in continuous innovation and realisation of benefits. A number of key projects have been undertaken to streamline data flows, digitize the field works management system and enable data visibility, including:

Streamlining of Data Flows

- The integration of the Advanced Distribution Management System (ADMS) with our Meter Data and Billing system, Velocity.
    - This enables the mapping of customers to up-to-date network supply points. This has improved the accuracy of customer notifications of planned outages.
- The integration of the geographical information system ArcFM with Velocity.

- This enables the automatic syncing of meter installations, increasing the speed by which our network information is updated while decreasing manual effort. This ensures the ADMS has up to date information of customer connection points.

Field Digitization

- Implementation of works management mobility.
    - This enables work crews to execute key works management activities in the field including the closure of work orders, leading to improved timeliness, availability and accuracy of data as well as minimising paper printing.

Data Visibility

- Development of a Customer Portal.
    - The customer portal enables end users to register and log in to a portal to view consumption data and provide feedback.

The future state asset information systems operational environment will continue to embody a single, integrated, geospatial solution and will be built upon enterprise integration, will improve data visibility and have a clear customer focus. The functionality of the asset information systems will be developed to meet the three key business capabilities: enabling and coping with disruption, operational effectiveness, and operational efficiency. This will be achieved through continuous functionality releases, upgrades or system replacements and the implementation of enterprise integration and data architecture. These projects will enable the following improvements:

4.10.1 Customer Engagement

A continued focus for ActewAGL is our customer centricity. Providing our customers with more information about their energy consumption and network outages are key aspects of improving data visibility and strengthening the relationship with our customers. In addition, we are digitizing customer interactions, making it easier for our customers to work with us and obtain the information they require, and receive an overall improved experience. The expected benefits include:

- More information, enabling customers to better manage their energy usage.
- Ensuring that our industry customers see interactions with us as adding value to their business.

4.10.2 Data Visibility

The value in our data is not in the collection or analysis, but using the data to change processes and improve outcomes. ActewAGL proposes to implement a data architecture that enables data to be more easily viewed, analysed, reported and displayed across the business and to our customers. The expected benefits are:

- Reduction in the effort involved in creating new reports.
- More in-depth trend analysis that can be leveraged to improve end to end business processes.
- Ability to make more meaningful information available to customers to improve interactions and enable our customers to have greater management of their energy usage.

4.10.3 Distributed Systems Operator / Manager (DSO/DSM)

Our asset information systems will evolve, as ActewAGL evolves into a DSO/DSM. Our systems must cope with the changes distributed energy resources (DERs) will bring to the management of the electricity grid. ADMS will need to have a more granular view of DERs, ensuring actions can be undertaken to manage two-way power flows, as well as the variability associated with increased renewable energy connected to the network. The key benefit is:

- Ensuring that we can encourage and enable the proliferation of DERs, embedded networks and micro-grids in the ACT. This ensures that our customers can have greater control over how they receive energy, manage consumption and reduce costs.

4.10.4 Field Digitization

With the implementation of works management mobility, there is an opportunity to continue to build on the mobility platform and devices to further digitize the workforce activities. This includes the provision of offline, regularly updated, network maps and safety work method statements. These additional digitization initiatives will follow the creation of an approved Mobility Roadmap, which will identify the overall strategy for field digitization as well as the various applications and platforms, ensuring the continued roll out is implemented effectively, and only delivering activities that have clear benefits to the customer. The benefits anticipated from further building on field mobility include:

- Faster data capture and higher degree of accuracy, enabling richer data analysis, and further improving the end to end process for planned outage notifications to customers.
- Continuing to improve the safety of our workforce and the public through increased information availability.

4.10.5 Enterprise Integration

The asset information systems are closely integrated, are point to point and are highly complex. The integration between our works management and meter data and billing system for example, consists of a total of nine point to point integrations. ActewAGL will implement a service bus to simplify the environment, and ensure the applications can be managed in a more efficient and prudent manner. The following benefits are expected:

- The service bus will enable the removal of point to point integrations, enabling applications to be built, maintained, and released independently. This reduces the implementation risk of large scale projects by reducing overall scope, as well as reducing project costs.
- Greater monitoring and more effective integrations will ensure that information is not lost between applications. This is key to cross system processes such as re-energisations.

4.10.6 Security

To ensure ActewAGL can continue to maintain secure asset information systems and a secure electricity network, we will undertake regular system and hardware upgrades that address security vulnerabilities.

4.11 Metering

ActewAGL has a population of approximately 209,000 domestic and commercial meters in operation. Following the commencement of the Power of Choice (PoC) changes that took effect on 1 December 2017, new meter installation became the responsibility of retailers. Final requests to ActewAGL Distribution to install meters (including alterations and replacements) were submitted by 30 November 2017. Any requested works will be completed by 30 March 2018.

As ActewAGL Distribution will not be installing meters moving forward, we expect a reduction in meter assets under management over time. ActewAGL will have ongoing responsibility for the maintenance and testing of all existing ActewAGL metering installations.

Customers should contact their retailer for metering installations and alterations.

4.11.1 Smart Meters

The proposed Power of Choice rules require all new and replacement meters to be Type 1-4 meters (smart meters). ActewAGL is exploring opportunities to work with retailers and metering providers to utilise smart meters to provide the following functionality:

4.11.1.1 Outage management

An enhanced smart meter can communicate with the control centre when supply is lost thus quickly indicating that a fault has occurred and its location. The network operator will also be able to ascertain if the fault is on the network side or the customer's side of the meter.

4.11.1.2 Network planning

Smart meters will provide accurate information of energy use and load data that can be used for network energy and demand forecasts. This will assist the future planning of low voltage networks in particular where standard values of load for customers are currently used, known as After Diversity Maximum Demand (ADMD) values. The impact of embedded generation such as rooftop PV and battery energy storage systems will be able to be analysed accurately so that future networks are designed appropriately. This will enable future network augmentations to be optimised and existing assets to be utilised fully.

4.11.1.3 Demand management

Enhanced smart meters can be used to support demand side management by providing customers with details of their energy consumption and costs via web-portals, and providing customers with a range of energy plans to meet their individual needs.

4.11.1.4 Power quality monitoring

Enhanced smart meters can be used to record condition monitoring parameters that can be used for analysing network power quality to ensure compliance with standards. For example, ActewAGL currently investigates voltage complaints by installing temporary logging equipment at the customer's premises. Such information will potentially be accessible remotely in future from a smart meter.

4.11.1.5 Remote disconnection and reconnection of supply

Smart meters have an integrated mains supply contactor that provides the capability to remotely disconnect or reconnect customers supplies from the network and enables special meter reads to be done remotely.

4.11.1.6 Safety

A smart meter can detect a faulty or broken neutral connection at a customer's premises and notify the network operator. This will enhance the safety of the customer and ActewAGL's field staff.

4.11.2 Transmission Network Service Provider (TNSP) Metering

ActewAGL is in the final stages of a project to install TNSP metering at its zone substations. TNSP metering is scheduled to be fully operational by 30 March 2018. TNSP metering is a necessary part of the electricity market settlement process as defined in the National Electricity Rules (NER) chapter 7 and administered by the Australian Energy Market Operator (AEMO).

The TNSP metering interfaces with secondary systems equipment at ActewAGL's zone substations. These interfaces are at defined connection points between the 132 kV transmission network and the 11 kV distribution network. The TNSP metering has been installed in new dedicated metering panels and complies with Australian Standard AS/NZS 1284.13:2002 (Electricity metering in-service compliance testing).

5. System load and energy demand, and the supply-demand balance

5.1. Introduction

This chapter describes the methodology and assumptions made for calculating a ten-year forecast of maximum summer and winter load demands for each zone substation, bulk supply point and whole of system. These forecasts are used to identify potential future constraints in the network.

Load demand forecasting is one of the main inputs to network planning. Load forecasts are used to identify parts of the network that may become overloaded due to load growth and require augmentation, and to identify other parts of the network where spare capacity may be available. Load demand forecasting is complex because of its dependence on a number of factors such as climatic conditions, population growth, uptake of embedded generation and emerging technologies, and economic factors such as electricity tariffs. ActewAGL prepares and updates a rolling 10-year load forecast, identifying expected summer and winter maximum demands for the whole network, each zone substation and each 11 kV feeder.

Load growth varies from year to year and is not uniform across the whole network. It is not unusual to find parts of the network that grow at three or four times the average network growth rate, while other parts of the network experience no growth at all.

ActewAGL has prepared forecasts of maximum demand for each zone substation and transmission system as follows:

- Whole of system and bulk supply points: refer Appendix B; and
- Zone substations: refer Appendix C.

5.2. Forecasting methodology

5.2.1. Key definitions

5.2.1.1 Maximum Demand

Maximum demand is the highest level of instantaneous demand for electricity averaged over a 30-minute period, and is estimated for summer and winter seasons. Maximum demand projections include load supplied by the network, network losses, and auxiliary loads.

5.2.1.2 Probability of Exceedance (POE)

Probability of Exceedance (POE) is a generalised approach to electricity demand forecasting. Probability of Exceedance is the probability, as a percentage, that the maximum demand level will be met or exceeded (eg due to ambient temperature) in a particular period of time. Due to the high proportion of residential load in the ACT, maximum demand is highly dependent on weather conditions. Thus, there is substantial uncertainty inherent in maximum demand forecasts. ActewAGL prepares maximum demand forecasts with 10%, 50% and 90% POE's:

- A 10% POE maximum demand projection is expected to be exceeded, on average, one year in 10.
- A 50% POE maximum demand projection is expected to be exceeded, on average, five years in 10 (or one year in two).
- A 90% POE maximum demand projection is expected to be exceeded, on average, nine years in 10.

The 50% POE maximum demand forecast is used for planning purposes.

5.2.1.3 Diversity Factor

Diversity factor is the ratio of the sum of the individual non-coincident maximum demands of the parts of a system to the maximum demand of the whole system under consideration. Diversity factor is generally ≥ 1.

$$\textit{Diversity Factor} = \frac{\textit{Sum of non} - \textit{coincident maximum demands of parts of system}}{\textit{Maximum demand on whole system}}$$

5.2.1.4 Load Factor

Load factor is defined as the average load divided by the peak load in a specified time period such as annually, quarterly or monthly. Load factor is generally ≤ 1. ActewAGL encourages its customers to improve their load factor, ie spread their load more evenly over the time period required.

$$Load\ Factor = \frac{Average\ demand\ in\ a\ given\ time\ period}{Maximum\ demand\ in\ the\ same\ given\ time\ period}$$

5.2.1.5 Power Factor

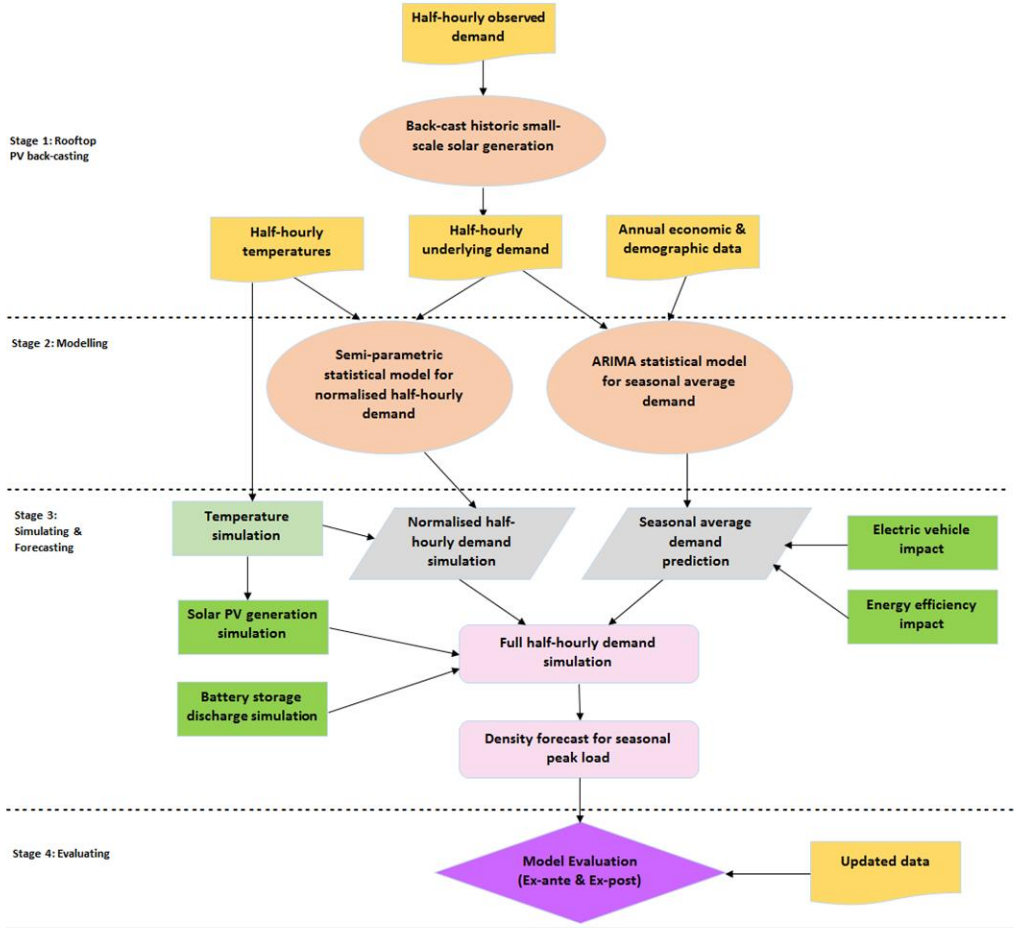
The power factor of an AC electrical power system is defined as the ratio of the real power (MW) used to do work to the apparent power (MVA) supplied to the circuit. Power factor is generally > 0 and ≤ 1. ActewAGL sets minimum target levels for power factor throughout the network and at customer connection points. Higher power factor allows the existing network to deliver more useful energy, ie real power.

$$Power\ Factor = \frac{MW}{MVA}$$

5.2.2 Forecasting methodology for distribution

ActewAGL has adopted and implemented AEMO's maximum demand forecast methodology which uses the Monash Electricity Forecasting Model (MEFM) which is based on the paper by Hyndman and Fan (2010)[6]. For more technical details about this methodology, the Monash Electricity Forecasting Model Technical Report is available at AEMO's website. Figure 5.1 illustrates the Integrated MEFM load forecasting process.

Figure 5.1: Block diagram of the Integrated Monash Electricity Forecasting Model.



[6] R. J. Hyndman and S. Fan (2010) "Density Forecasting for Long-term Peak Electricity Demand", IEEE Trans. Power Systems, 25(2), 1142–1153. http://robjhyndman.com/papers/peak-electricity-demand/

Key features of the integrated MEFM load forecasting methodology are:

- Integrated MEFM has four sub-models:
  1. Half-hourly model (HH model);
  2. Seasonal average demand model (annual model);
  3. Solar PV model (PV model); and
  4. Battery storage discharge model.
- Adjusted half-hourly demand where each year of demand is normalised by seasonal average demand is an input to the HH model.
- Annual model considers seasonal average demand against all possible economic and demographic drivers including energy efficiency variables.
- Forecasts calculated from the annual model are adjusted based on electric vehicle uptake impact on average energy consumption.
- Forecasts calculated from half-hourly and PV generation models are based on ambient temperature simulations.
- For the HH model, temperature and calendar variables are selected through a cross-validation procedure based on mean squared error (MSE).
- The coincident maximum demand contribution of block loads to the total maximum demand of bulk supply points and zone substations are calculated using diversity factors.
- The final demand forecast simulation = (HH model forecast × Annual model forecast) - Solar PV simulation forecast –Battery storage discharge simulation forecast.

5.2.2.1 Demographic and Economic Factors

Long-term electricity demand is largely dependent on demographic and economic factors. The following two demographic and economic factors are the major ones that impact on ActewAGL's maximum demand and energy consumption forecasts:

1. Population Growth

   Actual population growth rate in the ACT over the last five years has varied from 1.0% pa to 1.9% pa. The forecast average population growth rate for the ACT over the next ten years is 1.5% pa.

2. Employment Rate

   Unemployment rate in the ACT over the last five years has varied from 3.5% per QTR to 5.1% per QTR. The forecast average unemployment rate for the ACT over the next ten years is 3.6% per QTR.

5.2.2.2 Rooftop Solar PV Generation

The uptake of rooftop solar PV generation in the ACT has been increasing steadily over the past five years. There is currently approximately 59.8 MW of small scale (primarily residential) rooftop PV installed capacity.

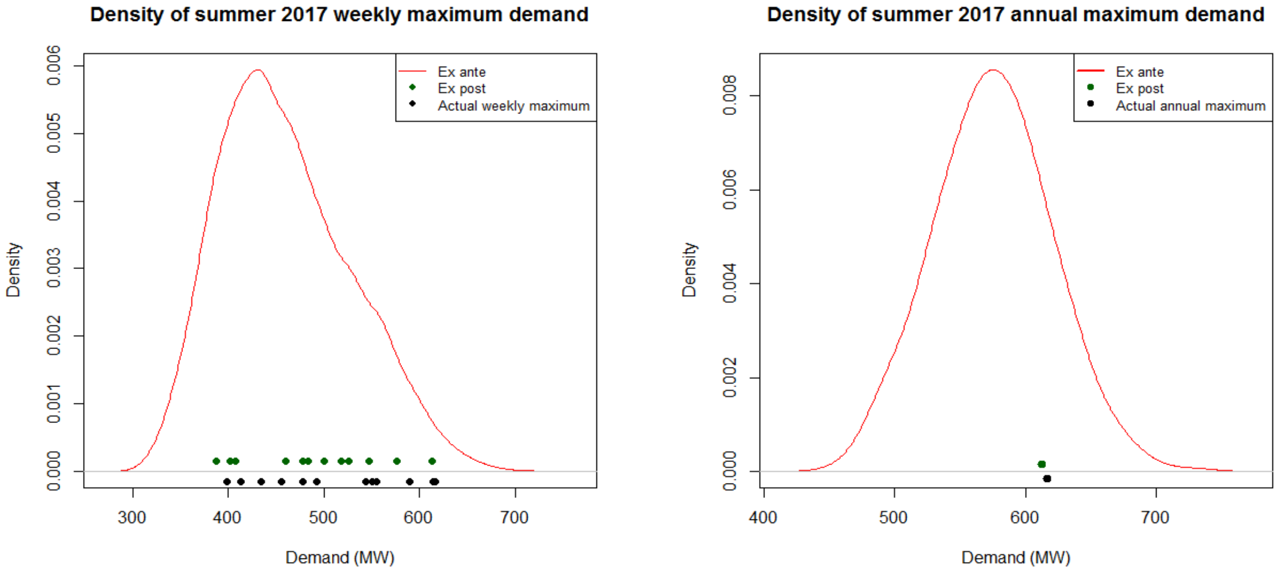
Summer peak demand on ActewAGL's network occurs around 4:00pm during the month of February so rooftop PV generation has a small impact on this (on cloudless days). Winter peak demand occurs around 6:30pm during the month of June so rooftop PV generation has no impact on this. Future installation of battery energy storage systems may impact in these peak demands.

Rooftop PV generation does impact on energy consumption however, throughout the year.

5.2.2.3 Forecasting model evaluation

The accuracy of the forecasting model has been verified by comparing ex-ante and ex-post forecasts. Figure 5.2 shows the system summer forecast evaluation. The graphs in Figure 5.2 show a close correlation between actual demand and ex-ante forecasts.

Figure 5.2: Ex-ante probability density functions for weekly maximum demand and annual maximum demand. Actual values and ex-post forecast values are also shown.



5.3. Historical demand

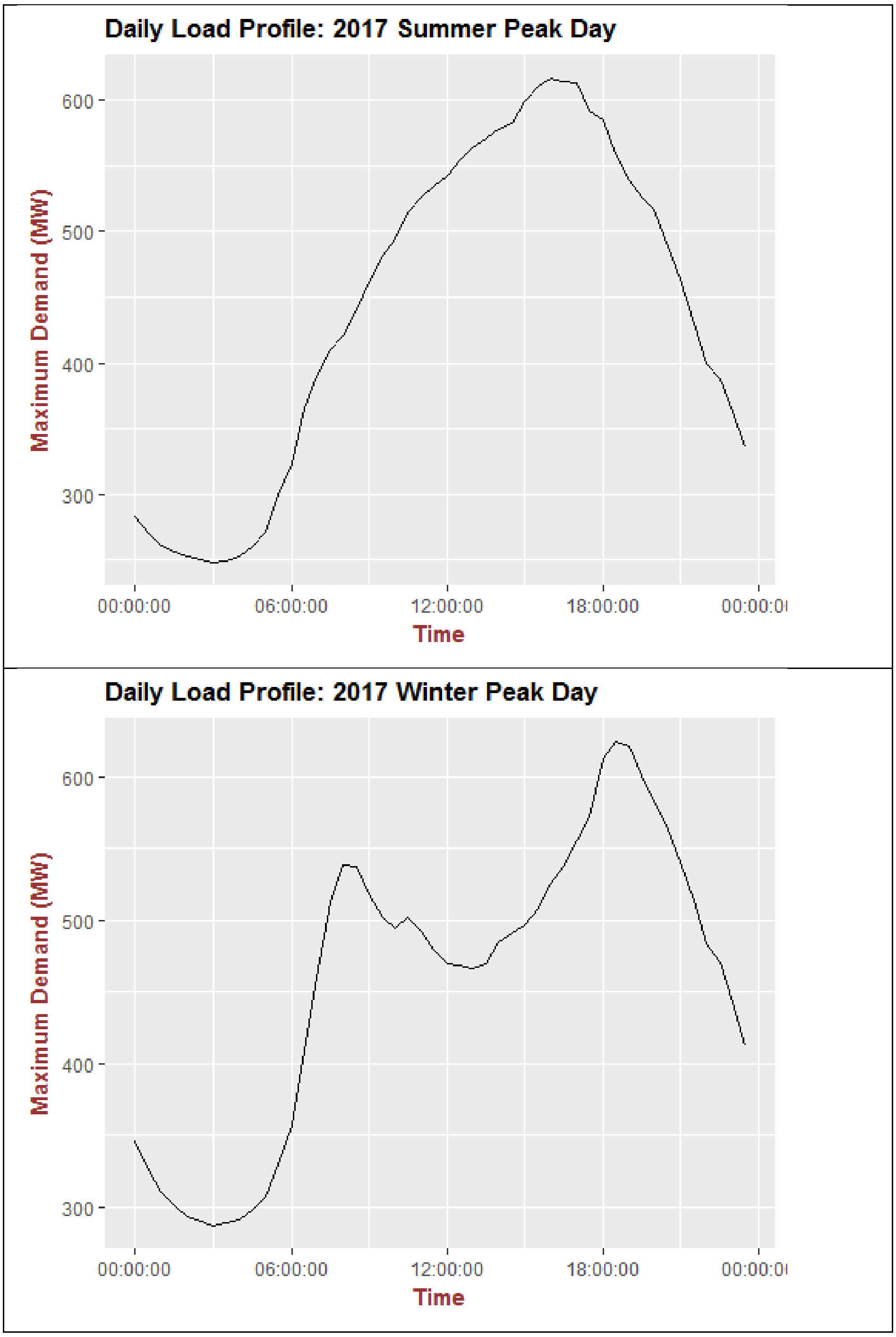
Key features of the past 10 years demand are as follows:

- Summer maximum demand is very weather dependent. For example summer 2012 and 2015 maximum demands fell below 500 MW due to mild weather conditions.
- Summer maximum demand increased steadily until 2011 and has experienced a decline from 2012 onwards. This is due to the introduction of the Government's solar generation incentive scheme and subsequent increase in rooftop solar PV installations.
- Winter maximum demand has been more consistent than summer. Improvements in the energy efficiency of new buildings, space heating and household appliances have resulted in small growth only of winter maximum demand despite an increasing customer base.
- In the 2016-17 summer period, the hottest day was 10 February 2017 when the peak summer demand occurred at 5:00pm and was 633 MW[7].
- In the 2017 winter period, the coldest day was 1 July 2017, whereas the peak winter demand occurred on 7 August 2017 and was 624 MW.

[7] Actual system peak demand during the summer season includes energy imports from both TransGrid and Royalla solar farm.

2017 summer and winter maximum demand day load profiles are shown in Figure 5.3.

Figure 5.3: Daily load profile for 2017 summer and winter maximum demand days



5.4. Forecast Demand and Energy

5.4.1 ACT System Demand Forecast

Load forecasts are calculated for three scenarios: Weak, Neutral and Strong. These scenarios are defined in AEMO's publication "Electricity Forecasting Insights for the National Electricity Market – June 2017" as listed in Table 5.1.

Table 5.1: Load Forecast and Planning Scenarios (as defined by AEMO)

Driver	Weak scenario	Neutral scenario	Strong scenario
Population growth	Weak	Neutral	Strong
Economic growth	Weak	Neutral	Strong
Technology uptake (rooftop PV, energy efficiency, electric vehicles)	Slow – Hesitant consumer in a weak economy	Moderate – Neutral consumer in a neutral economy	Rapid – Confident consumer in a strong economy

Load forecasts are also influenced by climatic conditions, i.e. low (mild weather conditions), medium (normal weather conditions), and high (extreme weather conditions).

In addition to these scenarios, ActewAGL calculates load forecasts based on 10%, 50% and 90% POE. Network planning is based on the medium 50% POE forecast. ActewAGL's maximum demand forecasts for the ten year period 2018–27 have been calculated based on these different scenarios and are presented in Figures 5.4 and 5.5, and Tables 5.2 and 5.3.

Figure 5.4: Summer 10-year system maximum demand forecast (2018–27)

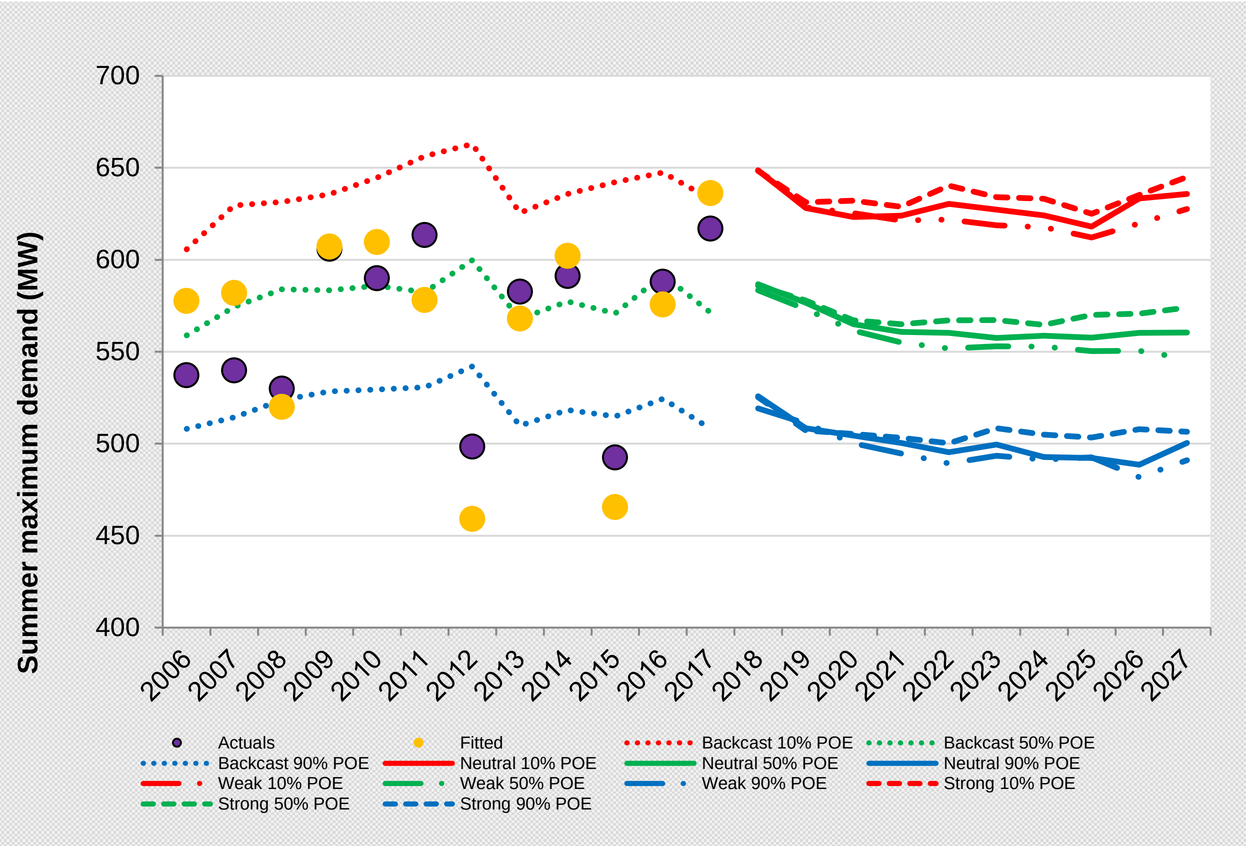


Table 5.2: System Summer Forecast in MW by economic scenario (growth rate)

Year	Low			Medium			High		
	90%	50%	10%	90%	50%	10%	90%	50%	10%
2018	519	583	648	526	587	649	525	586	648
2019	511	573	628	509	577	628	507	578	631
2020	500	561	625	504	565	623	505	567	632
2021	495	555	621	500	561	624	503	565	629
2022	489	552	622	495	560	630	500	567	640
2023	493	553	619	500	557	627	508	567	634
2024	491	553	618	493	559	624	505	565	633
2025	493	550	612	492	558	618	503	570	625
2026	482	551	620	489	560	633	508	571	635
2027	491	546	628	500	560	636	506	574	645

Figure 5.5: Winter 10-year system maximum demand forecast (2018–27)

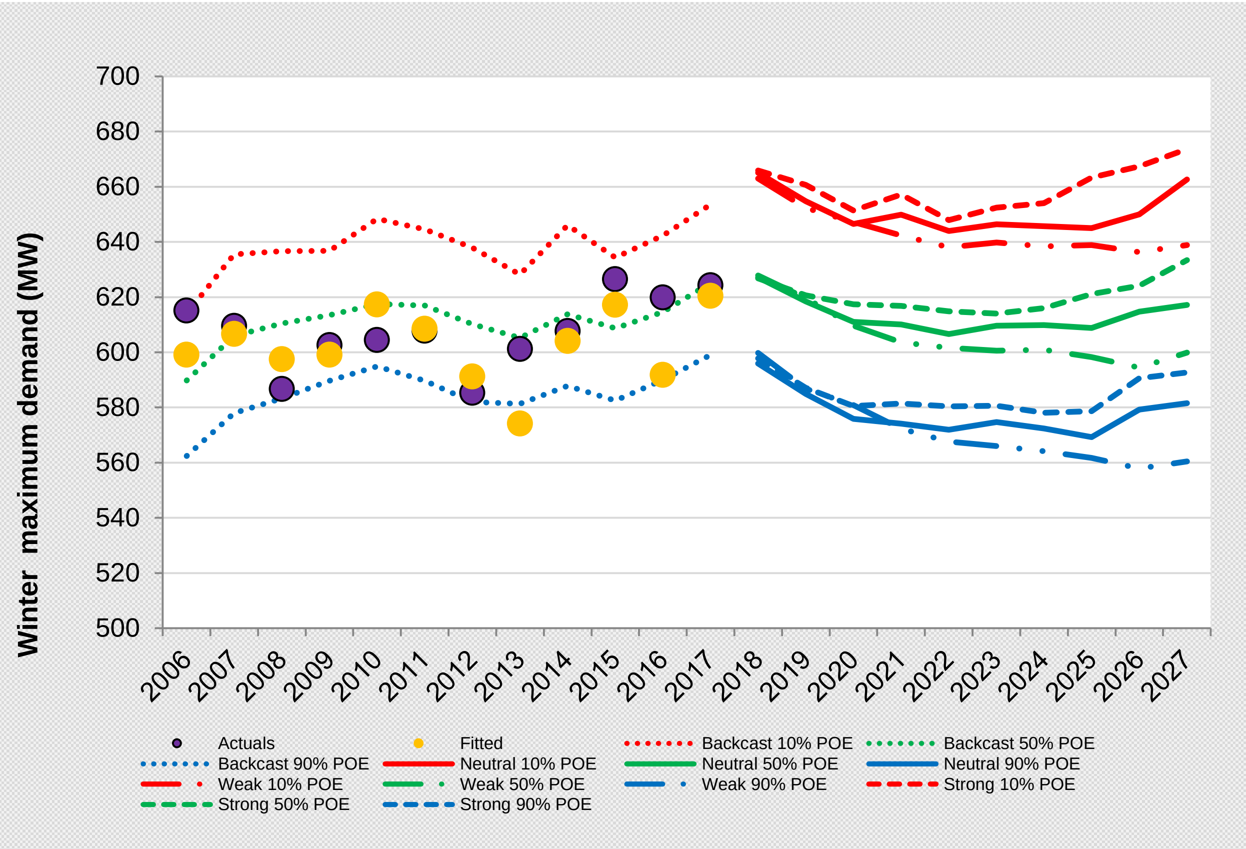
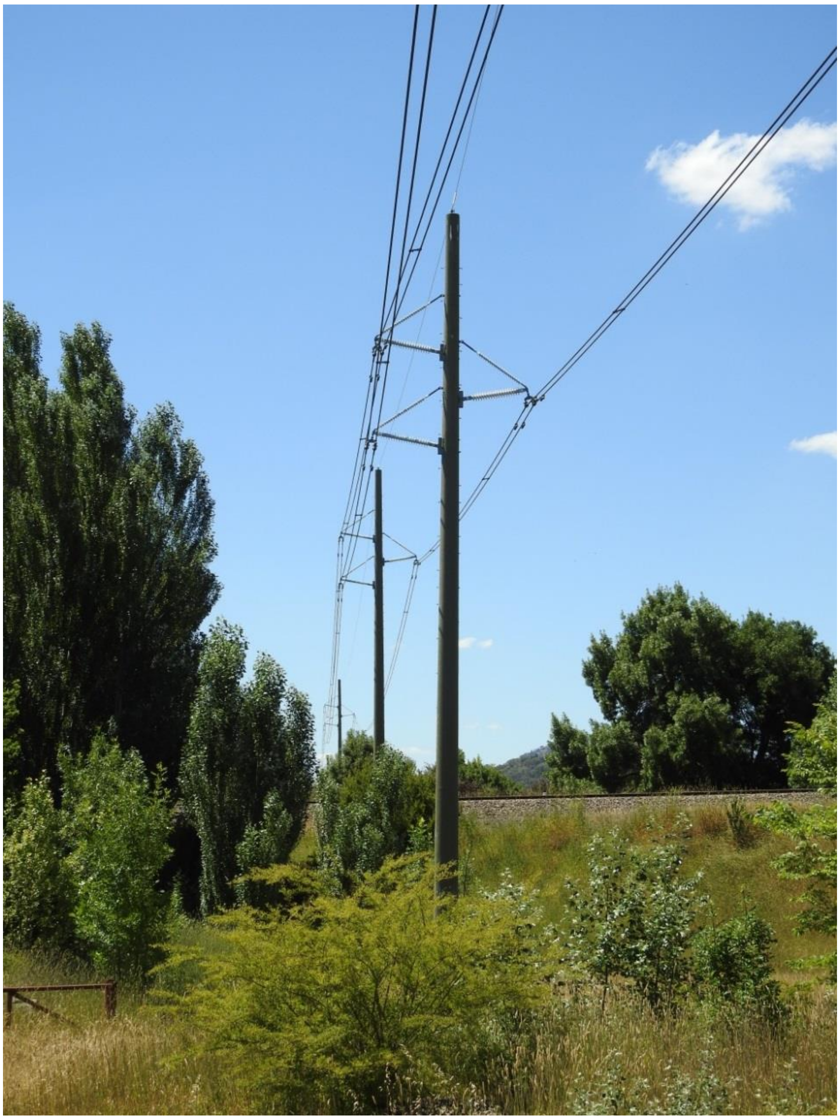


Table 5.3: System Winter Forecast in MW by economic scenario (growth rate)

Year	Low			Medium			High		
	90%	50%	10%	90%	50%	10%	90%	50%	10%
2018	600	628	663	596	627	665	598	627	666
2019	587	620	652	585	619	655	587	621	661
2020	581	610	647	576	611	647	581	617	651
2021	572	604	642	574	610	650	581	617	657
2022	568	602	638	572	607	644	580	615	648
2023	566	601	640	575	610	646	581	614	652
2024	564	601	638	572	610	646	578	616	654
2025	562	598	639	569	609	645	579	621	663
2026	558	594	636	579	615	650	591	624	667
2027	560	600	639	582	617	663	593	633	674



5.4.2 Zone Substation Load Forecasts

Table 5.4: Zone Substations Summer Maximum Demand Forecasts (MVA)

Zone Substation	Continuous Rating	Emergency two-hour Rating	PoE Forecast	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Belconnen	**55**	**63**	***50%***	58	62	62	65	65	65	66	66	68	69
			10%	65	69	70	73	73	74	73	74	76	77
City East	**95**	**95**	***50%***	75	78	80	73	74	74	73	72	73	73
			10%	86	88	90	84	84	85	85	83	84	83
Civic	**110**	**114**	***50%***	57	56	56	59	63	64	63	63	63	63
			10%	65	63	64	67	71	72	70	70	70	70
East Lake	**24**[1]	**43**[1]	***50%***	20	19	21	24	27	30	31	58	58	58
			10%	24	24	25	28	31	34	35	62	62	63
Fyshwick	**28**	**28**	***50%***	29	30	30	29	27	25	25	0	0	0
			10%	33	34	35	34	31	30	29	0	0	0
Gilmore	**45**	**62**	***50%***	34	36	37	37	36	38	38	38	38	39
			10%	42	44	44	46	46	47	46	47	47	48
Gold Creek	**57**	**76**	***50%***	60	64	67	70	72	72	73	74	78	78
			10%	73	76	81	84	85	89	90	92	95	95
Latham	**95**	**95**	***50%***	52	51	52	52	53	54	54	54	56	46
			10%	59	59	59	59	60	61	61	61	63	54
Molonglo	**12**[4]	**13**[4]	***50%***	0	0	0	0	0	1	2	3	4	4
			10%	0	0	0	0	0	1	2	3	4	4
Strathnairn	**55**[2]	**63**[2]	***50%***	0	0	0	0	0	0	0	0	0	10
			10%	0	0	0	0	0	0	0	0	0	10
Telopea Park	**100**	**114**	***50%***	86	87	89	89	89	89	89	89	89	90
			10%	94	96	97	98	98	98	98	97	98	101
Tennent	**15**[3]	**15**[3]	***50%***	3	3	3	3	3	3	3	3	3	3
			10%	3	3	3	3	3	3	3	3	3	3
Theodore	**45**	**62**	***50%***	24	24	23	23	23	22	22	22	22	22
			10%	30	29	29	28	29	28	28	27	27	28
Wanniassa	**95**	**95**	***50%***	63	63	64	64	63	62	60	60	58	57
			10%	72	73	74	73	73	71	70	68	67	67
Woden	**95**	**95**	***50%***	76	78	80	82	82	80	78	75	74	72
			10%	86	88	90	92	92	89	86	84	82	80

Table 5.5: Zone Substations Winter Maximum Demand Forecasts (MVA)

Zone Substation	Continuous Rating	Emergency two-hour Rating	PoE Forecast	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Belconnen	**55**	**76**	***50%***	60	62	63	65	65	66	66	67	68	69
			10%	64	66	68	70	70	71	71	72	73	74
City East	**95**	**112**	***50%***	68	71	72	67	66	66	65	65	64	64
			10%	74	76	78	73	72	72	72	72	71	71
Civic	**110**	**143**	***50%***	49	48	49	56	57	57	56	56	56	56
			10%	54	54	56	61	63	63	63	62	63	62
East Lake	**30**[1]	**54**[1]	***50%***	20	21	24	27	30	32	32	55	56	57
			10%	24	25	28	31	34	36	36	59	60	61
Fyshwick	**28**	**28**	***50%***	23	24	24	22	21	20	20	0	0	0
			10%	27	28	28	26	24	24	24	0	0	0
Gilmore	**45**	**69**	***50%***	35	36	37	37	38	38	39	39	40	40
			10%	41	41	43	44	44	44	45	46	47	47
Gold Creek	**57**	**76**	***50%***	68	73	75	79	80	82	84	86	88	91
			10%	76	81	84	89	90	93	95	97	99	103
Latham	**95**	**114**	***50%***	68	68	69	70	69	70	71	72	64	64
			10%	73	74	74	75	75	75	76	77	70	70
Molonglo	**14**[4]	**16**[4]	***50%***	0	0	0	0	0	1	2	3	4	4
			10%	0	0	0	0	0	1	2	3	4	4
Strathnairn	**55**[2]	**76**[2]	***50%***	0	0	0	0	0	0	0	0	9	10
			10%	0	0	0	0	0	0	0	0	9	10
Telopea Park	**100**	**114**	***50%***	84	86	88	88	88	88	88	88	89	89
			10%	89	90	92	92	92	92	93	93	93	93
Tennent	**15**[3]	**15**[3]	***50%***	3	3	3	3	3	3	3	3	3	3
			10%	3	3	3	3	3	3	3	3	3	3
Theodore	**45**	**69**	***50%***	29	28	28	28	27	27	27	27	27	27
			10%	33	32	32	31	31	31	30	30	30	30
Wanniassa	**95**	**114**	***50%***	77	78	77	77	75	74	74	72	71	71
			10%	83	83	84	83	82	81	79	78	78	77
Woden	***95***	***114***	***50%***	78	78	81	83	84	83	82	79	78	77
			10%	84	84	86	89	90	88	86	84	83	82

5.4.1.1 Key features of the maximum demand forecasts

Table 5.6 summarises summer and winter 10% POE and 50% POE maximum demand annual average growth rates. Key features are as follows:

- Summer maximum demand has fluctuated over the last seven years due to increasing installation of rooftop PV systems and milder summer weather conditions (with the exception of summer 2017).
- The long term (10 years) 10% POE and 50% POE growth rates are very similar.
- A small rate of decline is expected in summer and a small rate of growth is expected in winter.

