Supporting Document 12.1.8
Distribution Network Growth Strategy
2019-2024

April 2018

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1. Executive Summary

Asset Management Plan	Distribution Network Growth Strategy 2019-2024: CEOP2092
Description	This document provides the strategic basis for the short- and long-term management of load and demand growth on Essential Energy's distribution network.
Objectives	> Effective and efficient management of safety, regulatory and customer risks associated with load and demand growth on the network. > In addition, this document will break down the Asset Management Objectives, as directed by the overarching Strategic Asset Management Plan (SAMP), into more specific Asset System and Class objectives and targets, which are to be used in the Asset Management Plans and Investment Cases. > Ensure public safety is not compromised by increasing system loads, including maintaining effective electrical protection and prescribed ground clearances. > Minimise bushfire ignition causes that may result from overloaded equipment. > Prevent breaches of relevant statutory or other requirements, including NSW Licence Conditions, Independent Pricing and Regulatory Tribunal (IPART), National Electricity Rules (NER), Australian Energy Regulator (AER) and National Energy Customer Framework (NECF). > Minimise failure or degradation of network equipment due to excessive loads. > Facilitate customer connections in accordance with regulatory requirements. > Identify and manage thermal, voltage or fault-related growth constraints in a timely, economically prudent and effective manner. > Ensure all growth-related investments are warranted, prudent and efficient. > Maximise network utilisation and the deferral of augmentation investments. > Reduce loads where possible by using demand management and cost-effective reactive support. > Improve visibility and analysis of network loads, voltages and performance by using network technology. > Leverage other investment drivers to improve performance in growth areas (e.g. refurbishment, reliability). > Continue a semi-reactive management approach.
Approach	> Forecast customer numbers, network demand growth rates and growth-related network investment needs, based on historical data. > To help with analysing and managing projects and support the case for investments associated with demand growth on the distribution network, we have categorised projects under the following key growth drivers: • Thermal constraints - maintain safe, sustainable thermal capacity of network conductors and equipment while safely carrying increasing loads and/or excessive demands, including maintaining ground and inter-circuit clearances. • Voltage constraints - sustain voltage performance of the network within prescribed limits while carrying increasing loads and demands. • Fault level constraints - sustain safe and effective electrical protection and operational capability of the network while carrying increasing loads and demands. • Customer connections - ensure sufficient network capacity is available for new or additional customer loads and embedded generators; where necessary, fund shared asset work to facilitate new or additional customer connections and loads. > Further to these growth driver categorisations, a method for estimating the risk associated with the deferral of each has been modelled and applied. > It is planned that this risk model be further developed and used at a project level going forward.

	> Improve network monitoring and analysis capabilities by deploying network technology at strategic locations, including load and voltage monitoring equipment fitted with communications. > Implement demand management initiatives to defer augmentation investments. > Subject all projects to an Investment Case and approval to ensure all capital				
Customer benefits	> Provision of an affordable electricity supply of acceptable quality and reliability that will not be compromised by continued network load growth. > Minimise supply quality and reliability problems associated with load-related network equipment degradation or failures. > Sufficient network capacity is available to facilitate customer connections, loads and generators. > Supply voltages are maintained within acceptable limits under all loading and demand conditions to minimise customer disruption and/or equipment malfunction.				
Implementation timing	2019/20 – 2023/24				
CAPEX phased forecast $ million (2019 Real)[1]	2019/20	2020/21	2021/22	2022/23	2023/24
	$24.69	$23.48	$22.96	$22.67	$22.57
OPEX phased forecast $ million (2019 Real) Error! Bookmark not defined.	2019/20	2020/21	2021/22	2022/23	2023/24
	$0M	$0M	$0M	$0M	$0M
Total forecasts $ million (2019 Real) Error! Bookmark not defined.	CAPEX Total - $113.63M		OPEX Total - $0M		

[1] Forecasts are exclusive of labour and material cost escalation

1.1 Strategy Synopsis

Essential Energy is committed to using reasonable and practical methods to deliver cost-effective capacity and supply quality performance within our distribution network.

This document presents how we manage peak demand and load growth in a way that maintains adequate network capacity and facilitates increasing customer loads while sustaining acceptable network performance and safety.

It defines the components that constitute distribution network growth and how they should be managed and includes a strategy. This supports the investment needed to manage demand growth on the distribution network.

Distribution growth is not simply an extrapolation of global demand forecasting. The scale of Essential Energy's coverage means we service extremes: rural and urban centres, multiple communities and industries, growing coastal populations, and climatic extremes ranging from inland to coastal and snowfields to sub-tropical forests. This range turns global averages into statistics that allow benchmarking but are not always useful for micro-level decision-making.

Essential Energy's electricity network was largely developed from 1940 to 1980 in a way that was appropriate for the land usage of the time and used the planning, design and construction standards of the day.

Compared to that time of major system expansion, we now have far more connections, with more appliances and larger loads per installation. Complicating customer load growth is customers' reduced power quality tolerance due to their increased use of electronical appliances and computing equipment. While we have continually expanded our systems, our assets have been in service for 40 to 50 years and were not designed for the system demands that are built into today's designs. Their capacity and capability are continually challenged by the demands of modern equipment and appliances.

Essential Energy tests and measures the network's ability to provide customers with a reasonable quality of supply and adequate voltage levels. Issues are arising that, while not inherently critical, are sufficient to breach standards or cause consumer concerns.

This Distribution Growth Strategy and Investment Case is shaped heavily by the need to manage enterprise risks — particularly network, finance, reputation and environment— that are associated with a mismatch between distribution system assets and consumer expectations and behaviours.

To assist with analysing and managing projects and to support the case for investments associated with demand growth, we subcategorise distribution growth into the four key AER investment driver components:

> **Customer connections**: Obligatory shared asset work that we fund to facilitate new or additional customer connection loads and embedded generators.

> **Thermal constraints**: Maintain safe and sustainable thermal capacity of network conductors and equipment while safely carrying loads and increasing or excessive demands.

> **Voltage constraints**: Sustain voltage performance of network within prescribed limits while carrying loads and increasing demands.

> **Fault level constraints**: Sustain safe and effective electrical protection and operational capability of the network while carrying loads and increasing demands.

Further to this categorisation, we have developed a method for modelling the annualised risk associated with the deferral of projects from within each sub-category. It is planned that this modelling tool be implemented at a project level, in the coming regulatory period, to assist in the prioritisation of work with the growth program.

We will invest in demand management (or capital deferral) initiatives on a project by project basis as the need is established. Further detail regarding the process is outlined in the Demand Management Strategy. This will maximise use of the network and allow for the deferment or cancellation of some traditional augmentation projects.

Additional investments for network technology initiatives, such as programs for improving voltage and load monitoring of the network, are also included in this Distribution Growth Strategy. This investment will improve surveillance, performance monitoring and control of the network and facilitate modernisation. It will help deliver improved operational efficiencies, provide customer information, facilitate deferment of capital expenditure, and assist in cost reduction and management of the network and its performance.

Table 1 summarises the forecast capital investments for the 2019-2024 period. The forecast is based on historical expenditure patterns for each growth driver category during the 2016/17 to 2018/19 period.

This approach is appropriate and prudent, given the uncertainty and variability of demand growth or decline across local areas of Essential Energy's network. Most medium-term distribution growth investment needs are driven by increased customer numbers, and by the need to manage the risks associated with pre-existing network voltage and thermal constraints caused by past incremental demand growth. Also, most distribution growth expenditure is a reaction to demand growth constraints after they have been identified.

Therefore, most actual and defined medium- and long-term demand-growth-driven projects are largely unknown until specific constraints emerge or are identified, and they tend to be area-specific.

In addition to historic distribution growth augmentation investments, we have included investment in network technology initiatives. These will provide investment deferral opportunities, deliver improved efficiency and cost reductions for managing the network, provide better customer information services, and facilitate more accurate performance reporting.

Table 1 – Distribution Growth Investment Forecast Summary[2]

Financial Year	2019/20	2020/21	2021/22	2022/23	2023/24	5 Year Total
Distribution Growth Investment	$23.67	$22.49	$21.99	$21.71	$21.62	**$111.48**
Network Technology Investment	$1.02	$.99	$.97	$.96	$.95	**$4.89**
Total	**$24.69**	**$23.48**	**$22.96**	**$22.67**	**$22.57**	**$116.37**

The primary needs and justifications for the investments in Table 1 are:

- Prevent breaches of statutory requirements e.g. Licence Conditions, National Electricity Rules (NER), Australian Energy Regulator (AER) and National Energy Customer Framework (NECF) requirements.
- Maintain prescribed minimum ground or inter-circuit clearances of overhead lines.
- Ensure staff safety is not compromised when operating equipment under load.
- Ensure public safety is not compromised by increased system loads.
- Minimise bushfire ignition network causes that may result from overloaded, or under protected equipment.
- Ensure equipment is safely operated within design ratings.
- Prevent degradation and damage to network equipment from increased system loads or ineffective electrical protection.
- Maintain system volts (and customer-received volts) within prescribed limits when carrying present or expected loads.
- Maintain safe and effective electrical protection for the network.
- Maintain adequate network capacity for customer loads and contingencies.
- Meet our obligation to fund works that facilitate, and provide capacity for, the connection of new or additional customer loads (Essential Energy Policy CEOP2513.06 *Connection Policy – Connection Charges*, NECF and AER requirements)
- Minimise customer outages and power quality complaints resulting from increased system loads.
- Improve understanding and facilitate better management of network loads through increased network surveillance provided by network monitoring initiatives.

[2] All forecast costs use Real 2016 direct cost dollars with no CPI adjustments.

2. Introduction

2.1 Purpose

The purpose of this document is to provide input into Essential Energy's asset management functions and ensure the coordinated management of growth activities across our network during the 2019-2024 regulatory period.

We have developed it to:

> Instil a systematic and consistent approach to managing demand and load growth throughout our asset management functions.
> Break down the Asset Management Objectives, as directed by the overarching Strategic Asset Management Plan (SAMP), into more specific Asset System and Class objectives and targets, which are to be used in the Asset Management Plans and Investment Cases.
> Define the components that constitute distribution network peak demand and load growth, their impacts, and how these components need to be managed.
> Support continued investment for network optimisation, augmentation, and growth management.

It includes investments that will increase our active monitoring capabilities for network load and demand growth and voltage performance, which will assist with system optimisation and maximise network utilisation. These investments will allow for the deferral, reduction, or cancellation of investments to cater for demand growth on some parts of the network

The overarching aim of the Strategy is the prioritised and efficient management of safety, regulatory and customer risks associated with network load and demand growth. This includes the following objectives:

> Address customer connections in accordance with regulatory requirements.
> Identify and address growth-related constraints in a timely and effective way.
> Ensure all growth-related investments are warranted, prudent and efficient.
> Ensure planned investments are prioritised based upon their risk value.
> Maximise network use and defer augmentation investments.
> Reduce loads through demand management and cost-effective dynamic reactive support.
> Improve monitoring, data-gathering and analysis through network technology.
> Leverage other investment drivers to improve performance in growth areas e.g. refurbishment, reliability.
> Continue with a semi-reactive growth management approach.

2.2 Scope

This Strategy covers measuring, monitoring, optimising and augmenting capacity and supply quality across Essential Energy's distribution network. It does not apply to the sub transmission network or its associated assets, or to network reliability and customer supply outages.

2.3 Information Sources

The data used throughout this document is the best currently available from Essential Energy's information systems and is generally drawn from the current regulatory period of 2014/15 to 2018/19. These years are considered to contain the most reliable data.

This Strategy has also used information from the following documents:

> Network Planning Database
> CEOP8026 - *Electricity Supply Standards*
> CEOP8003 – *Subtransmission and Distribution Network Planning Criteria and Guidelines*
> CEOF6659 - *Network Planning: Low Voltage Pole Rebate*
> CEOM7011 - *Standard Overhead Conductor: Current Rating Guide*

- CEOM7081 - *Subtransmission Line: Design Manual*
- CEOM7092 - *Distribution Planning: Manual*
- CEOM7094 - *Engineering Services: Renewal & Refurbishment Manual*
- CEOM7097 - *Overhead: Design Manual*
- CEOM7098 - *Underground: Design Manual*
- CEOP1121 - *Demand Management: Electricity Network*
- CEOP2008 - *Network: Capital Expenditure*
- CEOP2009 - *Network Project Guidelines: Investment Appraisal & Business Case >$100000*
- CEOP2015 - *General Terms & Conditions: Supply of Electricity to New Subdivisions and Site Developments*
- CEOP2291 - *Subtransmission: Design Procedure*
- CEOP2513.06 – *Connection Policy – Connection Charges*
- CEOP8002 - *Essential Energy: High Voltage Protection Guidelines*
- CEOP8019 - *Infrastructure Strategy: Capital Contributions*
- CEOP8032 - *Transmission & Zone Substations: Design Guidelines*
- CEOP8044 - *Distribution Transformers: Ferro-resonant Over-voltage Risk Limitation*
- CEOP8046 - *Network Planning: Easement Requirements*
- Growth PIP ESS_1 to ESS_4 Model Description, Assumptions, and Risk Estimation Method
- NIEIR *Forecast Energy & Demand Report for Essential Energy*

2.4 Reporting, Responsibilities, and Review Timeline

This Strategy is an evolving document and requires periodic review to ensure it leads to the desired outcomes. Figure 1 shows the work group responsible for each part of the Strategy and the frequency of reports and review.