- Winter maximum demand occurs around 6:30pm when there is no PV generation, however future battery energy storage systems are expected to have an impact.

Table 5.6: Summer and winter 10% POE and 50% POE maximum demand annual average growth rates (medium growth rate scenario)

Forecast maximum demand annual average growth rate		Summer			Winter		
		Actual	50% POE	10% POE	Actual	50% POE	10% POE
2011 - 2017	Historical	0.1%	-0.3%	-0.3%	0.4%	0.1%	0.1%
2017 - 2018	0 -1 year growth		2.7%	2.5%		0.3%	1.8%
2019 - 2022	2 - 5 years growth		-1.1%	-0.7%		-0.8%	-0.8%
2023 - 2027	6 -10 years growth		0.0%	0.2%		0.3%	0.6%
2018 - 2027	1 - 10 years growth		-0.2%	0.0%		-0.1%	0.1%

5.4.1.2 Comparison of ActewAGL's forecasts with AEMO's forecasts

Figures 5.6 and 5.7 compare ActewAGL's system load forecasts with AEMO's load forecasts for the ACT.

Figure 5.6: ActewAGL system summer maximum demand forecast compared with AEMO's forecast

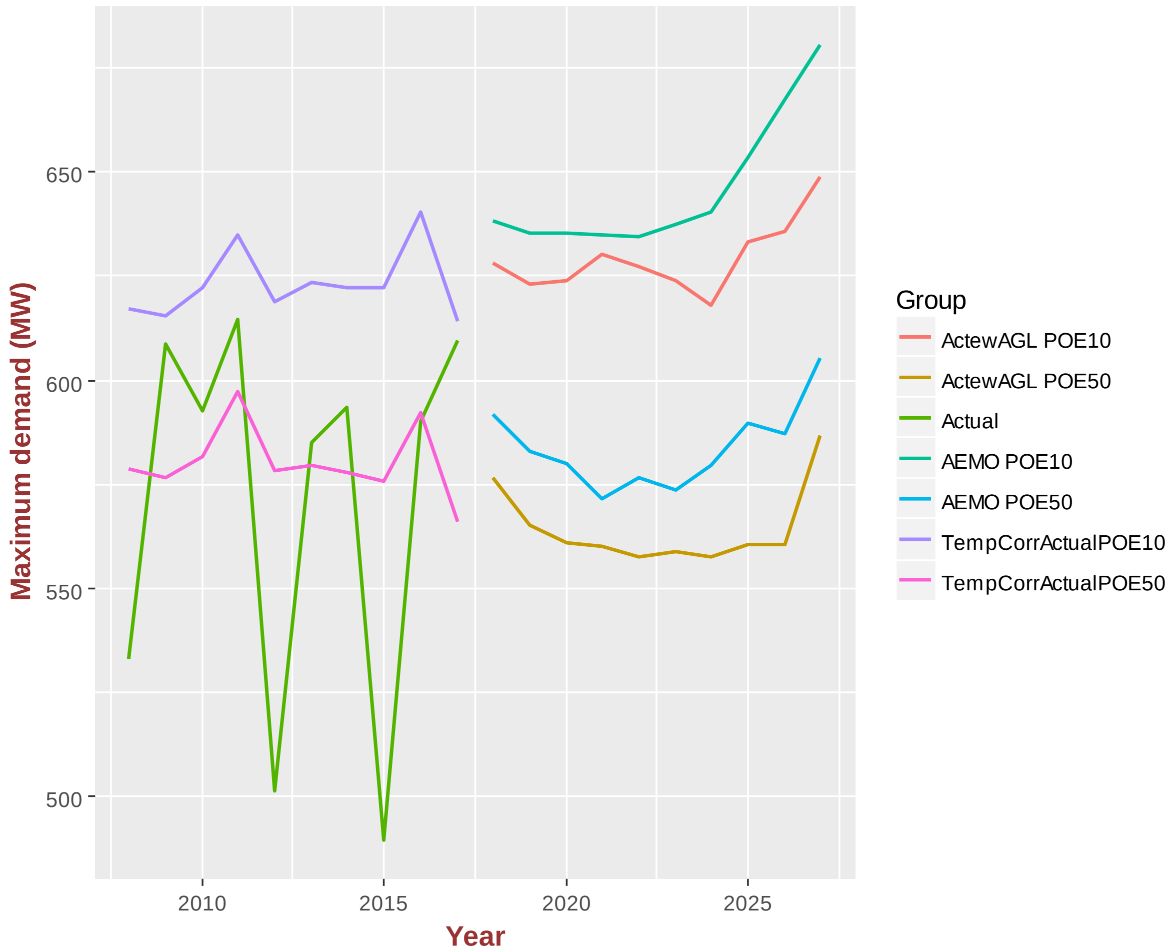
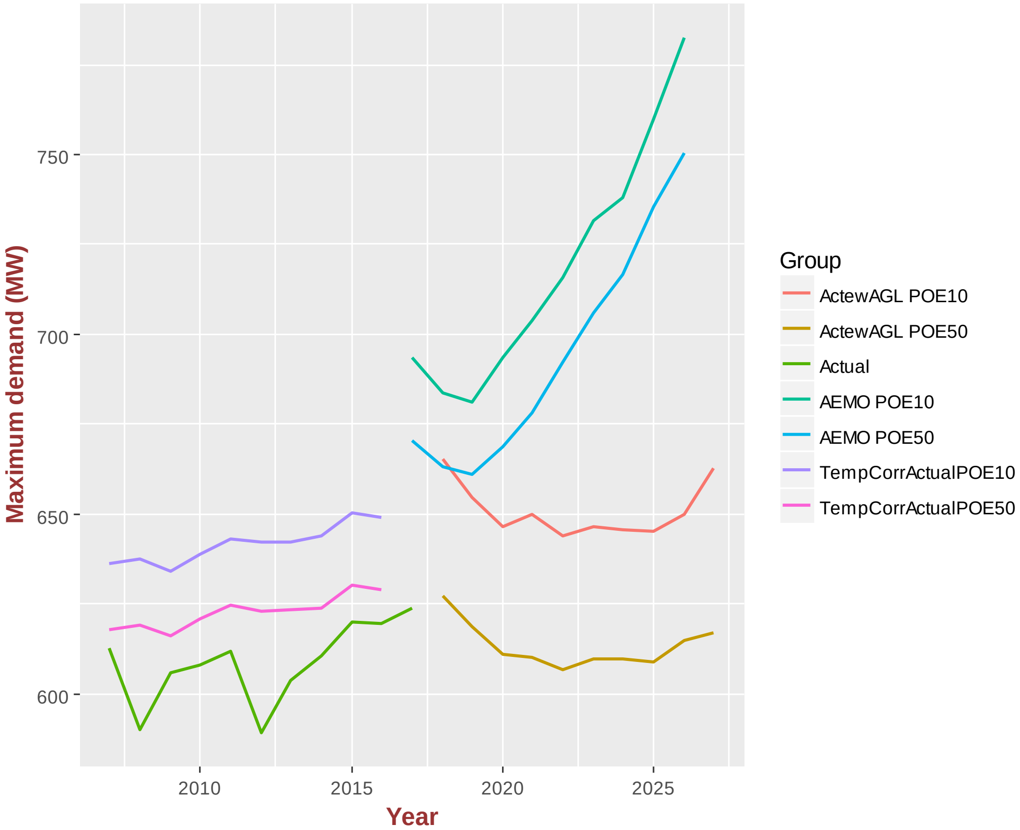


Figure 5.7: ActewAGL system winter maximum demand forecast compared with AEMO's forecast



AEMO and ActewAGL's system summer 10% POE and 50% POE forecasts are consistent.

AEMO and ActewAGL's system winter 10% POE and 50% POE forecasts show different trends. AEMO has commented on this discrepancy as follows: *"….The bulk of this gap is introduced by our regional (NSW/ACT) reconciliation process, which this year has led to our connection point forecast 'chasing' our regional forecast, i.e. we needed to increase our connection point forecasts in order to meet the total forecast regional demand. This effect has been particularly significant in winter."*

5.4.2 Bulk Supply Point (BSP) forecasts

Appendix B details the summer and winter maximum demand forecasts for the three TransGrid owned bulk supply substations Canberra, Williamsdale and Queanbeyan.
Canberra and Williamsdale are both 330/132 kV substations and supply ActewAGL's meshed 132 kV network. Queanbeyan 132/66 kV Substation supplies ActewAGL's Fyshwick Zone Substation only at 66 kV as well as some Essential Energy substations.

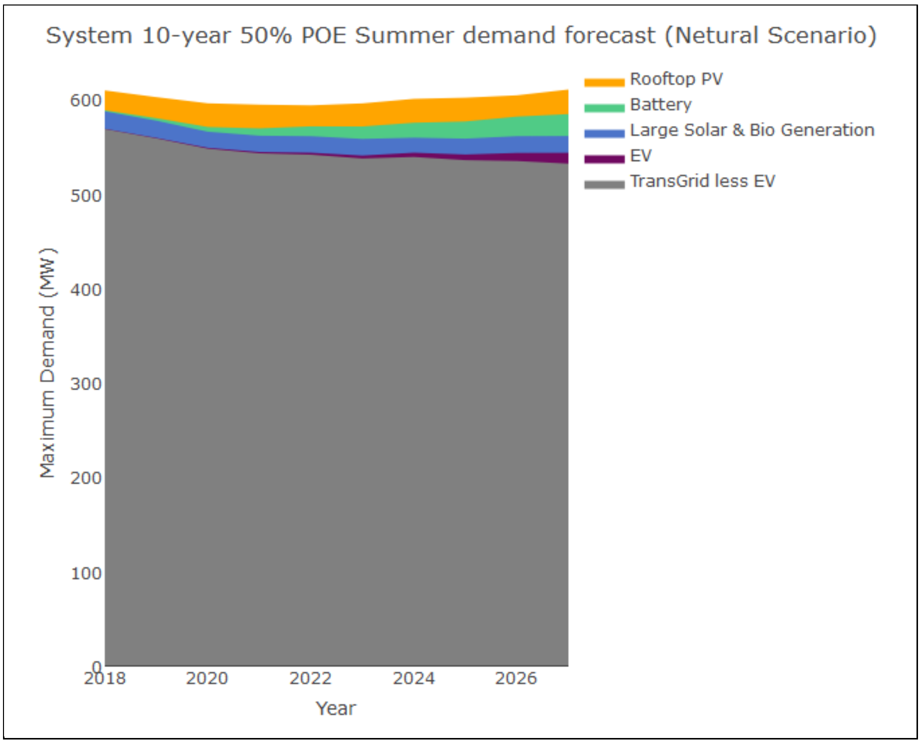
5.4.3 Zone Substation forecasts

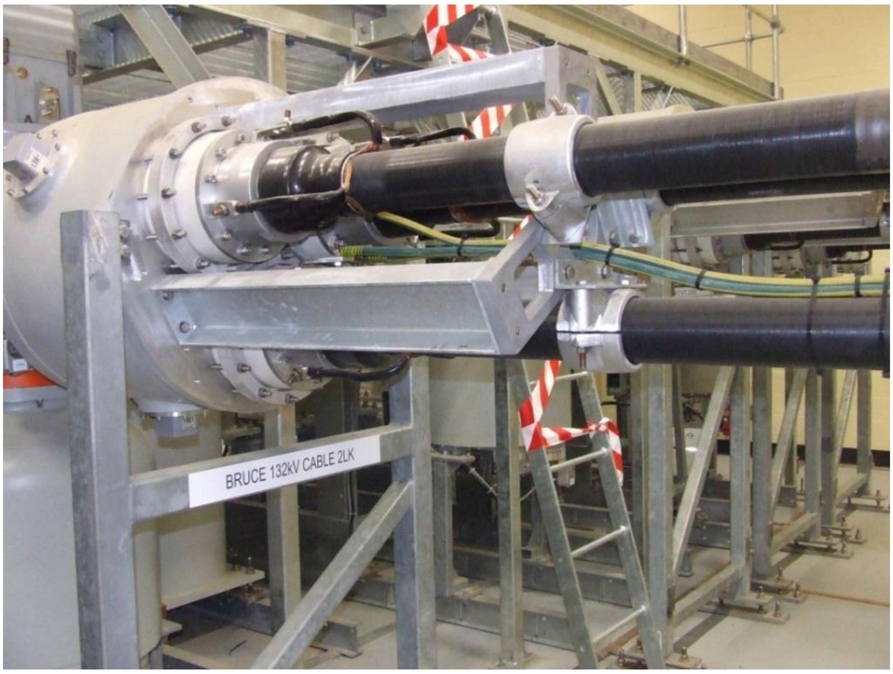
Appendix C details the summer and winter maximum demand forecasts for ActewAGL's zone substations.

5.5. Impact of emerging technologies on load forecasts

Figure 5.8 illustrates the impact of emerging technologies on ActewAGL's forecast system summer maximum demand.

Figure 5.8: Emerging technologies impact on 50% POE system summer maximum demand forecast



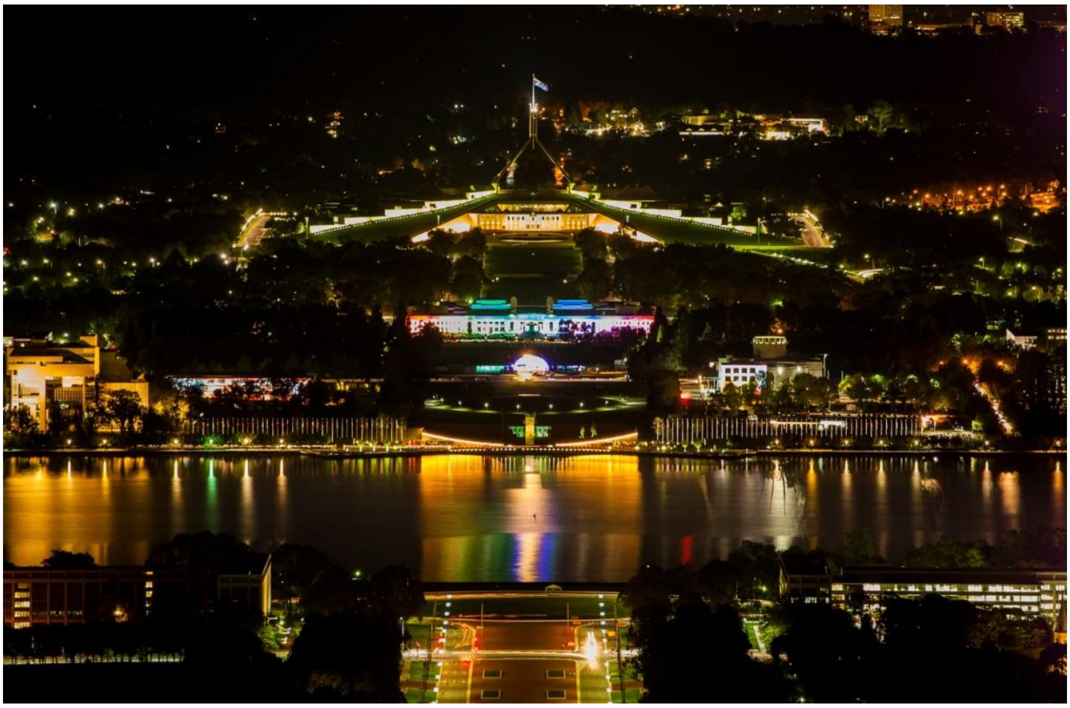


5.6. Load Transfer Capability

Table 5.7 shows the load transfer capability (in MW) between ActewAGL's zone substations. Transfer capability is calculated based on spare capacity of zone substation transformers and spare capacity of interconnecting 11 kV feeders between substations.

Table 5.7: Load Transfer Capability (in MW) between ActewAGL's Zone Substations

Zone Substation		From												
		Latham	Belconnen	Gold Creek	Civic	City East	Telopea Park	East Lake	Fyshwick	Woden	Wanniassa	Gilmore	Theodore	Tennent
To	Latham		7.13	2.47										
	Belconnen													
	Gold Creek													
	Civic		3.06			7.88								
	City East		5.69		7.29		2.9							
	Telopea Park					2.75		14.76	3.64	5.06				
	East Lake													
	Fyshwick						0.63	6.27			0.48	0.48		
	Woden						11.47				8.87			
	Wanniassa						2.8		2.8	18.39		10.57	1.44	
	Gilmore								1.5		15.13		6.66	
	Theodore										6.31	3.36		
	Tennent													



6. Asset Renewals

6.1. Introduction

Asset renewal is simply defined as works that return an asset to its “as-new” condition. Depending on the type of asset, the renewal process may involve the replacement of components, such as overhead line insulators. Major assets such as zone substation power transformers may undergo a “mid-life” refurbishment which would include de-tanking of the core and windings. In order to realise the full potential of any asset, routine maintenance is required. This maintenance does not return the asset to its “as-new” condition, but controls premature deterioration and potential failure.

The cost of asset renewal is included in the “whole-of-life” cost of the asset.

All assets are assigned a “health profile” which is determined by combining the asset’s condition rating with its criticality rating. Condition is determined by the asset’s capacity to meet its service requirements, level of reliability and its level of obsolescence. Obsolescence is determined by maintenance requirements and availability of spares and support from suppliers. Criticality is determined from operational, safety and environmental consequences due to asset failure.

6.2 Compliance with National Electricity Rules re Asset Replacement

In compliance with the NER Schedule 5.8 (b1) and (b2) requirement to report plans to retire, de-rate or replace network assets. ActewAGL has no plans to de-rate any network assets. Any assets to be retired due to condition will be replaced. Occasionally at customer request and funding an asset may be relocated to allow for a proposed development. This could require the retirement of a section of overhead distribution line and its replacement with an underground cable. Table 6.1 lists proposed network asset replacement expenditure where the total replacement cost of each asset type over the 5-year planning period is greater than $200,000.

Table 6.1: Asset Replacements (2018-2022)

Asset type to be replaced	Estimated Quantity and Cost											
	2018		2019		2020		2021		2022		Total	
	Qty	$ Cost	Qty	$ Cost	Qty	$ Cost	Qty	$ Cost	Qty	$ Cost	Qty	$ Cost
Distribution substation batteries	17	44,184	12	43,924	14	43,944	12	43,784	19	44,624	**74**	**220,460**
Distribution substation HV switchboard	2	402,500	2	402,500	2	402,500	2	402,500	2	402,500	**10**	**2,012,500**
Distribution substation LV switchboard	5	676,555	5	676,555	5	676,555	5	676,555	5	676,555	**25**	**3,382,775**
Distribution substations ground-mounted	5	467,575	5	467,575	5	467,575	5	467,575	5	467,575	**25**	**2,337,875**
Distribution transformers ground-mounted	2	134,486	2	134,486	2	134,486	2	134,486	2	134,486	**10**	**672,430**
Low voltage pillars	40	228,920	40	228,920	40	228,920	40	228,920	40	228,920	**200**	**1,144,600**
Overhead line hardware	570	1,632,660	570	1,632,660	570	1,632,660	570	1,632,660	570	1,632,660	**2,850**	**8,163,300**
Overhead service lines	140	232,120	140	232,120	141	233,426	140	232,120	140	232,120	**701**	**1,161,906**
Overhead switchgear and reclosers	51	541,356	51	541,356	51	541,356	51	541,356	51	541,356	**255**	**2,706,780**
Distribution substations pole-mounted	8	465,008	9	523,134	8	465,008	8	465,008	8	465,008	**41**	**2,383,166**
Poles	887	5,557,800	837	5,227,510	787	4,987,550	807	5,101,600	837	5,227,510	**4,155**	**26,101,970**
Ring main units	6	168,276	6	168,276	6	168,276	6	168,276	6	168,276	**30**	**841,380**
Underground HV cables	33	4,066,419	32	2,878,633	33	3,245,463	32	1,889,317	32	2,448,062	**162**	**14,527,893**
Underground LV cables	186	943,964	186	943,964	186	943,964	186	943,964	186	943,964	**930**	**4,719,820**
Transmission line structures	5	100,000	5	100,000	5	100,000	6	120,000	6	120,000	**27**	**560,000**
132 kV / 66 kV circuit breakers	4	136,000	4	136,000	4	136,000	4	136,000	4	136,000	**20**	**578,000**
Power transformers OLTC refurbishment	5	233,305	2	93,322	10	466,610	2	93,322	7	326,627	**26**	**1,213,186**

6.3 Transmission Asset Renewal Programs

Six 132 kV circuits breakers were replaced during the 2016-17 financial year at Bruce Switching Station. These were replacements of aging assets that had reached the end of their economic life.

6.4 Distribution Asset Renewal Programs

The major distribution asset renewal programs involve distribution poles with poor structural condition as identified by the condition monitoring program, and underground cables. These assets are typically more than 60 years of age and have reached the end of their economic life.

During 2016-17, electrical testing on the Sternberg 11 kV feeder indicated that a number of cable sections were in poor condition. This cable was over 60 years old and had numerous joints as the result of faults over its lifetime. As a result, approximately 6.5 km of PILC insulated copper cable was replaced with XLPE insulated aluminium cable. The replacement cable was commissioned in August 2017 at a cost of $3.6m.

ActewAGL has been undertaking a program to upgrade the earthing at its zone substations and 132 kV switching stations. Some of the earth grids at these sites are approaching 55 years of age. Testing has been undertaken at the following 12 oldest stations to assess the condition of the earth grids and measure soil resistivity and Earth Potential Rise:

1. 66/11 kV Fyshwick Zone Substation
2. 132/11 kV Wanniassa Zone Substation
3. 132/11 kV Latham Zone Substation
4. 132/11 kV Gold Creek Zone Substation
5. 132 kV Bruce Switching Substation
6. 132/11 kV Civic Zone Substation
7. 132/11 kV City East Zone Substation
8. 132/11 kV Woden Zone Substation
9. 132/11 kV Telopea Park Zone Substation
10. 132 kV Causeway Switching Substation
11. 132/11 kV Gilmore Zone Substation
12. 132/11 kV Theodore Zone Substation

While no major non-compliance or safety issue was identified, there are minor maintenance and remedial actions required at most of these stations to ensure safe operation of the earthing system. The overall testing and upgrade program is estimated to cost $1.1m and will be completed by June 2019.

All distribution assets are replaced via a rolling program based on an assessment of their condition and remaining economic life. All classes of distribution assets are renewed in this way (refer Table 6.1), including:

- Distribution transformers.
- 11 kV switchgear (switchboards, ring main units and air-break switches).
- 11 kV and 400 V underground cables and overhead conductors.
- Low voltage distribution pillars.
- Protection relays, communications and SCADA equipment.
- Batteries and battery chargers.
- Earthing equipment and systems.

6.5 Distribution Asset Maintenance

ActewAGL maintains its assets according to the principles of Risk Centred Maintenance (RCM). The governing factor in RCM analysis is the impact of a functional failure at the equipment level.

The process of developing an RCM program depends on selecting scheduled tasks that are both applicable and effective for a given asset. The fact that failure consequences govern the entire decision process makes it possible to use a structured decision approach, both to establish maintenance requirements and to evaluate proposed tasks.

Maintenance tasks are directed at assets where failure might have safety, environmental or economic consequences. Assets are classified as:

- Significant item - where failure may have serious safety, environmental, financial or operational consequence.
- Non-significant item - where failure has no impact on operating capability.
- Item with hidden function - where failure will not be evident and might therefore go undetected.

The net result of the decision process is a scheduled maintenance program that is based at every stage on the known reliability characteristics of the equipment in the operating context in which it is used.

6.6 Telecommunications upgrade programs

Planned telecommunications projects – fibre optic network:

ActewAGL has a program to roll out Optical Ground Wire (OPGW) within our network. This involves replacing the existing overhead earth wire on 132 kV transmission lines with hybrid OPGW cables to provide an optical fibre communications capability to meet the following regulatory and business requirements:

- Updating our 132 kV transmission line protection systems to meet current NER network performance standards, ensuring regulatory compliance and safety for the community. Currently some 132 kV transmission line protection systems within the ActewAGL transmission network are non-compliant with the required fault clearance times under the NER and need to be updated.
- Providing a secure SCADA communication network enabling the Control Centre to monitor and operate zone substations in the ActewAGL network.
- Providing inter control centre SCADA communications and communications to the TransGrid and AEMO control centres, required by our role as a Transmission Network Service Provider (TNSP) in the national grid.
- Providing communications for security monitoring of substations and other corporate communication services.

Communications Wide Area Network Deployment:

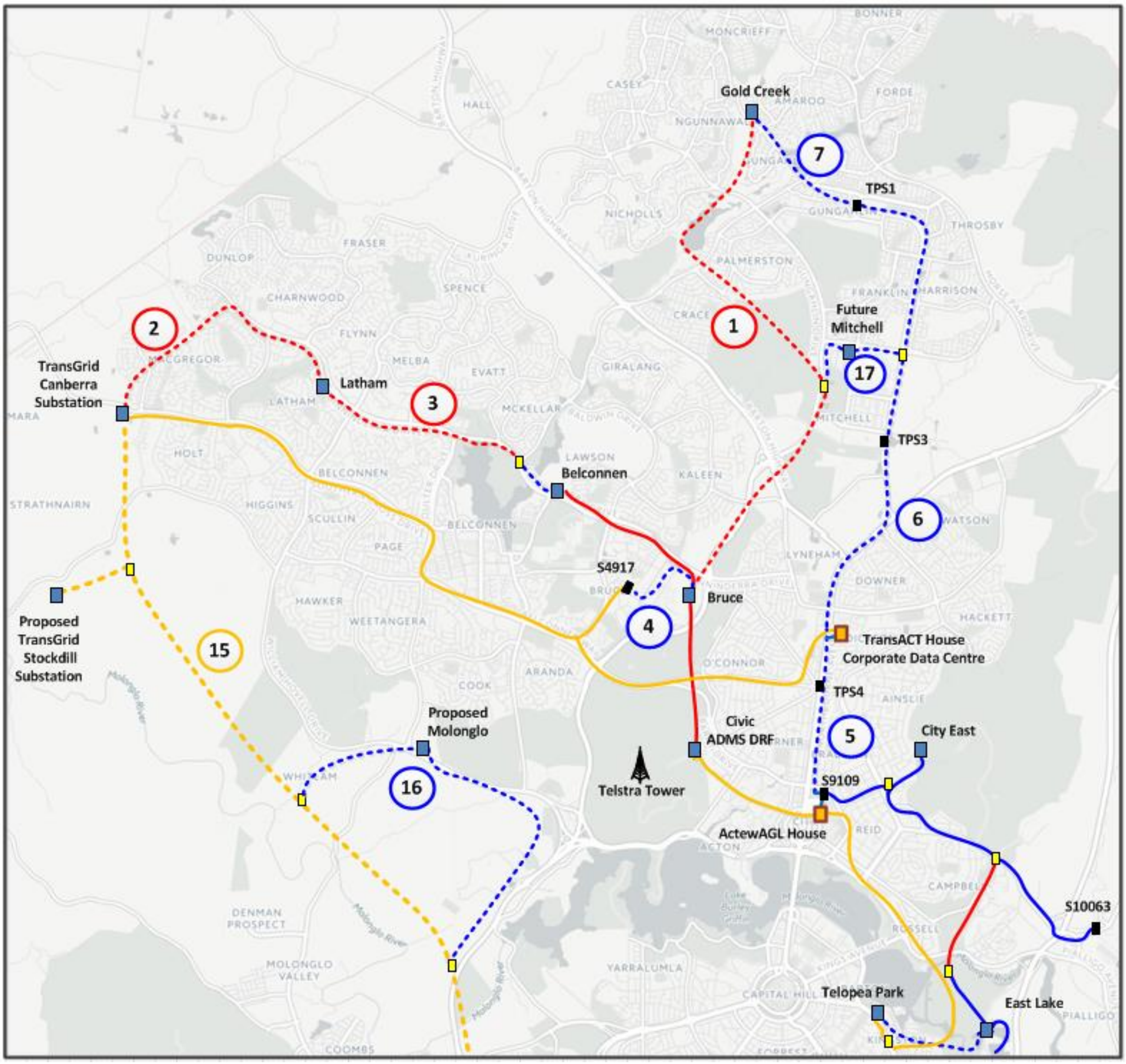
ActewAGL has a program to roll out a Multiprotocol Label Switching (MPLS) based Wide Area Network (WAN) to corporate office and zone substation locations. The WAN will utilise the fibre optic and microwave links. This will deliver the business requirement for a secure SCADA communication network for the effective operation of the electrical network.

Other telecommunications upgrade programs include:

- Replacement of aging copper pilot cables with Optical Fibre cables. Pilot cables are used for 11 kV feeder protection and SCADA communications. This is necessary for providing safety and reliability in the 11 kV network.
- Progressive replacement of radio equipment in the SCADA Digital Data Radio Network (DDRN). This program will replace SCADA data radios as they reach the end of their serviceable life.
- Retirement of the aging ActewAGL VHF voice radio system and consolidation of all radio voice communications onto the ActewAGL TMR radio system. The VHF system is at the end of its service life and needs to be replaced. ActewAGL also owns and operates a UHF TMR voice radio system in the ACT. The scope of this project is to fully transfer and consolidate all operational voice communication requirements to TMR.

The telecommunications upgrade program plans to provide communications to all zone substations in the ActewAGL transmission network by 2018. Figures 6.1 and 6.2 depict the proposed communications network program.

Figure 6.1 Proposed Fibre Optic Network – Northern ACT



Legend

- Existing OPGW
- Proposed OPGW
- Existing underground optical fibre
- Proposed underground optical fibre
- Existing leased fibre
- Proposed leased fibre
- External splice point
- Zone Substation
- Chamber Substation
- Office or Data Centre
- Radio communications site

Current OPGW Projects

1. Bruce to Gold Creek (13.2 km)
2. Latham to TransGrid Canberra (5.2 km)
3. Belconnen to Latham (4.6 km)

Current UG Optical Fibre Projects

4. Bruce to S4917 and S4987

Planned UG Optical Fibre Projects

5. Capital Metro S9109 to TransACT House
6. Capital Metro TPS1 to TransACT House
7. Gold Creek to Gungahlin TPS1

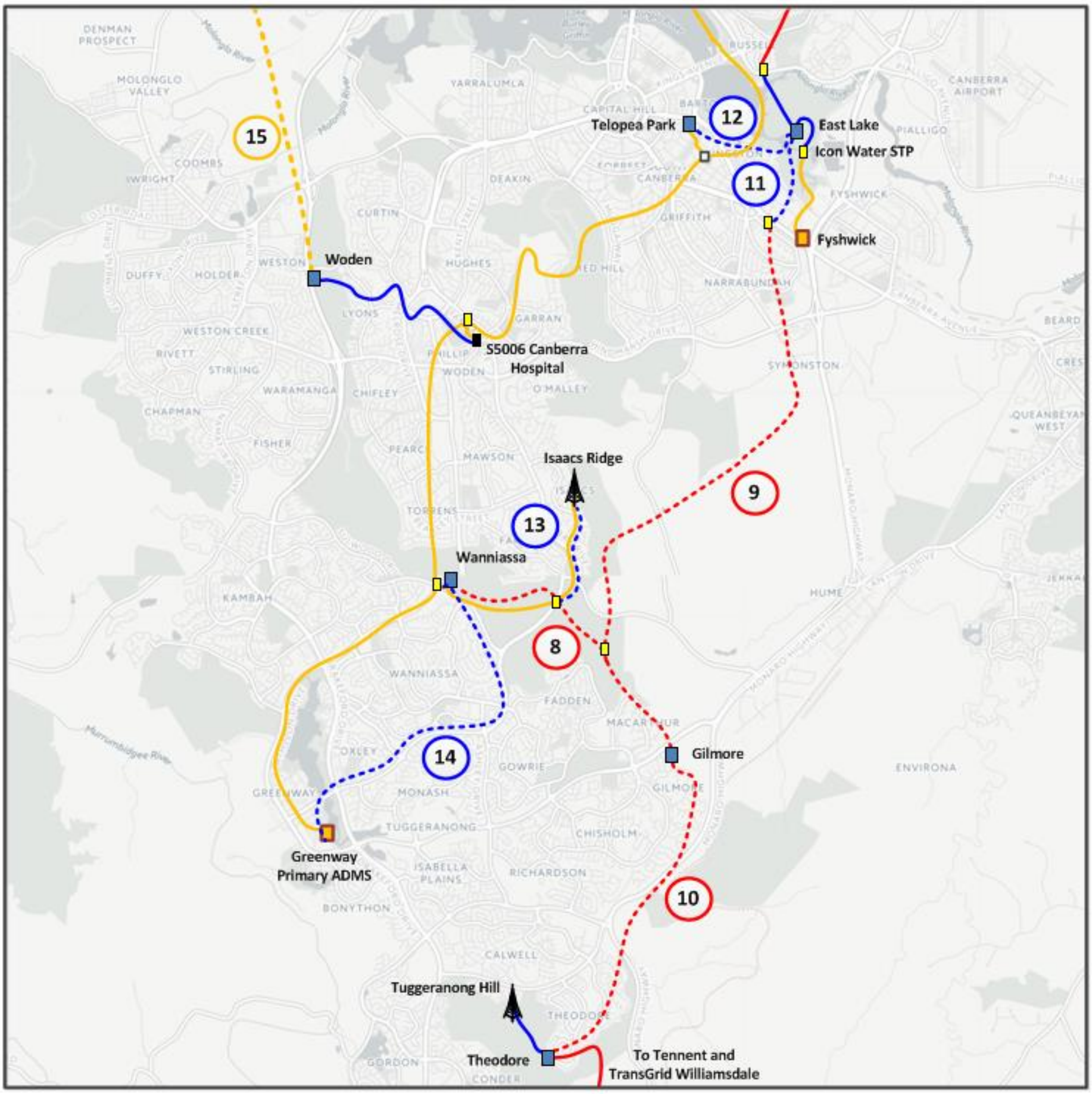
Proposed OPGW Projects

15. Woden to TransGrid Stockdill

Proposed UG Optical Fibre Projects

16. Proposed Molonglo Zone Substation
17. Future Mitchell Zone Substation

Figure 6.2 Proposed Fibre Optic Network – Southern ACT



Legend

- Existing OPGW
- Proposed OPGW
- Existing underground optical fibre
- Proposed underground optical fibre
- Existing leased fibre
- Proposed leased fibre
- External splice point
- Zone Substation
- Chamber Substation
- Office or Data Centre
- Radio communications site

Current OPGW Projects

- 8 Gilmore to Wanniassa (6.2 km)
- 9 Gilmore to East Lake (13.1 km)
- 10 Theodore to Gilmore (7.1 km)

Planned UG / ADSS Optical Fibre Projects

- 11 UG / ADSS East Lake to Diary North
- 12 UG East Lake to Telopea Park
- 13 ADSS Mugga Feeder to Isaacs Ridge
- 14 UG Wanniassa to Greenway

Proposed OPGW Projects

- 15 Woden to TransGrid Stockdill

7. System Planning

7.1. Introduction

System planning studies are undertaken to assess the adequacy of the transmission and distribution network to meet current and forecast demands whilst meeting the quality of supply criteria stipulated in the NER. The key performance criteria that are addressed are: thermal overloading, voltage performance, supply security, and supply reliability. The studies have been conducted using ActewAGL's 2017 medium growth, 50 per cent POE demand forecast.
System planning is the process of investigating present and future system capability, optimising and fully utilising the existing system, and identifying, evaluating and initiating system upgrade requirements where required and where economically justified to do so. Long term system planning is necessary to ensure the security of the power system is maintained.

Maintaining the security of the power system requires the safe scheduling, operation and control of the power system on a continuous basis within system standard and technical limitations. A disturbance occurs when the power system unexpectedly incurs a change in supply, demand, connectivity or voltage level. Such disturbances can be the result of external incidents such as a line tripping due to a storm, or internal influences such as equipment failure. A disturbance that is considered to be reasonably possible under normal operating conditions is classified as a credible contingency, while low probability events are classified as non-credible.

System upgrades are driven by the need to maintain system reliability, to provide capacity for demand growth, and to relieve current or future system constraints.

The planning process is set out in the NER, and involves consultation with the public on any proposed upgrade requirements and the proposed options to address those requirements. The NER specifies the method for selecting the preferred option to addressing an issue from the feasible alternatives, which must include non-network options.

This chapter describes existing and emerging constraints on the ActewAGL network that have been identified to occur over the next ten years. It describes those issues that are proposed to be addressed over the next five-year planning period, and discusses options identified and proposed solutions. Opportunities for non-network solutions such as demand side management or embedded generation support required to defer the emerging issues are identified.

Details of system performance are included in Chapter 4. Details of demand forecasts are included in Chapter 5 and Appendices B and C.

ActewAGL's network is a meshed 132 kV transmission and meshed 11 kV distribution system, with the exception of Fyshwick Zone Substation which is supplied radially at 66 kV from TransGrid's Queanbeyan Substation. There are also two radial 22 kV feeders emanating from Woden Zone Substation, feeding Cotter and Tidbinbilla.

Figure 3.1 shows the transmission network and location of zone substations and switching stations geographically, and Figure 3.2 shows this information schematically.

7.2. Embedded generation

7.2.1 Solar Photovoltaic (PV)

Embedded generation connected to the ActewAGL network includes 17,975 domestic rooftop PV installations (as at 30 June 2017) of average size of approximately 3.4 kW connected to the low voltage 400 V system. These installations as spread all over the ACT (refer 2016 distribution shown in Appendix E). Total installed capacity is 59.8 MW.

There are currently three large scale solar embedded generation installations connected to the ActewAGL network. PRV Solar Farm, Royalla, which has a peak output capacity of 20 MW is connected to Theodore Zone Substation via two dedicated 11 kV feeders. Mugga Lane Solar Park, Hume which has a peak output capacity of 12.85 MW is connected to Gilmore Zone Substation via a dedicated 11 kV feeder. Williamsdale Solar Farm, Williamsdale, which has a peak output capacity of 10.6 MW is connected to Tennent Zone Substation via a dedicated 11 kV feeder.

There is currently one medium scale solar embedded generation installation connected to the ActewAGL network, Mount Majura Solar farm, Mount Majura, which has a peak output capacity of 3.6 MW. This is connected to City East and East Lake zone substations via two shared 11 kV feeders.

There are several solar PV installations in the range 20-200 kW, typically on the roofs of commercial or industrial buildings.

Potential solar generation projects include the Environa Solar Farm with a design output of 14 MW, the Renew Energy Solar Farm with a design output of 20 MW, a 2 MW solar generation installation proposed to be constructed at the Belconnen Waste Transfer Station, and a 2 MW solar generation installation proposed to be constructed at the Lower Molonglo Water Quality Control Centre.

7.2.2 Hydro-electric

There is an existing micro-hydro generator connected to the ActewAGL network, the Stromlo micro-hydro which has a peak output capacity of 700 kW. This is connected to Woden Zone Substation via a shared 22 kV feeder.

There is another small hydro generator at Googong Dam, which recovers energy in the event that water is pumped from Angle Crossing to Googong Dam.

7.2.3 Gas

There are two existing bio-gas fuelled open-cycle gas turbine (OCGT) generators connected to the ActewAGL network:

Mugga Lane Waste Transfer Station 4 MW. This is connected to Gilmore Zone Substation via a shared 11 kV feeder.

Belconnen Waste Transfer Station 3 MW. This is connected to Latham Zone Substation via a shared 11 kV feeder.

7.2.4 Co-generation

There is one gas fuelled co-generation plant at Harman 1.2 MW. This is connected to Fyshwick Zone Substation via a shared 11 kV feeder.

7.2.5 Waste to Energy

There is a proposed recycling and thermal electricity generation facility (waste to energy) to be constructed at Fyshwick with a potential capacity of 15 MW. Connection options are currently being evaluated.

7.3. Joint Planning with TransGrid

ActewAGL and TransGrid hold joint planning meetings bi-annually. The joint planning process ensures that the most economic solutions to issues are implemented, whether they are a network or non-network option, transmission or distribution option. The joint planning process covers:

- Evaluation of relevant limitations of both networks and progression of joint planning activities to address these limitations.
- Demand and energy forecasts.
- Non-network development proposals.
- Long term transmission and distribution developments.
- Annual planning reports and presentations.

Major projects are discussed such as TransGrid’s proposed Stockdill Drive 330/132 kV bulk supply point substation as required for the second point of bulk supply to the ACT (refer sections 7.5.1 and 7.7). Regular project development meetings and exchanges of information (e.g. design drawings) are exchanged as such projects progress.

ActewAGL and TransGrid also have regular discussions in addition to the formal joint planning meetings, to discuss and resolve technical issues such as bulk supply point (BSP) bus voltage levels.

TransGrid proposes to carry out replacement of some of its aging major assets at Canberra BSP Substation. ActewAGL will liaise closely with TransGrid throughout the implementation of this project to ensure continuity and security of supply to the ACT is maintained. Refer to TransGrid's Transmission Annual Planning Report 2017[8].

7.4. Emerging needs

Customer-initiated load growth is steady in the ACT, around 0.7 % per annum during winter months. New developments are primarily residential greenfield estates and in-fill housing, community developments such as schools, commercial developments such as shopping centres and data centres, and infrastructure developments such as the proposed Canberra light rail project. Load growth rates are expected to decrease slightly during summer months over the planning period due to the increasing effects of embedded generation, energy storage, and energy efficient appliances. This will result in decreasing investment in network augmentations and increasing investment in asset replacements.

Accurate demand forecasting is essential to the planning and development of ActewAGL's distribution network. ActewAGL uses the same demand forecasting model as AEMO. Demand forecasts are calculated at the whole of system level, at each zone substation, and at each distribution feeder for the forward planning period. These forecasts are used to identify emerging network limitations, and identify network risks, that need to be addressed by either network or non-network solutions. The forecasts are then used as an input to the timing and scope of capital expenditure, or the timing required for demand reduction strategies to be established, or risk management plans to be put in place.

ActewAGL has analysed existing and emerging needs on its network using the Advanced Distribution Management System (ADMS). Such needs are met firstly by utilising available spare capacity within the network, e.g. by transferring load between feeders or between zone substations whilst ensuring all security and reliability criteria are maintained. Analysis is conducted on feeder tie points to determine the feeder capacity to support loads of adjacent feeders during contingency events.

Section 7.5 describes network developments with a capital cost in excess of $2 million proposed to be carried out over the five-year planning period to meet emerging needs.

7.5. Proposed Network Developments

Proposed developments have been identified through the planning process for the forward ten-year planning period. Load forecasts and new major customer connection requests have been the inputs for the maximum demand forecasting. Because of the relatively small geographic area of the electricity network within the ACT, it is not broken down into separate regions for planning purposes. The full geographic extent of the network is shown in Fig. 3.1. Figure 7.1 shows a schematic diagram of the existing ACT transmission network.

8 https://www.transgrid.com.au/newspublications/Documents/Transmission Annual Planning Report 2017.pdf

Figure 7.1 Existing Transmission Network

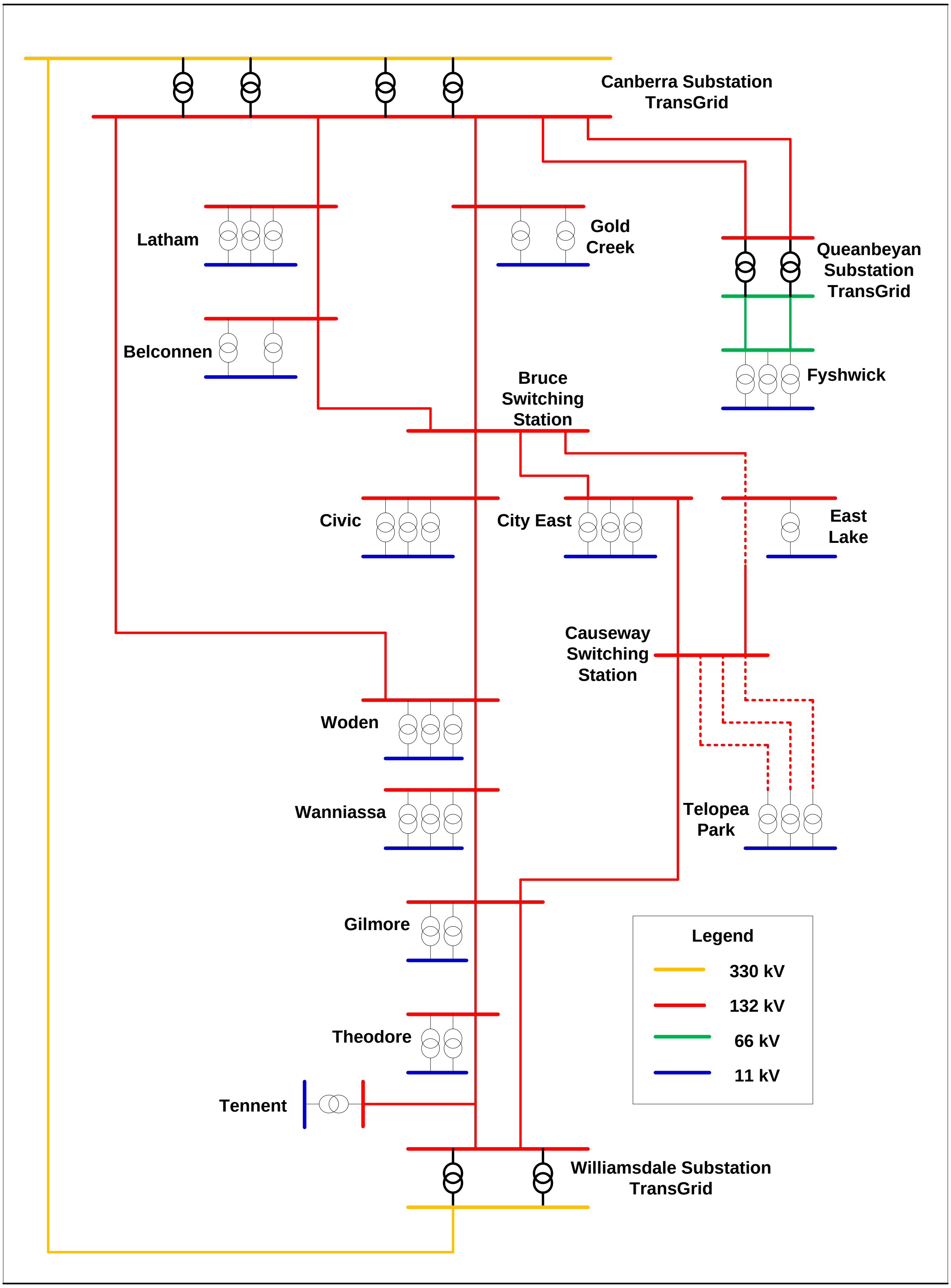


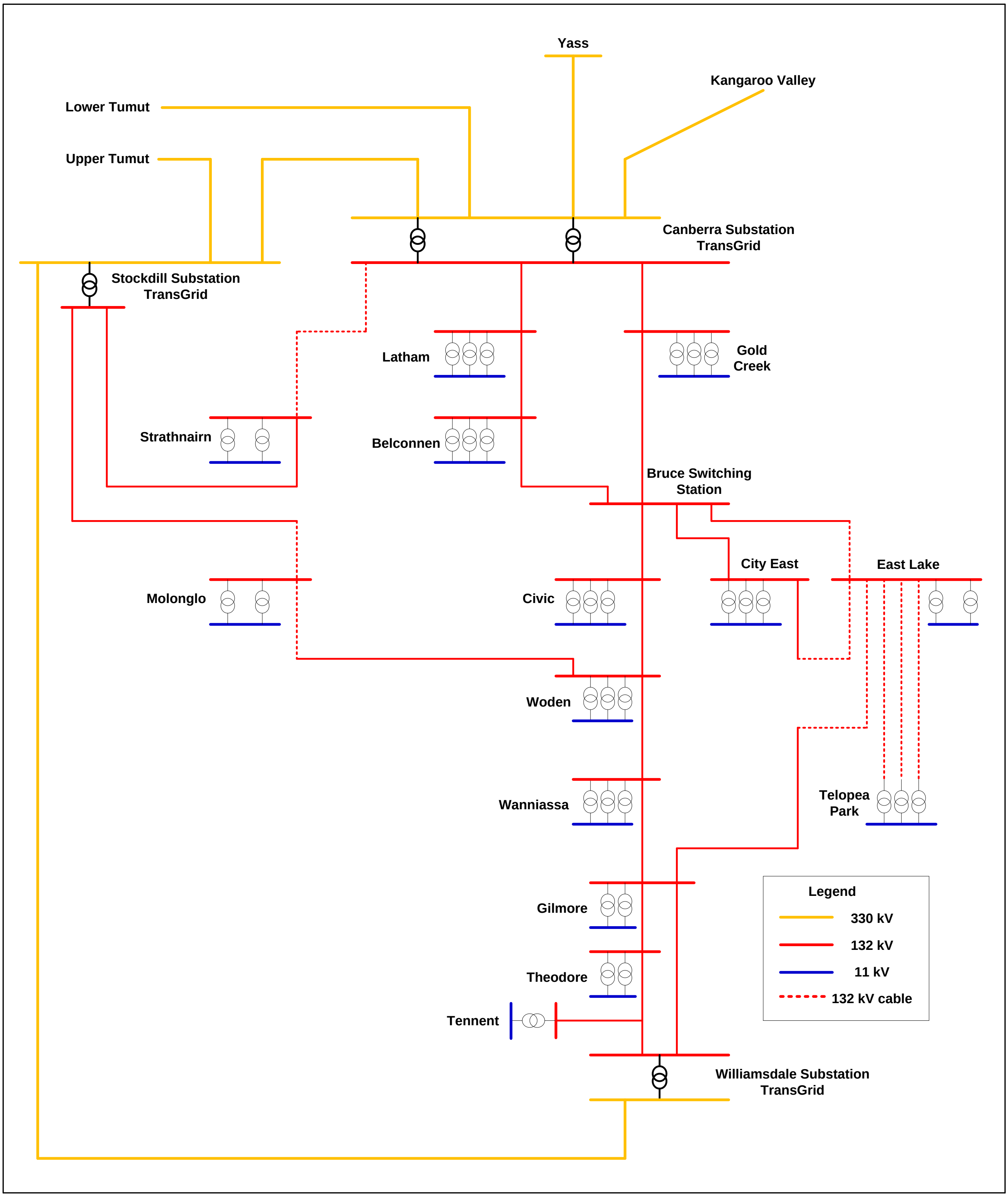
Table 7.1 presents future proposed developments estimated to cost more than $2 million that are programmed to commence during the five-year planning period, and the timing of their completion. These projects are described in the following sections.

Table 7.1: Proposed ActewAGL Network Developments in Excess of $2.0 m

Asset Type	Proposed Development	Estimated Start	Estimated Completion	Estimated Cost
TransGrid – ActewAGL Connection Point	Stockdill Substation	2018	2019	NA
Transmission System	Construct 132 kV transmission line from Stockdill Substation to Canberra–Woden line.	2018	2020	$7.15 m
Zone Substation	East Lake Zone Substation second transformer and 11 kV switchboard	2018	2019	$4.16 m
	Molonglo Zone Substation	2020	2022	$22.51 m
	11 kV 10 MVAR capacitor banks at Latham, Gold Creek, Belconnen and Molonglo zone substations	2020	2022	$2.21 m
	Decommission Fyshwick Zone Substation 66 kV assets	2022	2024	$5.46 m
Switching Station	Decommission Causeway 132 kV Switching Station	2019	2020	$2.00 m
Distribution System	Supply to Gungahlin Town Centre	2017	2018	$3.54 m
	Supply to Canberra CBD West	2018	2019	$2.77 m
	Supply to Strathnairn	2019	2019	$1.58 m
	Supply to Canberra CBD Central	2019	2020	$1.27m
	Supply to Kingston	2019	2020	$1.02 m
	Supply to Tuggeranong Town Centre	2019	2020	$2.48 m
	Supply to Pialligo	2019	2020	$4.28 m
	Supply to Canberra City and Dickson	2020	2021	$4.16 m
	Supply to Mitchell	2021	2022	$5.70 m
	Supply to Belconnen Town Centre	2022	2023	$3.39 m
	Molonglo Valley Feeders	2022	2025	$6.71 m
Secondary System	Installation of Optical Ground Wire (OPGW) on 132 kV transmission lines	2015	2017	$5.25 m
	SCADA communications upgrade, optic fibre to distribution substations	2015	2024	$4.28 m

Figure 7.2 shows future development of the transmission network over the next ten years.

Figure 7.2 Future (10 years) Transmission Network



7.5.1 Security of Bulk Supply to the ACT

The commissioning of TransGrid's Williamsdale 330/132 kV Substation in February 2013 introduced a second 132 kV bulk supply point into the ACT to address power system security requirements by providing two geographically independent 330 kV points of connection to the ACT network. Williamsdale Substation is linked to ActewAGL's network at Theodore and Gilmore 132 kV Zone Substations (refer Figure 7.1).

The latest version of the ACT Electricity Transmission Supply Code (July 2016) states:

TransGrid must plan, design, construct, test, commission, maintain, operate and manage its electricity transmission networks and geographically separate connection points that supply customers in the ACT and that will operate at 66 kV and above, whether or not those networks and connection points are in the ACT, to achieve the following:

(a) the provision of two or more geographically separate connection points operated at 132 kV and above to supply electricity to the ACT 132 kV network;

(b) at all times provide continuous electricity supply at maximum demand to the ACT 132 kV and 66 kV network throughout and following a single credible contingency event;

(c) until 31 December 2020, provide electricity supply at 30 MVA to the ACT 132 kV or 66 kV network within one hour following a single special contingency event and 375 MVA within 48 hours of this event; and

(d) from 31 December 2020, provide continuous electricity supply at 375 MVA to the ACT 132 kV network immediately following a single special contingency event and agreed maximum demand within 48 hours of this event.

To meet the above criteria TransGrid proposes:

Item (a) is met already by Canberra and Williamsdale 330/132 kV bulk supply point substations.

Item (b) is met already by Canberra and Williamsdale 330/132 kV, and Queanbeyan 132/66 kV bulk supply point substations, all of which have N-1 security.

Item (c) can be met by supplying 30 MVA via Queanbeyan 132/66 kV (to Fyshwick 66/11 kV Zone Substation) in the event of a special contingency event affecting Canberra Substation (and consequently affecting Williamsdale Substation also as Williamsdale is connected radially at 330 kV from Canberra). The 375 MVA criteria within 48 hours requirement would be met by constructing a temporary 330 kV connection between the Upper Tumut–Canberra line and the Canberra–Williamsdale line, thus bypassing Canberra Substation.

To comply with Item (d) TransGrid proposes to construct a new 330/132 kV Substation at Stockdill Drive, West Belconnen. This will have one 375 MVA transformer. The Upper Tumut–Canberra and Canberra–Williamsdale 330 kV lines will be reconnected to Stockdill Substation. A new 330 kV line section will be constructed from Stockdill to Canberra. ActewAGL will construct a new double circuit 132 kV line section from Stockdill to connect to the Canberra–Woden 132 kV line to form a Stockdill–Canberra circuit and a Stockdill–Woden circuit. This will provide the immediate 375 MVA back-up capability to the ACT.

Within one hour of a special contingency event affecting Canberra Substation, TransGrid proposes to reconnect Queanbeyan 132 kV from Yass Substation (via Spring Flat Switching Station) and within 48 hours to construct a temporary connection from the Yass 330 kV line to the Canberra–Latham 132 kV line and reconnect to Yass 132 kV bus. This would provide full load capacity to the ACT.

TransGrid proposes to retire two aged single-phase transformer banks at Canberra Substation.

Power systems analysis shows that under this development the originally proposed Theodore–Gilmore 132 kV line upgrade will not be required. However analysis shows that in the event of a total Canberra Substation outage, voltage levels in the northern part of ActewAGL's network would fall below regulation levels. In order for voltage levels to be maintained, ActewAGL has investigated the installation of reactive support equipment, with the most cost effective solution being the installation of an 11 kV 10 MVAr capacitor bank at each of

ActewAGL's northern zone substations as follows: Latham, Gold Creek, and Belconnen (by December 2020), Molonglo (by June 2022), and Strathnairn (by June 2040).

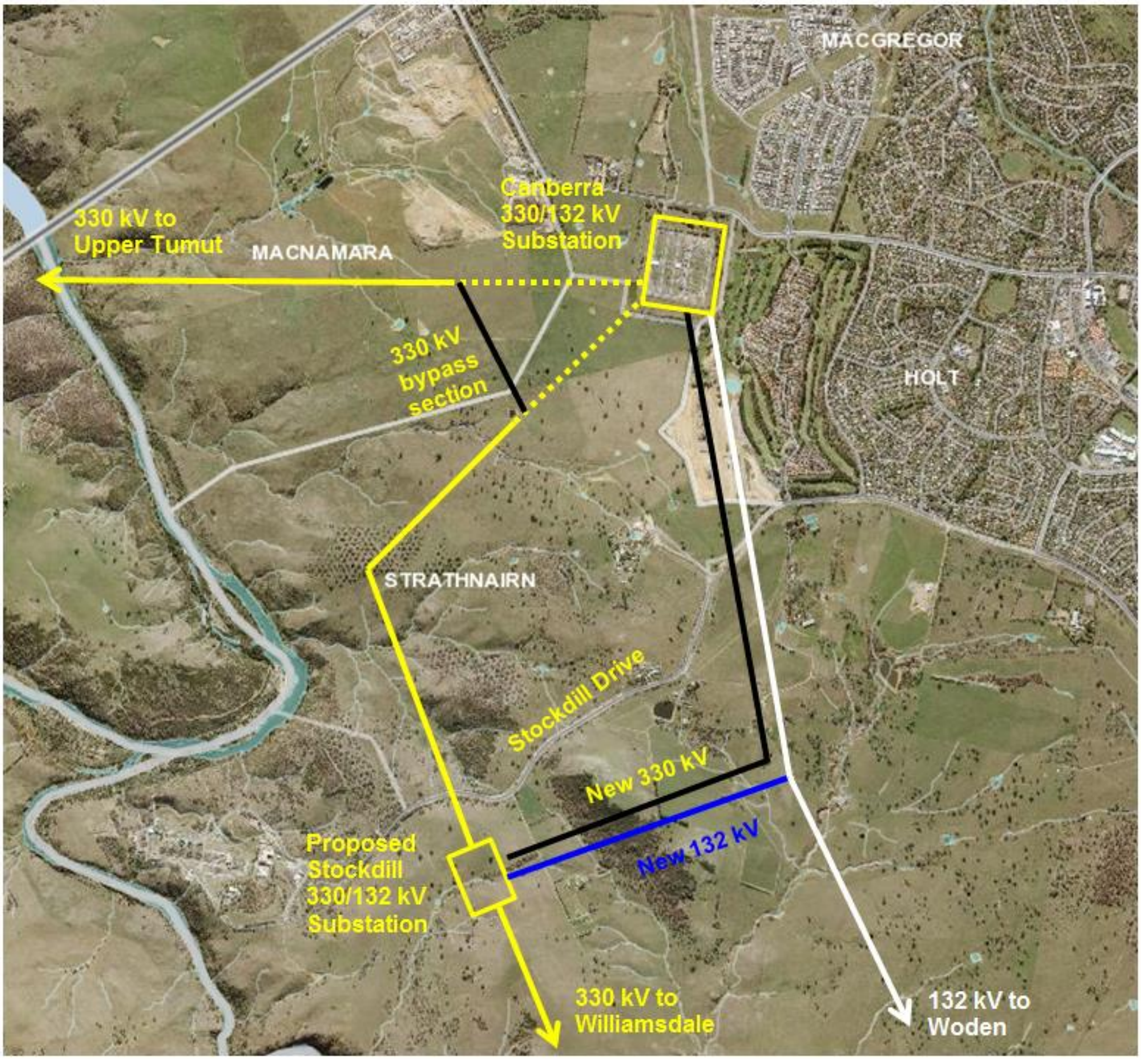
Other options investigated regarding reactive power support devices included a 132 kV 50 MVAr capacitor bank and a 132 kV 50 MVAr statcom. These options are both more expensive than 11 kV capacitor banks and would be used only in the event of a special contingency event affecting the whole of Canberra Substation. The 11 kV capacitors can be installed in stages and can be used continuously to improve 11 kV bus voltages and reduce MVA loads on zone substation transformers.

No non-network alternative to this project has been identified. Estimated cost of the Stockdill Substation to Canberra–Woden132 kV transmission line plus installation of OPGW on the Canberra–Stockdill–Woden line is $7.15 m and proposed project completion is by December 2020.

A joint Regulatory Investment Test for the Security of Supply project was completed by ActewAGL and TransGrid in 2009.

Figure 7.3 illustrates the scope of this project

Figure 7.3: Proposed Stockdill Substation and 132 kV line connection



In the interim period until completion of this project, in the event of a loss of Canberra Bulk Supply Substation, a contingency plan has been made by TransGrid which has constructed assets at its Yass and Canberra substations to deal with this eventuality.

Estimated cost of the 11 kV 10 MVAr capacitor banks is as follows:
Stage 1 – Latham, Gold Creek and Belconnen $1.64 m with proposed completion by December 2020.
Stage 2 – Molonglo $0.57 m with proposed completion by June 2022.
Stage 3 – Strathnairn $0.57 m with proposed completion by June 2040.

7.5.2 East Lake Zone Substation second transformer

East Lake Zone Substation was commissioned in 2013 with one 132/11 kV 30/55 MVA transformer and one 11 kV switchboard. Space and foundation pads have been provided in the switchyard for a further two transformers. Space and cable trenches have been provided in the control building for a further two 11 kV switchboards. The 132 kV switchgear at East Lake is indoor GIS and has an existing spare circuit breaker complete with secondary systems, designated for a second transformer.

The maximum demand at East Lake Zone Substation is currently approximately 18 MVA and is forecast to increase steadily to 30 MVA over the next ten years as load grows in the Kingston, Pialligo, Majura and Fyshwick areas. This growth rate will be exceeded should some customer-initiated projects currently at enquiry/design stage, continue to be fully implemented. More 11 kV feeders will need to be installed and supplied from East Lake. Growth is being driven primarily by the commercial and industrial sectors in the Fyshwick area (eg data centres) and in the Kingston area (eg multi-storey residential apartment buildings).

The maximum demand at Telopea Park Zone Substation is increasing steadily towards its continuous rating of 100 MVA. It is desired to transfer some load from Telopea Park to East Lake.

The maximum demand at Fyshwick Zone Substation is increasing steadily and is forecast to exceed its continuous rating of 28 MVA by winter 2018. It is proposed to decommission the 66 kV assets at Fyshwick Zone Substation and convert it to an 11 kV switching station only, to be supplied by three high capacity express 11 kV feeders from East Lake (refer Section 7.5.4).

Should the sole transformer at East Lake fail, the contingency plan is to transfer its load to Telopea Park and Fyshwick via inter-connecting feeders. Beyond June 2019 it is forecast that there will be insufficient capacity in these inter-connecting feeders to enable full load transfer and this would result in unserved energy.

It is proposed to procure a second 132/11 kV 30/55 MVA transformer and install it at East Lake Zone Substation by June 2019, where it will provide additional capacity and N-1 security. It is also proposed to install and connect a neutral earthing transformer and a second 13-panel 11 kV switchboard at East Lake Zone Substation, to provide connection points for proposed and future 11 kV feeders to supply the East Lake, Kingston, Pialligo, Majura and Fyshwick areas.

An alternative option considered was to redeploy ActewAGL’s mobile 132/11 kV 14 MVA substation from Angle Crossing to East Lake. This would be a temporary arrangement only as it is proposed to redeploy the mobile substation as Stage 1 of the Molonglo Zone Substation establishment in 2022. This option would provide East Lake with 14 MVA continuous rating only. ActewAGL does not own a system spare power transformer, so the mobile substation is required to act as spare for emergency replacement should a zone substation transformer fail, or for temporary deployment at zone substations to enable scheduled refurbishment of power transformers to be carried out.

Estimated cost is $4.16 million and proposed project completion is by June 2019.

No non-network alternative to this project has been identified.

7.5.3 Molonglo Zone Substation

The Molonglo Valley District is situated in Canberra's west, approximately 10 km from the Canberra Central Business District (CBD). It lies to the north of the urban areas of Weston Creek and south of Belconnen. The area is being developed by the Suburban Land Agency as a residential district. Land servicing has commenced for the initial developments and when fully developed over the next 30 years, the Molonglo Valley District including the new suburbs of North Weston, Coombs, Wright, Denman Prospect and Whitlam will support an estimated 21,000 dwellings plus shopping centres, schools and community facilities.

The first phase of development of the Molonglo Valley is underway, comprising Denman Prospect, Wright and Coombs suburbs. Supply is being provided to these developments through two extended 11 kV feeders from Woden Zone Substation and one extended 11 kV feeder from Civic Zone Substation. The first stage of the new Whitlam suburb is due to commence construction in 2019. Initial supply to Whitlam will be provided by the Black Mountain feeder from Civic Zone Substation.

Load forecasts indicate that these feeders will reach their firm capacity limits around mid-2022 as the load of new developments in the Molonglo Valley increases. The maximum demand in the Molonglo Valley is forecast to increase steadily to 50 MVA over the next 30 years. ActewAGL proposes to provide long-term capacity and security to the Molonglo Valley District by constructing a new 132/11 kV Molonglo Zone Substation at a site on the northern side of William Hovell Drive, east of Coulter Drive.

The *Electricity Distribution (Supply Standards) Code* issued by the ACT Independent Competition and Regulatory Commission (ICRC) sets out certain performance standards for the distribution network in the ACT. A Distribution Network Service Provider (DNSP) is required to 'take all reasonable steps to ensure that its Electricity Network will have sufficient capacity to make an agreed level of supply available'. The processes defined in these criteria serve to limit network augmentation expenditure to instances where the increase in demand is clear and above the secure or firm capacity.

The proposed Molonglo Zone Substation is required to meet the Electricity Distribution (Supply Standards) Code.

ActewAGL has considered four options to supply the Molonglo Valley District as follows:

Option	Option type	Description	Evaluation
1	Network	Construct new 11kV cable feeders from Latham Zone Substation	Discounted
2	Network	Construct new 11kV cable feeders from Belconnen Zone Substation	Discounted
3	Non-network	Demand side management	Insufficient
4	Network	New Molonglo Zone Substation	Preferred

Options 1 & 2 are discounted due to their high capital cost and the forecasted loading on Latham and Belconnen zone substations.

Option 3 considers demand side management initiatives including demand reduction and alternative supply measures such as embedded generation. The majority of demand of these developments is residential dwellings. The developer of Denman Prospect proposes to make detached dwellings in Denman Prospect energy efficient by requiring the mandatory installation of 3 kW rooftop solar PV generation per dwelling. This will reduce energy demand but would require significant uptake of energy storage, e.g. battery storage installations, to have a major impact on the overall maximum demand of the network. In particular winter demand usually occurs around 6:00pm throughout the month of July when there is no PV generation, so peak shaving would require the use of battery storage devices.

Stage 1B of Denman Prospect Estate includes 34 apartment buildings comprising 1888 units. North Wright and North Coombs developments also include 7 proposed apartment buildings. Installation of solar PV or battery energy storage is not mandatory for apartment buildings so standard demand levels are expected for these units. ActewAGL has calculated After Diversity Maximum Demand (ADMD) of 2.5 kVA per unit for apartment buildings. There is also a recent trend towards the installation of instantaneous electric hot water systems in apartment buildings, which will potentially increase the ADMD per unit.

ActewAGL is undertaking a Smart Network trial project (refer section 9.9.2 for details) in Stage 1A of Denman Prospect Estate (comprising 400 dwellings) to assess the viability and effectiveness of network-controlled load demand of customer devices beyond the meter (eg PV output, battery storage systems, hot water heating systems, air conditioning, swimming pool pumps and electric vehicle charging stations). The outcome of this project may influence the timing of the proposed Molonglo Zone Substation.

Other demand reduction measures such as on-site generation, co-generation and tri-generation[9] which are associated with commercial and industrial businesses will not be applicable in the immediate future and are therefore not considered further.

Option 4 proposes to establish a new 132/11 kV zone substation at Molonglo by winter 2022. The new Molonglo Zone Substation will initially be equipped with ActewAGL's 132/11kV 14 MVA mobile substation (previously installed at Angle Crossing). Stage 2 comprising installation of one 132/11 kV 30/55 MVA transformer and one 11 kV switchboard is proposed to be completed by the end of the 2026-27 financial year though this will depend on the actual rate of load growth. Stage 3 comprising installation of a second 132/11 kV 30/55 MVA transformer and second 11 kV switchboard is proposed to be completed by the end of the 2029-30 financial year though this will depend on the actual rate of load growth.

Ultimate maximum demand of Molonglo Zone Substation is forecast to reach 53 MW by 2046 based on a 30-year development plan for the Molonglo Valley. 132 kV connection will be via loop-in-loop-out to the Canberra–Woden 132 kV circuit.

This is the preferred option. Estimated cost is $22.51 million, comprising $8.34 m for Stage 1 (establishment of the substation site and installation of the mobile substation; $9.43 million for Stage 2 (installation of one transformer and switchboard) and $4.74 million for Stage 3 (installation of second transformer and switchboard). Proposed project completion is by June 2022 for Stage 1, June 2027 for Stage 2 and June 2030 for Stage 3.

The augmentation cost of this proposal exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). A RIT-D will be commenced in 2019.