Category	Activity	Work Group	Frequency
Growth CAPEX projects and programs progress reports	Produce network performance reports	Planning Group	Monthly to Planning Group Quarterly to Essential Energy Executive
	Annual Status Report in preparation for the annual audit in accordance with the Licence Conditions		Annually to Regulator
Strategy review	Monitor emerging issues, opportunities and resource constraints and review the Distribution Network Growth Strategy	Distribution Planning	Annually or as required

Figure 1 – Responsibilities of Work Groups

3. Background

3.1 History and Need for an Electrical Distribution Network

Historically, Essential Energy's predominantly rural network developed in response to community needs. In the early twentieth century, most people lived without electric power, with a few using some form of local generation, complete with fuel and maintenance issues. With electrification, houses were wired with lights but few power outlets, which were mainly in the kitchen. Maximum demands and energy usage back then were low.

As these small systems expanded, communities welcomed the convenience of mains power and paid to extend the systems to un-serviced premises. The formation of County Councils led to a more organised approach to engineering and expansion. Given the distances involved, the key focus for network expansion was cost and post-war availability of materials.

Since these early days, social expectations around electricity supply have grown. Nowadays, it viewed as an essential service rather than the privilege it was before 1980. Our current lifestyle depends on the availability of a safe and reliable power supply.

Today's connections are far more numerous, with many more appliances and larger loads per installation. Customers demand high power quality, so they can properly operate a proliferation of electrical appliances and computing equipment.

3.2 Essential Energy's Distribution Network

While its roots are in the early 1900s, Essential Energy's electricity network was largely developed from 1940 to 1980, using the planning, design, and construction standards of the day. The County Councils that built these systems used more than 200 different conductor types. Figure 2 shows more than 400 conductor types, as imperial and metric versions are counted separately.

Figure 2 shows that most conductors fall into a high impedance category. Approximately half the network has a DC resistance greater than 5 ohms per kilometre, with steel conductors approximating 15 to 25 ohms per kilometre.

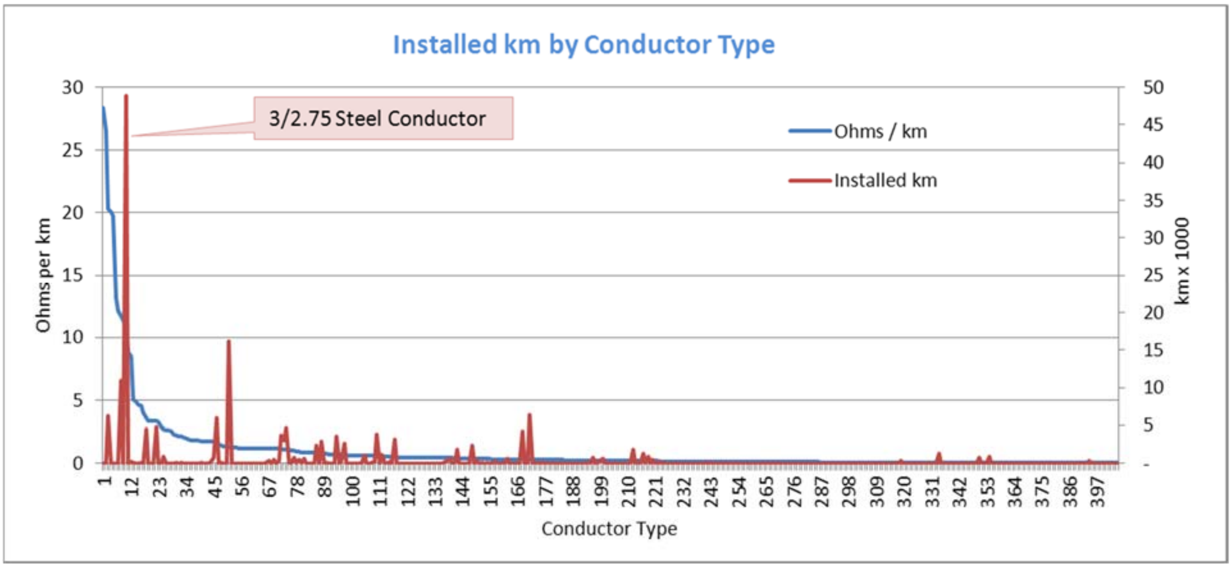

Figure 2 – Installed Conductor Type by km

Essential Energy's distribution network has over 75,000 kilometres of rural lines built using steel conductors.

Steel conductors presented a low cost and high strength-to-weight ratio conductor (so fewer poles per kilometre were required), and post-war availability of steel was good. The relatively high resistance levels of steel were manageable because of the low levels of electrical loading at the time.

Figure 3 provides a graphical representation of all the steel conductors installed across Essential Energy's distribution network.

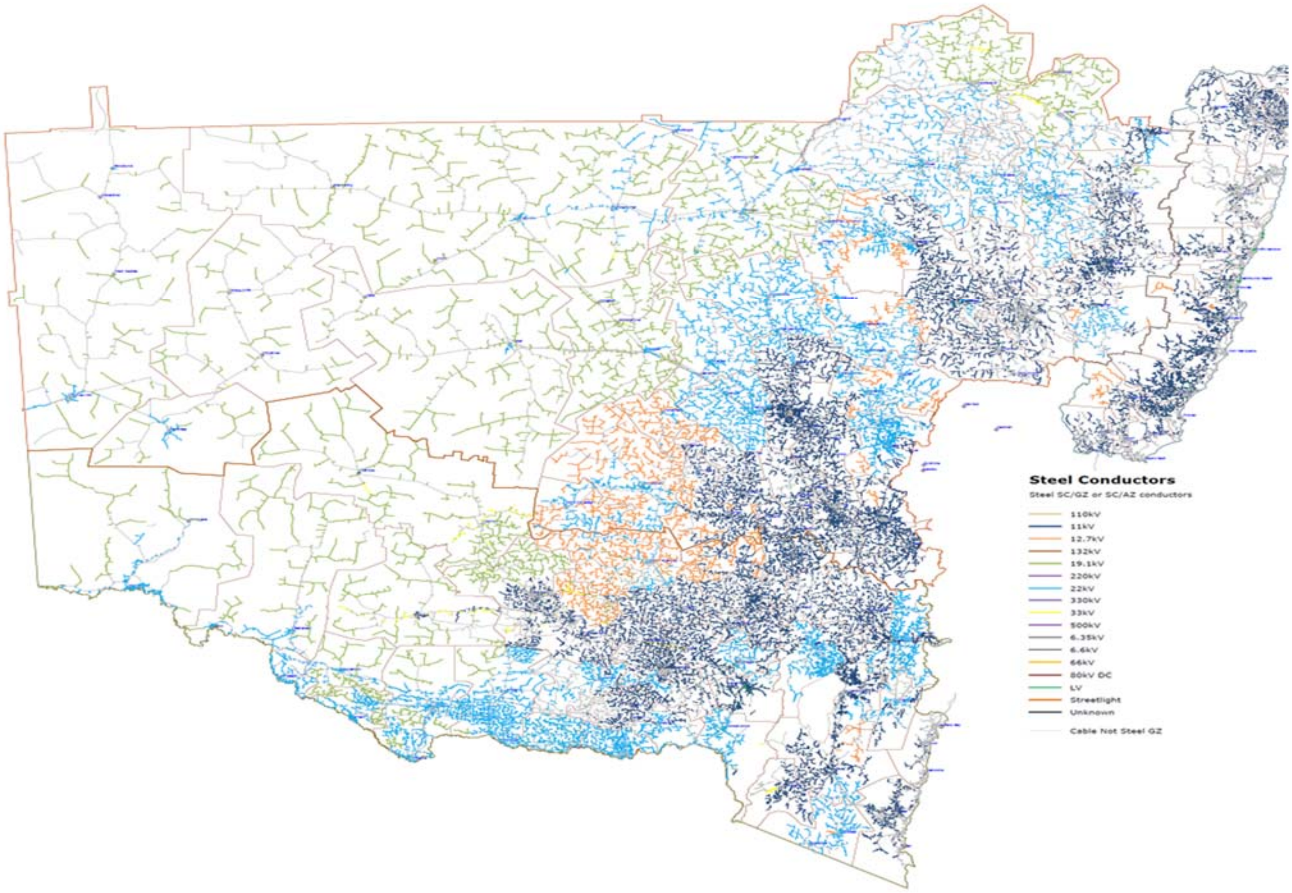

Figure 3 – Steel Conductors Installed across the Essential Energy Network

The capacity of a distribution feeder is also impacted by its physical construction. Distribution feeders are built as three wire lines (HV3, or three-phase availability), two wire lines (HV1, or single-phase availability) or Single Wire Earth Return (single-phase SWER).

In addition to having long backbones, power lines in western areas of the Essential Energy catchment often exceed 100 kilometres or more, with many connected single-phase and Single Wire Earth Return branches traversing hundreds of kilometres to supply smaller groups of remote customers.

A high proportion of Essential Energy's rural area is covered by long length, high impedance, and low capacity single-phase systems, as illustrated in Figure 4.

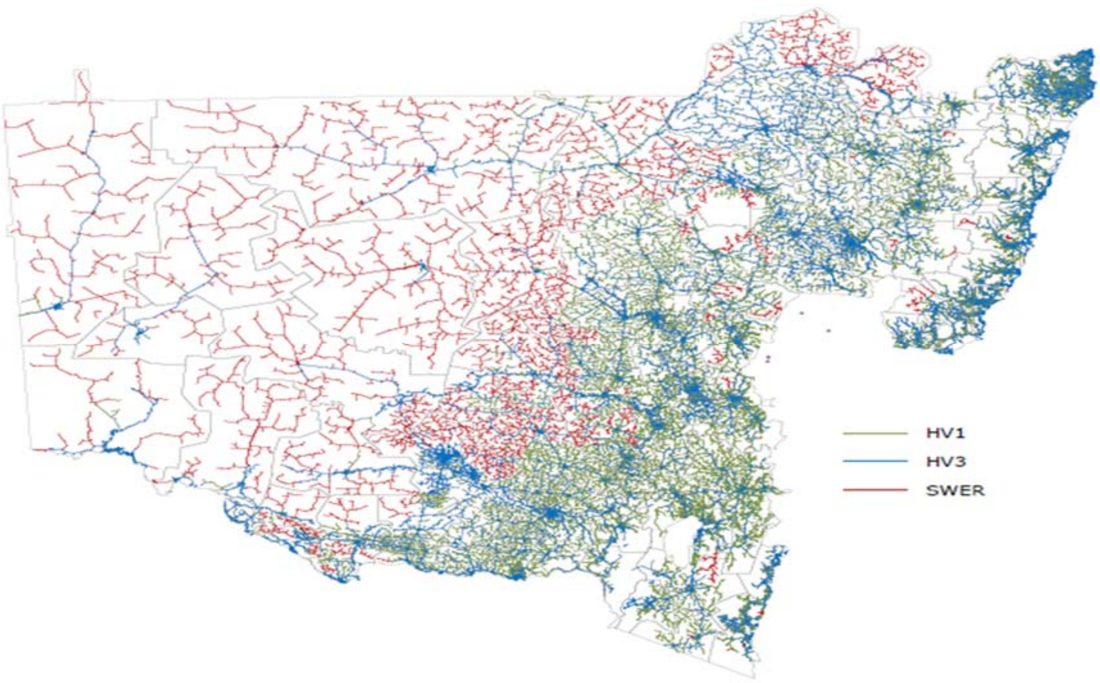

Figure 4 – Essential Energy Distribution Feeders

Essential Energy's distribution system is reaching a stage where asset lifecycles are complete, or are nearing completion, and consumer demands are challenging the network's capacity to deliver an adequate supply. Issues are arising that, while not inherently critical, are enough to breach standards or cause customer concerns.

Distribution feeders are supplied from zone substations near larger load centres (i.e. regional cities and towns) that service nearby urban areas and surrounding rural areas. In many cases, feeders have a short section supplying an urban area and longer extensions into the adjacent countryside, with reclosers segregating the service areas in the event of a line fault. These feeders are generally classified as 'short rural', even though the majority of the load is probably from urban connections.

Statistically, Essential Energy has around 150,000 circuit kilometres of high voltage distribution across 1,454 distribution feeders. Approximately 20.5 per cent (299) of these feeders are classified as urban but account for less than 1.5 per cent of the total circuit length.

Table 2 – HV Distribution Feeder Classes and Lengths[3]

Feeder class	Number	Total km	Average km
Urban	299	1,949	7
Short Rural	912	50,646	56
Long Rural	243	98,106	404
TOTAL	1,454	150,701	104

While some distribution feeders supply both urban and rural loads, feeder types are classified in two broad categories: urban and rural. Urban feeders are generally shorter, with higher load densities, and supply major urban centres, including residential, commercial, and industrial loads. Their asset management considerations are usually associated with the thermal rating of the associated assets because of the greater load densities in urban areas.

By contrast, rural feeders typically supply much more sparsely populated areas and are characterised by lower loads distributed across long sections of high impedance conductors that are susceptible to voltage drop issues.

The utilisation rates across all our feeders vary considerably as they have large variations in load densities, vastly different design characteristics, and are spread across a wide, geographically diverse area.

[3] HV1 – Data as at October 2016

Some feeder segments will never be challenged thermally or by voltage constraints because of low levels of connected loads. However, even these segments can be challenged by burndown or load-to-fault ratios (i.e. excessively high or low fault levels). This is more about the location of the segment in the system rather than the electrical loading alone. This challenge is discussed further in section 4.4 Growth – Fault.

3.3 Distribution Network Augmentation

To respond to the growth in demand and load across the network, Essential Energy uses well-developed, proven, and documented network planning and development processes to ensure customers receive cost-effective energy services. This includes exploring non-traditional means of service provision such as demand management and distributed generation.

Our centralised Asset Management Group and Distribution Planning Team develop efficient capital works programs using best practice approaches based on:

- The network's augmentation needs.
- The business's organisation-wide capital investment policies and procedures.
- Regional requirements relating to customer needs and the condition of the local network.