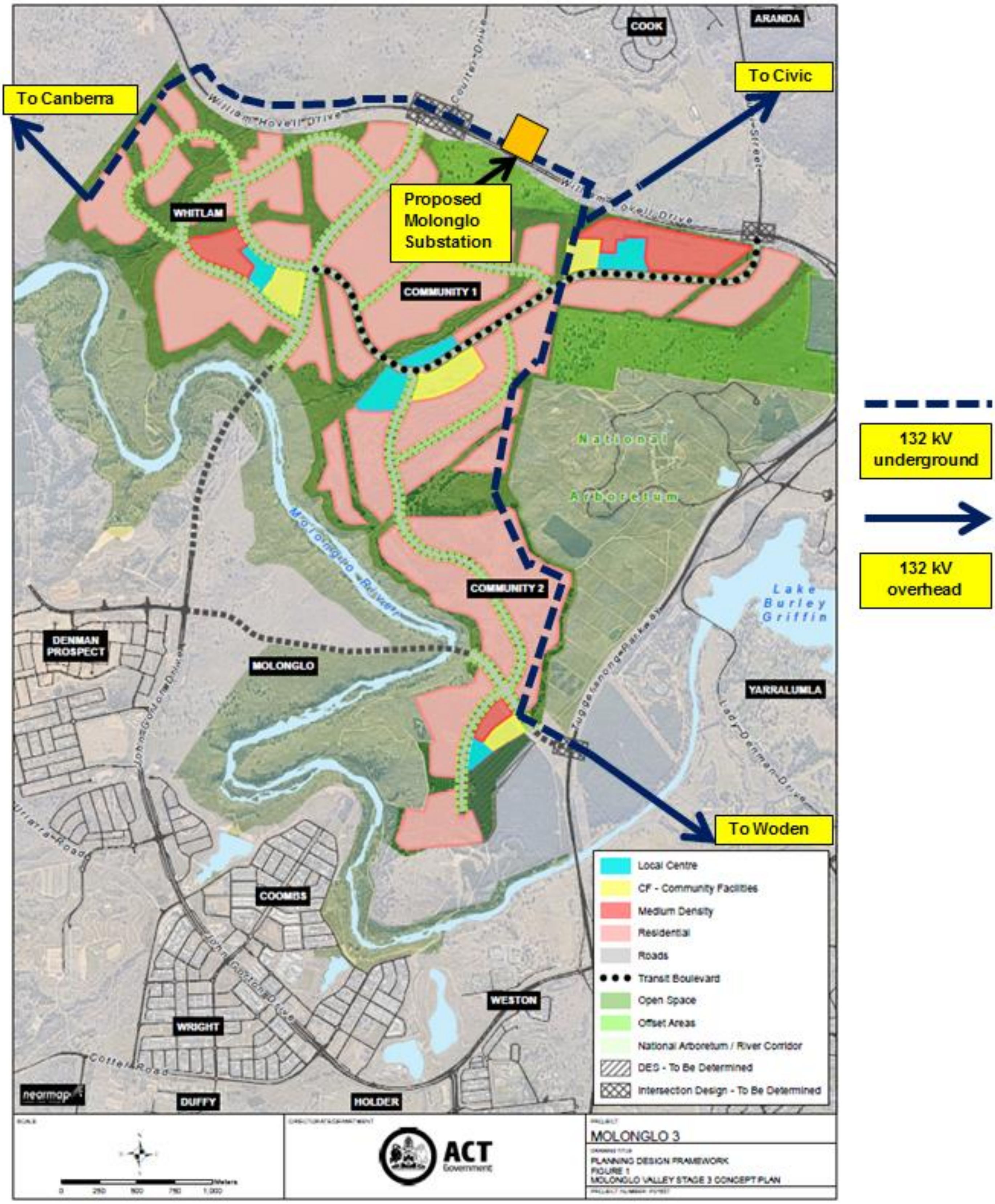
Viable proposals from third parties that can significantly reduce maximum demand of the Molonglo Valley developments and enable ActewAGL to defer construction of the Molonglo Zone Substation are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 1.9 MW in 2022, 3.9 MW in 2022, 5.9 MW in 2023 and so on, to enable the Molonglo Zone Substation project to be deferred. This would be in addition to currently proposed rooftop PV installations on all detached dwellings.

As part of the Molonglo Valley development, the Suburban Land Agency has requested the relocation of sections of two ActewAGL 132 kV transmission lines; approx 4.7 km of the Canberra–Woden line and 3.4 km of the Civic–Woden line. These relocations will be done in conjunction with development of the Molonglo Zone Substation. The preferred option for these relocations is to replace these sections of overhead132 kV transmission lines with underground cables.

Figure 7.4 shows the site of the proposed Molonglo Zone Substation and associated undergrounding of 132 kV transmission lines (blue dashed lines denote proposed underground cable sections).

[9] Tri-generation is the production of electricity, heat and cooling in the one process. Typically this means a gas fired generator producing electricity and heat with the exhaust heat going to an absorption chiller which produces chilled water and hot water for air conditioning or alternatively the heat is used to heat a swimming pool.

Figure 7.4 Proposed development of Molonglo Valley



7.5.4 Decommissioning of Fyshwick Zone Substation 66 kV Assets

Fyshwick Zone Substation was constructed and commissioned in 1982. It was originally deemed to be a "temporary substation". It is supplied from TransGrid's Queanbeyan 132/66 kV Substation via two single circuit wooden pole 66 kV transmission lines.

Primary assets supplying and at Fyshwick Zone Substation are approaching the end of their economic lives. The two 66 kV transmission lines from Queanbeyan to Fyshwick (3.6 km) were constructed in 1982 with wooden poles and Lemon 30/7/3.00 ACSR/GZ conductor. Most of the 52 x 66 kV poles have been nailed and will require replacement within the next 5-10 years. The steel core of ACSR conductors corrodes over time so the Lemon conductor will also require replacement in the near future with AAC, AAAC or similar type conductor. The 66 kV circuit breakers at Fyshwick are ASEA type; four are 1971 vintage and one 1985. These are nearing the end of their economic lives and will require replacement within the next 5-10 years. 66 kV protection relays are approaching the end of their economic lives. Approximately $5.7 million will need to be expended over the next 5-10 years to upgrade / replace these 66 kV assets.

One of the original drivers for the establishment of East Lake Zone Substation in 2013 was to transfer the Fyshwick load to East Lake to enable Fyshwick Zone Substation to be retired and the 66 kV assets decommissioned. This is still an ActewAGL strategic objective which is proposed to be achieved by installing some high capacity express 11 kV feeders (ie feeders with no intermediate loads) from East Lake to Fyshwick, and converting Fyshwick to an 11 kV switching station only. Cables proposed are 11 kV 3c/400mm^2 Cu XLPE and these would replace the existing transformer incomer cables at the three Fyshwick 11 kV switchgear groups. These express cables would be rated at approximately 10.5 MVA each continuous, providing 31.5 MVA maximum capacity to Fyshwick and 21 MVA firm capacity. Other feeders would be run from East Lake to the Fyshwick and Majura areas (under separate projects), to reduce the maximum demand on the Fyshwick 11 kV switchboard to less than 21 MVA.

The proposed cable route length from East Lake to Fyshwick is approximately 2.7 km. Three spare 150mm diameter PVC conduits exist from East Lake Zone Substation approximately 1.8 km towards Fyshwick. Thus only 900m would be required to be directional drilled and have conduits installed to Fyshwick Zone Substation.

Estimated cost is $5.46 million. Proposed project completion is by June 2024.

The augmentation cost of this proposal exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). A RIT-D will be commenced in 2022.

7.5.5 Decommissioning of Causeway 132 kV Switching Station

The Causeway Switching Station located in the Kingston suburb at the eastern end of Lake Burley-Griffin, provides a point of 132 kV interconnection between City East, East Lake, Telopea Park and Gilmore zone substations. Connections to Causeway Switching Station comprise three 132 kV underground cable circuits to Telopea Park Zone Substation, a single circuit 132 kV overhead line to Gilmore Zone Substation, a single circuit 132 kV overhead line to City East Zone Substation, and a single circuit 132 kV overhead line to East Lake Zone Substation. Sections of these latter two lines traverse the Jerrabomberra wetlands nature reserve.
The site of Causeway Switching Station is surrounded by new apartment buildings and there is a desire by the SLA to redevelop the switching station site for similar residential purposes. The SLA has requested ActewAGL to convert the 132 kV overhead lines in the vicinity of Causeway to underground cables and decommission the switching station. The proposed scope of works is as follows:

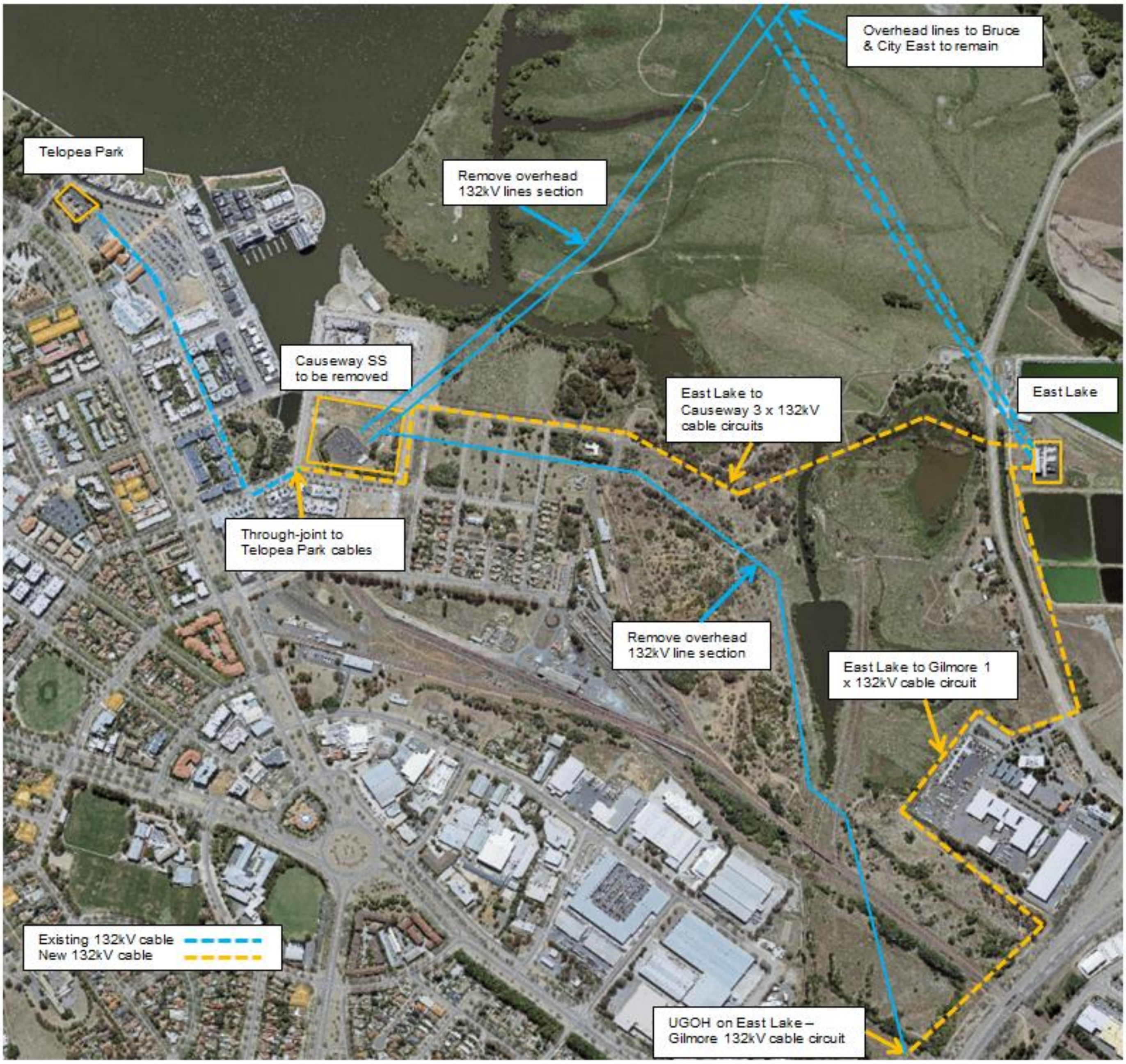
- Install three 132 kV cable circuits comprising one single core cable per phase (each circuit 3 x 1c/630mm^2 Cu XLPE) from East Lake Zone Substation through the Jerrabomberra wetlands to Causeway Switching Station to through-joint to the existing Causeway–Telopea Park cable circuits. This route includes directional drilling under the Jerrabomberra Lake. This will create three 132 kV underground cable circuits all the way from East Lake to Telopea Park, each rated at 127 MVA. These existing circuits are currently transformer feeders as there is no 132 kV bus at Telopea Park Zone Substation. It is proposed to retain them as transformer feeders.

- The East Lake–Causeway 132 kV circuit is currently approx 1.4 km underground cable connected to approx 1.6 km overhead line. The cable section will be reconnected to the City East line and the overhead section demolished. This will create a new East Lake–City East 132 kV circuit rated at 220 MVA.

- The Causeway–Gilmore 132 kV circuit is currently all overhead. A 132 kV underground cable circuit comprising twin single core cables per phase (6 x 1c/1200mm^2 Cu XLPE) will be installed approx 2.0 km from East Lake Zone Substation to connect to the existing overhead line at a new three concrete pole UGOH structure to replace pole no T87 at the corner of Canberra Ave and Monaro Highway. This will create a new East Lake–Gilmore 132 kV circuit rated at 457 MVA.
- Causeway Switching Station will be subsequently decommissioned and dismantled.

The overhead to underground conversion works will be funded by the developer. Decommissioning of Causeway Switching Station by ActewAGL is estimated to cost $2.00 million and proposed project completion is by June 2020. Figure 7.5 illustrates this proposed development.

Figure 7.5: Causeway Switching Station – Proposed 132 kV Cabling



7.5.6 Supply to Gungahlin Town Centre

The maximum demand in the Gungahlin Town Centre East area is forecast to increase by approximately 16.2 MVA by winter 2018 with the development of new residential suburbs at Throsby, and Kenny, along with several commercial and residential developments in the Gungahlin Town Centre East precinct, including the Gungahlin Cinema, Canberra Metro Traction Power Station (TPS), medical centre, and other mixed use buildings.

Approximately 6.8 MVA of this load can be met by fully utilising the existing 11 kV network in the area, transferring loads between feeders and between zone substations, and by the new Hamer feeder which is due to be installed by December 2017. This leaves a shortfall of 9.4 MVA additional supply capacity required to the area by June 2018.

Network and non-network options have been evaluated including new 11 kV feeders from Gold Creek or Belconnen zone substations, demand side management and embedded generation.

ActewAGL has considered two options to supply the Gungahlin Town Centre East area as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct two new 11 kV cable feeders from Belconnen Zone Substation	$7.77 m	Not Preferred
2	Network	Construct two new 11 kV cable feeders from Gold Creek Zone Substation	$3.54 m	Preferred

Option 1 involves the installation of two new 11 kV cable feeders from Belconnen Zone Substation to the Gungahlin area. There are no spare 11 kV feeder circuit breakers at Belconnen Zone Substation so the new feeders would have to be connected in parallel with existing feeders. The length of these feeders would be approximately 11.6 km. This is not the lowest cost option and is not preferred.

Option 2 involves the installation of two new underground 11 kV cable feeders from Gold Creek Zone Substation to the Gungahlin area. Two feeder circuit breakers will be made available at Gold Creek Zone Substation through another project. The length of these feeders will be approximately 4.6 km and 5.3 km. Spare conduits will be installed along the feeder routes to provide for future developments. This is the lowest cost option and is preferred.

Estimated cost is $3.54 million and proposed project completion is by June 2018.

7.5.7 Supply to Mitchell

Mitchell is a light industrial and commercial suburb in the Gungahlin District. Peak demand at Mitchell is forecast to grow by 12.3 MVA by 2022. The objective of this project is to provide capacity to the growing industrial load in the Mitchell area. There is insufficient spare capacity in existing 11 kV feeders in the area. ActewAGL has considered two options to supply this load as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct three new 11 kV cable feeders from Belconnen Zone Substation to Mitchell	$8.16 m	Not Preferred
2	Network	Construct three new 11 kV cable feeders from Gold Creek Zone Substation to Mitchell	$5.70 m	Preferred

Option 1 involves the installation of three new 11 kV cable feeders from Belconnen Zone Substation to the Mitchell area. The length of these feeders would be approximately 8.1 km. This is not the lowest cost option and is not preferred.

Option 2 involves the installation of a three new 11 kV cable feeders from Gold Creek Zone Substation to the Mitchell area. The length of these feeders would be approximately 6.3 km. Spare conduits will be installed along the feeder route to provide for future developments. This is the lowest cost option and is preferred. Estimated cost is $5.70 million and proposed project completion is by June 2022.

The augmentation cost of this proposal exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). ActewAGL proposes to commence the RIT-D consultation process in July 2020.

7.5.8 Supply to Belconnen

There are several proposed developments in the Belconnen area that will increase demand in the area over the next few years. Developments such as the Republic, a precinct of five proposed apartment buildings, is driving residential growth, and proposed development of the Belconnen Trades Centre is driving commercial and light industrial growth.

Load is forecast to increase by up to 9.5 MVA by 2022. There is insufficient spare capacity in existing 11 kV feeders in the area.

ActewAGL has considered two options to supply this load as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct three new 11 kV cable feeder from Latham Zone Substation to Belconnen Town Centre	$5.03 m	Not Preferred
2	Network	Construct three new 11 kV cable feeder from Belconnen Zone Substation to Belconnen Town Centre	$3.39 m	Preferred

Option 1 involves the installation of three new 11 kV cable feeders from Latham Zone Substation to the Belconnen Town Centre area. The length of these feeders would be approximately 4.8 km. This is not the lowest cost option and is not preferred

Option 2 involves the installation of three new 11 kV cable feeders from Belconnen Zone Substation to the Belconnen Town Centre area. The length of these feeders would be approximately 2.6 km. This is the lowest cost option and is preferred. Estimated cost is $3.39 million and proposed project completion is by June 2022.

The augmentation cost of the most expensive credible option exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). ActewAGL proposes to commence the RIT-D consultation process in July 2020.

7.5.9 Supply to Tuggeranong Town Centre

The maximum demand in the Tuggeranong Town Centre area is forecast to increase by approximately 8 MVA by 2020 with the development of a number of mixed-use residential and commercial buildings adjacent to Lake Tuggeranong (4.35 MVA) and in the West Greenway area (3.66 MVA).

The 11 kV feeders supplying the developments in the West Greenway area (Rowland and Pitman) have sufficient spare capacity available to meet this demand.

The 11 kV feeders supplying the developments around Lake Tuggeranong (Matthews and Fincham) do not have sufficient spare capacity available to meet this forecast additional demand. Short term load transfers have been arranged to free up spare capacity on the Matthews feeder however further network augmentation will be required.

ActewAGL has considered two options to supply the Tuggeranong Town Centre area as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct new 11 kV cable feeder from Wanniassa Zone Substation	$2.48 m	Preferred
2	Network	Construct new 11 kV cable feeder from Theodore Zone Substation	$7.62 m	Not Preferred

Option 1 involves the installation of a new underground 11 kV cable feeder from Wanniassa Zone Substation to the Tuggeranong Town Centre area. There is no spare 11 kV feeder circuit breaker at Wanniassa Zone Substation so a circuit breaker would be made available by paralleling two other lightly loaded feeders. Wanniassa Zone Substation has a continuous summer rating of 95 MVA with maximum demand around 80 MVA, so has spare capacity available for this development. The length of this feeder will be approximately 7.2 km. A spare conduit is available for approximately 6.9 km of this route. This option includes the installation of a new 11 kV cable feeder tie between the Sternberg and Matthews feeders. This is the lowest cost option and is preferred. Estimated cost is $2.48 m and proposed project completion is by December 2020.

Option 2 involves the installation of a new 11 kV cable feeder from Theodore Zone Substation to the Tuggeranong Town Centre area. There is a spare 11 kV feeder circuit breaker at Theodore Zone Substation. The length of this feeder would be approximately 8.1 km. There is no spare conduit available along any of this route. This is not the lowest cost option and is not preferred.

Viable proposals from third parties that can significantly reduce maximum demand of the Tuggeranong Town Centre development and enable ActewAGL to defer construction of the new 11 kV feeder are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 0.5 MVA in 2017, 2.03 MVA by 2018, 3.43 MVA by 2019, and 4.03 MVA by 2020, to enable the proposed 11 kV feeder project to be deferred.

The augmentation cost of the most expensive credible option exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). ActewAGL proposes to commence the RIT-D consultation process in July 2018.

7.5.10 Supply to Canberra City and Dickson

The maximum demand in central Canberra City is forecast to increase steadily to 20 MVA, and that in the Dickson area to 8.25 MVA over the next 7 years as proposed new residential and commercial developments are completed. The load in this area is typically summer peaking.

The current maximum demand at City East Zone Substation is approximately 75 MVA. The substation's continuous summer rating is 95 MVA. The existing combined summer firm rating of 11 kV feeders supplying the Canberra City and Dickson areas is 53.8 MVA (Canberra City 25.9 MVA, Dickson 27.9 MVA), and the combined available spare capacity is 13.4 MVA (Canberra City 9.8 MVA, Dickson 3.6 MVA). The forecast load growth in these areas indicates the available spare capacity will be fully utilised by 2021 and around 11.9 MVA (Canberra City 10.5 MVA, Dickson 1.4 MVA) will be at risk by 2023.

The proposed developments include block loads such as the Canberra Metro Traction Power Station TPS4, and multi storey residential and commercial buildings proposed to be constructed in the Canberra City and Dickson areas. According to the Suburban Land Agency's Indicative Land Release program for 2017-21, there is approximately 24,500 m^2 of mixed-use development, 3,400m^2 of commercial development, and 1,140 residential dwellings proposed to be constructed in the Canberra City and Dickson areas.

ActewAGL has considered three options to supply the Canberra City and Dickson developments as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct new 11 kV cable feeder from City East Zone Substation to Canberra City and extend Haig feeder to Dickson area in two stages during 2019-20 and 2020-21 financial years.	$4.16 m	Preferred
2	Network	Construct new 11 kV cable feeder from Civic Zone Substation to Canberra City and extend Haig feeder to Dickson area in two stages during 2019-20 and 2020-21 financial years.	$7.22 m	Not preferred
3	Network	Demand side management and embedded generation	N/A	Not preferred as does not meet need

Option 1 involves the construction of a new 11 kV feeder from City East Zone Substation to the Canberra Centre extension, and extension of the Haig feeder to the Dickson area. The combined length of these feeder extensions would be approximately 4.5 km. This option has the highest NPV and is preferred.

Option 2 involves the construction of a new 1 kV feeder from Civic Zone Substation to the Canberra Centre extension, and extension of the Haig feeder to the Dickson area. The combined length of these feeder extensions would be approximately 8.1 km. This option has a lower NPV and is not preferred.

Estimated cost is $4.16 million and proposed project completion is by June 2021.

Viable proposals from third parties that can significantly reduce maximum demand of the Canberra City and Dickson areas and enable ActewAGL to defer construction of the new 11 kV feeder are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 3.9 MW pa from 2018 onwards, to enable the proposed 11 kV feeder project to be deferred.

The augmentation cost of the most expensive credible option exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). ActewAGL proposes to commence the RIT-D consultation process in July 2019.

7.5.11 Supply to Canberra CBD Central

The maximum demand in the Canberra Central Business District (CBD) is forecast to increase steadily over the next five years with major residential and commercial developments along with the ACT Government's City to the Lake long term urban renewal plan. The load in this area is typically summer peaking.

The current loading of Civic Zone Substation is approximately 60 MVA. Its continuous summer rating is 110 MVA. The existing combined summer firm rating of the four 11 kV feeders in the vicinity of the proposed developments around Canberra CBD is approximately 17.8 MVA and the combined available spare capacity is 5.6 MVA. The forecast load growth in these areas indicates the available spare capacity will be fully utilised by 2021 and approximately 4.1 MVA load will be at risk by 2023.

Notable preliminary connection enquiries have been received for redevelopment of existing open air carparks including: 8.3 MVA in 2020 for expansion of the Canberra Centre at City S96; 6.5 MVA in 2019 for a multi-use complex at City B21 S63; 2 MVA in 2020 for a commercial development on Constitution Avenue; 1.5 MVA in 2019 for a multi-use complex at City B4 S 19; and 2 MVA in 2018-19 for other miscellaneous mixed-use developments around London Circuit and Northbourne Ave.

ActewAGL has considered three options to supply the Canberra CBD developments as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct new 11 kV cable feeder from Civic Zone Substation to London Circuit during 2019-20 financial year.	$1.27 m	Preferred
2	Network	Construct new 11 kV cable feeder from City East Zone Substation to London Circuit during 2019-20 financial year.	$3.86 m	Not preferred
3	Network	Demand side management and embedded generation	N/A	Not preferred as does not meet need

Option 1 involves the construction of a new 11 kV feeder from Civic Zone Substation to the Canberra CBD at London Circuit. The length of this feeder would be approximately 3.6 km. This option has the highest NPV and is preferred.

Option 2 involves the construction of a new 11 kV feeder from City East Zone Substation to the Canberra CBD at London Circuit. The length of this feeder would be approximately 4.0 km. This option has a lower NPV and is not preferred.

Estimated cost is $1.27 million and proposed project completion is by June 2020.

Viable proposals from third parties that can significantly reduce maximum demand of the Canberra CBD area and enable ActewAGL to defer construction of the new 11 kV feeder are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 3.9 MW pa from 2018 onwards, to enable the proposed 11 kV feeder project to be deferred.

7.5.12 Supply to Canberra CBD West

Canberra City CBD west area is experiencing significant growth in terms of residential redevelopments (old detached houses being replaced by multi-storey apartment buildings), particularly in the Acton, Braddon, O'Connor and Lyneham areas. The load forecast for these developments is estimated to be an additional 6.0 MW of residential load.

There are several existing 11 kV feeders in the area supplied by Civic Zone Substation, all of which are heavily loaded. There is insufficient spare capacity available in these feeders that could be used to supply these new developments, so a new feeder is proposed. Civic Zone Substation has a continuous summer rating of 110 MVA with maximum demand around 70 MVA, so has spare capacity available for these developments.

It is proposed to install an 11 kV cable feeder to an existing11 kV switching station at Edinburgh St, CBD west, from a spare feeder circuit breaker at Civic Zone Substation. The length of this feeder will be approximately 3.3 km. The first section of this feeder (approximately 2 km) will be installed in a common trench with proposed new feeders to the Australian National University. Spare conduits will be installed along the feeder route to provide for future developments.

Estimated cost is $2.77 million and proposed project completion is by June 2019.

Demand management could possibly defer the need for this project. Potential demand management options to relieve existing and forecast feeder constraints include:

- On-site embedded generation used to reduce peak demands.
- Demand response by larger commercial customers to reduce peak demands.

Suitable embedded generation would be required to operate daily during peak load periods. Demand response by larger customers requires predetermined and guaranteed demand reduction actions at the participating customer sites.

Viable proposals from third parties that can significantly reduce maximum demand of the Canberra Central City area to defer construction of the new 11 kV feeder are welcome.

7.5.13 Supply to Kingston

The ACT Government's Environment and Sustainable Development Directorate (ESDD) has prepared a plan for the development of the area of land at the eastern end of Lake Burley-Griffin between Kingston and Fyshwick, including commercial and residential developments.

The development will comprise approximately 3,850 residential dwellings, a commercial centre and a school. The residential dwellings will be primarily multi-storey apartment buildings.

The load forecast for this development is estimated to be 9.7 MW, comprising 7.7 MW of residential load and 2.0 MW of commercial and community use (school) load.

There are no existing 11 kV feeders in this area which is approximately 3 km east of Telopea Zone Substation and 2 km west of East Lake Zone Substation. Telopea Zone Substation has a continuous summer rating of 100 MVA with maximum demand around 108 MVA, so has no spare capacity available for this development.

East Lake Zone Substation has a single 55 MVA transformer only at present though a second 55 MVA is planned by June 2019 (refer section 7.5.2), with maximum demand around 16 MVA, so has spare capacity available for this development.

ActewAGL has considered three options to provide additional capacity to the Kingston Foreshore area as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct three new 11 kV cable feeders from Telopea Park Zone Substation to Kingston Foreshore area	$3.14 m	Not Preferred
2	Network	Construct three new 11 kV cable feeders from East Lake Zone Substation to Kingston Foreshore area	$1.02 m	Preferred
3	Network	Demand side management and embedded generation	N/A	Not preferred as does not meet need

It is proposed to install two 11 kV cable feeders to this area from East Lake Zone Substation from existing spare feeder circuit breakers. The length of each feeder will be approximately 2.0 km. Spare conduits will be installed along the feeder routes to provide for future developments.

Estimated cost is $1.02 million and proposed project completion is by June 2020.

7.5.14 Supply to Pialligo

The electricity demand in the Pialligo area near Canberra Airport is forecast to increase due to commercial development including the Brindabella Business Park and Fairbairn Business Park. The maximum demand of the area is forecast to increase by 8 MW over the next 5 years.

The Pialligo area is currently supplied by the Aero Park 11 kV feeder from City East Zone Substation, the Airport and Pialligo 11 kV feeders from Fyshwick Zone Substation, and the Dairy North 11 kV feeder from East Lake Zone Substation. There is insufficient spare capacity in these feeders to meet the forecast growth in demand.

ActewAGL has considered three options to supply the Pialligo area developments as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct two new 11 kV cable feeders from East Lake Zone Substation, and link Dairy North to Abbatoir feeders	$4.28 m	Preferred
2	Network	Construct new 11 kV cable feeder from Fyshwick Zone Substation, new 11 kV cable feeder from East Lake Zone Substation, and link Dairy North feeder to Abbatoir feeder	$4.37 m	Not preferred
3	Network	Demand side management and embedded generation	N/A	Not preferred as does not meet need

Option 1 involves the installation of two new 11 kV cable feeders from East Lake Zone Substation. One feeder from East Lake is proposed to be installed to the Brindabella Business Park near Canberra Airport to meet the growing customer demand. The length of this feeder would be approximately 3.2 km. The second feeder from East Lake would enable the overloaded Dairy North feeder to be split into two separate feeders – Dairy North and Dairy East. The proposed Dairy East feeder would supply the forecast demand of the Fairbairn Business Park. Additionally it is proposed to link the Dairy North and Abbatoir feeders via a new 1.2 km long cable feeder tie. This would improve backup security to these two feeders and enable some load transfer from Dairy North to Abbatoir feeder. This option has the highest NPV and is preferred.

Option 2 is similar to Option 1 except a new feeder would be installed to Brindabella Park from Fyshwick Zone Substation (instead of from East Lake). This option has a lower NPV and is not preferred.

Estimated cost is $4.28 million and proposed project completion is by June 2020.

Viable proposals from third parties that can significantly reduce maximum demand of the Pialligo area and enable ActewAGL to defer construction of the new 11 kV feeders are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 2.0 MW pa from 2018 onwards, to enable the proposed 11 kV feeders project to be deferred.

7.5.15 Molonglo Valley 11 kV Feeders

The maximum demand in the Molonglo Valley is forecast to increase steadily to 50 MW over the next 30 years as load grows in the new and developing suburbs of North Weston, Coombs, Wright, Denman Prospect and Whitlam. The development of this area will include 21,000 residential dwellings, plus commercial and community facilities. Existing 11 kV feeders to the area have insufficient capacity to meet the forecast load beyond winter 2021.

A new zone substation is to be constructed to supply the growing demand of the Molonglo Valley. The proposed Molonglo Zone Substation will be equipped initially with ActewAGL's 132/11 kV 14 MVA mobile substation by June 2022.

The proposed new 11 kV feeders from Molonglo Zone Substation will supply the new suburbs and will eventually inter-tie with Civic, Woden, Belconnen and Latham zone substations, with the opportunity to offload these zone substations onto Molonglo Zone Substation, especially Woden which is forecast to become non-firm by 2025.

The proposed Molonglo Zone Substation site is on the northern side of William Hovell Drive approximately 500 m to the east of Coulter Drive.

11 kV feeders from the new zone substation will be installed progressively to serve the residential areas as they develop.

Estimated cost for seven new 11 kV feeders is $6.71 million. Feeder installations will be carried out in stages as development and load increases.

7.5.16 Supply to Strathnairn

The development of the West Belconnen District is being carried out by a joint partnership between the ACT Government's Suburban Land Agency and Riverview Developments Pty Ltd. 11 kV feeders along with low voltage reticulation will be installed throughout the new suburbs of Strathnairn and Macnamara as they are developed. The maximum demand in the West Belconnen District is forecast to increase steadily to 45 MVA over the next 30 years as development proceeds. The development of this area will include 11,500 residential dwellings, plus commercial and community facilities.

ActewAGL proposes to construct a new Strathnairn Zone Substation to supply this area with timing scheduled for approximately 2025-26. Until then, supply to the area will be from existing 11 kV feeders from Latham Zone Substation that will be extended into the area.

Maximum demand is forecast to grow initially at approximately 0.8 MVA per annum.

There are two existing 11 kV feeders to this area, Macrossan and Latham feeders from Latham Zone Substation. Together they have approximately 1.4 MVA spare summer firm capacity only.

To meet demand until the Strathnairn Zone substation is available it is proposed to extend the existing O'Loghlen feeder from Latham Zone Substation into Strathnairn. Load transfers will be made from this feeder to other adjacent feeders to provide sufficient spare capacity to meet the forecast demand.

The developers of Strathnairn have mandated the compulsory installation of rooftop PV generation on all dwellings plus energy efficiency initiatives including reverse-cycle heat pumps and in-home demand management systems. These systems will be used to manage the combined load on the feeders to as low a level as possible.

11 kV feeders from the new zone substation will be installed progressively to serve the residential areas as they develop.

Estimated cost for extending the O'Loghlen feeder to the first stage of Strathnairn is $1.58 million with proposed completion by December 2019. Future feeders will be installed from the proposed Strathnairn Zone Substation in stages as development and load increases.

7.5.17 Installation of OPGW on 132 kV transmission lines

The existing ActewAGL SCADA telecommunications network is a mix of UHF digital radios (DDRN) and pilot wires, with some small scale use of optical fibre and microwave links. The network is extremely limited in capacity and does not provide adequate and timely real time SCADA information for effective Control Centre operations, with some analogue and digital changes taking several minutes to be reported.
The performance constraints of the network present a roadblock to realising the benefits of the SCADA system and this will only become more apparent with the implementation of the Advanced Distribution Management System (ADMS), where real time data is critical to correctly calculate the network state, load flows and correctly report network outages.

In addition to SCADA communications, the other critical application for communications is with ActewAGL's network protection. Increasingly some aspects of the protection systems will require communications to overcome protection performance and grading issues. In particular, the performance of the existing 132 kV network protection falls short of technical compliance with the current National Electricity Rules. These performance shortcomings are considered acceptable due to 'grandfathering' provisions within the Rules, but as network upgrades and augmentations occur the network protection will need to be brought into compliance with current standards.

Augmentations such as connecting generators to the network, or when the 132 kV network is upgraded or modified, are triggers for protection upgrades. Required protection upgrades may include the implementation of inter-tripping and line differential protection schemes and these are dependent on reliable and secure communications. In the future, the emergence of IEC 61850 as the industry standard substation automation and protection communications standard will require a very high level of reliability in the communications network.

The objective of this project is to replace existing communication networks with an optical fibre network that can deliver the speed, security, reliability and functionality required for the electricity network. It will be used to provide the communications bearer for the following systems:

- Zone substation protection signalling, including communications for inter-tripping and line differential protection.
- SCADA communications to zone substations, fault passage indicators, reclosers, switches and distribution substations.
- Security video and remote access management.
- Substation VoIP telephone.
- Corporate data services.
- Advanced metering infrastructure (AMI) communications.
- Inter station protection and control schemes.
- Intra station protection schemes utilising IEC 61850 and "GOOSE" messaging. Generic Object Oriented Substation Events (GOOSE) is a controlled model mechanism in which any format of data (status or analogue value) is grouped into a data set and transmitted within a time period of 4 milliseconds.
- Substation engineering access, for example remote access to protection relay fault records.
- Mobility communication to vehicles & deployed mobile tablets/computers.
- Network video, for example infrared cameras for switchyard fault detection.
- Monitoring and management of the communication network.

The optical fibre cables will follow each of ActewAGL's 132 kV transmission lines, and will be strung on the same pole or tower structures.

Estimated cost is $5.25 million and the project will be implemented over a four year period from 2015 to 2018.

No non-network alternative to this project has been identified.

7.5.18 SCADA communications upgrade, optic fibre to distribution substations

The installation of fibre optic cables to individual distribution substations will be required in the following situations:

- Replacement of existing copper pilot cables with fibre due to failure of the metallic pilot.
- Additional business requirement such as chamber substation SCADA.
- Additional network protection requirements such as protection inter-tripping.
- Network automation requirements such as flop-over schemes for critical customers such as hospitals.
- High voltage customer and generator network connections.

It is proposed to roll out an optic fibre network to distribution substations over the next ten years at an annual estimated cost of approximately $407,000 pa.

No non-network alternative to this project has been identified.

7.5.19 Distribution System Limitations

Appendix F lists the proposed distribution augmentation projects and provides details of capacity and timing of non-network or demand management options required to defer the augmentation project.

7.6 Projects Subject to the Regulatory Investment Test

If the augmentation or replacement cost of a credible option for a proposal exceeds $5 million, we undertake a Regulatory Investment Test in line with the requirements of the NER (Section 5.16 for transmission RIT-T and Section 5.17 for distribution RIT-D). The purpose of the Regulatory Investment Test is to identify the credible option that maximises the present value of net economic benefit to all those who produce, consume and transport electricity in the market. A preferred option may have a negative net economic benefit (that is, a net economic cost) where the identified need is for reliability corrective action. The RIT process considers all credible options that are technically and economically feasible, including non-network options.

Table 7.2 lists the projects proposed to commence in the five-year planning period that have a credible option augmentation or replacement component cost exceeding $5 million and will be subject to the RIT-D.

Interested parties are invited to participate in the planning process through the RIT-D consultation process.

Table 7.2: Projects Subject to the Regulatory Investment Test for Distribution

Proposed project	Identified Need	Estimated Cost	Start RIT-D
Supply to Tuggeranong Town Centre	Load growth in the Tuggeranong Town Centre area will require additional 11 kV feeders to be supplied from Wanniassa Zone Substation.	$2.48 m	July 2018
Establishment of Molonglo Zone Substation	The existing network will not be able to meet forecast demand from new residential developments in the Molonglo District due to supply capacity constraints.	$22.51 m	July 2019
Molonglo Valley 11 kV Feeders	Load growth in the Molonglo Valley will require additional 11 kV feeders to be supplied from proposed Molonglo Zone Substation.	$6.71 m	July 2019
Supply to Canberra City and Dickson	Load growth in the Canberra City and Dickson areas will require an additional 11 kV feeder to be supplied from City East Zone Substation.	$4.16 m	July 2019
Supply to Mitchell	Load growth in the Mitchell area will require additional 11 kV feeders to be supplied from Gold Creek Zone Substation.	$5.70 m	July 2020
Supply to Belconnen	Load growth in the Belconnen Town Centre area will require additional 11 kV feeders to be supplied from Belconnen Zone Substation.	$3.39 m	July 2020
Decommission Fyshwick Zone Substation	Fyshwick Zone Substation has 66 kV primary and secondary approaching their end of life. It is more economic to convert Fyshwick to an 11 kV switching Station and supply it from East Lake Zone Substation.	$5.46 m	July 2022

Note the proposed Second Point of Supply to the ACT project (as described in Section 7.5.1) was part of a joint RIT-T completed in 2009 by ActewAGL and TransGrid for the program of projects required to provide a second point of supply to the ACT. Works are expected to be completed on this project by March 2020.

ActewAGL has no projects subject to the RIT-D currently underway or completed within the last year.

7.7 Inter-Regional Impact of Projects & Relevant National Transmission Flow Path developments

National Transmission Flow Paths (NTFPs) are those portions of transmission networks used to transport large amounts of electricity between generation and load centres. These are generally transmission lines of nominal voltage 220 kV and above. The Australian Energy Market Operator (AEMO) publishes an annual National Transmission Network Development Plan (NTNDP), the purpose of which is to facilitate the development of an efficient national electricity network that considers forecasts of constraints on the NTFPs.

ActewAGL has no network infrastructure above 132 kV operating voltage.

The 2016 NTNDP discusses the integration of renewable generation and emerging technologies to the transmission grid, and the trend of expenditure to replacing ageing infrastructure outweighing investment in new network capacity. Ancillary services such as Network Support and Control Ancillary Services (NSCAS) and Frequency Control Ancillary Services (FCAS) are not regarded as an issue for ActewAGL due to the relatively small size of our network compared with other networks in the NEM, and the relatively small percentage of embedded generation connected to our network.

The 2016 NTNDP suggests there could be significant growth of residential battery storage systems with a 14 kWh battery with integrated inverter currently selling in Australia for approximately $10,150. Prices are expected to continue to decline as technology and manufacturing processes improve.

None of the proposed projects described in this chapter will have a material inter-regional impact, ie they will not impose power transfer constraints or adversely influence the quality of supply to adjoining transmission or distribution networks.

7.8 Strategic Planning

ActewAGL is preparing a long-term strategy (ie 30-year plan) for development of the transmission and distribution network. This strategy document will examine the long term load forecasts for the ACT; long term known developments such as the Molonglo Valley, Mitchell, West Belconnen, Gungahlin and Tuggeranong precincts; the potential impact of emerging technologies such as micro grids, embedded generation, smart networks, smart metering, electric vehicles, battery storage, hydronic and vacuum waste services; dynamic ratings for transmission lines and power transformers; and identify any opportunities for stakeholder input.

The impact of our changing environment, e.g. climate change and the Government’s renewable energy targets and plan to reduce greenhouse gas emissions, are key drivers in determining future investment in both the generation and demand-side management sectors. The extent that customers will generate and store energy both for their own use and export, will have a major impact on the topology and dynamic control of the distribution network. These factors will influence future transmission and distribution infrastructure development and operation.

The ACT’s climate provides for future extensive solar power generation, though is not conducive to generation from other sources such as hydro and wind. The effectiveness of future battery energy storage systems coupled with solar PV generation, could have a major impact on ActewAGL’s future network operations.

Many of ActewAGL’s distribution assets are approaching the end of their economic life and strategies will be developed regarding their replacement. Such assets include urban backyard overhead low voltage lines. With increasing in-fill housing developments, these backyard lines are becoming increasingly difficult to access and maintain.

The long-term strategy plan will provide strategic direction for the efficient utilisation of existing assets and future development of ActewAGL's transmission and distribution networks, to ensure a long-term sustainable and reliable electricity supply to the ACT.

8. Demand Management

8.1. Overview of Demand Management

Demand management in the context of an electricity distribution network is deliberate action taken to reduce demand from the grid, rather than increasing supply capacity to meet increased demand.

Traditionally customers have consumed energy as and when they require it and network service providers such as ActewAGL have constructed their infrastructure to meet the maximum demand on the network allowing for adequate redundancy. Existing regulatory and revenue models in the Australian electricity industry have not provided any incentive for network service providers to manage peak energy use.

Demand management seeks to influence the patterns of energy consumption including the amount and rate of energy use, the timing of energy use and the source and location of energy supply. Demand management is an important part of efficient and sustainable network operations and can involve the voluntary reduction of customer electricity demand at peak times, network service provider controlled reduction of electricity demand, or the supply of electricity from generators or storage connected at customer’s premises or to the distribution network.

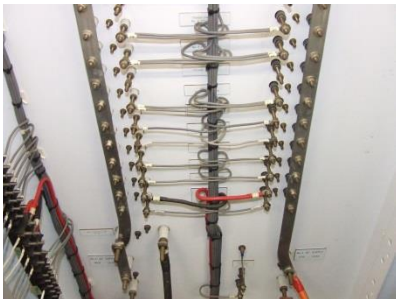
The majority of Australian electrical grids have very uneven loading, with a major portion of the grid capacity being unused for the majority of any given day or year. Nevertheless, significant expenditure is required to install and maintain this capacity to meet very short peak demand periods. By reducing peak load on the grid, security of supply can be maintained without installing additional infrastructure and its associated expenditure.

Historically there has been limited ability to manage peak demand on a network, but recent advances in smart metering and communications technologies mean that there are now a large number of methods to control loads and the cost of these options are reducing. We recognise that in order for the network to continue to provide high quality low cost service to consumers, demand management including peak load management, energy efficiency and distributed generation will be an integral part of future operations.

A demand management solution is referred to as a non-network solution and a demand management provider is referred to as non-network provider. ActewAGL actively engages with its customers and non-network solution providers to identify demand management options and will be striving to achieve significant advances in demand management in the future.

The growth in demand across our network is uneven; in some areas there is little or no growth, while in other areas demand is growing rapidly. Drivers for demand growth are varied, and include the development of new greenfield residential areas, urban renewal areas where single level dwellings are demolished and replaced by multi-storey apartment buildings, and the development of energy intensive businesses such as data centres.

Effective use of demand management can remove or defer the need to augment load-constrained parts of the network to meet growth in demand, and reduce the cost of replacing ageing assets, leading to lower costs to customers.ActewAGL is investigating ways to maximise the benefits of non-network technologies such as PV generation and battery energy storage, as well as manage the use of new loads such as electric vehicle charging stations, to reduce daily system peaks and produce as smooth a load profile as possible. The future use of alternative energy sources such as natural gas will greatly influence the demand on the electricity network.



8.2 Demand Side Engagement Strategy

We actively engage with our customers and non-network solution providers to identify demand management options. Our Demand Side Engagement Strategy (DSES) aims to create a cooperative and proactive relationship with customers and proponents of non-network solutions and involve them with our network planning and expansion. We encourage customers and potential non-network service providers to participate in our demand management activities with the objective of ensuring that a full range of solutions is considered and that emerging network constraints are resolved in a way that achieves optimal economical and technical outcomes.

The objectives of ActewAGL's Demand Side Engagement Strategy are:

- embrace Demand Side Management (DSM) and provide opportunities for our customers and non-network service proponents to participate in resolving network and customer supply limitations;
- develop and apply a transparent DSM process for network planning and development;
- identify DSM options for individual and broad based demand management situations;
- provide proponents of non-network solutions with simple and effective mechanisms for obtaining information on network development proposals; and
- develop demand management tools and industry alliances to readily facilitate non-network options.

A non-network option may involve reducing demand overall or at critical times on a particular part of the network. This reduction could be achieved in a number of ways, including demand response (DR) programs, peak shaving generation, embedded generation, energy storage at customer level or energy storage at a network level.

Central to our demand management strategy is that demand management must be cost effective. By deferring costly network solutions demand management actions will effectively be able to generate a revenue stream, part of which will then be accessible to the proponents of the demand management. This approach reduces the overall cost to augment and maintain the network and results in lower electricity costs to customers, while still incentivising demand management proponents.

8.3 Demand Side Management Programs

DSM programs are developed in a way that residential, commercial and industrial customers and third party businesses such as demand aggregators and curtailment service providers can easily participate.

These programs encourage customers to reduce their demand or use alternative energy sources for their energy needs when the network capacity is constrained.

We have introduced a number of initiatives under the AER's Demand Management Incentive Scheme (DMIS) which includes a Demand Management Innovation Allowance (DMIA). The capped allowance is to encourage distributors to investigate and conduct broad based and/or peak demand projects. Our current innovation allowance of $100,000 per annum will continue through the 2015-19 regulatory period.

Projects that have been or are being funded under the DMIA include the installation of power factor correction equipment at strategic locations around the distribution network, a trial of small scale batteries in residential customer installations, and the trial of a short term, short notice voluntary demand curtailment program.

ActewAGL is working with a number of partners on additional research and development projects, some of which may be funded through the DMIA. These will include a collaborative trial of demand management through a world first virtual demand trading platform, peak load lopping utilising existing customer owned embedded generation, incentivising operation of residential batteries for grid support, and a broad scale residential demand shifting program utilising our newly developed customer information portal.

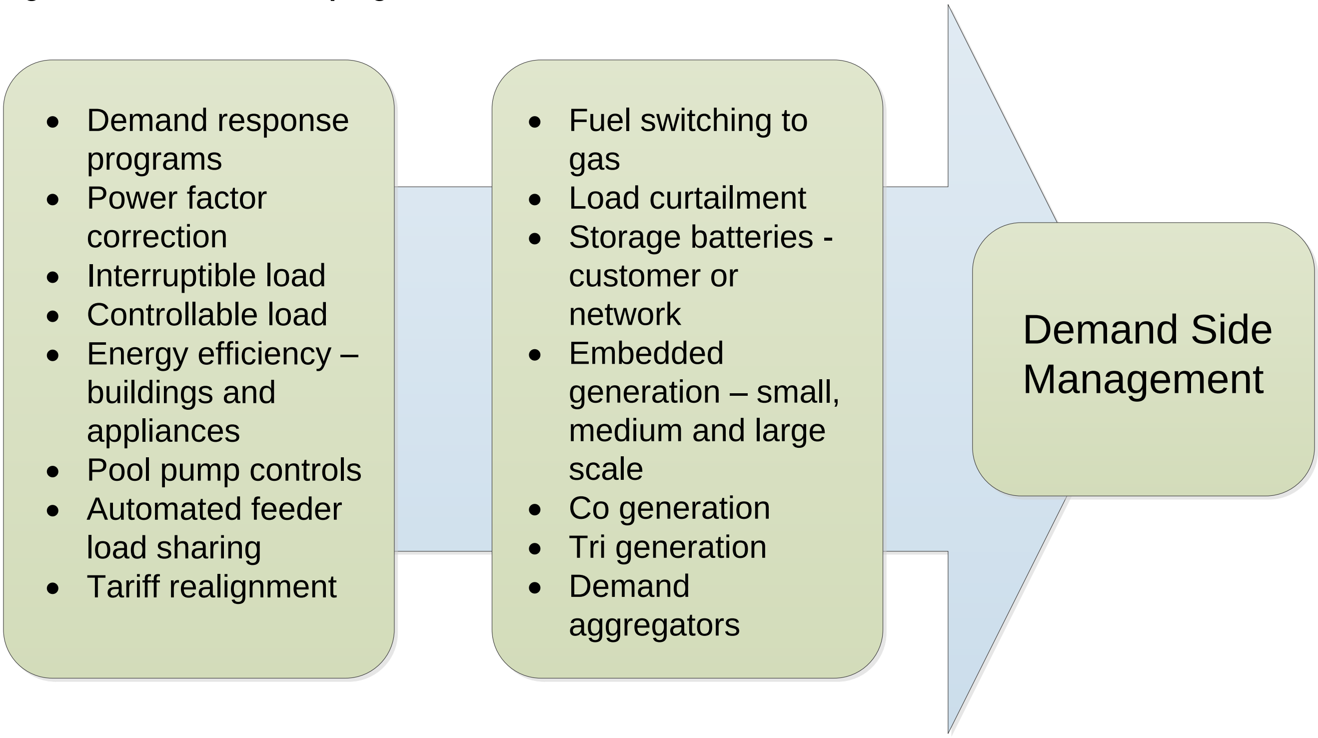
Beyond this we are developing a "smart suburb" in a new Canberra residential development, with smart meters providing customers with consumption data that they can use to reduce their electricity peak demand by making simple changes to how and when they operate a broad range of appliances and processes. As retailers roll out smart meters across the ACT this consumption data will become more valuable with the introduction of tariffs that include pricing signals to encourage customers to reduce demand at certain times of the day. This will serve to reduce maximum demand on the network as well as provide financial benefit to customers.

ActewAGL is looking to the future and planning for an increasing number of electric vehicles in the ACT. As a part of this we are investigating the Power to Grid potential of the battery storage of these vehicles.

ActewAGL continues to investigate the potential to supply customers in new micro-grid developments (refer to Section 9.7) with smart meters providing consumption data that they can use to reduce their electricity peak demand by making simple changes to how and when they operate a broad range of appliances and processes.

Potential DSM programs are illustrated in Figure 8.1.

Figure 8.1: Potential DSM programs



ActewAGL's demand management staff consults with customers and customer groups to identify their expectations and drivers for DSM participation and what they can offer in terms of demand reduction or switching to alternative energy sources. We maintain a Register of Interested Parties for Demand Management, and we actively consult with those parties. Public consultations, awareness programs and trial programs also form part of our investigation process. Details of potential DSM programs to be investigated will be published on the ActewAGL website as they arise.

8.4 Demand Management Options

Our demand management strategy aims to identify demand management options and assess their potential to solve network limitations and constraints for broad based and more specific local situations. Demand management options may be developed to reduce demand or supply the increasing demand from alternative sources. Some practical demand management options have been identified and categorised into the following groups.

8.4.1 Demand Reduction

The following demand management options are examples of schemes that aim to reduce demand and may be applicable to residential, commercial or industrial situations.

1. Demand response programs – we are currently investigating a number of options for these including simply asking customers to reduce demand at key times, directly controlling customer installations, working with demand aggregators who will provide the desired response, and creation of a demand response trading platform that will enable an open market.
2. Power factor correction.
3. Pool pump controls.
4. Water heating load controls.
5. Air conditioning controls.
6. Under-floor heating controls.
7. EV charging station control - discharging EV batteries into the home at peak demand times or simply controlling charging rates and charging times to avoid contributing to a new increased peak.
8. Automated feeder load sharing - dynamically transferring load between feeders as their relative loading changes to relieve pressure during localised peak demand periods.
9. Interruptible load controls and pricing.
10. Critical load reduction controls and pricing
11. Tariff realignment.
12. Energy efficiency – e.g. replacing streetlight mercury vapour and high pressure sodium luminaires with LED dimmable luminaires.
13. Building management systems for office buildings and apartment blocks.

8.4.2 Alternative Supply

The following demand management options are examples of where demand may be shifted by using alternative sources of supply.

1. Fuel switching to gas to supply space heating, water heating, cooking appliances and evaporative cooling systems.
2. Energy storage using battery banks, fuel cells and thermal storage systems.
3. Alternative fuel sources such as rooftop solar hot water heating or ground-source heat pumps.
4. Non-dispatchable embedded generation such as rooftop PV and micro-wind turbines (dispatchable systems are those that can simply be turned on or off when required, non-dispatchable systems are those that rely on an external driver, such as the sun shining or the wind blowing, to determine whether they operate or not).
5. On-site dispatchable generation such as diesel generators, open cycle gas turbines, co-generation and tri-generation[10] systems.

Customers and non-network proponents will be able to respond to demand management options and programs as they become available, or propose new innovative demand management options through our demand side engagement process.

[10] Tri-generation is the production of electricity, heat and cooling in the one process. Typically this means a gas fired generator producing electricity and heat with the exhaust heat going to an absorption chiller which produces chilled water and hot water for air conditioning or alternatively the heat is used to heat a swimming pool.

8.5 Network Opportunity Maps

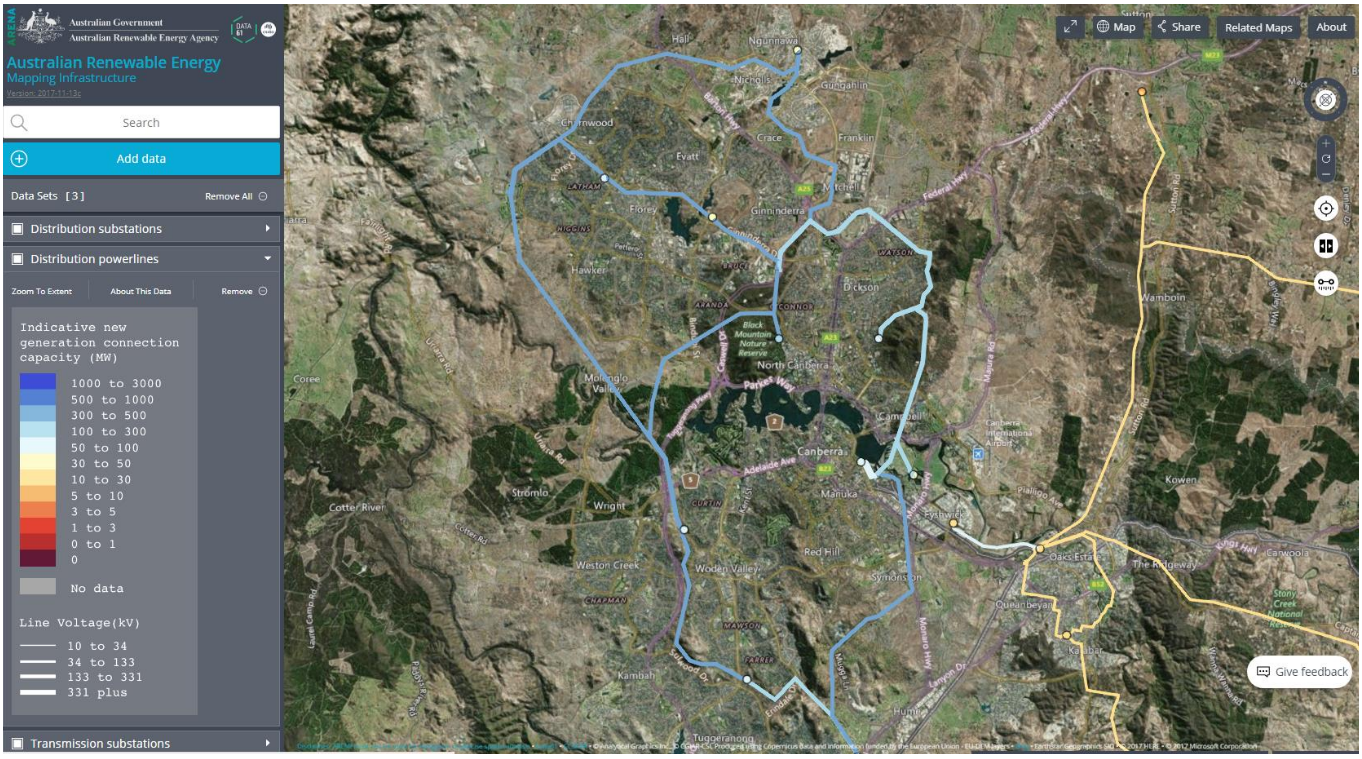
The Australian Renewable Energy Mapping Infrastructure (AREMI) is a website for map-based access to spatial data relevant to the renewable energy industry. The latest interactive maps of the Australian electricity grid to support more reliable, cleaner and local energy solutions were released on 31 October 2017. As an AREMI participant we have contributed data to generate these maps that highlight opportunities for demand management across our network area.

The Network Opportunity Maps provide detailed information to encourage local renewable energy, battery storage and smart demand management in the Australian electricity grid. The free, publicly available online maps aim to provide the information required to underpin the development of vibrant markets for new energy services, and avoid spending more on electricity distribution infrastructure in the future.

Alongside the 2017 released maps on the AREMI platform is the unveiling of a new “generator connection opportunity” layer that indicates how much new generation – such as solar and wind farms – can be connected to the grid in each geographical area. This resource will make it faster and easier to select the right location and size of clean energy projects. The Network Opportunity Maps are available on the AREMI site[11].

A sample view of the ACT is shown in Figure 8.2.

Figure 8.2: ACT generation connection opportunity (from AREMI website)



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11 https://nationalmap.gov.au/renewables/

9. Emerging Technologies

9.1 Overview of Emerging Technologies

The generation, transmission and distribution of electrical energy is changing rapidly with new advances in technology. These emerging technologies are impacting on all parts of the supply chain, for example:

Generation – traditional hydro and thermal generation is being supplemented by wind and solar generation, and emerging technologies such as fuel-cells, biomass generation and geothermal generation. This is being driven by an international desire to reduce carbon emissions and expand the use of renewable energy sources. Large generating plants which are typically distant from load centres are being supplemented with local embedded generation facilities located close to load centres.

Transmission – large capacity transmission lines are required to transport bulk energy from power stations to load centres. With the generation landscape changing to more local embedded generation, the need for such large transmission lines will decrease. Conductor types and shapes are changing, e.g. circular stranded copper and steel-cored aluminium conductors are being replaced by lighter aluminium alloy and composite-cored conductors with trapezoid-shaped strands to produce a smooth-bodied conductor that can operate at higher temperature and have lower wind drag than conventional conductors. The changes to conductor types as well as developments in materials science, are allowing a change in the size and shape of support structures from traditional lattice steel towers with suspension insulators to steel or concrete poles with cantilever insulators.

Distribution – areas of new development within the ACT such as greenfield estates are all reticulated with underground cables and underground pits where previously they would have featured surface-mounted pillars. Areas with high rooftop PV penetration are experiencing reverse power flow and voltage fluctuations which need to be managed. Energy storage systems such as batteries are becoming more efficient and affordable, and electrical appliances are becoming more energy efficient. These advances have the potential to reduce maximum demands on distribution systems which will reduce the required capacity of these systems. The proliferation of instantaneous hot-water heating systems and electric vehicles may have the opposite effect, driving an increase in demand. Remote-controlled and automated devices are leading to smart networks (e.g. automatic load transfer), self-healing networks (e.g. automatic isolation of faults), and smart meters that allow customers to monitor and control their energy usage, will lead to an entirely different load profile on the network.

ActewAGL is keeping abreast of these emerging technologies and future network planning will embrace these technologies to shape our network and benefit our customers.

9.2 Distributed Energy Resources

Distributed Energy Resources (DER) include localised embedded generation and energy storage facilities provided by a variety of small grid-connected devices. Conventional power stations such as hydro and coal-fired power stations are centralised and often require electricity to be transmitted over long distances. DER systems however, are decentralised, use a variety of non-conventional fuels (typically renewable energy sources such as solar, wind, bio-gas or bio-mass), and are located close to the load they serve. They usually have capacities of less than 10 MW.

ActewAGL's transmission and distribution network has grown from its inception in 1915 to an extensive overhead and underground network covering the ACT. Many assets are approaching the end of their economic lives. Increasing proliferation of DERs is forecast to decrease energy and demand growth on the network over the planning period. As demand growth decreases or flattens the requirement for network augmentation works decreases. Asset replacement is becoming a greater investment driver than network augmentation. ActewAGL is investigating ways to reduce future asset replacement costs, and the increasing use of DERs is regarded as a means to achieve this.

9.3 Embedded Generation

Generators connected directly to ActewAGL's distribution network rather than through the transmission network are called Embedded Generators (EGs).

There are a number of different types of embedded generator connected to our network as follows:

- Solar Photovoltaic
- Bio-gas (from land fill sites)
- Micro Hydro
- Cogeneration
- Fuel Cell

Capacities of these EGs vary from domestic solar PV systems of typically 1-3 kW to a 20 MW solar PV farm. The total installed capacity of embedded generation is approximately 115 MW. Of this 59.8 MW is rooftop solar PV (refer Appendix E) and the remainder is a mixture of solar, hydro, gas and co-generation (refer Section 7.2).

The process for connecting an Embedded Generator to ActewAGL's network depends mainly on its capacity. Capacity is divided into three categories: micro, medium and large. Table 9.1 below lists the categories, capacities and network connection points that apply to each.

Table 9.1: Embedded Generator Network Connection Points

Category	Capacity	Network Connection Point	Type of Generator
Micro	Less than 30 kW	230 V ~ 400 V – Low Voltage Network	Solar PV Micro Wind (Future) Micro Gas (Future)
Medium	30 kW – 200 kW	400 V – Low Voltage Network	Any
Large	200 kW – 1500 kW		
	1500 kW – 5000 kW	11 kV to 132 kV High Voltage Network	
	> 5000 kW		

Large scale embedded generators connected to ActewAGL's network are required to be scheduled in accordance with AEMO's operating rules as intermittent generators whereas smaller PV units are not required to be registered as they have either automatic or small generation exemption.

ActewAGL has developed technical guidelines and business processes to facilitate the connection of embedded generators. The published charges improve the clarity and transparency of requirements for embedded generators. Details are available on ActewAGL's external website. Refer to document "Requirements for Connection of Embedded Generators up to 5 MW to the ActewAGL Distribution Network (August 2016)".

The ACT Government has mandated that the ACT will be supplied by 100% renewable energy by 2020. This rules out any standby, back-up or peak shaving generation fuelled by non-renewable sources such as natural gas, diesel, compressed natural gas, liquefied petroleum gas, oil or coal. The ACT Government has also set a target for the ACT to be carbon-neutral by 2050.

Other than solar PV generation there is little potential for other renewable energy generation within the ACT such as wind power, hydro power or bio-gas fuelled generation. However a waste to energy thermal power station generating 15 – 30 MW is planned for construction at Fyshwick within the planning period by Capital Recycling Solutions Pty Ltd.

9.3.1 Solar Photovoltaic Generation

There are 17,975 rooftop solar PV installations in the ACT (as at 30 June 2017) with a total installed capacity of 59.8 MW. Most of the generation produced by these installations is used by the customers at their premises, although some is exported into ActewAGL's low voltage distribution network. As these installations are widely distributed on the network (refer Appendix E) ActewAGL has thus far experienced limited technical issues only such as excessive voltage rise, thermal overload of low voltage feeders, harmonic saturation, or load balancing issues on 11 kV distribution feeders.

The developers of several new residential developments in the ACT are mandating that rooftop solar PV generation be installed on all detached dwellings. It is anticipated that the take-up rate will be sufficient that during times of peak generation and low load the total local generation will exceed demand by such a large margin that the net export from the area will be greater than the peak import to the area, meaning that the PV will be driving system sizing decisions. Potential power quality issues are discussed in Section 9.3.2.

This low voltage inverter based generation can contribute to higher voltages being seen on some parts of the low voltage network. ActewAGL has reviewed its connection standards regarding the maximum export voltages allowable from such inverters (refer Section 4.8.8).

Reliability of solar PV generation is inherently high as the equipment is primarily electronics based with no moving parts, compared with other forms of generation such as hydro or thermal. PV generation is unpredictable due to intermittent cloud cover. It is difficult to forecast availability and output accurately although research is being undertaken to correlate weather forecast information more closely with solar generation to provide a degree of forecasting capability in real time.

There is a large solar farm at Royalla which has a rated peak output of 20 MW, another at Hume which has a rated peak output of 12.85 MW, and another at Williamsdale which has a rated peak output of 10.6 MW. The Mount Majura Solar Farm currently has a rated peak output of 2.3 MW, with a second stage planned for construction during 2018 which will increase the rated peak output to 3.6 MW.

ActewAGL has received connection enquiries for two new solar farms, one at Harman with a design output of 20 MW and the other at Symonston with a design output of 50 MW. Connection options are being evaluated.

9.3.2 Power Quality Issues Associated with Embedded Generation

Maintaining the supply-demand balance of the network will become more challenging as synchronous generation is replaced with asynchronous wind, large-scale PV and rooftop PV generation (possibly combined with battery storage) which are subject to intermittency as wind strength fluctuates and passing clouds affect solar generation. It will be particularly difficult at times when demand is low and renewable generation is high and it is conceivable that the network could become a net importer of energy in certain areas in the future, such as residential areas will 100% penetration of rooftop PV and battery storage. The challenges relate to how the system behaves during disturbances, and how much generation can be dispatched in order to match supply and demand.

Large-scale solar PV generation has a lower capacity factor (average power generated divided by rated peak power) than other forms of generation, and can be intermittent and difficult to forecast. The same applies to small-scale rooftop PV. Consecutive days of rain or cloud cover will significantly reduce PV output, so the network cannot rely on such generation and must be capable of operating without it.

Power quality issues that could result from an increase in asynchronous generation include voltage stability, frequency stability due to a lack of system inertia, and low fault levels which would impact on protection schemes and system strength.

Synchronous generators such as the Snowy Hydro scheme generators, produce power through directly connected alternating current machines, rotating at a speed synchronised to power system frequency. These generators produce inertia, which lessens the impact of changes in power system frequency following a disturbance such as loss of a generator or transmission line, resulting in a more stable system. Power systems with low inertia experience faster changes in system frequency following a disturbance, which could lead to system instability and under frequency load shedding. Asynchronous generators such as wind turbines and solar PV generators are connected to the power system via power electronic inverters. These generators contribute little inertia to the system unless coupled with a fly-wheel or similar.

Synchronous generators provide dynamic voltage support to the power system, particularly during and immediately following system faults. Synchronous generators provide considerably more fault current to the power system than asynchronous generators. Fault current helps maintain voltage stability during network faults. The replacement of synchronous generation with asynchronous generation reduces the fault current and can lead to a “weak” system. This can cause the following issues:

- DC/AC inverters not remaining operational through network faults, tripping off and requiring resetting to reconnect their generation. This is commonly known as ‘fault ride-through’ capability.
- Inability to achieve steady-state stability during system normal.
- Protection schemes unable to distinguish between system normal load current and fault current leading to an inability to detect and clear faults on the system.
- Slow rate of recovery following network faults.

Access to real time information of equipment connected beyond-the-meter such as rooftop PV generation, battery storage, EV charging etc, will also become increasingly important in order to maintain power system stability and security

9.3.2.1 Voltage Stability

Synchronous generators provide considerable fault current to the network which helps maintain voltage stability during and immediately following network faults. Asynchronous generators provide much less fault current. This could lead to voltage instability during network faults. Most wind and large-scale PV generators in areas with poor voltage stability will struggle to remain connected to the network during network faults, and their power output may need to be restricted to manage this risk. Increasing rooftop PV could eventually cause high voltage issues on the distribution network so output from DC/AC inverters will need to be strictly adhered to.

ActewAGL’s distribution network has been designed and constructed to allow for voltage drop from power flow through the high voltage network to the end of the low voltage network. With increasing connections of rooftop solar PV to the low voltage network, at times of low load and high generation, power flows in the reverse direction from the low voltage network to the high voltage network. This reverse power flow can cause voltage rise on the distribution network which has to be managed to keep voltage within regulatory limits, ie 230 V +10% / -6% at customer points of connection. High voltage may affect or damage connected appliances or electronic equipment.

9.3.2.2 Frequency Stability

Traditional synchronous generators (rotating plant) have inertia which can support system frequency following a system disturbance such as loss of a transmission line or large generator. Asynchronous generators such as wind turbines and solar PV have little or no inertia, so a fast change to system frequency could result from a fault (sudden loss of generator or transmission line) which could lead to under-frequency load shedding on the distribution network. As the amount of non-scheduled embedded generation in the ACT increases, ActewAGL’s network could become reliant on frequency controlled ancillary services (FCAS) provided by other regions to maintain frequency stability and the supply-demand balance.

9.4 Battery Energy Storage

Small battery energy storage systems (BESS) are becoming more popular for domestic use (associated with rooftop PV generation) as technology improves and costs reduce. Larger battery energy storage systems are used by some utilities for peak shaving and load balancing, day to night shifting of renewable PV energy, and reducing the fluctuations in PV generation output caused by passing clouds or wind power output caused by changing wind conditions.

The battery industry is changing rapidly with several different battery technologies available, such as lithium-ion, zinc-bromine, lead-acid, nickel-cadmium, and sodium-sulphur. Lithium-ion batteries are recommended for high power applications and lead-acid batteries for high capacity applications. Lead-acid batteries cannot be charged at the same rate as lithium-ion batteries, but their discharging behaviour is equivalent. Lead-acid batteries are a proven technology; their main advantages continue to be their low price, high availability and simplicity. Lithium-ion batteries offer high energy density and are low maintenance. Zinc-bromine batteries offer high energy density, have 100% depth of discharge capability on a daily basis, and last longer than other battery types.

ActewAGL is currently participating in a trial of small scale 8 kWh lithium-ion battery storage systems which could be applicable for residential or small commercial customers, and also assist demand management during peak demand periods. In addition we are looking at situations in which larger batteries may provide a network benefit.

Although residential battery storage can reduce regional demand peaks when the residential and regional peaks coincide, it could also increase regional peaks. For example, if the regional peak occurs during the middle of the day and residential battery storage is charging from rooftop PV, this reduces the PV generation available to contribute towards meeting the regional peak. How storage operates in relation to both residential and regional demand profiles is likely to be driven by the tariff structure. A benefit to the customer is 'arbitrage' where the customer can charge the battery during off-peak periods when energy prices are lowest, then use this stored energy during peak demand periods when energy is more expensive.

9.5 Ginninderry Energy Pilot Project

Ginninderry Estate is a large new residential estate being developed in the West Belconnen area, with new suburbs to be named Strathnairn and Macnamara. It will be developed in stages over the next 30 years and ultimately include 11,500 dwellings. The Ginninderry Energy Pilot Project aims to assess the real time implications from an electricity-only residential estate with a high penetration of rooftop PV generation systems. The first stage of approximately 1,150 dwellings will include mandatory rooftop PV systems (ranging in size from 2 – 5 kW), demand management systems, and solar or heat pump hot water heating system. All dwellings will be fitted with smart meters. Residential scale battery storage systems are not mandatory but will be encouraged. Network scale batteries will also be trialled, along with other innovative devices such as OLTC distribution transformers, HV and LV voltage regulators. Performance of the network will be monitored using ActewAGL's ADMS, in particular the impact on power quality (voltage stability etc).