Initially, we establish the need for augmentation by assessing whether the network can deliver the requirements in our planning and development processes, which are based on ensuring:

- Capacity availability for customer needs.
- Equipment electrical and thermal design ratings (under normal and overload conditions) are not exceeded.
- Supply security and reliability are in accordance with our Licence Conditions and published standards.
- Quality of supply meets published standards and system voltage regulation levels are maintained within acceptable standard limits.
- Acceptable safety standards are maintained.
- Environmental constraints are satisfied.

The network augmentation planning process balances capital and recurrent expenditure to ensure that maintaining, renewing, and augmenting the network delivers the required level of services at an optimal cost.

Our network planning and capital investment framework can be driven by technical, rather than economic, drivers. This is primarily due to the mandatory requirements for provision of supply, network performance, distribution Licence Conditions and other legislative requirements, and the inherent geographical/topographical challenges in maintaining system security, reliability, and quality of supply standards in rural areas.

Our forecasting process determines annual capital expenditure programs for growth-related capital works and sets priorities. Its planning methodology includes:

- Consideration of legislative, regulatory, and related codes of practice requirements.
- Analysis of current loading levels and predicted peak demand growth.
- Results of network planning studies.
- Application of documented planning criteria.
- Identification of network constraints.
- Identification of augmentation and demand management options.
- External consultation.
- Cost-benefit assessment.
- Quantitative risk assessment-based prioritisation of identified projects.
- Assessment of historical expenditures.
- Future network growth-related work programs and the required levels of capital investment needed to maintain ongoing capacity in the medium-term term.

Time-lags between drivers and actual investment, and the amount of risk accepted by Essential Energy, also impact the amount of capital per unit of growth.

4. Performance Requirements, Analysis, and Forecast Expenditures

This section sets out the definitions, analysis and forecast expenditures for the growth components of Essential Energy's network.

From a distribution perspective, growth is broadly defined as any increase in loads and or connections that requires system capacity augmentation or extension to support it. It also includes work required to cope with upstream augmentation, which both enhances capacity of the upstream network and has a flow-on effect on local distribution systems. To date, such growth has caused areas of system non-compliance that have not yet been addressed.

Growth can be driven by a specific customer or by a group of customers — whenever a minimal change in individual loads becomes visible in the distribution network.

To help with managing the associated work, Essential Energy subcategorises growth into four components:

- Connections: Obligatory work to facilitate customer connections and embedded generators.
- Thermal: Sustaining thermal capacity of the network for carrying loads/overloads.
- Voltage: Sustaining voltage performance of the network when carrying loads.
- Fault and operation: Sustaining protection and operational capability of the network.

shows a six-year historical investment view (20013/14 to 2018/19) of these combined growth components and demonstrates the investment trend over the period. Over this period, growth expenditure has been reduced to be managed within a capital constraint. This has been coupled with a more rigorous assessment of projects and resulted in taking on a greater level of risk to achieve improved outcomes for customers. The Asset Investment Planning System is enabling a change to quantified, objective, assessments of projects.

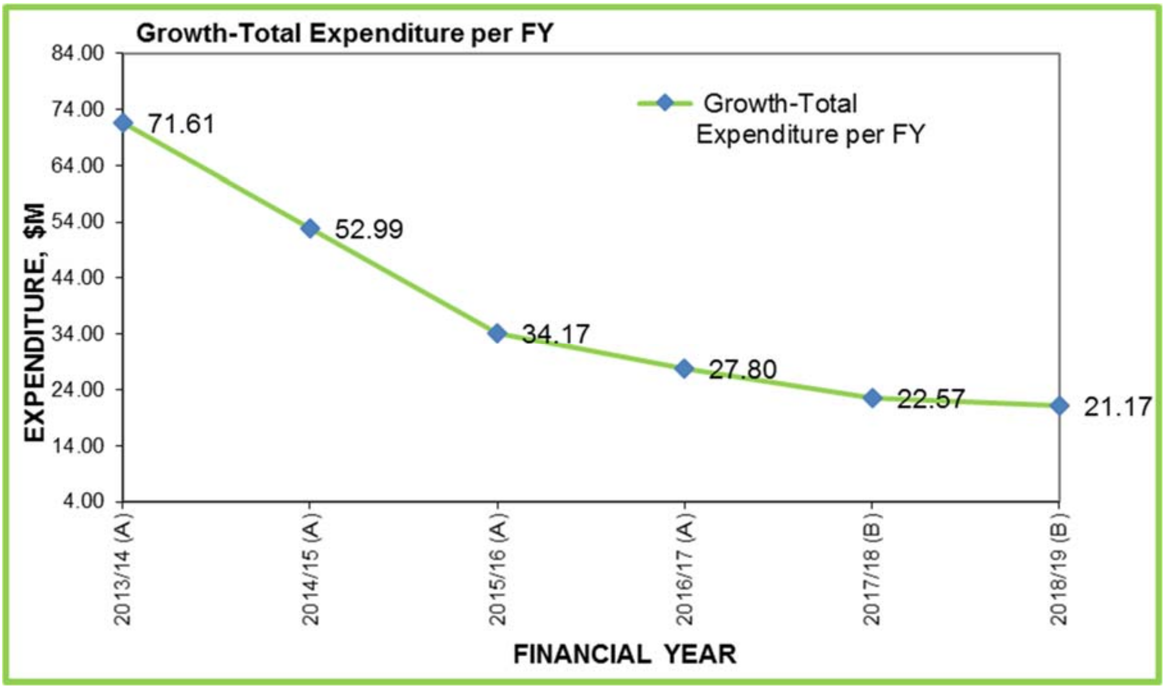

Figure 5 – A Six-Year Total Growth Investment View (20013/14 to 2018/19)[4]

[4] Expenditures for 2018/19 are projected actuals

Table 3 shows the relative investment size between the components for the same period.

Table 3 – Growth Investment Split 2013-2019

Voltage	$46M	20%
Thermal	$72M	31%
Fault	$56M	24%
Connections	$57M	25%
TOTAL	$230M	100%

4.1 Growth – Connections

This subcategory covers work required to service new or additional customer connection loads, as defined in Section 4 of the NSW Electricity Supply Act 1995.

The funding of certain defined connection-related works is obligatory for Distribution Network Service Providers (DNSPs) and generally cannot be deferred. Connections are contestable in NSW and Essential Energy manages customer connections in accordance with the NSW Code for Contestable Work. We use Essential Energy Policy CEOP2513.06 *Connection Policy – Connection Charges* to determine the investment we will make in works associated with customer connections.

As at June 2013, Essential Energy had approximately 810,000 customers of all classes. This is predicted to rise to 850,000 in 2022 at the National Institute of Economic and Industry Research (NIEIR) forecast growth rate of around 0.57% per annum.

Figure 6 and Figure 7 show the quantity and growth trend of contestable connection projects that were gifted to Essential Energy in the six years from 2010/11. We reduced our involvement in the construction of contestable connection works in 2010. Since that time, significantly increased numbers of connections have been constructed by Accredited Service Providers (ASPs).

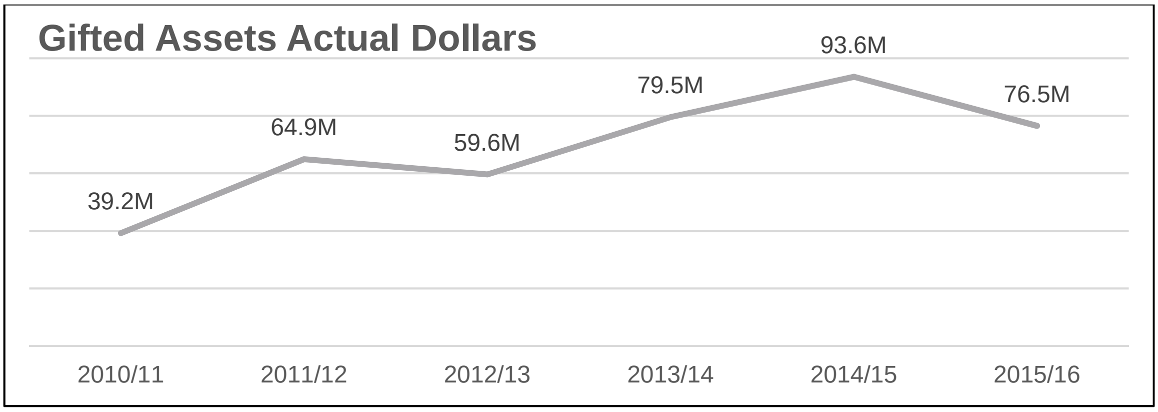

Figure 6 – Gifted Assets Actual Dollars Spent 2011-2016

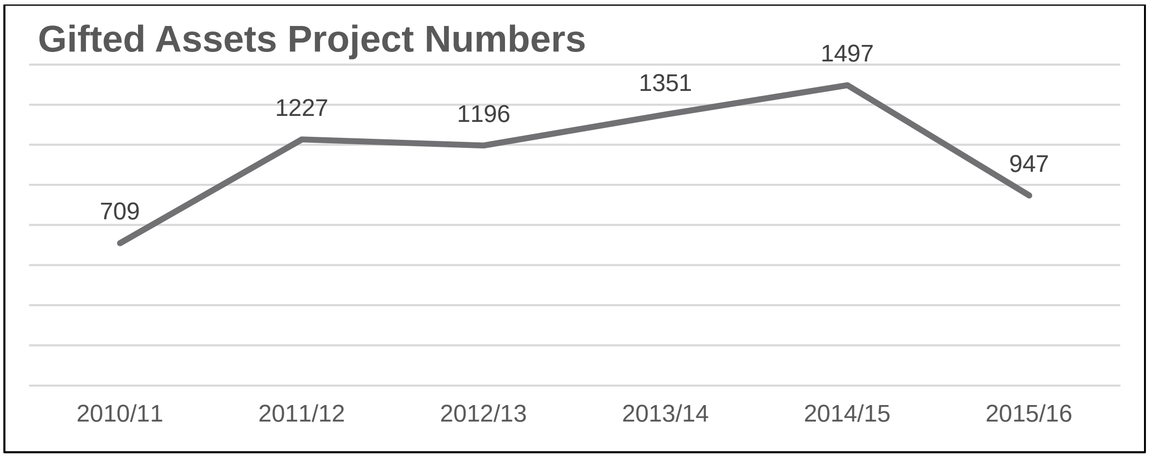

Figure 7 – Gifted Assets (ASP Constructed Connection Works) 2011-2016

Figure 8 illustrates the quantity and growth trend of new connections from 2009/10 to 2015/16

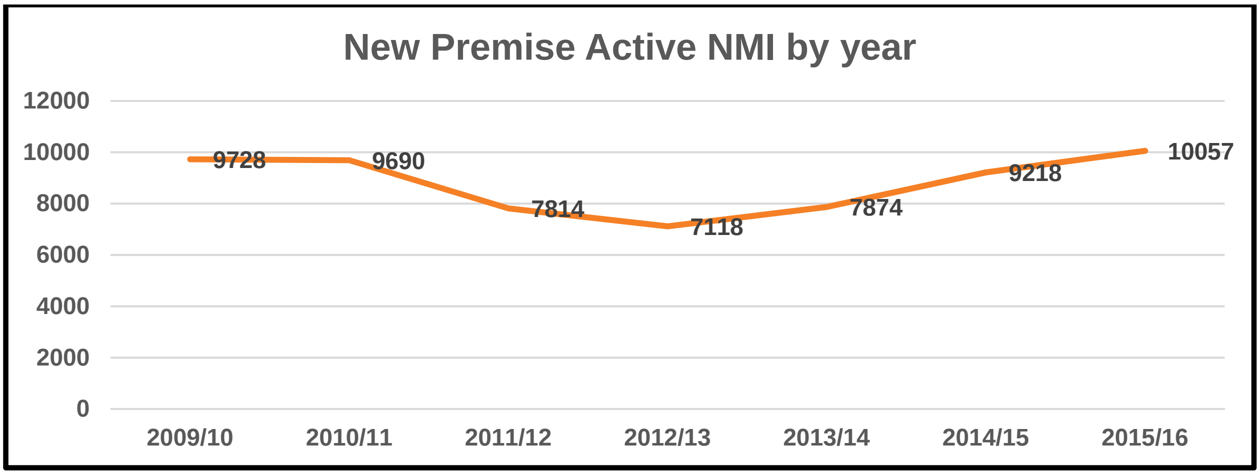

Figure 8 – Essential Energy National Meter Identifier (NMI) Statistics 2009-2016

Some new loads may be connected to an existing low voltage network without any augmentation. These connections are generally handled by Level 2 ASPs and the costs are totally funded by the connecting customer. These customers are not considered as individual connections in this document.

Electrically, connections can be either loads (consuming power) or generation (providing power). Some installations may do both and swing between provision and consumption of power. We have covered both cases separately.

4.1.1 Growth – Connections: Loads

Providing new or augmented shared asset substations/transformers and associated substation connection lines represents most of the funding we require to facilitate customer connections.

Large load connections

Large load customer connections can significantly impact the network, particularly locally. From 1 July 2015 to 30 June 2016, the following large loads were added to Essential Energy's distribution network:

> 11 large loads totalling 37.4MW.
> Ranged in size from 2.0MW to 5.3MW, with an average size of 3.4MW.

4.1.2 Growth – Connections: Generation

New embedded generation connections to the network include photovoltaics (PV), wind generators, biomass fuelled generators and hydro-generators. The associated issues include:

> What is needed to make a system work at a micro level.
> Impacts on demand needs from local assets to network system perspectives.
> Supply quality impacts on other customers, particularly where multiple small installations aggregate.

We established the Growth – Connections: Generation category so we could micro-manage the impacts of the connection processes. We will analyse what we learn to see if we can establish useful trends and expenditure needs.

Out of a total of 138,061 Essential Energy distribution substations in June 2016, 41,224 had some level of PV connection. The collective value of the connected PV was 451.99 MW. Of these 41,224 substations, 3,202 had more than 50 per cent PV penetration (PV kW/Transformer kVA).

In addition to small-scale solar generators (predominately less than 10 kW), large solar and non-solar embedded generators are also being connected to the network. These could significantly impact the network's operating characteristics, particularly local network voltage.

Figure 9 details the embedded generation connected to the distribution network since 2004.

Embedded Generation Connections (MW) 2004 - 2016				
Years	*Hydro*	*Solar*	*Wind*	*Yearly Total*
2004		0.04		0.04
2005		0.07	0.00	0.08
2006		0.47		0.47
2007		0.86		0.86
2008		2.12	0.00	2.12
2009		7.24		7.24
2010		57.51	0.31	57.83
2011	0.00	90.17	0.23	90.40
2012		48.61	0.02	48.63
2013		64.49	0.01	64.50
2014	0.20	69.35	0.00	69.55
2015		64.33	0.01	64.34
2016		34.49		34.49
Total	**0.20**	**439.76**	**0.58**	**440.54**

Embedded Generation Connections (MW) by Unit Range				
Unit Range	Hydro	Solar	Wind	Grand Total (MW)
0 - 5kW	0.00	235.12	0.04	**235.16**
5 - 10kW		112.88	0.23	**113.11**
10 - 100kW	0.00	86.63	0.00	**86.94**
100 - 200kW	0.20	3.83	0.00	**4.03**
>200kW	0.00	1.30	0.00	**1.30**
Total(MW)	**0.20**	**439.76**	**0.27**	**440.54**

Embedded Generation Connections by Count				
Unit Range	Hydro	Solar	Wind	Grand Total
0 - 5kW	1	110,227	25	**110,253**
5 - 10kW	0	13,177	49	**13,226**
10 - 100kW	0	2,119	0	**2,119**
100 - 200kW	1	5	0	**6**
>200kW	0	4	0	**4**
Total	**2**	**125,532**	**74**	**125,608**

Figure 9 – Embedded Generation Connection Details 2004-2016

4.1.3 Growth - Connections: Forecast Capital Investment Plan

Historical investment

Figure 10 shows a six-year historical investment view of this component, which demonstrates the investment trend over the period.

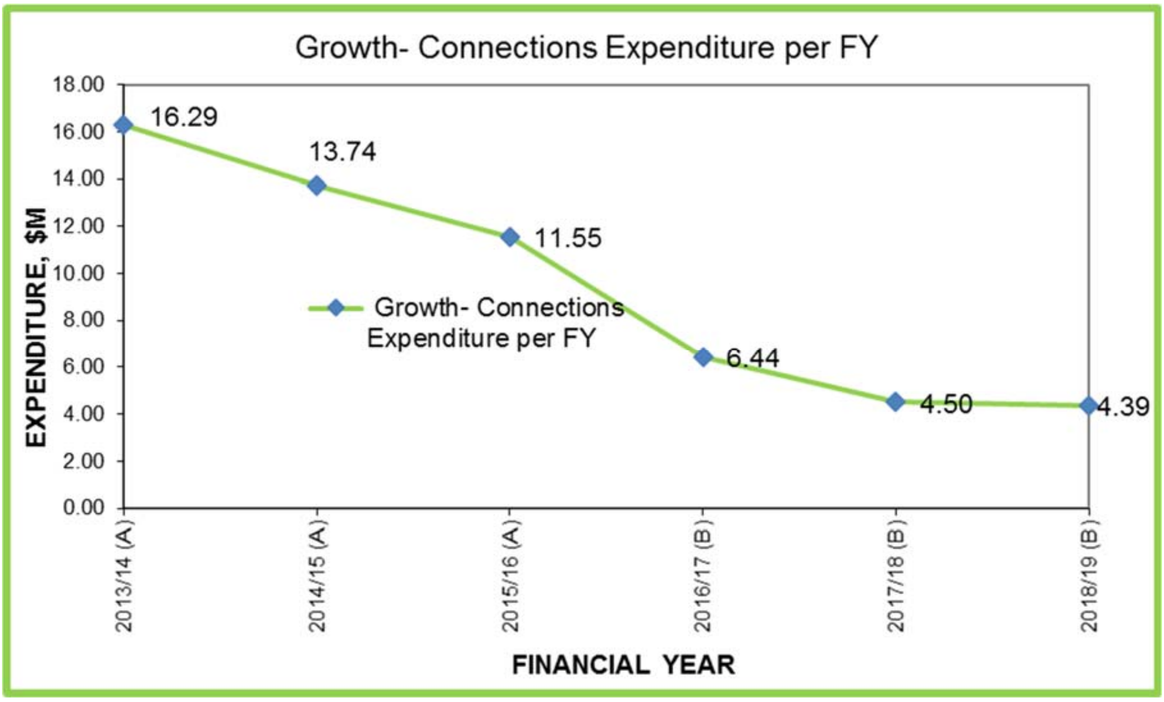

Figure 10 – **A Six-Year Growth - Connections Investment View 20013/14 to 2018/19**The expenditure will not align with Figure 10 as this is just selected projects to determine average project costs.

Table 4 – Completed Growth - Connections Projects and Average Cost per Project 2013/14 to 2018/19

GROWTH CONNECTIONS COMPLETED PROJECTS			
Financial Year	**EXPENDITURE, $M**	**No. Projects**	**$/project**
2013/14	16.29	247	$65,951
2014/15	11.14	369	$30,190
2015/16	8.52	317	$26,877
2016/17	1.36	356	$3,820
2017/18			
2018/19			

shows the number of completed projects fully funded from Growth - Connections and the average cost per project for the same period. The expenditure will not align with Figure 10 as this is just selected projects to determine average project costs.

Table 4 – Completed Growth - Connections Projects and Average Cost per Project 2013/14 to 2018/19

GROWTH CONNECTIONS COMPLETED PROJECTS			
Financial Year	**EXPENDITURE, $M**	**No. Projects**	**$/project**
2013/14	16.29	247	$65,951
2014/15	11.14	369	$30,190
2015/16	8.52	317	$26,877
2016/17	1.36	356	$3,820
2017/18			
2018/19			

Example projects are in Appendix A.

The less generous conditions in Essential Energy's *Connection Policy* CEOP2513.06 led to a drop in our Growth - Connections projects from 2015/16 onwards. Under this revised Policy, large load customers and developers must carry a greater share of the cost of upgrading the shared assets involved in connections.

For the purposes of this Strategy document, we have assumed that:

- Load connection activity needs will match the levels we allowed for from 2016/17 to 2018/19.
- Generator connection activity needs may increase.
- Investment reductions achieved under Essential Energy *Connection Policy* CEOP2513.06 remain substantially unaltered.

Future investment

Our future investment requirements within the Growth – Connections subcategory will depend on complex drivers and relationships from many diverse inputs, including economic performance and outlook, weather, technology, and government policy. While analysing these drivers and their relationships is outside the scope of this document, there is enough information to make us confident that investment in generation will increase, and load connections will at least maintain their status quo.

For example, low voltage, micro, residential PV will have a bright future as customers pursue a renewable component in their energy mix. Since the gross feed-in tariff closed, we have received an average of 400 applications a week. This supports the NIEIR forecasts shown in Figure 11.

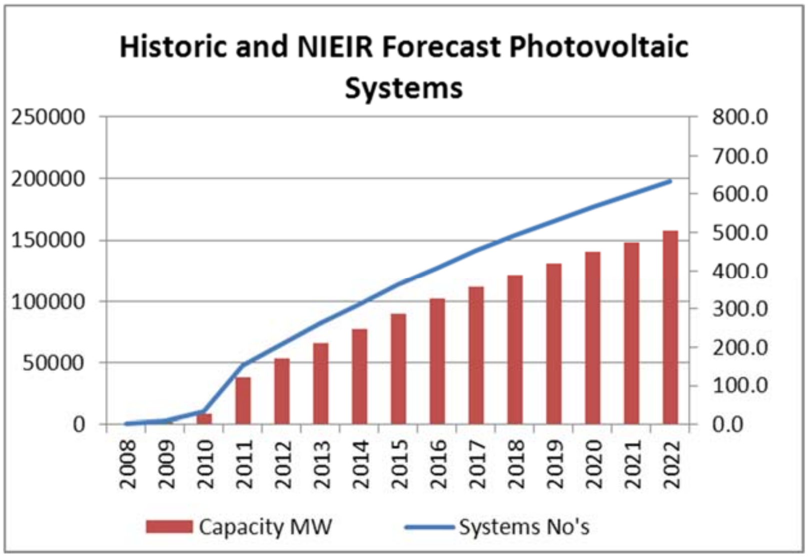

Figure 11 – Solar PV Forecast NIEIR 2013-2022

Small PV appears to be used for energy purchase offset, providing customers with savings that have reasonable payback periods. Since the end of the solar bonus scheme, there have been more approvals for connecting larger PV installations, which may create additional network-related issues.

Overall, generator connection numbers are accelerating, and specialist studies such as Housing Industry Association forecasts are predicting constant levels of activity over the next regulatory period. This means increased investment may be required to cater for a potential increase in generation connections.

However, it is difficult to quantify the level that may be required, so we have not allowed for any additional investment level or indexing for the 2019-2024 period.

We have made a $24.21M investment allowance over the five-year period for the Growth – Connections subcategory. This forecast is based on the three-year average of historical expenditure patterns for the growth driver category over the previous 2016/17 to 2018/19 period.

Investment justification

Essential Energy must fund these obligatory works to facilitate and provide capacity for connecting new or additional customer loads/generation.

The items required are defined in Essential Energy's *Connection Policy* CEOP2513.06, which includes IPART/AER requirements.

Risks of deferring or cancelling investment

> Breaching Licence Conditions, AER and NECF requirements.
> Breaching Essential Energy *Connection Policy* CEOP2513.06.
> Unable to supply customer loads and/or provide customer connections.
> Damage or faults to Essential Energy equipment due to overloads caused by increased customer loads.
> Creating network power quality problems for the connecting or surrounding customers.

As per the *'ESS_4 Growth – Customer Connection Model',* the annualised risk associated with deferral of the planned works from the customer connection portfolio has been approximated as shown below in Table 5.

PIP	ESS_4
Name	Customer Connections
Growth Portfolio Annualised Budget	$4,700,000
Annualised Safety Risk Estimate	$0
Annualised Network Risk Estimate	$59,320,550
Annualised Financial Risk Estimate	$30,504
Annualised Reputational Risk Estimate	$50,341

Table 5 – Customer Connections Annualised Risk Forecast

PIP	ESS_4
Name	Customer Connections
Growth Portfolio Annualised Budget	$4,700,000
Annualised Safety Risk Estimate	$0
Annualised Network Risk Estimate	$59,320,550
Annualised Financial Risk Estimate	$30,504
Annualised Reputational Risk Estimate	$50,341

4.2 Growth – Thermal

This subcategory is associated with a generic interpretation of growth i.e. the ability of network infrastructure to service a load while withstanding the heating effects of transporting that load. The network's constraints are reached when working temperatures exceed its designed thermal limits.

There are three main potential failure modes when thermal constraints are exceeded:

> Insulation degradation: The insulation on covered or underground cables may melt, or oil in transformers may degrade or reach flashpoint.
> Ground clearance: Overhead lines will sag more with increased temperatures and may breach safety clearances to the ground, structures, other circuits, or other conductors in the same circuit.
> Connections. Heat generated at a connection can make it fail.

Heat is a function of load current and time so it takes time for a certain load to heat up equipment. We use this physical I^2t time-lag to allow short-term equipment overloading in accordance with *Subtransmission and Distribution Network Planning Criteria and Guidelines* CEOP8003. See clause 4.2.2 in Figure 12.

4.2.2 Overhead Subtransmission Circuit Emergency Ratings

Interim emergency overhead circuit ratings are listed in the table below:

Condition	Load Limit
Sustained Emergency	Continuous, but peak cyclic for winter night
10-Minute Emergency	120% of sustained emergency, subject to protection limit
5-Minute Emergency	140% of sustained emergency, subject to protection limit

Table 2: Overhead Subtransmission Circuit Emergency Ratings

Figure 12 – Extract from *Subtransmission and Distribution Network Planning Criteria and Guidelines* CEOP8003

4.2.1 Growth – Thermal: Forecasts, Macro (Global) View

Whilst there may be various and sometimes contradictory forecasts for global demand growth at the highest level for Essential Energy's network, the fact is that as the perspective of the network becomes more micro, deviations from any global demand forecast vary.

This is because the global demand forecast does not necessarily reflect the reality of asset management at the distribution network level across such a large and geographically diverse and dispersed asset base as ours. For example, section 4.1 Growth – Connections has already demonstrated the level of micro activity occurring, even during times of reduced global energy consumption and low levels of demand growth rates.

4.2.2 Growth – Thermal: Forecasts, Micro View

Figure 13 and Figure 14 show the recorded apparent power (MVA) across the 21 Essential Energy subregions for 2013, 2014 and 2015. Connected embedded generation is also shown. The charts show that ten subregions had positive increases, ten had negative increases and one had a zero increase.