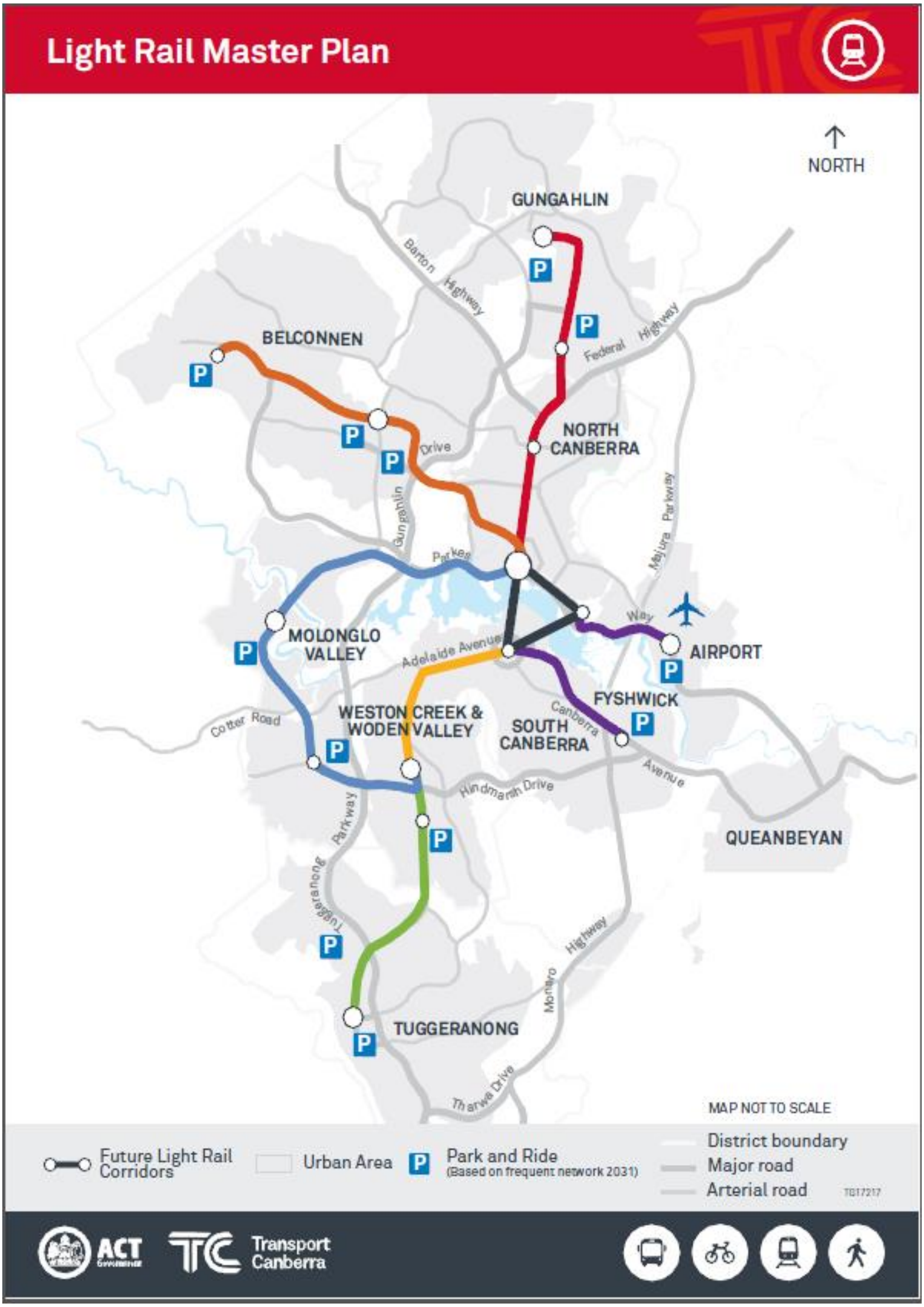
It is anticipated that the majority of new detached dwellings to be constructed in the ACT in the future will feature rooftop PV, battery storage, electric vehicle chargers, and in-home demand management systems

9.6 Electric Vehicles & Light Rail

The ACT Government is undertaking the construction of a light rail system (known as Capital Metro) which will feature electric passenger trams running on purpose-laid tracks, the first stage of which will run from Central Canberra City approximately 10 km northwards to Gungahlin town centre. This rail network will include the installation of two main traction power stations that will require an 11 kV 5.2 MW supply to each from ActewAGL's distribution network, plus a depot / control centre that requires an 11 kV 1.2 MW supply. Construction is underway with Stage 1 scheduled to be commissioned by June 2018. Stage 2 from Canberra CBD to Woden is at preliminary design stage.

ActewAGL is working with Capital Metro to monitor and mitigate the effects of stray currents emanating from the light rail network. Further expansion of this network is planned for the future, shown indicatively in Figure 9.1.

Figure 9.1: Light Rail Master Plan (source Transport Canberra)



There are few privately-owned electric vehicles (EV's) on the streets of the ACT at present but it is anticipated that their prevalence will increase significantly in coming years as costs decrease and battery range increases. Globally EV's are forecast to increase to 15% of the motor vehicle population by 2030. As travelling distances within the ACT are relatively short compared with other states, coupled with the ACT Government's plan for the territory to be carbon-emission-neutral by 2050, it is anticipated that the uptake of EV's in the ACT will exceed this. Penetration of EV's in the ACT could well be 30% by 2030.

ActewAGL is trialling the installation of electric vehicle charging stations in the ACT. To date three rapid chargers type Tritium Veefil Level 3 have been installed. These have a capacity of 50 kW and can fully charge a car within 30 minutes. In addition five fast chargers type eBee Level 2 have been installed. These have a capacity of up to 22 kW and can fully charge a car in 2-6 hours.

As part of this trial, ActewAGL is investigating the following:

Roaming: allowing EV customers to access ActewAGL's EV charging solution at public charging stations or privately in the customers home or business premises, whereby a driver would be able to drive freely and access the network.

Load levelling: allowing ActewAGL or other commercial operators to run a cluster of chargers without exceeding the maximum available load of a distribution substation.

Bi-directional chargers: allowing ActewAGL to use energy available within the EV's battery and also charge the EV to optimise the network.

Open Smart Charging Protocol (OSCP): can be used in the optimisation of the network by providing constant feedback and communications between the charging hardware and the software cloud environments. This protocol also allows dynamic allocation of available capacity, load levelling and management of hardware which will ensure our network is up to date with the latest technology available. ActewAGL has representation on the OASIS Open Charge Point Protocol Technical Committee and has actively engaged with this development.

To avoid electric vehicle charging stations creating new peak demands on distribution feeders or substations, intelligent controls will be required to distribute charging throughout the day and maintain system voltage within regulation levels. Ideally public charging stations will be sited to meet customer needs and at locations on the electricity network where they will not create loading issues. If sufficient charging stations are installed in public places such as shopping centres and workplace carparks, this would minimise the impact of EV drivers plugging in to recharge their vehicles upon arriving home from work which could overload residential LV and HV feeders.

Expansion of EV charging network: ActewAGL is working with various local councils to establish a network of EV charging stations between Canberra and Batemans Bay, Sydney and Thredbo, to encourage the use of EV's to popular destinations near the ACT.

Electric buses: Transport Canberra is currently trialling an all-electric bus, which takes approximately 7 hours to fully charge via a 400V 3-phase 130 Amp charger. A fully charged bus has a range of approximately 450 km. Transport Canberra is hoping to introduce 120 such electric buses to its Canberra fleet by mid-2019, and proposes to construct a new electric bus depot at Woden to house, charge and maintain this fleet. Maximum demand of this depot is expected to be approximately 3.8 MW.

Autonomous vehicles and plugless chargers: In the future it is expected that electric vehicles will be driverless. As well as providing increased safety to passengers, this will increase their appeal and could potentially increase the electrical demand to charge their batteries – eg a driverless EV could provide a 24 hours per day taxi service, stopping only to recharge itself when required. Plugless chargers that work by parking an EV above an induction pad are expected to enter the Australian market in the near future and will enhance the convenience and ease to charge an EV. In the future it is expected that plugless EV chargers will be located in public car parking spaces and operate in tandem with parking meters.

EV energy consumption in the ACT is forecast to grow steadily over the next 20-30 years. This will serve to offset the reduction in energy demand caused by embedded generation and storage systems.

In the future the energy stored in an EV's battery could be used to back-feed into the network via an inverter at times of maximum demand. Similar to fixed battery storage systems, EV's could be considered as a potential distributed energy resource.

9.7 Micro-grids

A micro-grid is a small power system with generation and consumption occurring locally. Micro-grids can function autonomously as well as being connected to the distribution network. Energy sources can include PV, wind, diesel generators, fuel cells and micro-hydro amongst many others. Around the world micro-grids can be found in scales varying from a single residential house or industrial/production site to a complete island power system. A micro-grid can balance generation and demand with or without energy storage and is capable of operating in 'island-mode' whether connected or not connected to the electricity distribution network. A micro-grid can have lower transmission losses because the energy is generated and consumed in close proximity.

ActewAGL is currently investigating the viability of micro-grids within its network with proponents of such schemes. To date none of the proposed schemes has proven to be viable but we continue to assess schemes as the technical and financial barriers reduce and regulatory barriers are clarified.

9.8 Virtual Power Plants

A virtual power plant consists of a combination of several small scale distributed energy resources, such as rooftop PV generators and battery energy storage systems that can be controlled to act in a similar way to a large conventional power plant to minimise system demand in a local area.

ActewAGL is preparing to conduct a trial of a virtual power plant at its Greenway depot with the assistance of Sunverge cloud-based energy management software.

9.9 Dynamic Rating of Transmission Lines and Power Transformers

Static ratings of transmission lines and power transformers are based on probabilistic weather conditions and equipment loadings. Weather and loading conditions are dynamic hence static ratings may not accurately reflect the load transfer capability of these assets at any particular point in time. Dynamic rating of transmission lines is done by assigning conductor current ratings in real time taking into account the heating effects of the electrical current, ambient air temperature, solar radiation and reflected radiation, and the cooling effects of wind and emitted radiation, so that the conductors do not heat to such an extent that they sag below allowable ground clearances.

Weather stations are installed at various points along a transmission line to measure such data in real time and transmit it to the Control Centre's computer where it is analysed and a dynamic current rating assigned to the transmission line. This allows the network operator to apply load to a line based on its dynamic rating which enables increased power flows above its static rating when weather conditions are favourable. This permits such assets to be fully utilised without the risk of overloading.

The same principle can be applied to zone substation power transformers to enable them to be operated above their normal continuous name-plate rating when conditions are favourable.

ActewAGL currently does not have dynamic rating capability on its network, but is investigating it as a possible future development as system load changes.

9.10 Smart Networks

9.10.1 Smart Networks

Emerging technologies such as embedded generation, energy storage, electric vehicles, and smart street lighting networks, are rapidly changing the electricity distribution industry. To improve the supply-demand balance and meet all power quality standards, ActewAGL will need to monitor and control load and generation flows at the domestic customer level. In order to do this, a reliable and secure means of communicating with customers will be required along with means to remotely control load and generation flows.

ActewAGL's Advanced Distribution Management System (ADMS) is being developed to provide real time information allowing for network switching decisions and the realisation of self-healing network principles. A self-healing system will detect and isolate a fault on the network and automatically restore power to as much of the network as possible until repairs have been carried out.

ActewAGL is investigating the installation of additional smart devices such as voltage regulators, dynamic volt-amp reactive compensators (D-VARs), auto-reclosers and sectionalisers on its distribution network to improve quality, security and reliability of supply.

9.10.2 Denman Prospect Smart Network Trial

Denman Prospect is a new residential suburb currently under development in the Molongo Valley to the west of Canberra City. Stage 1 will comprise 400 dwellings that will all be equipped with mandatory 3 kW rooftop solar PV generation panels, and it is anticipated that some will also feature battery storage systems. This will be the first residential estate in the ACT and one of the first in Australia with 100% PV penetration.

To support this ActewAGL has identified an opportunity to establish an industry leading multi-utility smart network including smart metering for electricity, gas and water. ActewAGL is also developing a customer portal to provide customers with up to date access to their electricity and gas consumption to pass on the benefits of smart metering to customers.

ActewAGL recognises that a smart grid is much more than just smart meters and includes grid sensors, distribution automation equipment, monitoring and control devices for renewable resources, load control devices, in-home energy management devices and smart charging stations for electric vehicles. We understand that emerging technologies such as embedded generation, energy storage, electric vehicles, and smart street lighting networks, are rapidly changing energy usage and the electricity distribution industry.

The Denman Prospect Smart Network Trial will specifically investigate issues related to data collection and trial devices for intelligent street lighting and electric vehicle charging. This will be achieved through the following investments and activities:

- Install and pilot a radio mesh network for communications supporting a multi-utility smart network platform.
- Trial the ability of ActewAGL's network control software, ADMS, to use real time data and respond dynamically.

- Install and trial electricity demand management of customers' devices including PV inverters and battery storage systems, and remote control of smart street light luminaires and electric vehicle charging stations.
- Provide a network gateway at each house to enable:
    - Monitoring and capture of solar generation data in real time.
    - Monitoring and control of demand data and power quality data in real time.
- Trial of gas and water metering with our partners.

This project creates a communications 'umbrella' to enable smart meter data reads, demand management control, smart street lighting control and electric vehicle charger management. This complements ActewAGL's existing fibre optic communication networks as well as our Digital Data Radio Network and Trunked Mobile Radio communication networks which encompasses numerous towers in and around the ACT.

ActewAGL is in the process of installing smart meters in Denman Prospect as part of a pilot phase. The pilot will allow us to test whether the meters can talk to the communications canopy, and whether we can read this information back at a central point. We will also be testing whether we can communicate effectively with the market. Our intention is to demonstrate a multi-utility solution with electricity, gas and water smart meters.

9.11 Smart Meters

ActewAGL has been managing the supply, installation, maintenance and metering data management of metering infrastructure for over 100 years. Since 2003 ActewAGL has been operating in the NEM as a Responsible Person and an accredited Metering Provider and Metering Data Provider, and currently provides metering services for over 200,000 customer metering points. ActewAGL's managed services include metering for domestic and commercial customers within the ACT.

The Power of Choice (PoC) rules implemented by the AEMC from 1 December 2017 will require all new and replacement meters to be Type 1-4 meters (smart meters) and be provided by independent Metering Coordinators acting for retailers. The PoC will enable customers to have a greater ability to manage their power usage and costs through choosing demand-side management (DSM) products and services that may better suit their needs, and can assist DNSPs to reduce capital and operating costs. New meters will be smart meters that are specified by the relevant retailer.

This rule change redefines who will have the overall responsibility for the provision of metering services. The role and responsibilities of the Responsible Person must be undertaken by a new type of Registered Market Participant – a Metering Coordinator. Metering Provider and Metering Data Provider are retained as separate accredited roles; however a Retailer will now be required to appoint the Metering Coordinator to coordinate suitably qualified parties to conduct metering services for its retail customers.

Smart meters enable energy consumption data to be available to both customers and utilities on a real time basis via two-way communications networks. This will assist the customer and the service provider with demand management initiatives, to respond to price signals and automatically control or shift demand during high demand periods, and facilitate future retail contestability.

Some of the potential uses of smart meters are as follows (refer section 4.11.1 for further details):

- Outage management
- Support and enhance network modelling functionality of ADMS
- Improved network forecasting and planning
- Reduced network investment
- Power quality monitoring
- Reduced manual meter reads
- Remote connection and disconnection of customers
- Demand management
- Support smart network initiatives, e.g. battery storage and embedded generation

9.12 Remote Area Power Supplies

ActewAGL's network is primarily urban, but there are some long overhead 11 kV distribution feeders in rural areas that supply remote small loads only. As these feeders age, their maintenance costs increase. Vegetation management is also costly, particularly where a feeder traverses a bushfire prone area.

ActewAGL is currently evaluating options to install Remote Area Power Supplies (RAPS) to supply loads at the ends of two such long rural feeders. Options being considered for these RAPS consist of a mixture of solar PV generation, battery energy storage, mini-hydro generation, with back-up diesel generators. The two RAPS being investigated are at:

Gudgenby Homestead – the ACT Department of Parks, Conservation and Lands owns and operates this facility within the Namadgi National Park. Maximum demand of this facility is around 10 kW. Current supply to this site is via a single phase overhead 11 kV line (Matthews feeder) approximately 7 km long.

Corin Dam – the ACT Department of Parks, Conservation and Lands owns and operates this facility within the Namadgi National Park. Maximum demand of this facility is around 9 kW. Current supply to this site is via a three phase overhead 11 kV line (Reid feeder) approximately 9.5 km long.

At both sites following installation and commissioning of the RAPS, it is proposed to operate and monitor their performance over the next two years. If successful, the overhead 11 kV feeder line sections connected to these sites will be decommissioned and dismantled.

ActewAGL is investigating the feasibility and economics of establishing RAPS at other similar sites.

9.13 Drones

ActewAGL engaged in a trial using drones to perform pole top, pole equipment, transmission tower and vegetation inspections. Inspection methods used were photographic and thermal imagery. The pole top photography captured is used to identify defects on the pole top, cross-arm, insulator, and conductors. The pole equipment photography and thermal imagery is used to capture any defects on the equipment, also any hotspots which may be present using thermography. Transmission tower inspections were carried out by taking multiple photo images of the tower, insulators, and conductors. Vegetation encroachments on power lines were also captured to identify where encroachments exists in order to arrange remedial works.

Since backyard poles exist in the ACT, the use of drones removes the need for inspection personnel to access residential properties in order to perform visual inspections. Capturing images of assets allows for the defect assessment to be performed in the office in a safer environment and removes the need to climb transmission structures that require an inspection. The images also provide a pictorial history of the asset which can assist in the management of particular assets. ActewAGL is currently considering the permanent use of drones to inspect transmission towers and transmission lines

Appendix A: Glossary of Terms

Term	Definition
ACT	Australian Capital Territory
ActewAGL	ActewAGL Distribution
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
APR	Annual Planning Report
BESS	Battery Energy Storage System
BSP	Bulk Supply Point
CAIDI	Customer Average Interruption Duration Index
CESS	Capital Expenditure Sharing Scheme
DMIS	Demand Management Incentive Scheme
DMP	Demand Management Process
DNSP	Distribution Network Service Provider
DR	Demand Response
DSES	Demand Side Engagement Strategy
DSM	Demand Side Management
DSMP	Demand Side Management Planning
DUOS	Distribution Use of System
ENA	Energy Networks Australia
EOI	Expression of Interest
HV	High voltage
ICRC	Independent Competition and Regulatory Commission
MVA	Mega Volt Amperes
MW	Mega Watts
NEL	National Electricity Law
NEM	National Electricity Market
NER	National Electricity Rules
NPV	Net Present Value
NTFP	National Transmission Flow Path
NTNDP	National Transmission Network Development Plan
N-1	Security Standard where supply is maintained following a single credible contingency event
OPGW	Optical Ground Wire
PFC	Power Factor Correction
PoC	Power of Choice
PoE	Probability of Exceedance
PV	Photovoltaic
QOS	Quality of Supply
RDSE	Register of Demand Side Engagement
RIT-D	Regulatory Investment Test for Distribution
RIT-T	Regulatory Investment Test for Transmission
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
STPIS	Service Target Performance Incentive Scheme
TNSP	Transmission Network Service Provider
TOU	Time of Use
TUOS	Transmission Use of System
Utilities Act	ACT Utilities Act 2000
UTR	Utilities Technical Regulation team

Appendix B: Bulk Supply Point Load Forecasts

Tables B.1 and B.2 show the summer and winter maximum demand forecasts for the three TransGrid owned bulk supply point substations Canberra, Williamsdale and Queanbeyan. Table B.3 lists the seasonal diversity factor for each BSP. Tables B4 and B5 show the impact of emerging technologies on system forecasts.

Table B.1: TransGrid bulk supply point substations summer maximum demand forecast

Summer	Canberra		Queanbeyan		Williamsdale		Stockdill	
Year	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10
2018	431	476	29	33	211	233	0	0
2019	423	459	30	34	207	225	0	0
2020	413	455	30	35	202	223	0	0
2021	274	304	29	34	201	223	137	152
2022	274	308	27	31	201	226	137	154
2023	273	307	25	30	201	226	137	154
2024	275	306	25	29	202	225	137	153
2025	284	314	0	0	208	231	142	157
2026	285	322	0	0	209	236	142	161
2027	285	323	0	0	209	238	142	162

Table B.2: TransGrid bulk supply point substations winter maximum demand forecast

Winter	Canberra		Queanbeyan		Williamsdale		Stockdill	
Year	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10
2018	450	477	23	27	218	230	0	0
2019	444	469	24	28	214	226	0	0
2020	292	309	24	28	212	224	146	154
2021	292	311	22	26	212	225	146	155
2022	291	308	21	24	211	223	146	154
2023	293	309	20	24	212	224	146	155
2024	293	309	20	24	212	224	146	155
2025	298	316	0	0	216	229	149	158
2026	301	318	0	0	218	230	150	159
2027	302	324	0	0	219	235	151	162

Table B.3: TransGrid bulk supply point substations seasonal diversity factor

Season	Canberra	Queanbeyan	Williamsdale	Stockdill
Summer	88%	77%	88%	88%
Winter	88%	57%	100%	88%

Table B.4: 10-year System summer forecast (Neutral Scenario) by structure change technologies

Summer	TransGrid less EV		Plus EV (TransGrid Import)		Plus Large Solar & Bio Gen (Operational Demand)		Plus Battery		Plus Rooftop Solar (Underlying Demand)	
Year	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10
2018	568	631	568	631	587	649	588	650	609	674
2019	558	610	559	610	577	628	579	631	602	655
2020	547	606	548	607	565	623	570	628	595	651
2021	542	606	544	608	561	624	569	632	594	653
2022	541	609	543	611	560	630	571	641	593	665
2023	537	607	540	610	557	627	571	640	595	665
2024	538	602	543	607	559	624	575	640	600	665
2025	535	594	541	601	558	618	576	636	601	660
2026	534	606	543	616	560	633	581	654	604	674
2027	531	604	543	616	560	636	584	659	610	676

Table B.5: 10-year System winter forecast (Neutral Scenario) by structure change technologies

Winter	TransGrid less EV		Plus EV (TransGrid Import)		Plus Large Solar & Bio Gen (Operational Demand)		Plus Battery		Plus Rooftop Solar (Underlying Demand)	
Year	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10
2018	623	660	623	660	627	665	628	666	631	670
2019	613	650	614	650	619	655	621	657	626	662
2020	606	641	607	642	611	647	616	652	619	657
2021	604	642	606	644	610	650	618	658	621	662
2022	599	634	601	636	607	644	617	654	618	658
2023	600	637	603	640	610	646	623	660	624	662
2024	598	631	603	636	610	646	626	662	627	662
2025	596	634	602	640	609	645	627	663	627	665
2026	598	635	607	644	615	650	635	671	635	671
2027	598	640	610	653	617	663	640	686	640	681

Appendix C: Zone Substations Load Forecasts

Figures C.1.1 – C.13.2 illustrate the 10-year summer and winter maximum demand forecasts for the thirteen zone substations: Belconnen, City East, Civic, East Lake, Fyshwick, Gilmore, Gold Creek, Latham, Telopea Park, Tennent, Theodore, Wanniassa and Woden.

Figure C.1.1: Belconnen Zone Substation summer maximum demand forecast

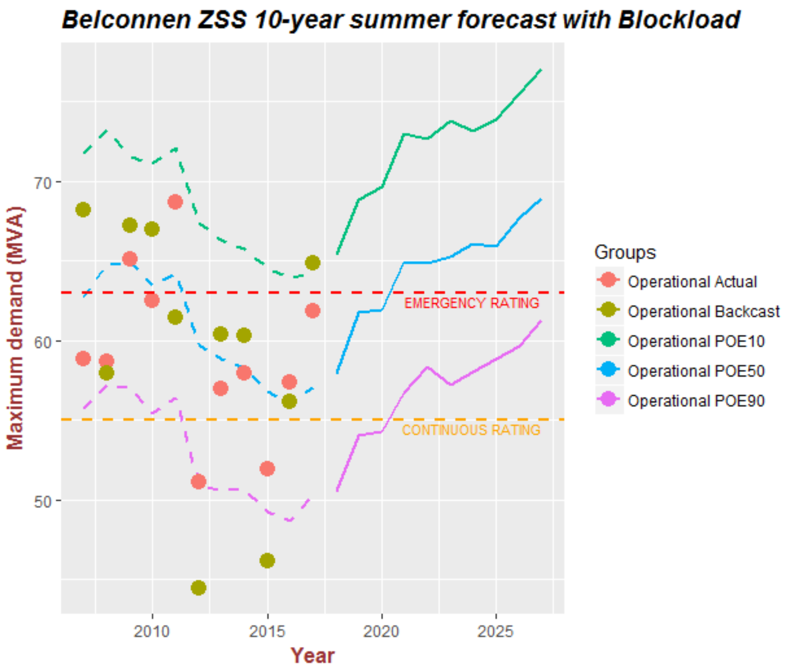


Figure C.1.2: Belconnen Zone Substation winter maximum demand forecast

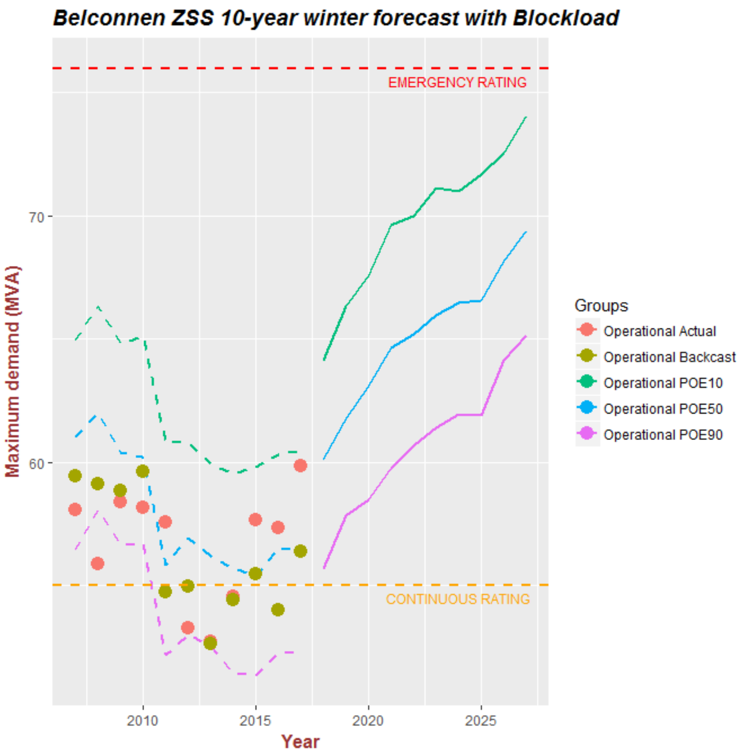


Figure C.2.1: City East Zone Substation summer maximum demand forecast

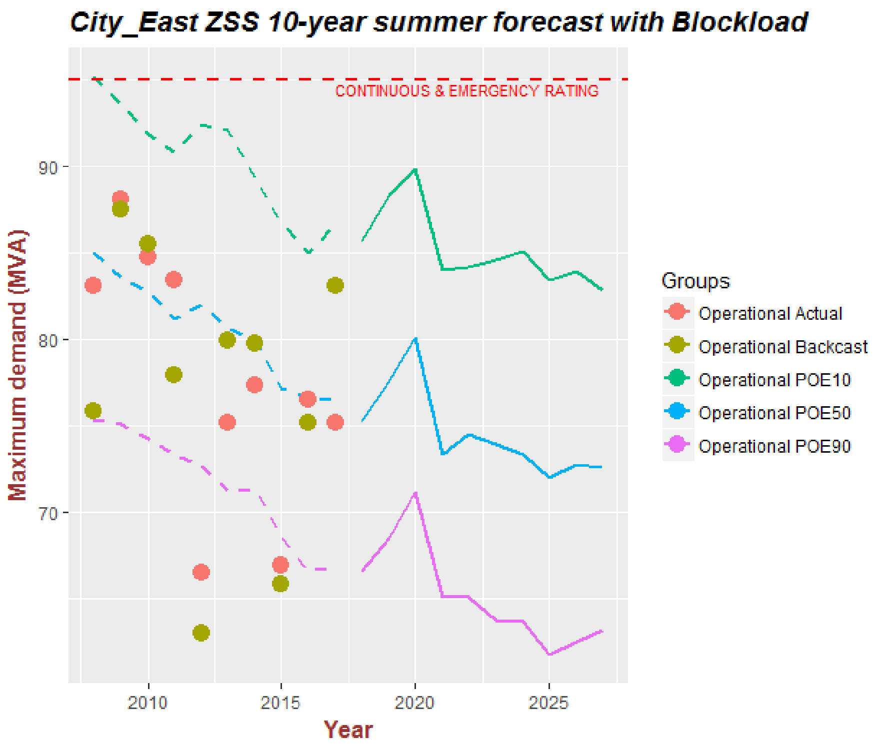


Figure C.2.2: City East Zone Substation winter maximum demand forecast

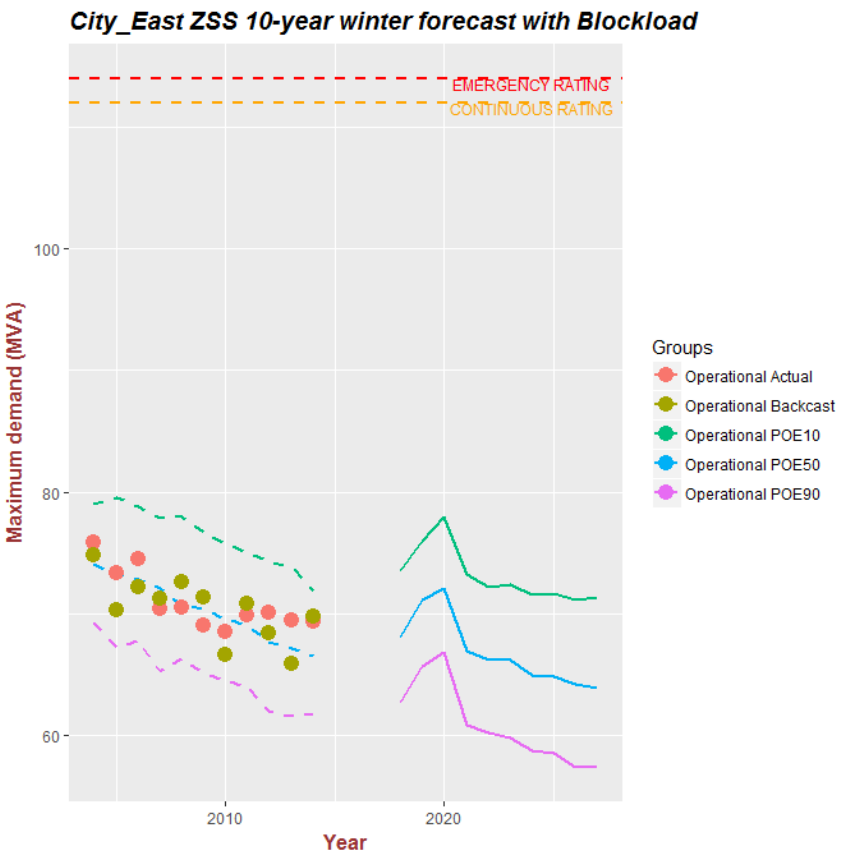


Figure C.3.1: Civic Zone Substation summer maximum demand forecast

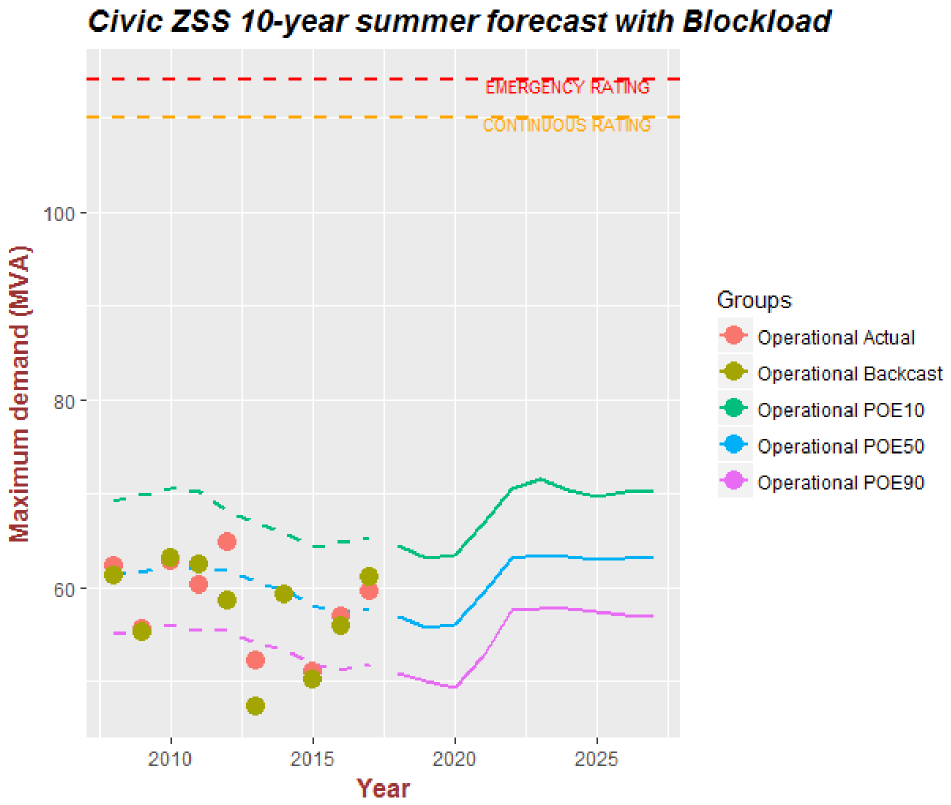


Figure C.3.2: Civic Zone Substation winter maximum demand forecast

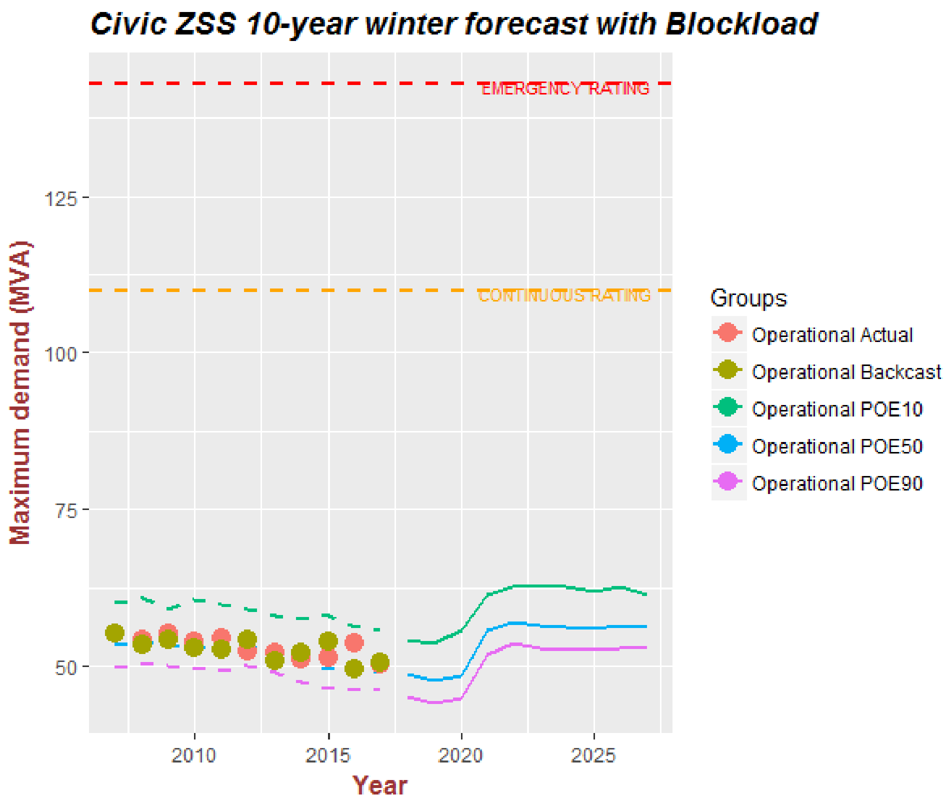


Figure C.4.1: East Lake Zone Substation summer maximum demand forecast

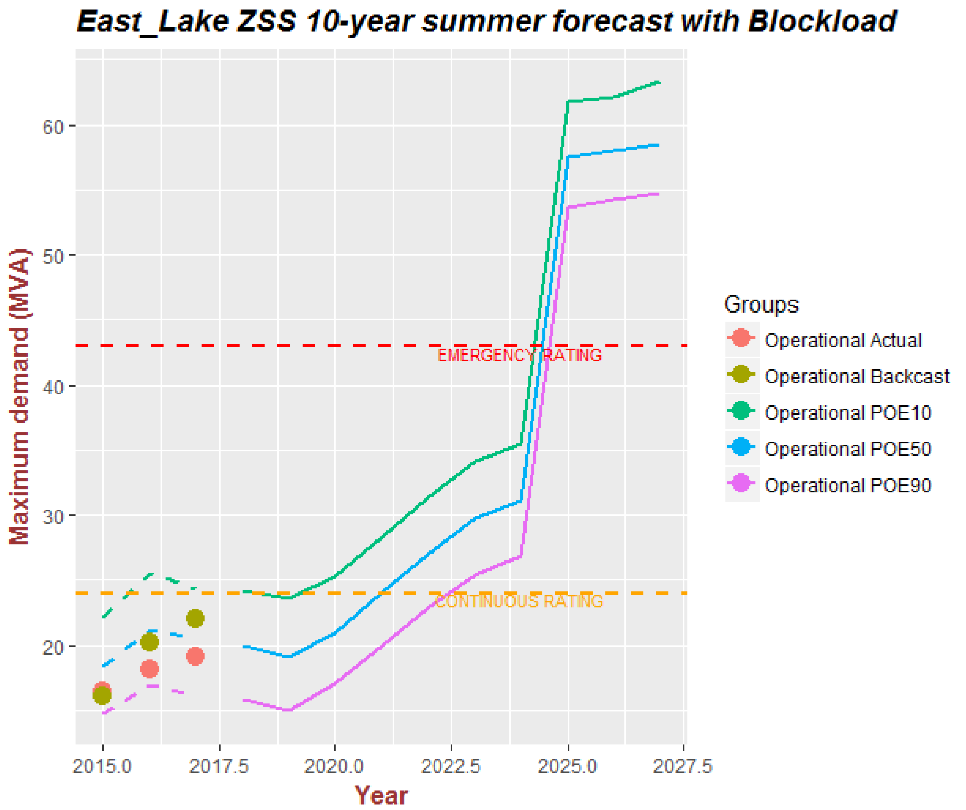


Figure C.4.2: East Lake Zone Substation winter maximum demand forecast

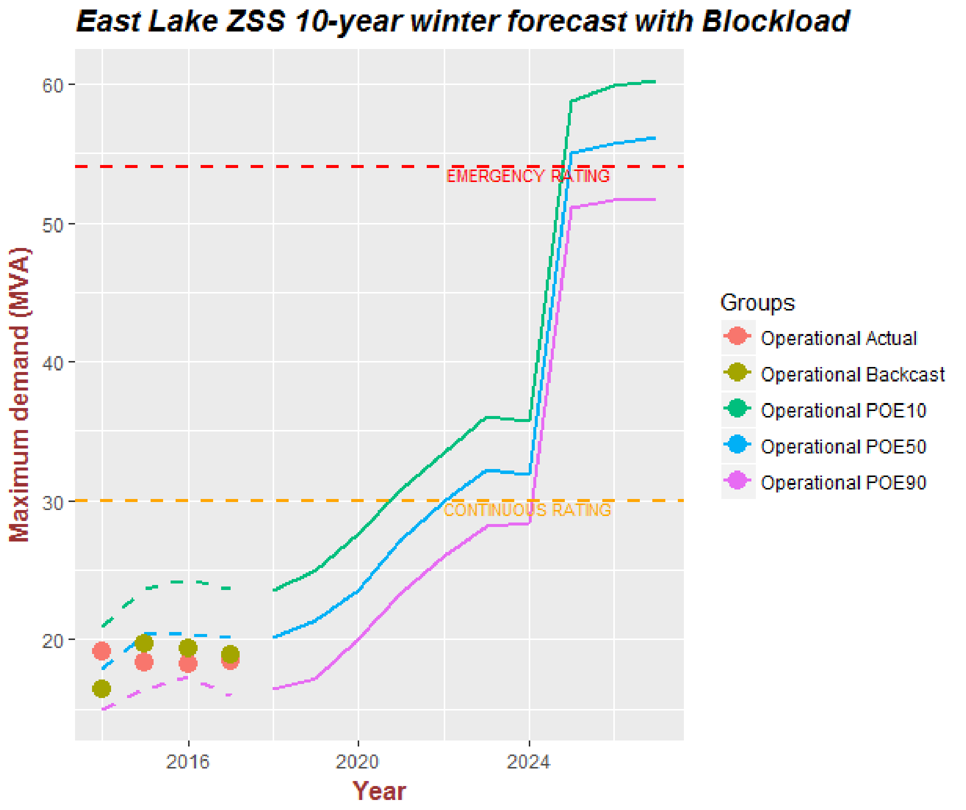


Figure C.5.1: Fyshwick Zone Substation summer maximum demand forecast

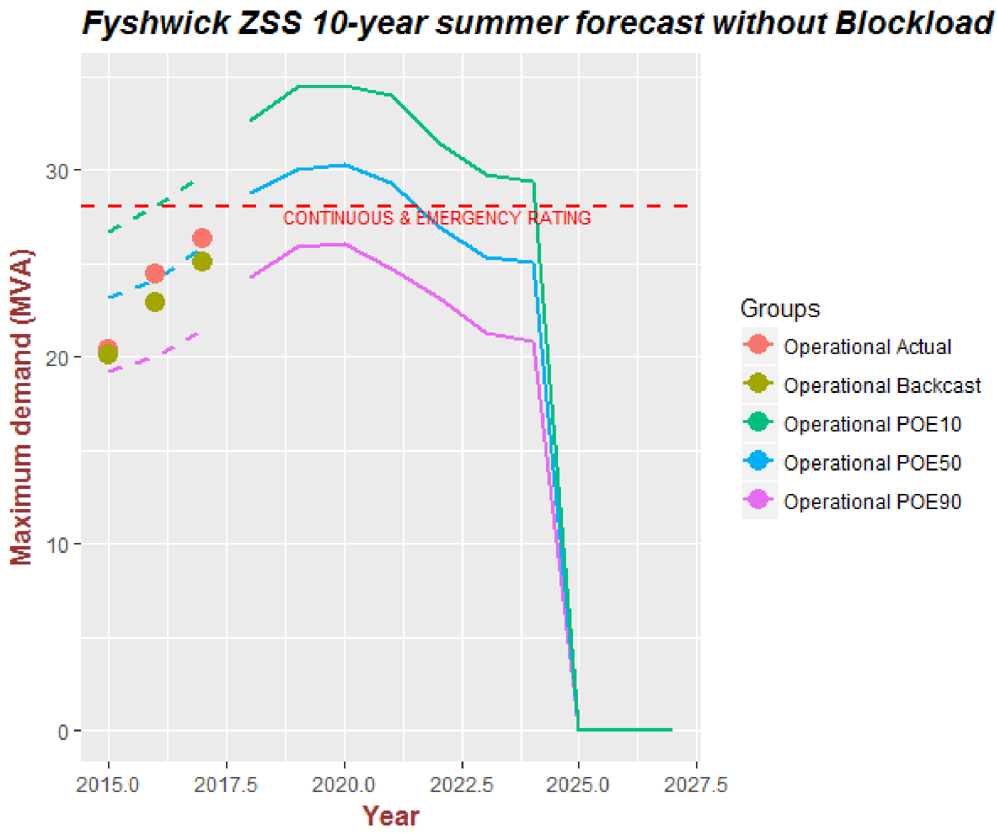


Figure C.5.2: Fyshwick Zone Substation winter maximum demand forecast

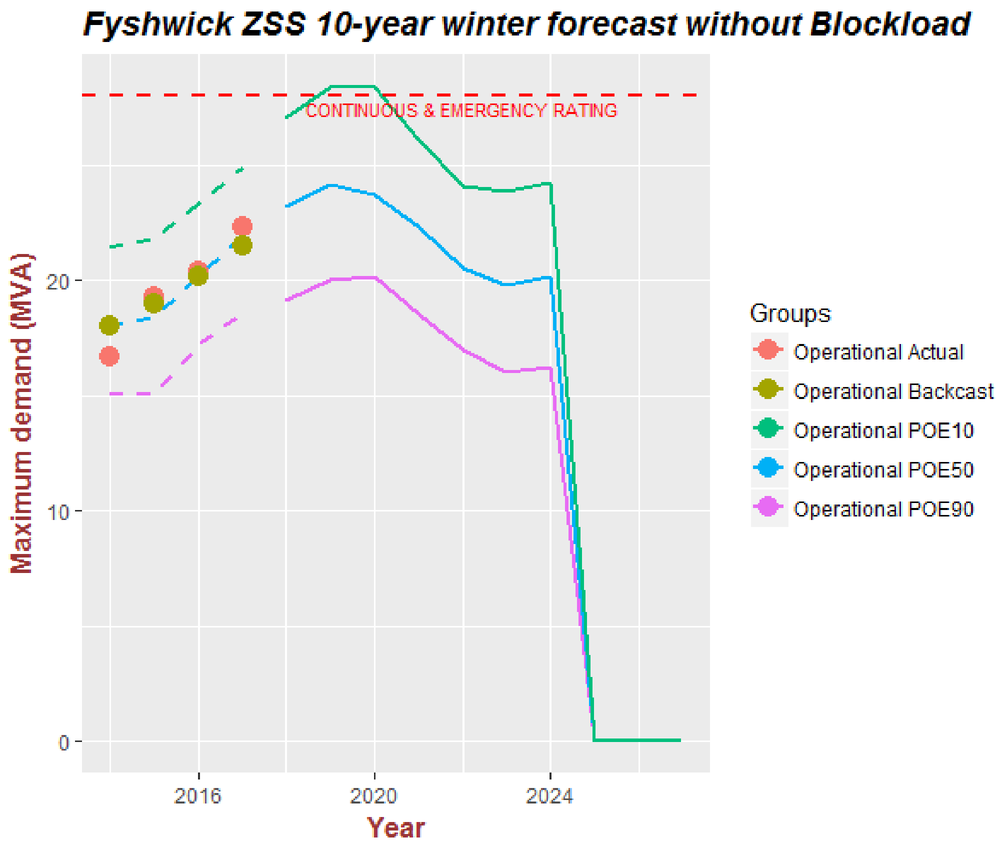


Figure C.6.1: Gilmore Zone Substation summer maximum demand forecast

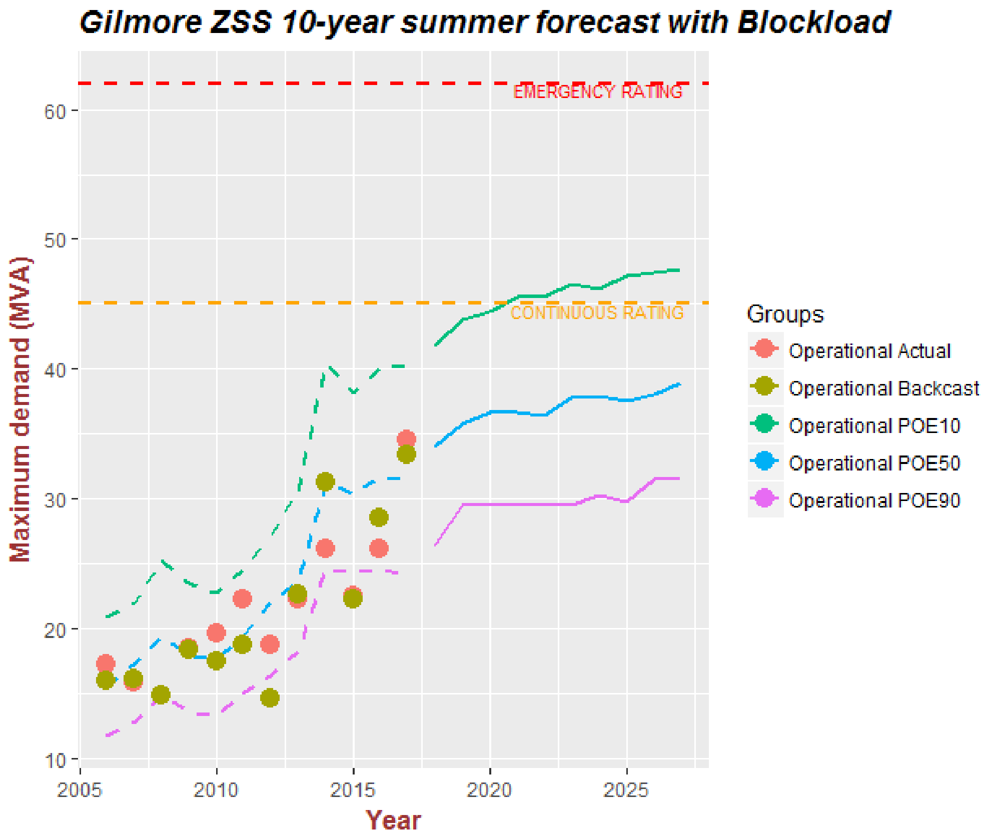


Figure C.6.2: Gilmore Zone Substation winter maximum demand forecast

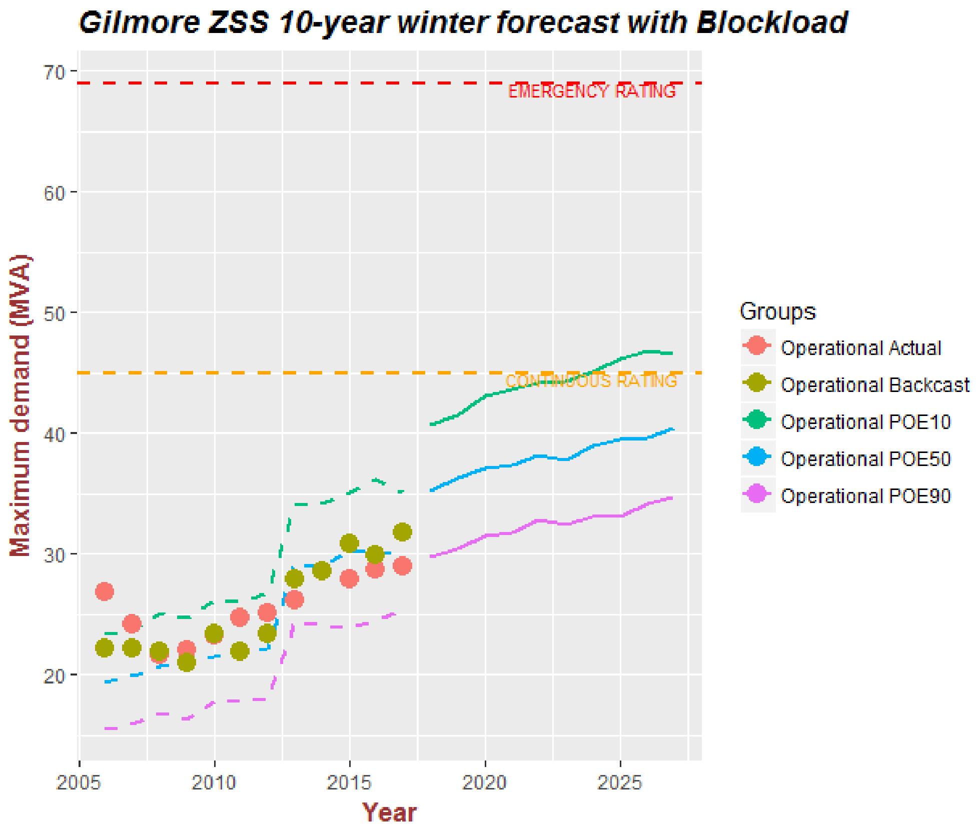


Figure C.7.1: Gold Creek Zone Substation winter maximum demand forecast

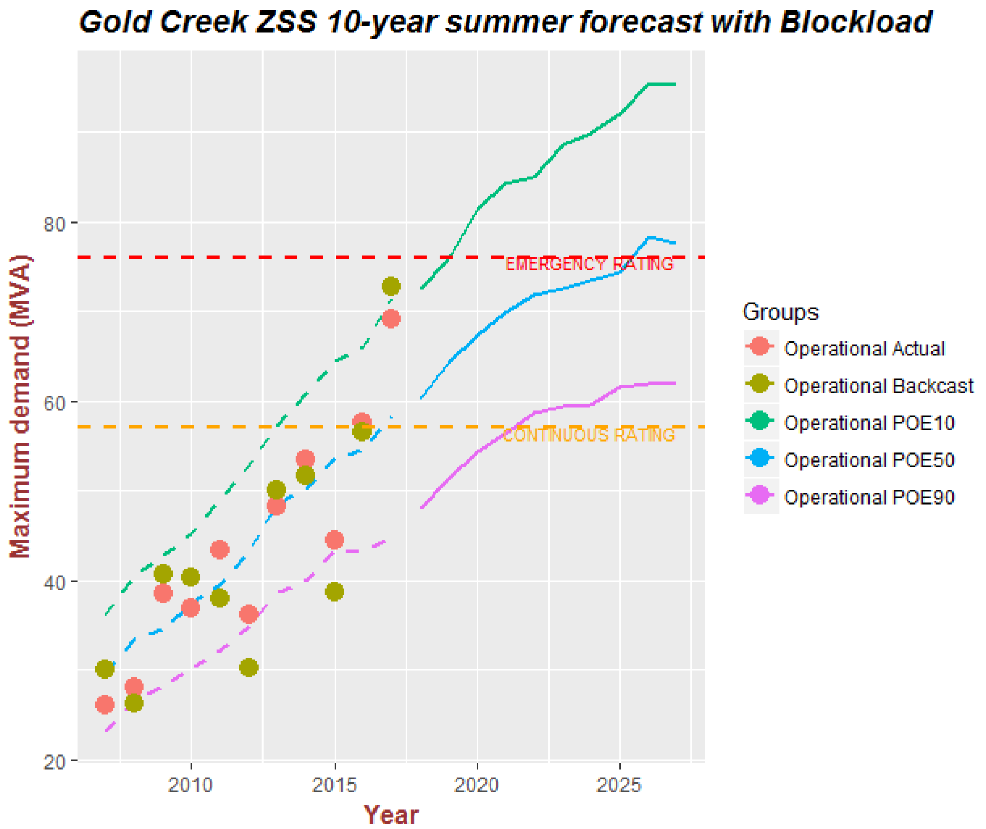


Figure C.7.2: Gold Creek Zone Substation summer maximum demand forecast

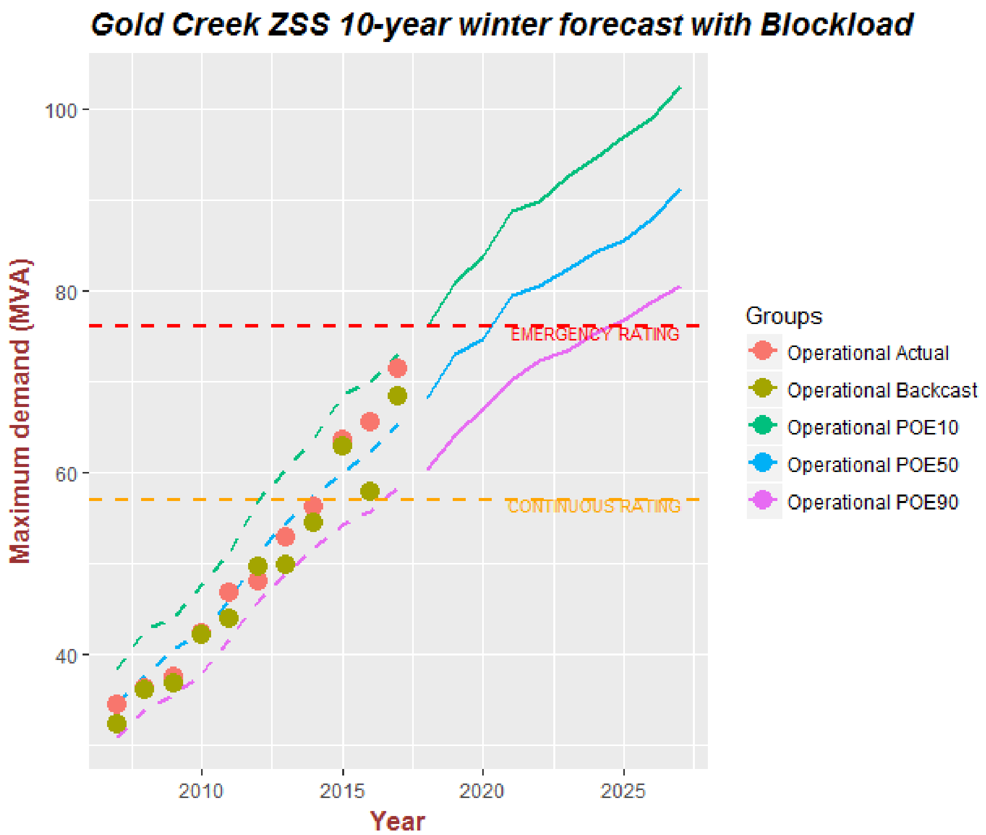


Figure C.8.1: Latham Zone Substation summer maximum demand forecast

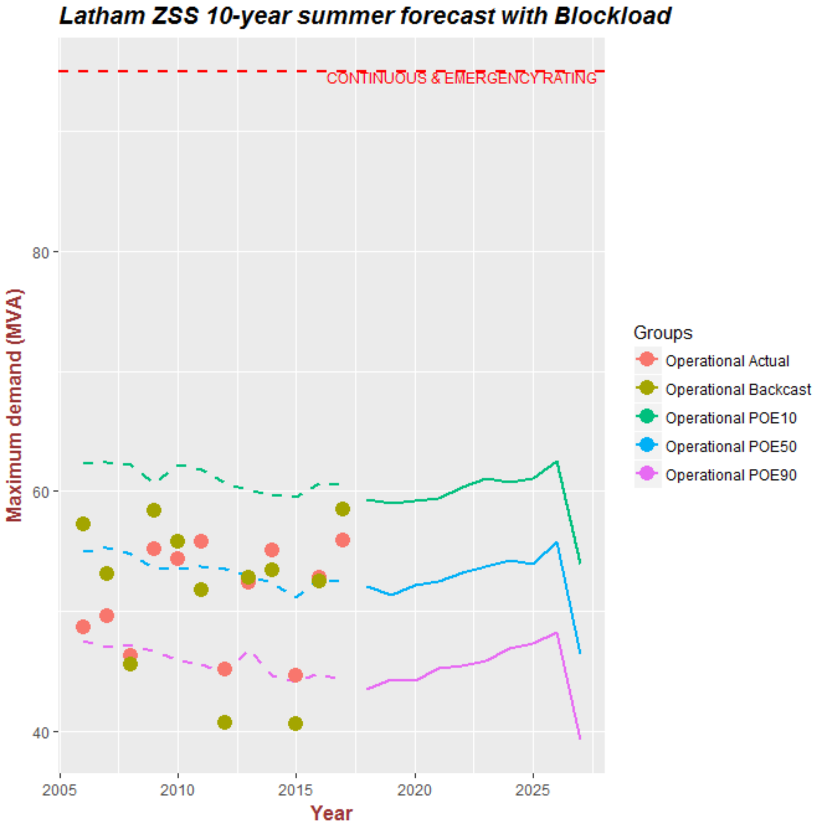


Figure C.8.2: Latham Zone Substation winter maximum demand forecast

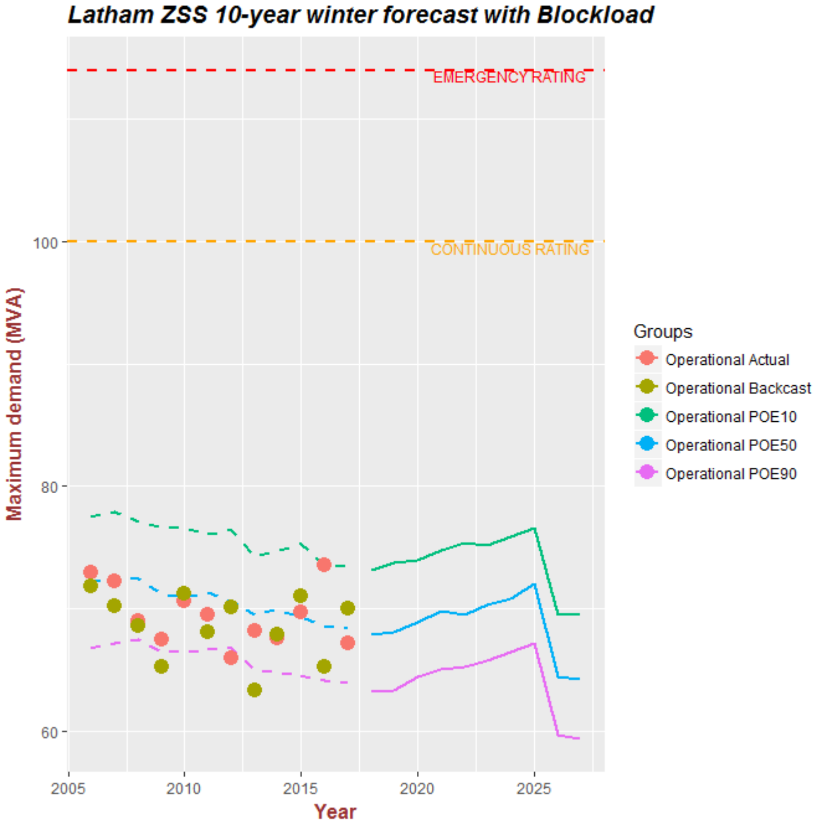


Figure C.9.1: Telopea Park Zone Substation summer maximum demand forecast

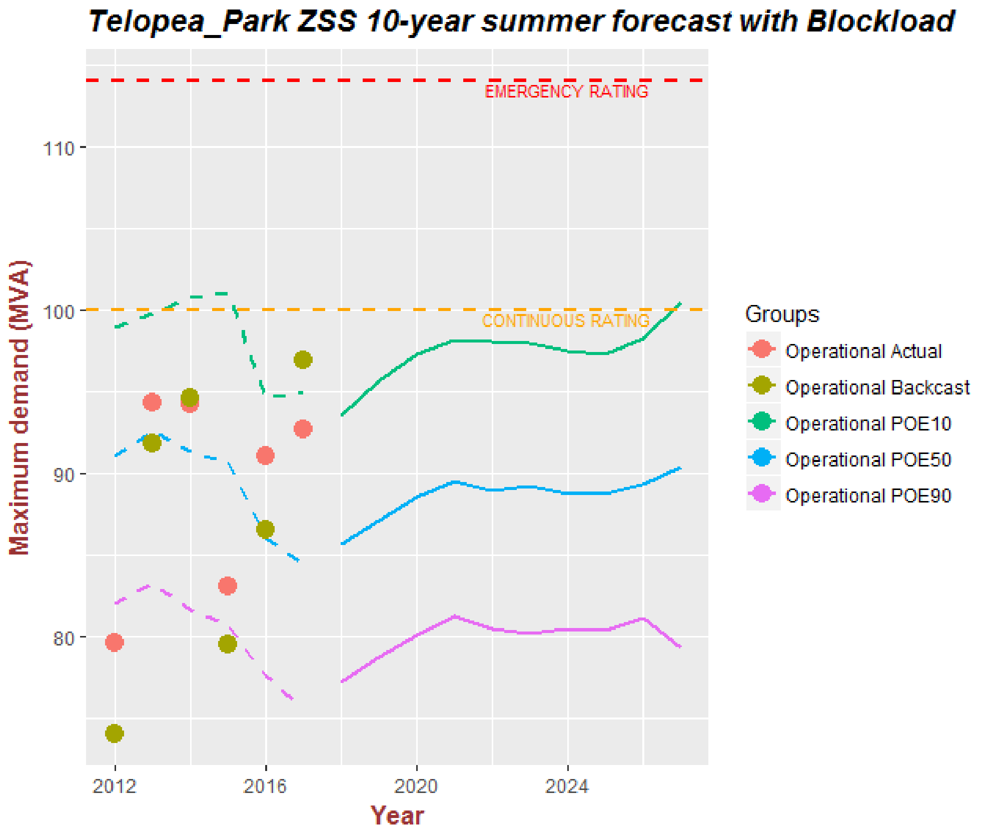


Figure C.9.2: Telopea Park Zone Substation winter maximum demand forecast

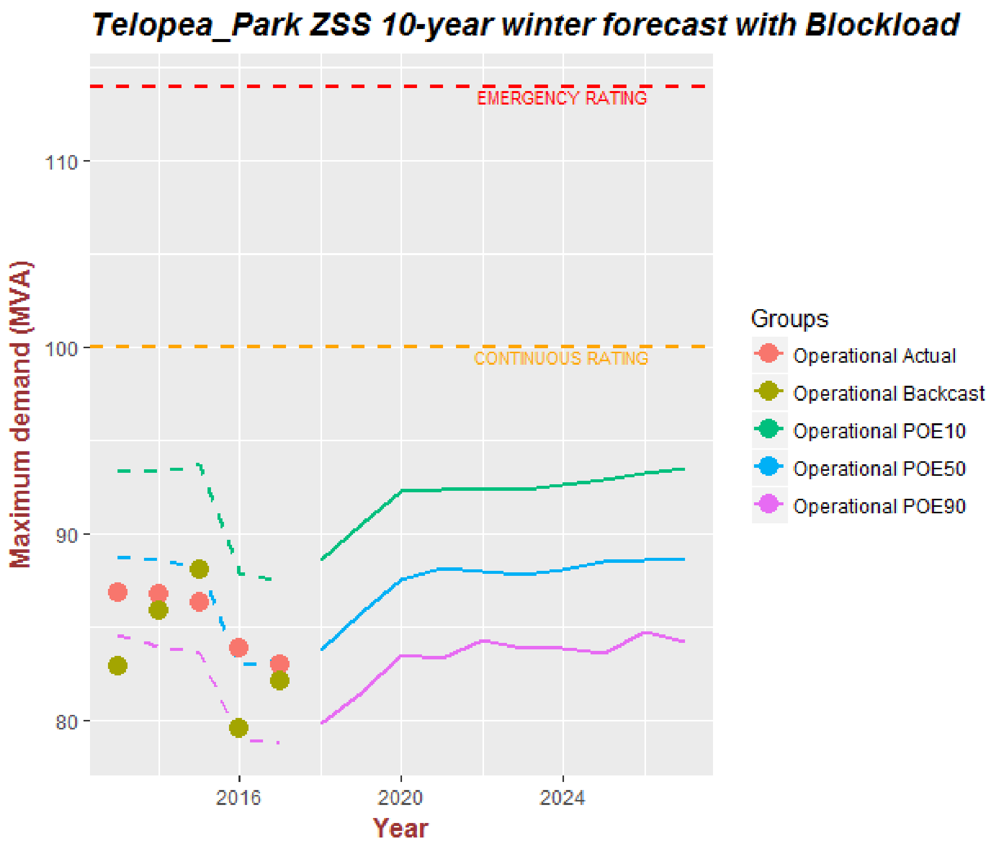


Figure C.10.1: Tennent Zone Substation summer maximum demand forecast

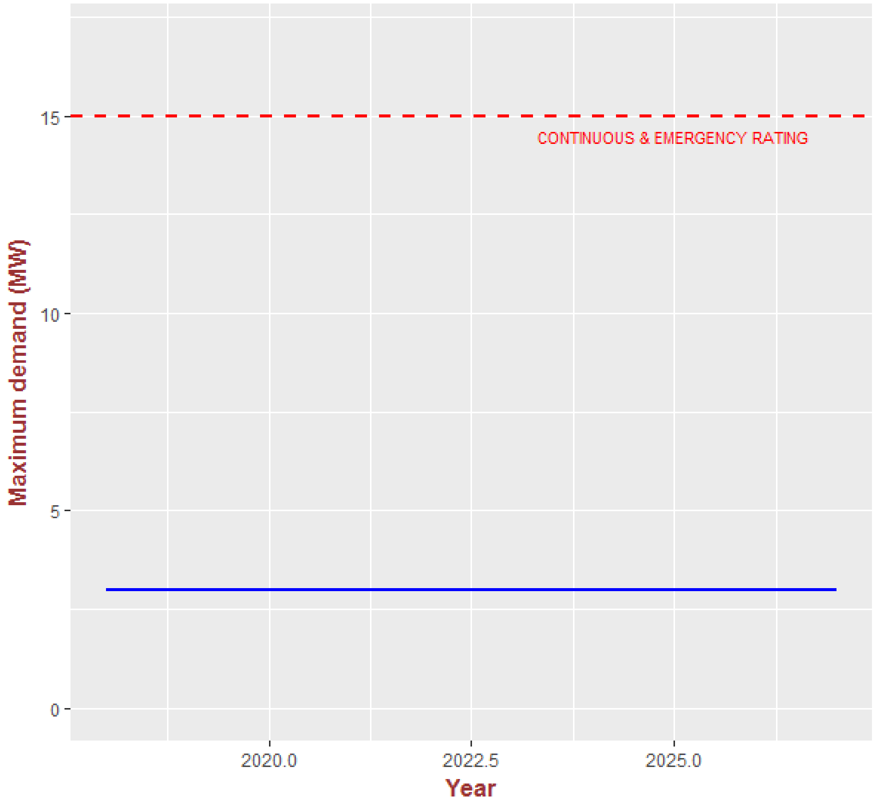


Figure C.10.2: Tennent Zone Substation winter maximum demand forecast

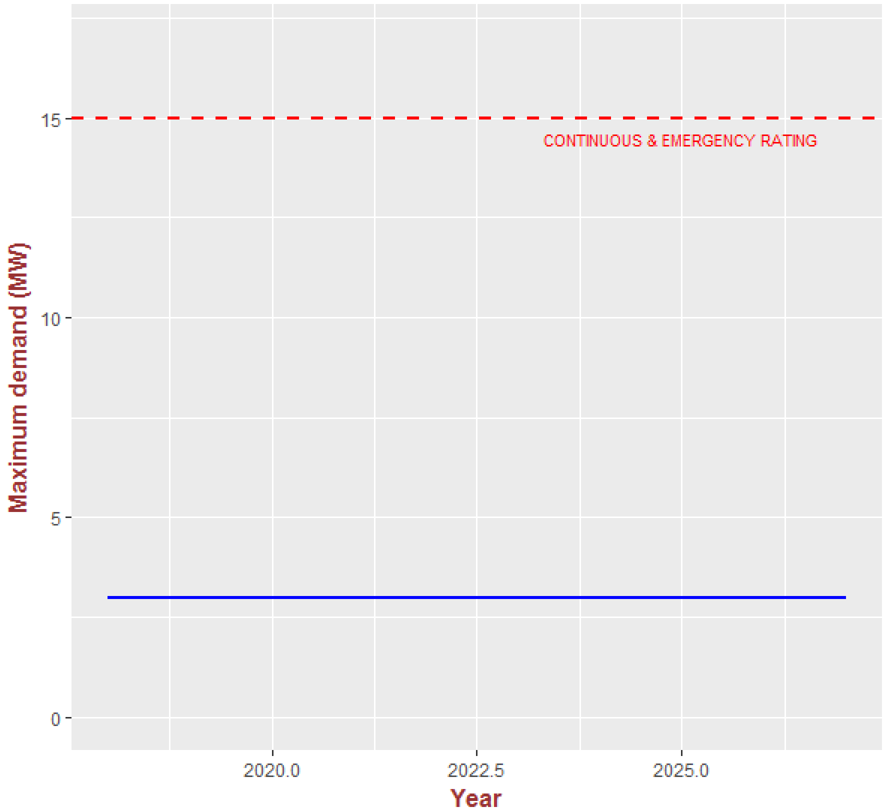


Figure C.11.1: Theodore Zone Substation summer maximum demand forecast

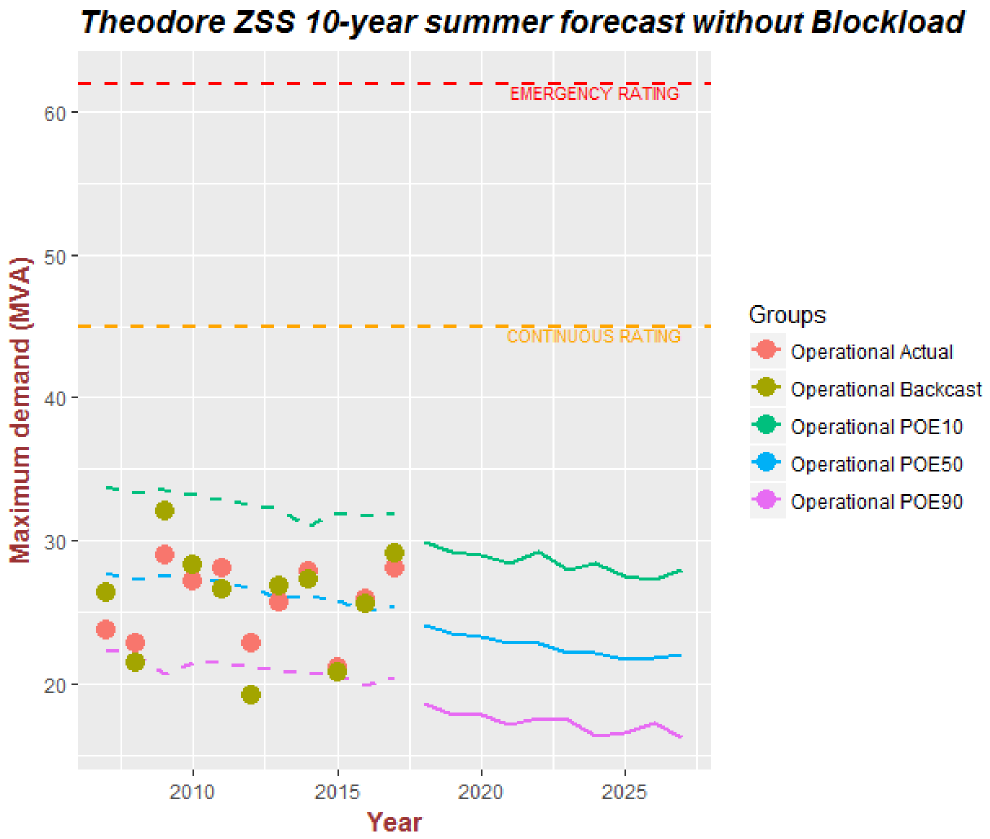


Figure C.11.2: Theodore Zone Substation winter maximum demand forecast

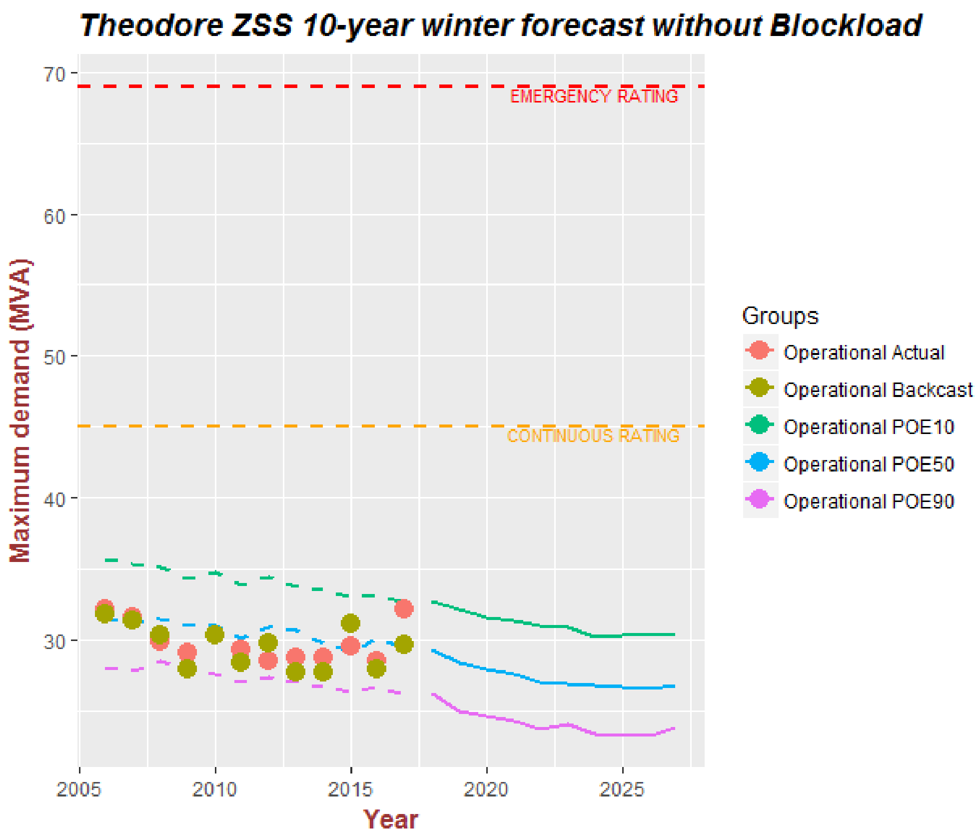


Figure C.12.1: Wanniassa Zone Substation summer maximum demand forecast

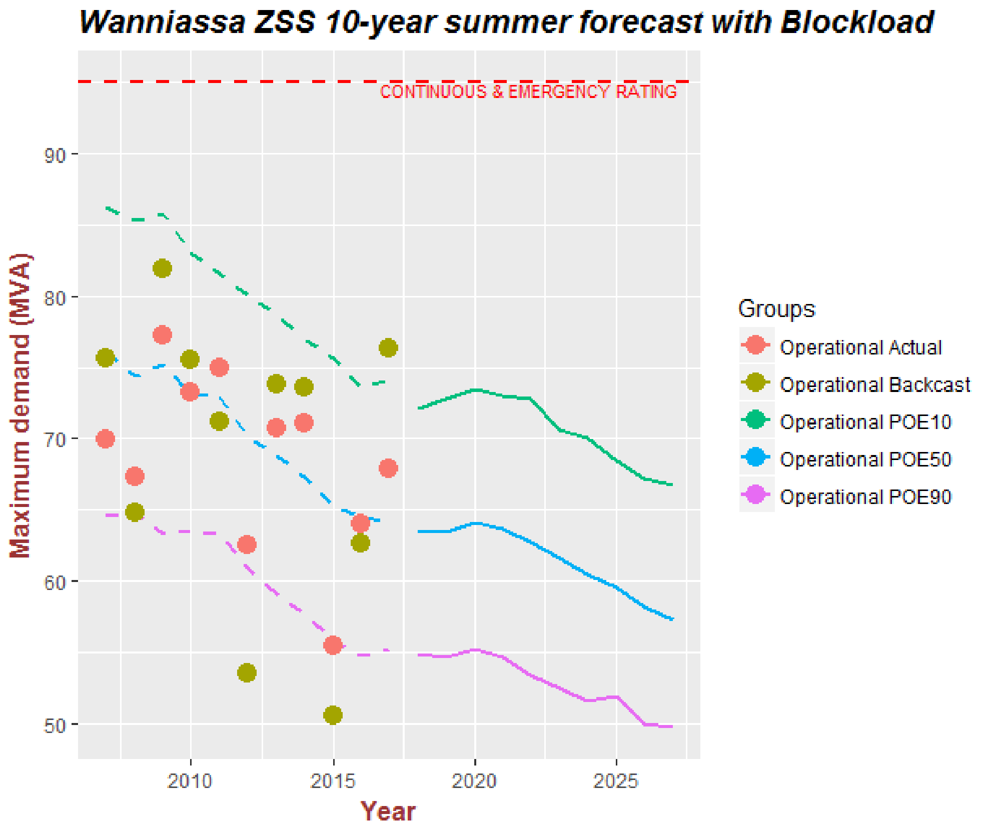


Figure C.12.2: Wanniassa Zone Substation winter maximum demand forecast

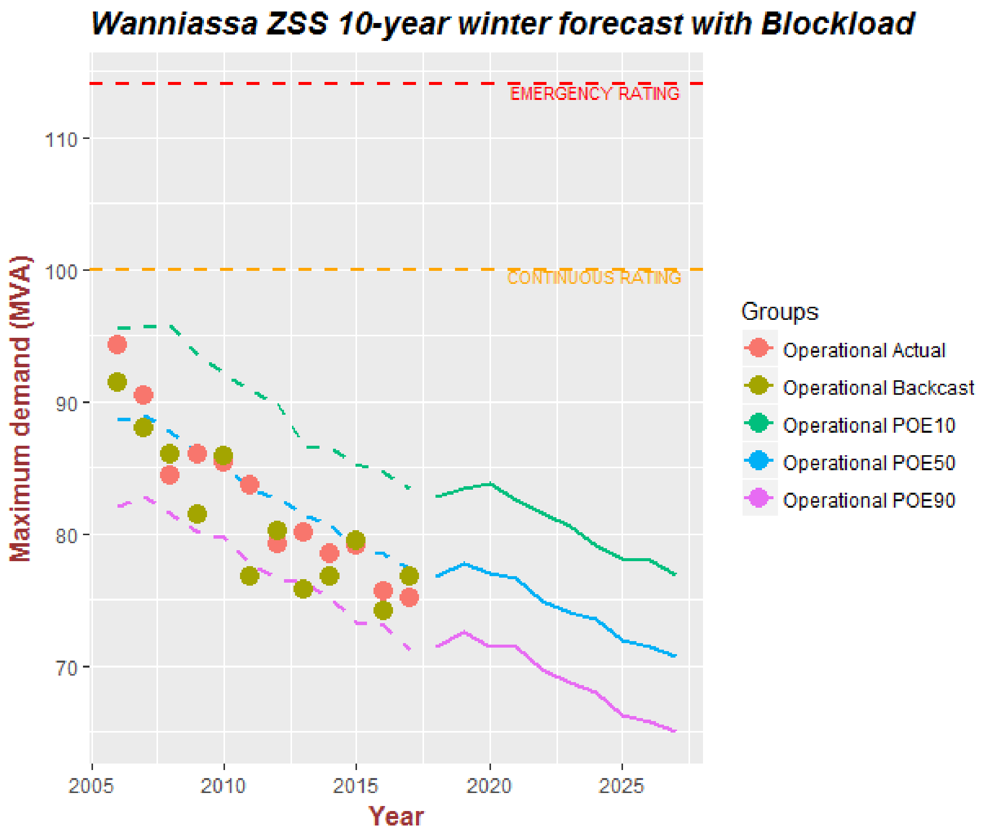


Figure C.13.1: Woden Zone Substation summer maximum demand forecast

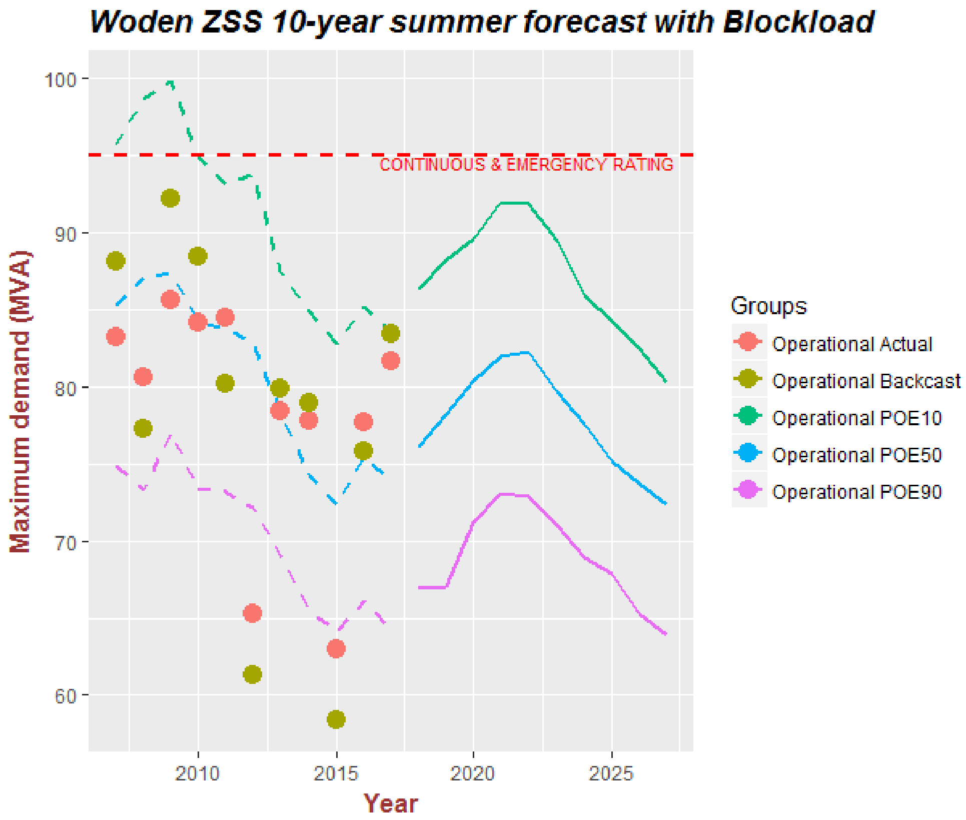
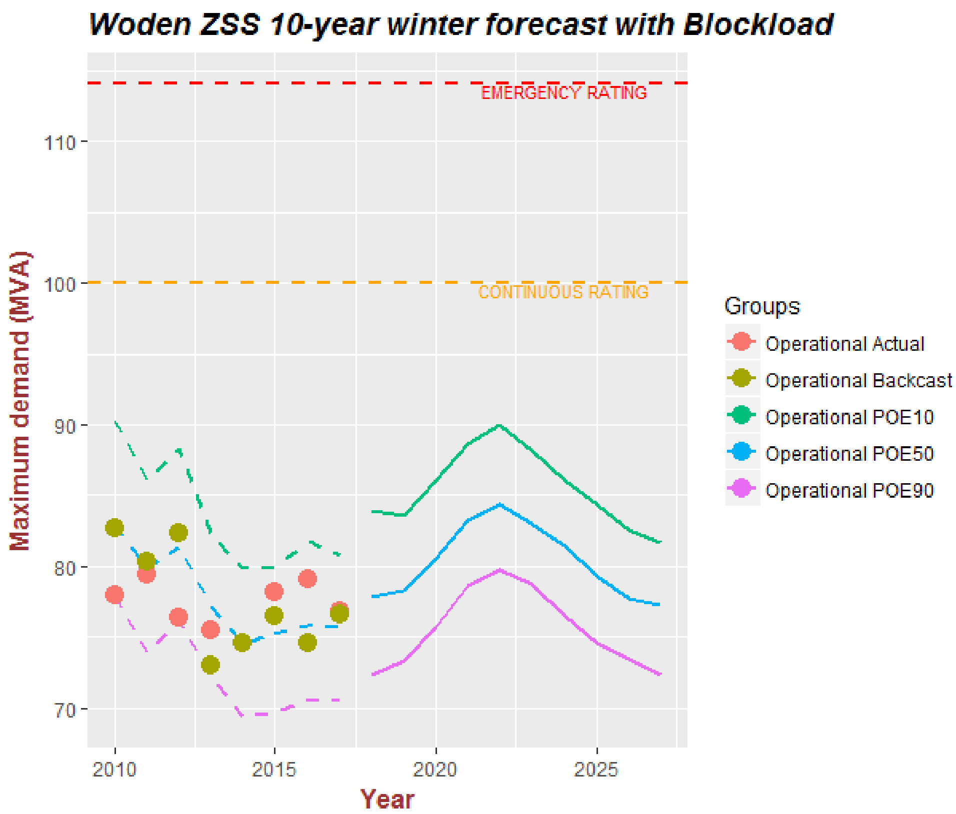


Figure C.13.2: Woden Zone Substation winter maximum demand forecast



Appendix D: Transmission Line Ratings

LINE			CURRENT RATING (AMPS)			
			Summer Day (35°C ambient temperature)		Winter Day (15°C ambient temperature)	
From	**To**	**ID No**	**Continuous**	**Emergency**	**Continuous**	**Emergency**
132 kV						
Belconnen	Bruce	A-21	1934	2916	2514	3277
Belconnen	Latham	A-20	1955	2958	2545	3325
Bruce	City East	A-54	967	1463	1259	1644
Bruce	Civic	A-11	1934	2926	2518	3289
Bruce	East Lake	A-45	967	1122	1122	1122
Bruce	Gold Creek	A-30	1934	2916	2514	3277
Canberra	Gold Creek	A-3	1934	2916	2514	3277
Canberra	Latham	A-2	1955	2958	2545	3325
Canberra	Woden	A-1	1955	2958	2545	3325
Causeway	City East	A-50	968	1458	1257	1638
Causeway	East Lake	A-46	968	1122	1122	1122
Causeway	Gilmore	A-44	1935	2916	2514	3277
Causeway	Telopea Park 1	A-51	390	390	390	390
Causeway	Telopea Park 2	A-52	390	390	390	390
Causeway	Telopea Park 3	A-53	390	390	390	390
Civic	Woden	A-10	1955	2958	2545	3325
Gilmore	Theodore	A-43	968	1458	1257	1638
Gilmore	Wanniassa	A-41	968	1458	1257	1638
Gilmore	Williamsdale	97F	968	1458	1257	1638
Tennent	Tennent Tee	97H/5	968	1458	1257	1638
Wanniassa	Woden	A-40	1990	3002	2586	3374
66 kV						
Fyshwick 1	Queanbeyan 1	0844	583	865	750	970
Fyshwick 2	Queanbeyan 2	0845	583	865	750	970

Appendix E: Small Scale (≤ 200 kW) PV Generation by Feeder as at 30 June 2017

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
Belconnen	Aikman	0	0	City East	Chisholm	92	264,131
Belconnen	Baldwin	162	491,978	City East	CNBP2	0	0
Belconnen	Battye	2	13,468	City East	Constitution	1	39,708
Belconnen	Bean	97	318,666	City East	Cooyong	0	0
Belconnen	Benjamin	11	32,301	City East	Cowper	79	256,778
Belconnen	CAE No 1	0	0	City East	Duffy	116	508,729
Belconnen	CAE No 2	0	0	City East	Ebden	210	608,193
Belconnen	Cameron North	3	6,100	City East	Electricity House	0	0
Belconnen	Cameron South	21	52,757	City East	Fairbairn	5	25,104
Belconnen	Chan	0	0	City East	Ferdinand	117	422,250
Belconnen	Chandler	0	0	City East	Haig	16	79,912
Belconnen	Chuculba	133	404,316	City East	Ijong	6	17,923
Belconnen	Eardley	40	0	City East	Lonsdale	0	0
Belconnen	Emu Bank	0	0	City East	Mackenzie	193	600,630
Belconnen	Haydon	96	310,580	City East	Masson	2	38,054
Belconnen	Joy Cummins	70	171,577	City East	Northbourne	4	14,648
Belconnen	Lampard	32	106,710	City East	Petrie	3	82,946
Belconnen	Laurie	132	390,179	City East	Quick	9	32,693
Belconnen	Maribyrnong	33	217,727	City East	Stott	178	519,206
Belconnen	McGuinness	118	423,124	City East	Wakefield	88	282,745
Belconnen	Meacham	282	909,347	City East	Wolseley	70	204,241
Belconnen	Shannon	159	468,999				
Belconnen	Swinden	14	44,126	Civic	ANU No1	0	0
Belconnen	William Slim	174	535,071	Civic	ANU No2	0	0
				Civic	ANU No3	0	0
City East	Aero Park	0	0	Civic	ANU No4	0	0
City East	Ainslie	0	0	Civic	ANU No5	0	0
City East	Akuna	0	0	Civic	Belconnen Way North	120	364,572
City East	Allara	0	0	Civic	Belconnen Way South	189	554,428
City East	Binara	0	0	Civic	Black Mountain	105	369,284

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
City East	Braddon	1	33,672	Civic	Christian	0	0
City East	Bunda	0	-	Civic	CSIRO	0	0
Civic	Dryandra	174	542,000	Gilmore	Tralee	1	33,586
Civic	Girrahween	0	0	Gilmore	Willoughby	82	291,709
Civic	Hobart Long	2	16,540				
Civic	Hobart Short	0	0	Gold Creek	Anthony Rolfe	161	569,045
Civic	Jolimont	0	0	Gold Creek	Barrington	250	749,940
Civic	McCaughey	11	29,367	Gold Creek	Birrigai	73	212,910
Civic	Miller	179	559,040	Gold Creek	Boulevarde North	15	53,567
Civic	Nicholson	23	66,477	Gold Creek	Bunburung	36	107,170
Civic	Telecom Tower	0	0	Gold Creek	Ferguson	304	885,237
Civic	Wattle	11	62,200	Gold Creek	Gribble	12	64,481
				Gold Creek	Gungahlin	5	66,213
East Lake	Dairy North	7	41,429	Gold Creek	Gurrang	113	376,684
East Lake	Isa	4	261,544	Gold Creek	Hughes	124	364,640
Fyshwick	Abattoir	13	59,564	Gold Creek	Lander	361	1,213,369
Fyshwick	Airport	0	0	Gold Creek	Lexcen	196	692,153
Fyshwick	Barrier	4	395,349	Gold Creek	Ling	41	145,426
Fyshwick	Collie	4	285,016	Gold Creek	Magenta	92	347,735
Fyshwick	Domayne	1	165,252	Gold Creek	Nona	272	814,298
Fyshwick	Gladstone	3	18,861	Gold Creek	Riley	91	307,674
Fyshwick	Newcastle	0	0	Gold Creek	Saunders	178	549,650
Fyshwick	Pialligo	5	141,204	Gold Creek	Wanganeen	43	125,865
Fyshwick	Tennant	9	238,412	Gold Creek	Wellington	0	0
Fyshwick	Whyalla	4	43,480	Gold Creek	West Street	221	613,560
Gilmore	Alderson	4	87,402	Latham	Bowley	225	687,013
Gilmore	Beggs	93	329,961	Latham	Conley	111	337,991
Gilmore	Edmond	122	404,942	Latham	Copland	128	388,031
Gilmore	Falkiner	83	290,942	Latham	Elkington	161	464,598
Gilmore	Findlayson	120	407,137	Latham	Fielder	29	187,968
Gilmore	Harman	0	0	Latham	Florey	151	486,670
Gilmore	Jackie Howe	142	487,949	Latham	Homann	145	572,692
Gilmore	May Maxwell	119	367,060	Latham	Latham	145	442,754
Gilmore	Monaro	2	152,466	Latham	Lhotsky	353	955,628

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
Gilmore	Penton	40	122,644	Latham	LM East	34	94,772
Gilmore	Rossman	98	302,461	Latham	LM West	29	82,425
Latham	Macrossan	246	678,308	Telopea Park	NSW	8	150,394
Latham	Markell	156	630,627	Telopea Park	Ovens	8	44,523
Latham	Melba	124	415,262	Telopea Park	Parliament House No 1	0	0
Latham	O'Loghlen	173	590,819	Telopea Park	Parliament House No 4	0	0
Latham	Paterick	75	246,407	Telopea Park	Power House	43	121,683
Latham	Powers	90	281,616	Telopea Park	Queen Victoria	0	0
Latham	Seal	146	480,515	Telopea Park	Riverside	1	2,548
Latham	Tillyard	134	436,221	Telopea Park	Russell No 1	0	0
Latham	Verbrugghen	87	306,434	Telopea Park	Russell No 2	0	0
Latham	Weir	192	652,988	Telopea Park	Russell No 3	0	0
				Telopea Park	Sandalwood	7	39,179
Telopea Park	ANU Backup	0	0	Telopea Park	Strzelecki	61	228,619
Telopea Park	Belmore	26	114,091	Telopea Park	Sturt	59	200,425
Telopea Park	Blackall	0	0	Telopea Park	Telopea Park East	4	15,708
Telopea Park	Bowen	0	0	Telopea Park	Throsby	96	363,583
Telopea Park	Brisbane	0	0	Telopea Park	York Park 1	0	0
Telopea Park	Broughton	0	0	Telopea Park	York Park 2	0	0
Telopea Park	CNBP1	0	0	Telopea Park	Young	0	0
Telopea Park	Cunningham	161	508,853				
Telopea Park	Edmond Barton	0	0	Theodore	Banyule	155	437,518

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
Telopea Park	Empire	107	328,345	Theodore	Callister	276	873,836
Telopea Park	Forster	44	184,285	Theodore	Chippindall	161	502,953
Telopea Park	Gallery	0	-	Theodore	Eaglemont	215	681,759
Telopea Park	Giles	38	130,424	Theodore	Fairley	154	527,060
Telopea Park	Jardine	0	0	Theodore	Lawrence Wackett	169	449,953
Telopea Park	Kelliher	0	0	Theodore	Lethbridge	135	513,390
Telopea Park	Kingston Foreshore 1	3	21,464	Theodore	Morison	162	473,888
Telopea Park	Kingston Foreshore 2	11	53,035	Theodore	Templestowe	77	232,374
Telopea Park	Kurrajong	1	3,474				
Telopea Park	Mildura	0	0	Wanniassa	Ashley	112	350,810
Telopea Park	Monash	5	17,229	Wanniassa	Athllon	155	406,507
Telopea Park	Mundaring	0	0	Wanniassa	Bissenberger	164	480,421
Wanniassa	Brookman	135	572,990	Woden	Deakin No 2	38	177,288
Wanniassa	Conolly	125	376,964	Woden	Devonport	29	91,520
Wanniassa	Erindale	0	0	Woden	Easty	1	10,920
Wanniassa	Fincham	1	1,655	Woden	Folingsby	191	803,040
Wanniassa	Gaunson	97	317,582	Woden	Garran	0	0
Wanniassa	Gouger	86	279,253	Woden	Hilder	173	634,079
Wanniassa	Grimshaw	479	1,114,139	Woden	Hindmarsh	0	0
Wanniassa	Hawker	95	290,983	Woden	Kent	0	0
Wanniassa	Hawkesbury	178	566,222	Woden	King	13	59,310
Wanniassa	Hemmings	96	276,927	Woden	Launceston	1	110,124
Wanniassa	Lambrigg	85	332,396	Woden	Lyons West	235	675,769
Wanniassa	Langdon	148	450,039	Woden	McInnes	138	478,600
Wanniassa	Longmore	172	556,203	Woden	Phillip North	4	53,104
Wanniassa	Mannheim	95	287,922	Woden	Phillip South	0	0
Wanniassa	Marconi	143	423,949	Woden	Streeton	162	512,972
Wanniassa	Matthews	156	453,292	Woden	Theodore	125	465,278

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
Wanniassa	Mugga	1	219,923	Woden	Tidbinbilla 22 kV	3	22,154
Wanniassa	Muresk	212	739,451	Woden	Weston East	152	441,770
Wanniassa	Pitman	2	222,277	Woden	Wilson	170	579,032
Wanniassa	Pridham	86	260,066	Woden	Yamba	0	0
Wanniassa	Reid	172	559,263	Woden	Yarralumla	56	220,606
Wanniassa	Rowland	0	0				
Wanniassa	Sainsbury	56	164,048		**TOTAL**	**17,975**	**59,783,854**
Wanniassa	Sternberg	2	6,508				
Wanniassa	Symers	81	271,966				
Woden	Bunbury	207	703,679				
Woden	Carruthers	125	385,822				
Woden	Cooleman	88	260,121				
Woden	Corrina	2	34,976				
Woden	Cotter 11 kV	198	731,915				
Woden	Cotter 22 kV	0	0				
Woden	Curtin North	140	431,815				
Woden	Daplyn	130	354,593				
Woden	Deakin No 1	87	242,797				

Appendix F: Distribution System Limitations

The following tables are included to comply with the requirements of the NER Section 5.13.3 and to provide information to the proponents of non-network solutions or demand-side management to meeting or deferring identified constraints on ActewAGL's distribution network.

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.17207° S, 149.11647° E
Location of constraint (end)	35.18530° S, 149.14469° E
Asset ID	Gold Creek - Hamer feeder
Network Element	Distribution Feeder
Residential customers affected	2,000
Residential customers affected	1.00%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 5.5 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 5.4 MW
Energy at risk	2018-2022; 26,280 MWh
Preferred network investment	New underground 11 kV feeder Gold Creek Zone Substation to Hamer St, Gungahlin
Preferred network investment capital cost	$2,261,148
Preferred annual network investment operating cost	$22,611
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	February 2018
Demand reduction required to defer investment by 1 year	2.4 MVA
Annual Deferral Value	$36,507
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.17207° S, 149.11647° E
Location of constraint (end)	35.18530° S, 149.14469° E
Asset ID	Gold Creek - Flemington feeder
Network Element	Distribution Feeder
Residential customers affected	0
Residential customers affected	0%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 5.5 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 5.5 MW
Energy at risk	2018-2022; 22,776 MWh
Preferred network investment	New underground 11 kV feeder Gold Creek Zone Substation to Flemington Rd, Gungahlin
Preferred network investment capital cost	$2,124,633
Preferred annual network investment operating cost	$21,246
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2018
Demand reduction required to defer investment by 1 year	5.5 MVA
Annual Deferral Value	$34,303
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.17207^{o} S, 149.11647^{o} E