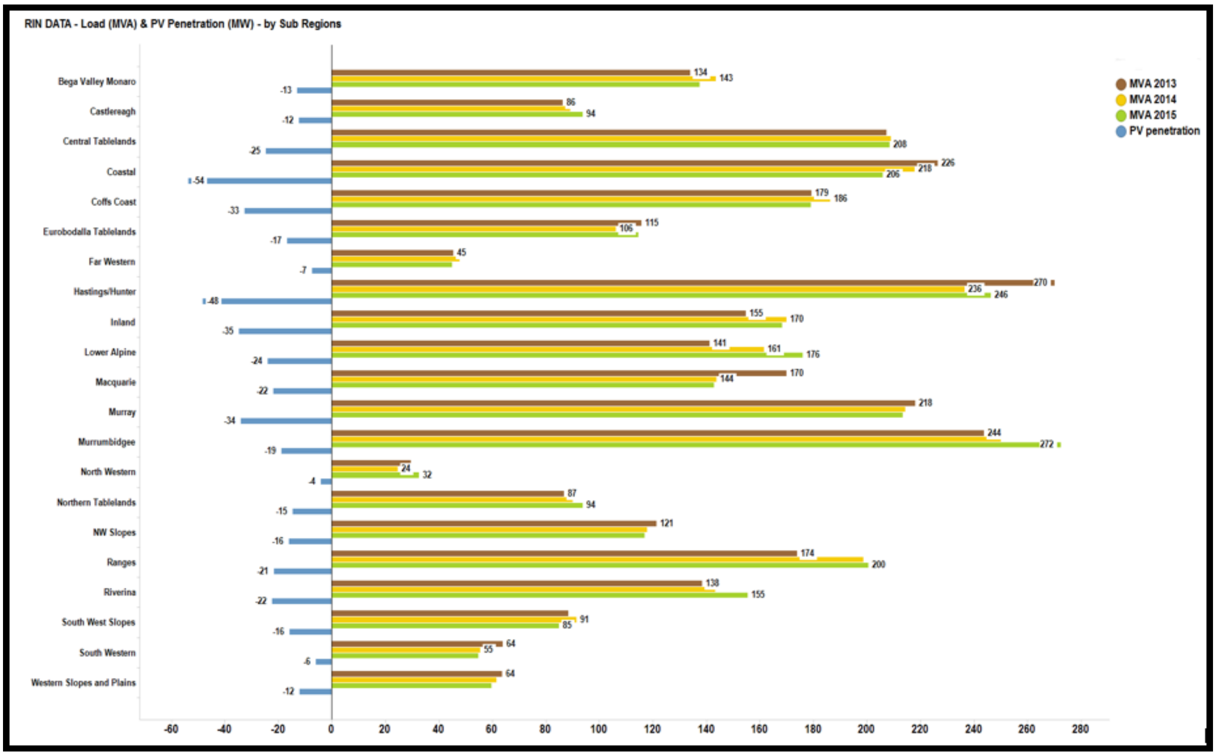

Figure 13 – Recorded Peak MVA across Essential Energy Subregions for 2013, 2014 and 2015.

Sub Region	MVA		% Km Change	% Customers Increase	Solar MW
Macquarie	-19%		0%	3%	22
South Western	-17%		-1%	1%	6
Coastal	-10%		1%	3%	54
Hastings Hunter	-10%		1%	3%	48
Western Slopes and Plains	-7%		0%	1%	12
South West Slopes	-4%		0%	1%	16
NW Slopes	-4%		0%	1%	16
Murray	-2%		3%	3%	34
Far West	-1%		2%	1%	7
Eurobodalla Tablelands	-1%		1%	2%	17
Coffs Harbour	0%	-	1%	2%	33
Central Tablelands	1%		1%	3%	25
Bega Valley Monaro	3%		0%	2%	13
Northern Tablelands	8%		1%	2%	15
Inland	8%		0%	1%	35
Castlereagh	8%		0%	1%	12
North Western	9%		1%	1%	4
Murrumbidgee	11%		-2%	2%	19
Riverina	11%		-2%	2%	22
Ranges	13%		0%	3%	21
Lower Alpine	20%		0%	3%	24

Figure 14 – Network Statistics across Essential Energy Subregions for 2013, 2014 and 2015.

Subregion	Forecast Growth,MW	Forecast % Growth	% PV Penetration
Bega Valley Monaro	-1.04	-0.59	15.08
NW Slopes	-0.54	-0.33	18.56
Western Slopes and Plains	-0.24	-0.24	22.67
Central Tablelands	-0.1	-0.03	12.44
Castlereagh	-0.09	-0.07	18.32
South Western	0.02	0.03	15.66
South West Slopes	0.25	0.19	20.52
Northern Tablelands	0.26	0.2	22.75
Far Western	0.65	0.86	19.8
Murrumbidgee	0.93	0.3	11.29
Murray	1.49	0.44	18.61
Macquarie	1.73	0.66	16.52
Ranges	1.73	0.63	14.7
North Western	1.82	1.53	6.63
Riverina	2.36	0.89	15.08
Inland	2.44	0.84	22.55
Coffs Coast	2.65	0.95	22.89
Hastings/Hunter	2.96	0.7	22.03
Lower Alpine	3.22	1.19	18.84
Eurobodalla Tablelands	3.91	1.46	11.79
Coastal	5.89	1.79	32.63

Figure 15 – Growth Forecasts and Connected PV from Essential Energy *Distribution Annual Planning Report* 2016

Note that for 2013-2015, all subregions experienced customer growth but connected PV restricted net increase in MVA. This shows there is much greater spread and variance in the percentage increases at subregion level than we could predict using global growth forecasts. Furthermore, distribution feeders, distribution substations and LV distributors that are connected within the subregions exhibit even greater growth rate variations and diversity than the subregions themselves.

With local distribution feeders, spot loads can easily dominate demand growth or reduction rates, with no apparent correlation to global load or demand forecasts.

For example, a rural town of 5MVA includes a sawmill that increases its capacity from 1MVA to 2MVA. This results in a 100 per cent increase for asset capacity at the customer’s installation. At the zone substation supplying the town (assuming zero base load growth), the maximum demand will increase by 20 per cent in just one step.

Conversely, if a local major industry shuts down, asset capacity is released, and assets are stranded. We can recover local assets, such as transformers, at a cost that may or may not have a positive cash flow impact. However, released capacity at the zone substation is rarely easy to recover and will not result in a positive cash flow.

Similar scenarios can occur simultaneously in the network, but usually with geographic separation. In this case, there is no opportunity to transfer one asset group’s surplus capacity to a new need. These micro movements generally require investment to facilitate an increased load, providing (at best) a marginal benefit for utilisation of any released capacities.

Growth rates are only relevant if, during a study period, constraints are exceeded. The reality of distribution growth is that other drivers may correlate better than a global growth rate when considering distribution system investment needs.

Specific expenditure forecasts at a micro level (particularly for distribution substations and LV networks) become difficult due to the volume of micro elements and costs associated with managing those elements. They may or may not have positive growth and even if they do, they may not exceed a thermal constraint.

This is why distribution growth investment forecasts tend to be related to program or asset class rather than forecasting for individual projects. Also, discrete individual projects are generally unknown until a constraint emerges or is identified.

Discretionary investment.

Thermal investment is predominantly driven by reactive or proactive identification of existing constraints during the planning review process. Discretional investment opportunities are those investment opportunities that would only be undertaken if there was a net value to the network and its stakeholders.

With Growth - Thermal investments, these discretionary opportunities usually involve reinforcing existing network elements or constructing new elements to provide improved supply reliability for customer communities.

Our Distribution Planning Group uses the Value of Customer Reliability (VCR) methodology to assess the worth and viability of these opportunities.

4.2.3 Growth - Thermal: Forecast Capital Investment Plan

Historical investment

Figure 16 shows a six-year historical investment view of the Growth – Thermal subcategory and demonstrates the trend over this period.

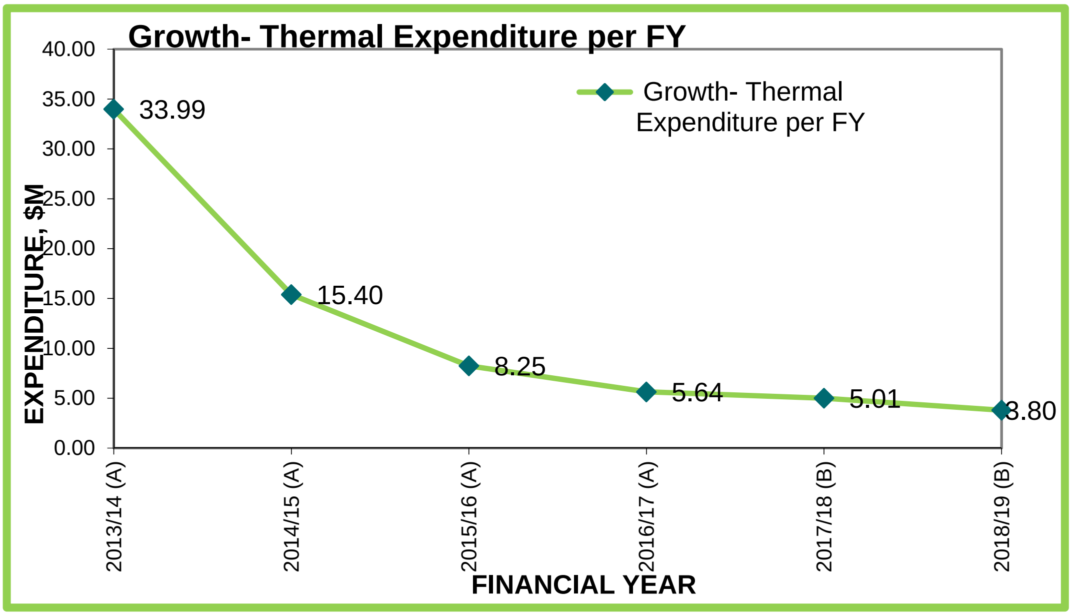

Figure 16 – Growth - Thermal Investment View 2013/14 to 2018/19

Table 6 shows the number of completed projects fully funded from Growth - Thermal and the average cost per project for the same period. The expenditure will not align with Figure 16 as this is just selected projects to determine average project costs.

Table 6 – Number of Completed Growth - Thermal Projects and Average Cost per Project 20013/14 to 2018/19

GROWTH THERMAL COMPLETED PROJECTS			
Financial Year	EXPENDITURE, $M	No. Projects	$/project
2013/14	33.93	714	$47,521
2014/15	4.26	106	$40,189
2015/16	1.97	51	$38,627
2016/17	0.95	74	$12,838
2017/18			
2018/19			

Examples of projects are in Appendix B.

Essential Energy's investment needs tapered off over this period. A contributing factor was the withdrawal of the N-1 Obligations in Schedule 1 of our licence conditions on NSW Utilities in 2014-2015. We now treat investment in N-1 projects as discretionary and assess their worth and viability using the *'ESS_2 Growth – Thermal Model'* ..

Future investment

For the purposes of this Strategy, we have assumed that activity associated with addressing thermal constraints will match the levels allowed for 2016/17 to 2018/19.

Increased investment may be required to cater for a potential predicted increase in generation connections. However, it is difficult to quantify the level of investment or indexing required to address subsequent thermal constraints, so we have not allowed for it in the 2019-2024 period.

We have made an investment allowance of $23.84M over five years for the Growth – Thermal subcategory. This forecast is based on the three-year average of historical expenditure patterns for the growth driver category over the previous 2016/17 to 2018/19 period. However, noting the substantial improvement Essential Energy has committed to delivering through demand management works, we have reduced this investment by 8.46 per cent to $21.82M, as outlined in our Demand Management Strategy.

This investment is necessary to fund distribution assets works that will increase capacity to thermally constrained parts of the network. Typically, these include:

> Upgrading the load-carrying capacity of HV and LV cables, conductors, transformers, and other network equipment (e.g. switches, reclosers, fuse links, regulators) where the currents being carried exceed, or are expected to exceed, the safe thermal capacity rating of these items because of general and incremental demand growth.
> Providing new or augmented HV and LV distribution mains to cater for general and incremental network demand growth and constraints.
> Providing new or augmented distribution substations to relieve overloading.
> Installing new HV mains to facilitate load redistribution, feeder reconfiguration flexibility and spare feeder capacity for contingency conditions.
> Increasing ground clearance of overhead conductors to maintain and/or increase their thermal rating.

We have excluded thermal constraint investments that are directly related to power quality complaints from this category. Although some power quality issues could be deemed as thermal constraints (e.g. upgrading transformer sizes of >100kVA), we have addressed and accounted for power quality investments in a separate document, *Network Strategy - Power Quality 2019-2024* CEOP2090.

Investment justification

> Maintain prescribed minimum ground or inter-circuit clearances of overhead lines that have been designed to achieve certain minimum ground or inter-circuit clearances at a particular maximum conductor temperature.
> Ensure staff safety is not compromised when they are operating equipment under load.
> Ensure equipment is operated within design ratings, particularly underground cables and transformers, to minimise damage and degradation of equipment caused by overloads (heat damage).
> Maintain distribution feeder network capacity that is adequate for contingency conditions.
> Minimise bushfire ignition causes that may result from overloaded equipment.

Risks of deferring or cancelling investment

> Public safety risks e.g. ground clearances and contact with live conductors.
> Potential causes for bushfire ignition.
> Staff safety e.g. safe operation of equipment, risk of explosions or fire.
> Network infrastructure damage and failure, including overhead conductor annealing.
> Degradation and ultimate failure of underground distribution cables, resulting in outages and high repair/replacement costs.

- Degradation of transformer insulation and oil, potentially resulting in failure, fire or explosion, outages and high remedial costs.
- Equipment faults causing outages, including heat-related connection failures.
- Increased power quality problems on the network.
- Compromised backup supply availability.

As per the *'ESS_2 Growth – Thermal Model',* the annualised risk associated with deferral of the planned works from the thermal portfolio has been approximated as shown below in Table 7.

PIP	ESS_2
Name	Thermal
Growth Portfolio Annualised Budget	$4,257,261
Annualised Safety Risk Estimate	$6
Annualised Network Risk Estimate	$29,774,723
Annualised Financial Risk Estimate	$339
Annualised Reputational Risk Estimate	$0

Table 7 – Thermal Annualised Risk Forecast

PIP	ESS_2
Name	Thermal
Growth Portfolio Annualised Budget	$4,257,261
Annualised Safety Risk Estimate	$6
Annualised Network Risk Estimate	$29,774,723
Annualised Financial Risk Estimate	$339
Annualised Reputational Risk Estimate	$0

4.3 Growth – Voltage

The voltage subcategory is associated with the interpretation of growth as related to the ability of the network to supply loads while maintaining system voltages within prescribed limits. Constraints are reached when voltage levels or variations are outside prescribed limits.

Essential Energy faces several major challenges in this area.

- Long circuit distances in rural areas and rural towns.
- Small conductors due to historical evolution.
- Increasing system loads.
- Embedded generation causing intermittent higher system voltages.
- Migration towards the preferred lower voltage range of the 230V standard for the LV network.

Voltage levels

All networks exhibit a physical attribute of impedance, which causes voltage to drop when they are conducting load current. Essential Energy's distribution system includes a large component of high-resistance conductors and single-phase lines and covers long distances. These attributes provide a base that is highly vulnerable to voltage swings, even with small loads. Low levels of growth are enough to increase the swings to unacceptable levels.

Figure 17 demonstrates how voltage levels swing between high and low loads on a rural feeder. The feeder backbone has a voltage swing greater than 23 per cent with a relatively small load of 685 kVA. The net swing is controlled by field voltage regulators, which are clearly visible as the vertical voltage adjustments.

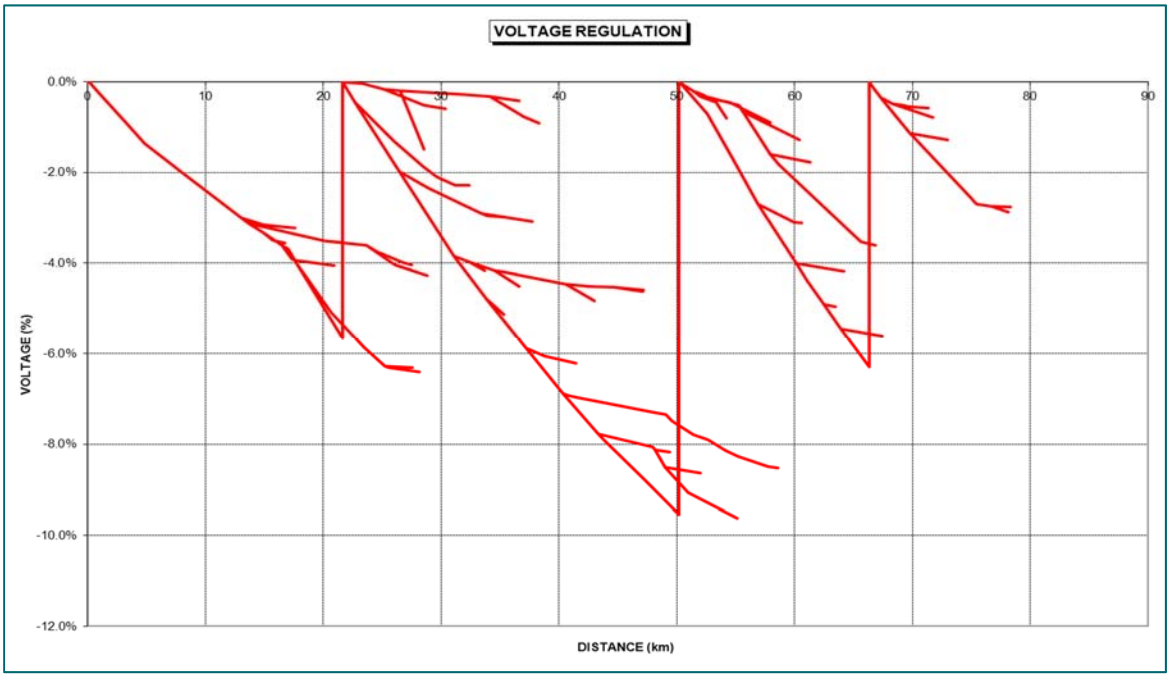

Figure 17 – Voltage Profile Example: Binda Bigga Feeder, Crookwell

Voltage drop can be managed in several ways.

- Using low cost voltage regulators, as Figure 17 demonstrates. However, while the effects of the three regulators on steady state voltages are clearly visible, the transient impacts are missed. These are caused by both load fluctuations and the response of the voltage regulators. With the latter, there is an increased risk of regulator-hunting occurring as the quantities of series regulators increase. Until the regulators catch up and lower the output volts, cascading of voltage regulators exposes customers to over-voltages when supply is restored after a significant load was disconnected from the feeder or segments.
- Reducing system impedance i.e. reconductor the existing lines with larger conductors.
- Reducing load current by:

- Improving power factor to reduce the reactive component of the load current.
- Running a third wire on single-phase lines to distribute existing loads across the phases.
- Upgrading system voltage to reduce current proportionally.
- Reducing peak current through demand management strategies.

> Adjusting transformer tap settings. Given the level of voltage drop in the HV network when it is loaded, a traditional approach is to position transformer voltage tap settings, so they supply a workable voltage to an installation when the system is at full load. This approach usually results in a higher voltage at the installation when the system is at minimum load.

As part of understanding the voltage performance of the system today, Essential Energy participates in the *Australian Long Term National Power Quality Survey* run by the University of Wollongong and the ongoing Australian Energy Market Operator (AEMO) *National Electricity Forecasting Report*, which provides customer voltage information.

4.3.1 Growth – Voltage: Impacts of Reverse Power Flow

Essential Energy's distribution network has been designed for single directional power flow i.e. from substation to customer loads.

Figure 18 represents a typical single-phase rural installation supplied though 330 metres of 6/1/3.00 ACSR Low Voltage mains[5]. The dotted line A to B indicates zero voltage drop along the mains during periods of no load, giving the same voltage at the transformer and the receiving installation. When a load of 10kW is applied to this installation, the voltage drop in the mains is over 25V (reflected by the line A to C), giving the consumer a voltage level equal to the minimum limit. This example highlights the traditional power flow of source to load with acceptable outcomes.

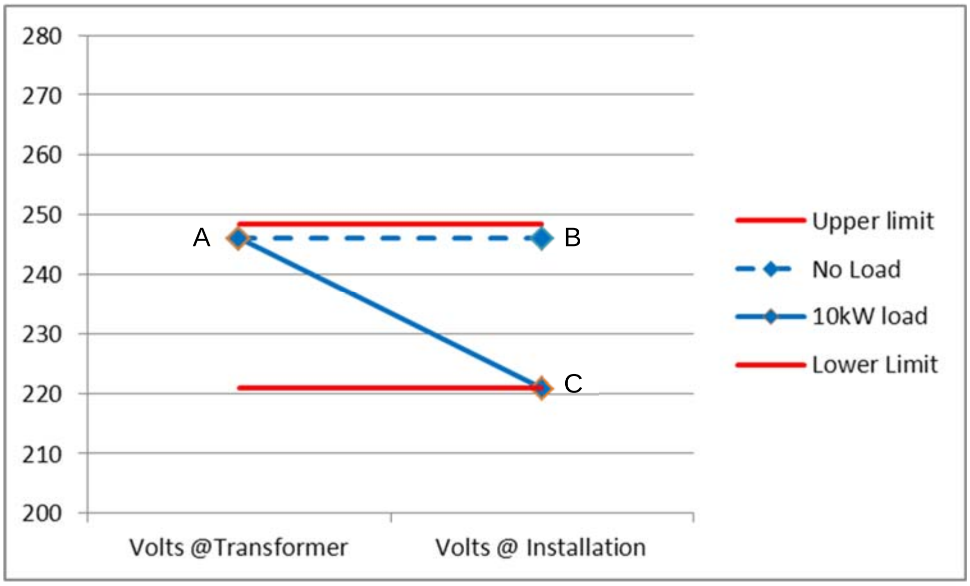

Figure 18 – Typical Voltage Profile of Rural LV[6]

Even this acceptable example becomes questionable when considering the voltage drop from the transformer impedance (around 2 per cent for active power when within transformer capacity rating), and the HV distribution system voltage swings (refer to Figure 12) that will be added to what the consumer actually receives.

Line A-B may often exceed the upper voltage limit and point C may fall below the lower voltage limit due to external influences.

[5] This example makes several assumptions, including a constant HV voltage level, zero voltage drop through the transformer, unity power factor and a tap setting that gives 246V at the transformer terminals. It also ignores flicker standards and harmonics.

[6] Limits reflect 230V standard bandwidth.

The situation becomes more complex with intermittent embedded generation, particularly rooftop solar, which is increasing. Here, voltage is the mechanism used to force power flow from an installation back into the distribution system. Voltage issues related to embedded generation are much more prominent in high impedance parts of the supply network. This could be due to impedance of the HV assets, LV assets or a combination of both.

Figure 19 shows the impact of a 10kW solar generator on the example described in Figure 18. The best-case scenario is when the generator is at maximum production at the same time there is an equal load at the installation.

When the load and generation are balanced, the customer has the same voltage at their installation as if they were at no load i.e. equivalent to the performance shown by line A-B in Figure 19.

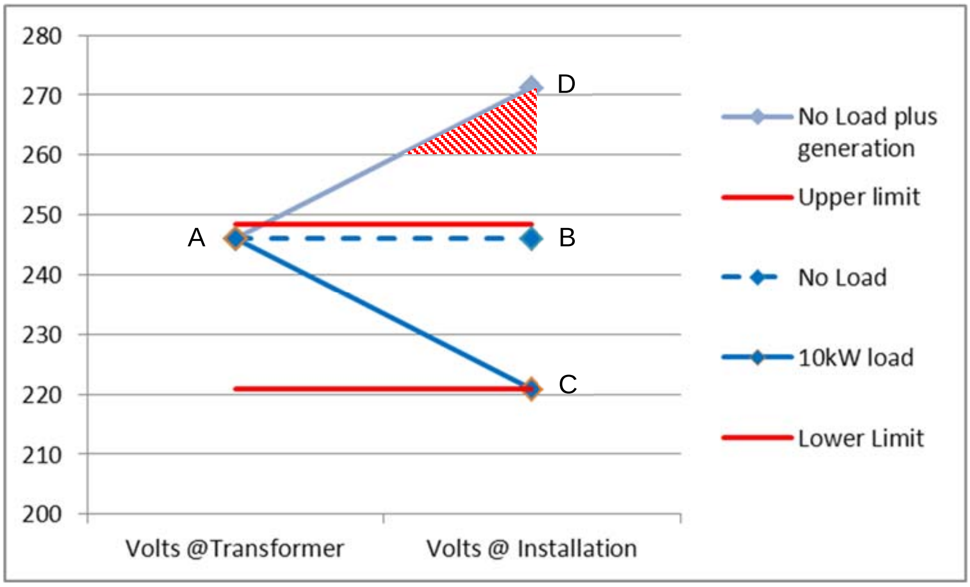

Figure 19 – Typical Voltage Profile of Rural LV with Local Solar PV Generation

However, if the installation is at light load when the generator is at maximum production, it is exposed to dangerously high voltages of greater than 270V, as depicted by point D in Figure 19. In this situation, the inverter on the solar PV system shuts down (indicated by the shaded triangle), ceasing production. While this removes the high voltage issue, the customer's investment in the solar PV system is not making a return, causing them angst and creating a litigation risk for Essential Energy.

Not all rooftop solar installations are as large as 10kW. However, multiple customers with smaller units can and do combine to cause similar problems. Usually, there is no dominant customer from whom to recover a capital contribution under the Connections Policy, leaving augmentation works to be funded by Essential Energy.

Despite these potential issues, embedded generation can also be a benefit as it helps to maintain system voltages.

4.3.2 Growth - Voltage: Forecast Capital Investment Plan

Historical investment

Figure 20 shows a six-year historical investment view of the voltage subcategory, which demonstrates the investment trend over the period.

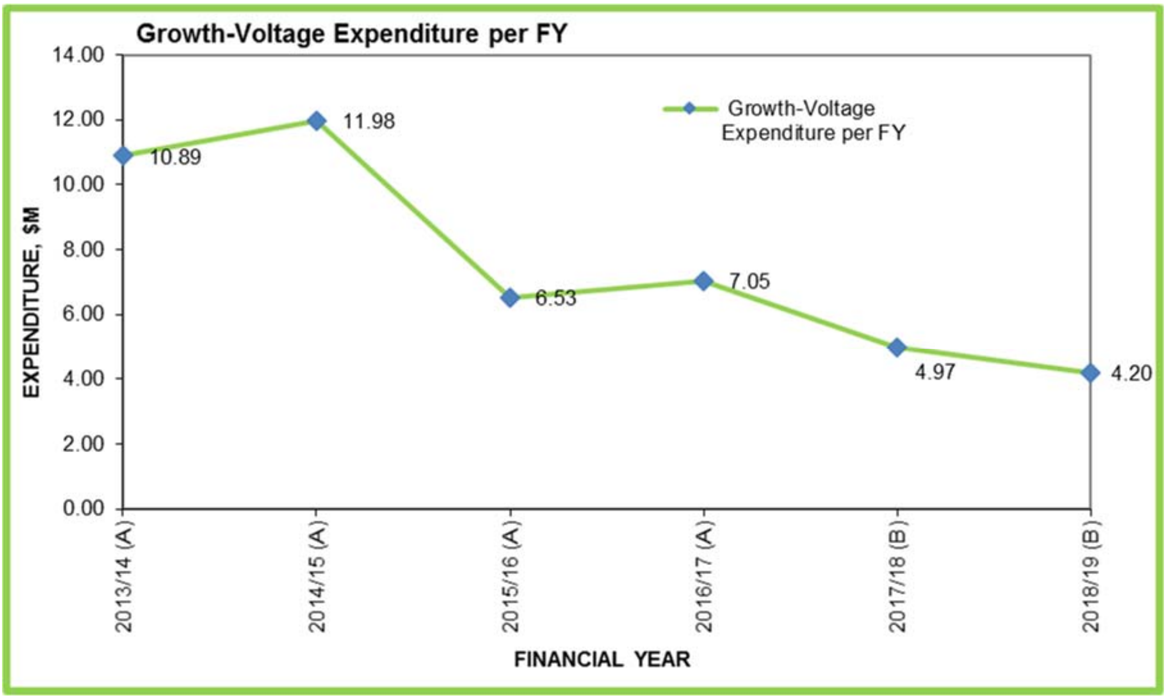

Figure 20 – Growth – Voltage Investment View 2013/14 to 2018/19

Table 8 shows the number of completed projects fully funded from Growth - Voltage and the average cost per project for the same period. The expenditure will not align with Figure 20Figure 16 as this is just selected projects to determine average project costs.