Location of constraint (end)	35.18862^{o} S, 149.14571^{o} E
Asset ID	Gold Creek - Valley feeder
Network Element	Distribution Feeder
Residential customers affected	2,000
Residential customers affected	1.00%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 5.5 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 5.3 MW
Energy at risk	2018-2022; 26,280 MWh
Preferred network investment	New underground 11 kV feeder Gold Creek Zone Substation to Valley Rd, Gungahlin
Preferred network investment capital cost	$2,447,948
Preferred annual network investment operating cost	$24,479
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2018
Demand reduction required to defer investment by 1 year	2.0 MVA
Annual Deferral Value	$39,523
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	**Information**
Constraint primary driver	Capacity
Location of constraint (start)	35.17207^{o} S, 149.11647^{o} E
Location of constraint (end)	35.20839^{o} S, 149.13533^{o} E
Asset ID	Gold Creek – Dacre feeder
Network Element	Distribution Feeder
Residential customers affected	0
Residential customers affected	0%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 5.5 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 5.5 MW
Energy at risk	2018-2022; 27,280 MWh
Preferred network investment	New underground 11 kV feeder Gold Creek Zone Substation to Dacre St, Mitchell
Preferred network investment capital cost	$3,299,051
Preferred annual network investment operating cost	$32,990
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	December 2018
Demand reduction required to defer investment by 1 year	3.2 MVA
Annual Deferral Value	$91,549
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.41000° S, 149.14149° E
Location of constraint (end)	35.39728° S, 149.15630° E
Asset ID	Gilmore – Hume West feeder
Network Element	Distribution Feeder
Residential customers affected	0
Residential customers affected	0%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 5.5 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 5.5 MW
Energy at risk	2018-2022; 131,400 MWh
Preferred network investment	New underground 11 kV feeder Gilmore Zone Substation to Tralee St, Hume West
Preferred network investment capital cost	$733,760
Preferred annual network investment operating cost	$22,611
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2018
Demand reduction required to defer investment by 1 year	3.2 MVA
Annual Deferral Value	$11,847
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.17207° S, 149.11647° E
Location of constraint (end)	35.20911° S, 149.13846° E
Asset ID	Gold Creek – Mitchell area 3 x feeders
Network Element	Distribution Feeder
Residential customers affected	0
Residential customers affected	0%
Asset rating	2019-2024; 16.5 MVA
Forecast Demand	2019-2024; 12.3 MVA
Voltage level	11 kV
Maximum Load at risk -	2019-2024; 12.3 MW
Energy at risk	2019-2024; 3,601,600 MWh
Preferred network investment	New underground 3 x 11 kV feeders Gold Creek Zone Substation to Hoskins St, Mitchell
Preferred network investment capital cost	$5,842,271
Preferred annual network investment operating cost	$58,422
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2022
Demand reduction required to defer investment by 1 year	3.8 MVA
Annual Deferral Value	$42,178
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.23326° S, 149.08432° E
Location of constraint (end)	35.23639° S, 149.06706° E
Asset ID	Belconnen – Belconnen Town Centre 3 x feeders
Network Element	Distribution Feeder
Residential customers affected	2,000
Residential customers affected	1.00%
Asset rating	2019-2024; 16.5 MVA
Forecast Demand	2019-2024; 16.4 MVA
Voltage level	11 kV
Maximum Load at risk -	2019-2024; 9.5 MW
Energy at risk	2019-2024; 603,167 MWh
Preferred network investment	New underground 3 x 11 kV feeders Belconnen Zone Substation to Emu Bank, Belconnen
Preferred network investment capital cost	$3,466,140
Preferred annual network investment operating cost	$34,661
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2023
Demand reduction required to defer investment by 1 year	3.5 MVA
Annual Deferral Value	$87,941
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.38376° S, 149.09575° E
Location of constraint (end)	34.41910° S, 149.07216° E
Asset ID	Wanniassa - Limburg feeder
Network Element	Distribution Feeder
Residential customers affected	2,000
Residential customers affected	1.00%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 5.5 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 2.1 MW
Energy at risk	2018-2022; 586,280 MWh
Preferred network investment	New underground 11 kV feeder Wanniassa Zone Substation to Limburg Way, Tuggeranong
Preferred network investment capital cost	$2,854,359
Preferred annual network investment operating cost	$28,543
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	December 2020
Demand reduction required to defer investment by 1 year	2.1 MVA
Annual Deferral Value	$120,699
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.26934^o S, 149.14976^o E
Location of constraint (end)	35.27695^o S, 149.13249^o E
Asset ID	City East – Genge St feeder
Network Element	Distribution Feeder
Residential customers affected	0
Residential customers affected	0%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 5.5 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 4.0 MW
Energy at risk	2018-2022; 537,020 MWh
Preferred network investment	New underground 11 kV feeder City East Zone Substation to Genge St, Canberra CBD
Preferred network investment capital cost	$4,583,722
Preferred annual network investment operating cost	$45,837
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2021
Demand reduction required to defer investment by 1 year	4.0 MVA
Annual Deferral Value	$101,758
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.31082^{o} S, 149.14272^{o} E
Location of constraint (end)	35.32226^{o} S, 149.13498^{o} E
Asset ID	Telopea Park – Stuart St feeder
Network Element	Distribution Feeder
Residential customers affected	1,000
Residential customers affected	0.50%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 2.5 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 2.5 MW
Energy at risk	2018-2022; 150,658 MWh
Preferred network investment	New underground 11 kV feeder Telopea Park Zone Substation to Stuart St, Griffith
Preferred network investment capital cost	$2,941,599
Preferred annual network investment operating cost	$29,415
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2021
Demand reduction required to defer investment by 1 year	2.5 MVA
Annual Deferral Value	$109,427
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.31521° S, 149.16432° E
Location of constraint (end)	35.31444° S, 149.15070° E
Asset ID	East Lake – Kingston Foreshore 3 x feeders
Network Element	Distribution Feeder
Residential customers affected	2,000
Residential customers affected	1.00%
Asset rating	2019-2024; 16.5 MVA
Forecast Demand	2019-2024; 12.5 MVA
Voltage level	11 kV
Maximum Load at risk	2019-2024; 8.1 MW
Energy at risk	2019-2024; 193,436 MWh
Preferred network investment	New underground 3 x 11 kV feeders East Lake Zone Substation to Eyre St, Kingston
Preferred network investment capital cost	$1,172,446
Preferred annual network investment operating cost	$11,724
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	December 2020
Demand reduction required to defer investment by 1 year	1.1 MVA
Annual Deferral Value	$94,648
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.31521° S, 149.16432° E
Location of constraint (end)	35.31705° S, 149.18976° E
Asset ID	East Lake – Pialligo 2 x feeders
Network Element	Distribution Feeder
Residential customers affected	1,000
Residential customers affected	0.50%
Asset rating	2018-2022; 11.0 MVA
Forecast Demand	2018-2022; 8.2 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 5.0 MW
Energy at risk	2018-2022; 237,964 MWh
Preferred network investment	New underground 2 x 11 kV feeders East Lake Zone Substation to Pialligo Ave, Pialligo
Preferred network investment capital cost	$4,921,166
Preferred annual network investment operating cost	$49,211
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2020
Demand reduction required to defer investment by 1 year	3.2 MVA
Annual Deferral Value	$136,562
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.22545° S, 149.03212° E
Location of constraint (end)	35.23325° S, 148.99891° E
Asset ID	Latham – O'Loghlen feeder
Network Element	Distribution Feeder
Residential customers affected	2,000
Residential customers affected	1.00%
Asset rating	2019-2024; 5.5 MVA
Forecast Demand	2019-2024; 5.0 MVA
Voltage level	11 kV
Maximum Load at risk	2019-2024; 5.0 MW
Energy at risk	2019-2024; 1,203,118 MWh
Preferred network investment	Extend 11 kV underground O'Loghlen feeder to Strathnairn
Preferred network investment capital cost	$2,490,924
Preferred annual network investment operating cost	$24,909
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	December 2019
Demand reduction required to defer investment by 1 year	1.0 MVA
Annual Deferral Value	$221,194
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.26926^o S, 149.05260^o E
Location of constraint (end)	35.27373^o S, 149.04849^o E
Asset ID	Civic – Black Mountain feeder
Network Element	Distribution Feeder
Residential customers affected	1,000
Residential customers affected	0.50%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 3.0 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 3.0 MW
Energy at risk	2018-2022; 3,893,716 MWh
Preferred network investment	Extend 11 kV underground Black Mountain feeder to John Gorton Drive, Whitlam
Preferred network investment capital cost	$451,415
Preferred annual network investment operating cost	$4,514
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2020
Demand reduction required to defer investment by 1 year	1.0 MVA
Annual Deferral Value	$40,085
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.26926° S, 149.05260° E
Location of constraint (end)	35.28462° S, 149.12277° E
Asset ID	Civic – Edinburgh Ave feeder
Network Element	Distribution Feeder
Residential customers affected	1,000
Residential customers affected	0.50%
Asset rating	2018-2022; 5.5 MVA
Forecast Demand	2018-2022; 5.2 MVA
Voltage level	11 kV
Maximum Load at risk	2018-2022; 3.0 MW
Energy at risk	2018-2022; 3,893,716 MWh
Preferred network investment	New underground 11 kV feeder Civic Zone Substation to Edinburgh Ave, Acton
Preferred network investment capital cost	$2,206,402
Preferred annual network investment operating cost	$22,064
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2018
Demand reduction required to defer investment by 1 year	5.2 MVA
Annual Deferral Value	$37,678
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.27080° S, 149.05753° E
Location of constraint (end)	35.27373° S, 149.04849° E
Asset ID	Molonglo – Molonglo Valley 7 x feeders
Network Element	Distribution Feeder
Residential customers affected	5,000
Residential customers affected	2.50%
Asset rating	2019-2024; 38.5 MVA
Forecast Demand	2019-2024; 5.9 MVA
Voltage level	11 kV
Maximum Load at risk	2019-2024; 5.9 MW
Energy at risk	2019-2024; 691,536 MWh
Preferred network investment	New underground 7 x 11 kV feeders Molonglo Zone Substation to John Gorton Drive, Molonglo
Preferred network investment capital cost	$5,227,942
Preferred annual network investment operating cost	$52,279
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2022 – June 2024
Demand reduction required to defer investment by 1 year	1.9 MVA
Annual Deferral Value	$78,685
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.26926° S, 149.05260° E
Location of constraint (end)	35.26926° S, 149.05260° E
Asset ID	Molonglo Zone Substation
Network Element	Zone Substation
Residential customers affected	5,000
Residential customers affected	2.50%
Asset rating	2019-2024; 14 MVA
Forecast Demand	2019-2024; 5.9 MVA
Voltage level	132/11 kV
Maximum Load at risk	2019-2024; 5.9 MW
Energy at risk	2019-2024; 691,536 MWh
Preferred network investment	New 132/11 kV zone substation at Coulter Drive, Molonglo
Preferred network investment capital cost	$10,160,708
Preferred annual network investment operating cost	$101,607
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2022
Demand reduction required to defer investment by 1 year	1.9 MVA
Annual Deferral Value	$152,927
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A

Field Name	Information
Constraint primary driver	Capacity
Location of constraint (start)	35.31521° S, 149.16432° E
Location of constraint (end)	35.31521° S, 149.16432° E
Asset ID	East Lake Zone Substation
Network Element	Zone Substation
Residential customers affected	5,000
Residential customers affected	2.50%
Asset rating	2018-2022; 55 MVA
Forecast Demand	2019-2022; 27.6 MVA
Voltage level	132/11 kV
Maximum Load at risk	2018-2022; 25.0 MW
Energy at risk	2018-2022; 2,560,000 MWh
Preferred network investment	Second 132/11 kV 30/55 MVA transformer and 11 kV switchboard at East Lake Zone Substation
Preferred network investment capital cost	$4,573,419
Preferred annual network investment operating cost	$45,734
Preferred network investment cost accuracy	+10%
Preferred network investment cost accuracy	-10%
Proposed timing	June 2019
Demand reduction required to defer investment by 1 year	13.2 MVA
Annual Deferral Value	$30,767
Load transfer capability	0 MVA
Emergency generation	0 MVA
Historic use of existing emergency response	N/A
Historic load trace	N/A
Historic asset rating	N/A