Table 8 – Completed Growth - Voltage Projects and Average Cost per Project 2013/14 to 2018/19

GROWTH VOLTAGE COMPLETED PROJECTS			
Financial Year	**Expenditure, $M**	**No. Projects**	**$/project**
2013/14	10.78	367	$29,373
2014/15	3.45	121	$28,512
2015/16	1.22	33	$36,970
2016/17	1.40	55	$25,455
2017/18			
2018/19			

Examples of projects are in Appendix C.

It can be seen that investment needs have tapered off over the period. As with Growth-Thermal projects, a contributing factor was the withdrawal of the N-1 Obligations in Schedule 1 of our licence conditions on NSW Utilities in 2014-2015. We now treat investments in N-1 projects as discretionary and assess their worth and viability using the *“Growth – Voltage Model”* to assess project deferral risk..

Future investment

For the purposes of this Strategy, we assumed that activity associated with addressing voltage constraints will match the levels allowed for in 2016/17 to 2018/19. Increased investment may be required to cater for a potential predicted increase in generation connections. However, it is difficult to quantify the level of any additional investment required to address subsequent voltage constraints, so we have not allowed for it in the 2019-2024 period.

We have made an investment allowance of $27.43M over five years for the Growth – Voltage subcategory. This forecast is based on the three-year average of historical expenditure patterns for the growth driver category over the previous 2016/17 to 2018/19 period. However, noting the substantial improvement Essential Energy has committed to delivering through demand management works, we have reduced this investment by 8.46 per cent to $25.11M.

This investment is necessary to fund distribution assets works to improve voltage performance for voltage constrained parts of the network. Typically, these include:

> Upgrading distribution infrastructure to improve the voltage capacity and performance i.e. maintain adequate voltage regulation and bandwidths and restrict voltage swings to within the prescribed limits while carrying existing and expected loads.
> Reducing the system impedance and improving voltage regulation by upgrading HV or LV conductors.
> Upgrading undersized transformers if they contribute to voltage constraints.
> Reducing network loads by redistributing and optimising loads on the network including:
  - Power factor improvement to reduce the reactive component of load current.
  - Installing a third wire on single-phase lines to distribute existing loads across the phases.
  - Upgrading system voltage to reduce current proportionally.
  - Reducing peak current through demand management strategies.
> Installing or upgrading voltage regulator and VAR control equipment on the HV network.
> Installing invertor and energy storage initiatives, particularly on remote lines.

Investment justification

> Maintain system volts and customer-received volts within prescribed limits when carrying present or expected loads.
> Rectify identified voltage constraints and performance issues on the network due to incremental general load and demand growth.
> Facilitate connection of new or additional loads to the shared network.
> Address limits to network load growth caused by voltage constraints that arise from Essential Energy’s predominantly high impedance rural network conductors; long distances between customer loads and supply points; and incremental load and demand growth. These result in poor voltage regulation and customers receiving volts.

Risks of deferring or cancelling investment

> Breaching statutory voltage level requirements, as prescribed by Essential Energy's Customer Service Standards, Australian Standards, NER (Schedule 5.1) and NSW Licence Conditions.
> Increased power quality problems on the network.
> Damage to, or malfunction of, customer equipment caused by inadequate system volts.
> Potential risk of fire or explosion for customer equipment due to severe over-voltage.
> Customer nuisance, disruption, dissatisfaction and potential damage/loss claims.
> Limitation on the connection of additional load to particular lines due to voltage constraints.

As per the *‘ESS_1 Growth – Voltage Model’,* the annualised risk associated with deferral of the planned works from the customer connection portfolio has been approximated as shown below in Table 9.

PIP	ESS_1
Name	Voltage
Growth Portfolio Annualised Budget	$4,899,600
Annualised Safety Risk Estimate	$0
Annualised Network Risk Estimate	$17,738
Annualised Financial Risk Estimate	$1,936,422
Annualised Reputational Risk Estimate	$0

Table 9 – Voltage Annualised Risk Forecast

PIP	ESS_1
Name	Voltage
Growth Portfolio Annualised Budget	$4,899,600
Annualised Safety Risk Estimate	$0
Annualised Network Risk Estimate	$17,738
Annualised Financial Risk Estimate	$1,936,422
Annualised Reputational Risk Estimate	$0

4.4 Growth – Fault and Operational

Electricity delivers enormous benefits to society. It is also inherently dangerous unless it is controlled.

The distribution network must have electrical protections which, in the event of a fault, safely isolate the faulty section of the network. This safeguard protects life and property, minimises fire ignition, prevents damage to system assets, maintains system stability and minimises supply interruptions.

In this Strategy, we use the term ‘fault’ to describe potential and actual constraints relating to the electrical protection of the network or elements within the network, as described in CEOP8002 *High Voltage Protection Guidelines*.

The Growth – Fault category also covers the investments required to maintain adequate switching, operational capabilities and performance for the network in areas where general load growth may have compromised them. This includes maintaining adequate load at risk levels for feeder sections and switching flexibility that may have been lost due to demand growth on parts of the network. Examples include:

- Additional switching and isolation points.
- Upgrading ABS plastic switches to gas switches to provide safer switching of increased network loads.
- Upgrading line sections to maintain network switching flexibility that may have been lost due to increased loads.

The three main risk areas in the Growth – Fault subcategory are: load-to-fault ratio (low fault levels); protection timing and coordination; and high fault levels (rapid and safe interruption).

Growth – Fault: Load-to-fault ratio

Every point in a distribution network has a prospective fault current i.e. a level of current that will flow if wires are shorted to each other and/or earth. The distribution system must be able to safely interrupt and isolate these fault currents and differentiate between normal maximum loads and fault current. A recognisable difference must exist.

High impedances in the Essential Energy distribution system result in end-of-line fault levels that are commonly less than 100A, with long rural lines often less than 30A.

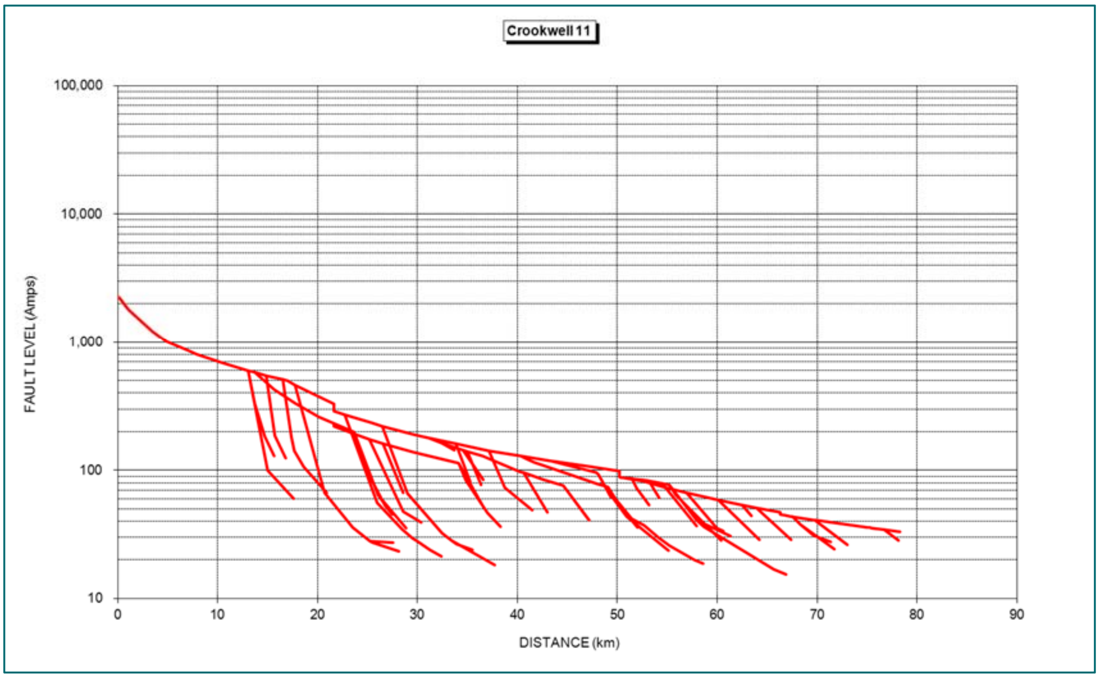

Figure 21 – Phase to Phase Fault Level Profile for Binda Bigga Feeder, Crookwell

Figure 21 is a typical fault level performance for a rural feeder displaying a stronger backbone than the laterals, the latter usually being steel conductors. The diagram demonstrates that the performance of good backbones will deteriorate with long distances, even at light loads.

The fault current profile can also be viewed geographically, as shown in Figure 22 and Figure 23.

Figure 22 – Geographic Fault Level Profile for Bourke

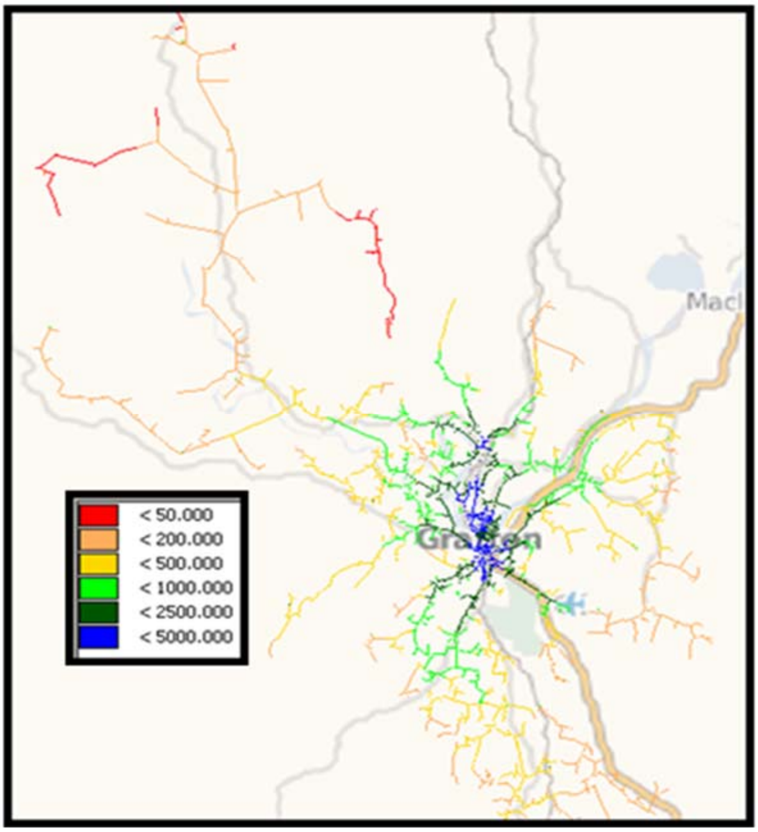

Figure 23 – Geographic Fault Level Profile for Grafton

While low fault levels are difficult for primary protection devices to detect (these devices are designed to detect a fault at a particular location), this is a more common problem for a backup protection device (the next device upstream). This must be able to operate in the event of a primary system failure.

At locations with low fault levels, small increases in load over many years may blur the clarity of load-to-fault differentiation, requiring reconductoring with a conductor of lesser impedance to resolve the problem.

Low fault levels in LV networks

Low fault levels are not uncommon on LV networks associated with distribution substations. The LV networks of older overhead reticulated regional centres and villages are typically long and made up of small conductors. Essential Energy's CEOM7097 *Overhead Design Manual* explains the protection requirements for these LV networks. LV circuits with route lengths of 400m and over are at risk of having fault levels low enough to not meet these protection requirements.

Often, protection constraints are identified when voltage issues present on longer LV circuits. They can only be addressed by replacing LV conductors with larger conductors, reducing circuit lengths by inserting additional distribution substations, or a combination of both.

At the end of December 2016, Essential Energy's asset information management system records showed we had 13,722 LV circuits greater than 400m in length. We do not have a remediation program that targets LV protection constraints. Instead, we address them as they present with voltage or other constraints.

It is difficult to quantify the level of any additional investment or indexing needed to address these constraints, so we have not allowed for it in the 2019-2024 period.

4.4.1 Growth – Fault: Timing and Coordination

Protection isolation devices use time-current characteristics to allow coordination between non-unit protection devices. The primary device should operate before the backup device to limit supply interruption and minimise the number of customers affected.

For example, to grade correctly, the minimum melting I^2t (instantaneous energy dissipated) of a fuse should be greater than the total clearing I^2t of the downstream device and the total clearing I^2t of the fuse should be less than the minimum melting I^2t of the upstream current-limiting device.

Figure 24 shows a protection coordination chart for a typical rural feeder with a feeder circuit breaker, a mid-line recloser, a 10A spur fuse and 5A substation fuse, all grading an earth fault.

For a fault current of 200A downstream of the substation fuse (line A), the first action is that the 5A fuse begins to melt. This is followed by the spur fuse also beginning to melt. At 0.09 seconds, the 5A fuse has cleared the fault and fault current ceases to flow. However, the 10A fuse has been damaged by the heat and will have a faster operating time at the next fault detection. It may also fail later without any fault current.

A second example (line B), indicates a fault level of 30A on the line side of the substation fuse, which will be cleared by the spur 10A fuse. However, this will take approximately 15 seconds. This requires an upstream sensitive earth fault detector to clear the fault sooner, causing a more widespread outage than that offered by the spur fuse and presenting a higher probability of fire ignition[7].

[7] *Powerline Bushfire Safety Taskforce - Final Report*, 30 September 2011

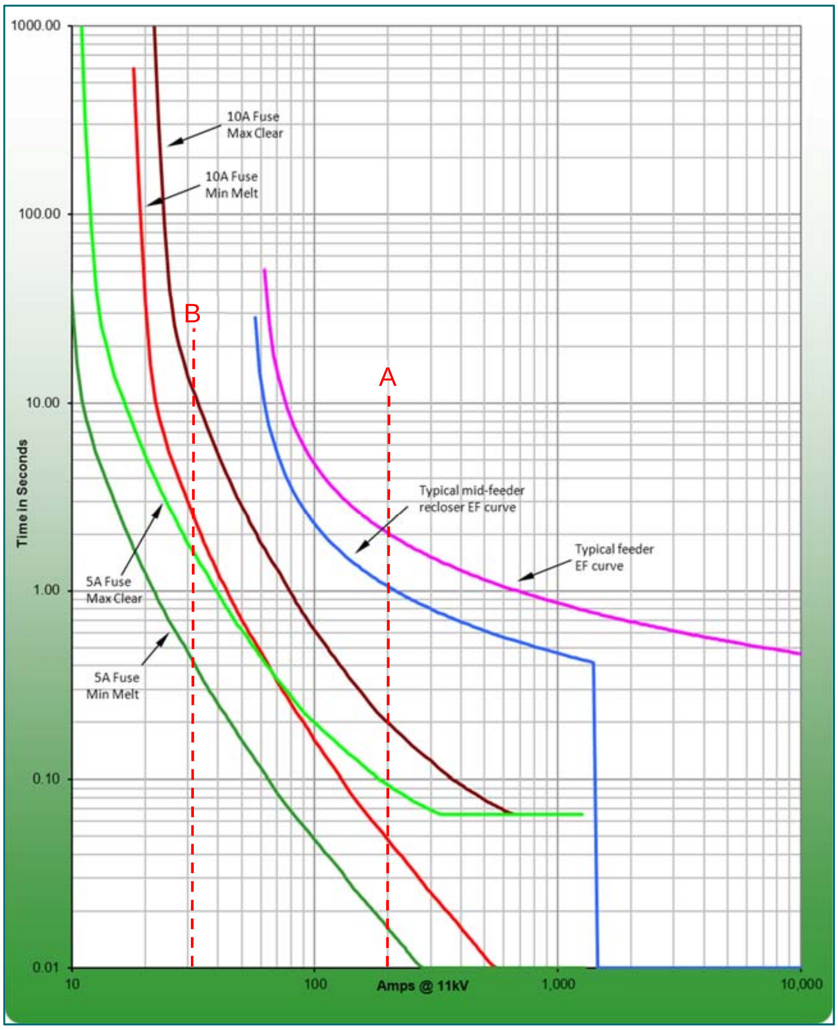

Figure 24 – Typical Time-Current Characteristic Curves

At lower fault currents, timing curve gradients tend to be more vertical, giving more margin of error and making grading more difficult.

While greater use of microprocessor detection, blocking and timing equipment greatly assists, only a limited number of devices can be cascaded in series as additional devices (with incrementally decreasing sensitivity settings) to try to cope with low load-to-fault ratios.

4.4.2 Growth – Fault: High Fault Levels

As the subtransmission system undergoes upgrading, the Thevenin source impedance for maximum fault situations reduces, resulting in increases to prospective fault levels.

While impedance within the distribution system will attenuate this increase quite quickly, the immediate connecting lines must be able to withstand maximum fault levels without physical failure until the fault is cleared by the electrical protection. This is often referred to as the burndown limit for conductors.

In addition, fault interruption capacity for switchgear is often under-rated, providing real risk of catastrophic uncontrolled energy release in the event of equipment failure.

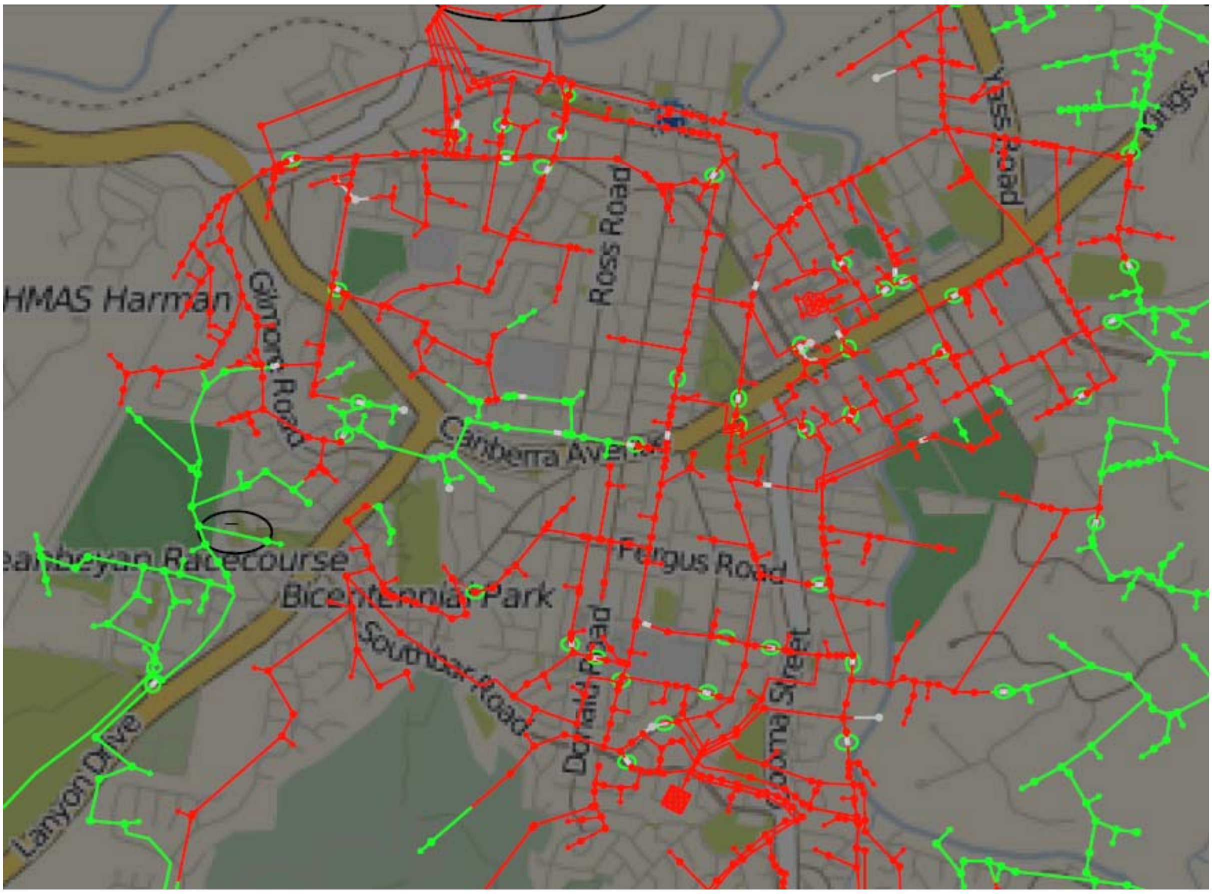

Figure 25 – Example of High Fault Levels in Queanbeyan

In Figure 25, the red lines indicate feeder segments with fault levels greater than 4kA. This fault level exceeds the interrupting capacity of many types of HV expulsion dropout fuses, leading to potential catastrophic failure of the fuse carrier under fault operation and presenting an extreme risk to staff operating the equipment.

If they are not interrupted quickly enough, high fault levels can cause damage or failure to network infrastructure through the passage of high fault currents. High fault currents also cause voltage depressions to all feeders connected to the busbar section for the duration of the fault, which often results in widespread customer equipment malfunction.

4.4.3 Growth - Fault: Forecast Capital Investment Plan

Historical investment

Figure 26 shows a six-year historical investment view of this subcategory, which demonstrates the investment trend over the period.

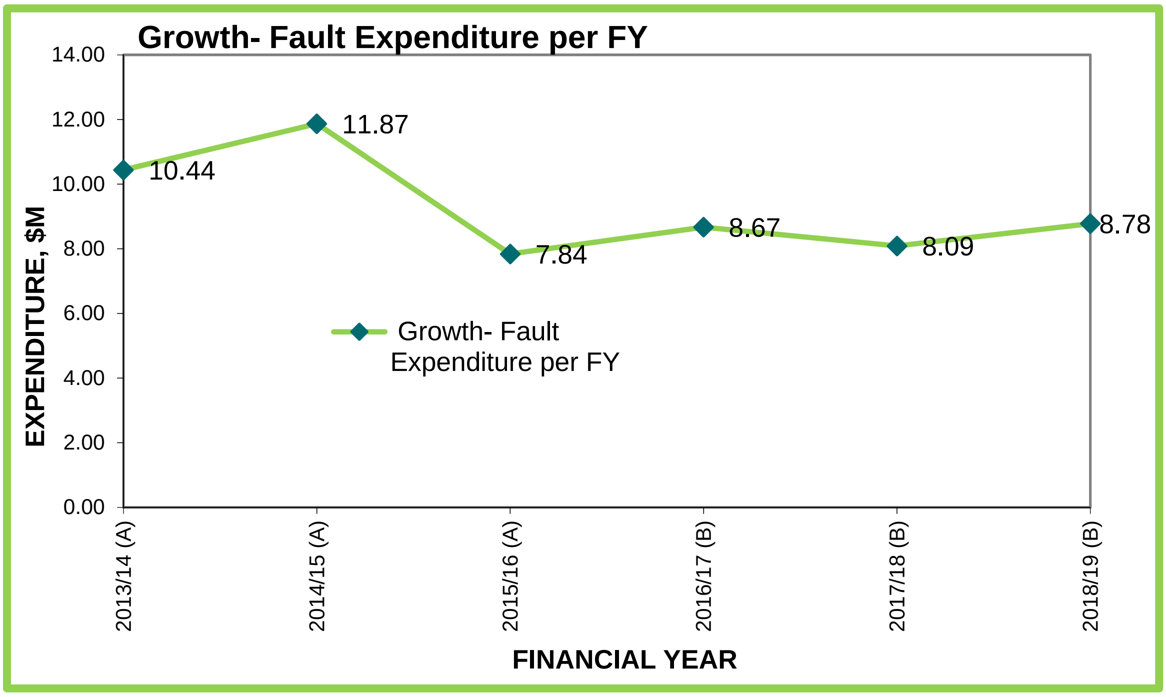

Figure 26 – Growth – Fault Investment View 2013/14 to 2018/19

Table 8 shows the number of completed projects fully funded from Growth - Fault and the average cost per project for the same period.

Example projects are in Appendix D.

Table 10 – Number of Completed Growth – Fault Projects and Average Cost per Project 20013/14 to 2018/19

GROWTH FAULT COMPLETED PROJECTS			
Financial Year	**Expenditure, $M**	**No. Projects**	**$/project**
2013/14	10.52	525	$20,038
2014/15	3.34	244	$13,689
2015/16	2.69	133	$20,226
2016/17	2.86	272	$10,515
2017/18			
2018/19			

Future investment

For the purposes of this Strategy, we have assumed that activity associated with addressing fault constraints will be similar to the levels allowed for in the period 2016/17 to 2018/19.

We have made an investment allowance of $40.33M over 2019/20 to 2023/24 for the Growth – Fault subcategory. This investment is necessary to fund distribution assets works that improve network protection and operational performance. Typically, they include:

- Installing larger cables and conductors to reduce the network supply impedance and increase fault levels. Replacing steel conductors in rural areas is a major contributor to this work program.
- Replacing LV conductors with larger conductors and reducing LV circuit lengths by inserting additional distribution substations.

- Installing new reclosers/sectionalisers and relocating existing reclosers to ensure adequate protection speed and reach, sectionalising, and grading margins. This work is not necessarily driven by reliability improvement programs. Typically, it becomes necessary following growth in network loads. The program includes communications to the equipment.
- Installing high fault level capacity protection devices (e.g. boric fuses) in high fault level areas.
- Installing switching equipment and interconnections on the network to maintain efficient and flexible operation e.g. gas switches for sectionalising/switching feeders and loads. This work becomes necessary following network growth of load at risk and peak demand.
- Installing network load, voltage and fault monitoring devices e.g. fault indicators.

Investment justification

- Ensure adequate primary and backup electrical protection and adequate safety and device grading margins for HV and LV distribution lines. This is primarily achieved by reducing system impedance to provide greater fault levels at a given point in the network. Higher over-current protection settings can then be applied to accommodate greater loads on the network while still achieving the prescribed safety factor multiples between the available fault level and the protection settings applied.
- Provide increased fault levels to increase load/fault ratios to facilitate protection at load connections.
- Provide increased fault levels to ensure proper protection operation and allow adequate sectionalising and grading between cascaded protection devices such as reclosers and fuses.
- Understand and manage network loads better through network monitoring.

Risks of deferring or cancelling investment

- Failures in fault detection and protection may result in a serious failure to protect life and property and damage to system assets.
- Critical risk faults on the network may not be detected and isolated by protection devices, potentially leading to live wires on the ground. This is a serious staff, public and livestock safety concern.
- Protection failure could result in bushfire initiation, particularly during adverse weather conditions.
- Breaches of statutory protection requirements prescribed by NER (Schedule 5.1) and NSW Licence Conditions. Breaches of CEOP8002 - *Essential Energy: High Voltage Protection Guidelines*.
- Damage to network conductors and equipment due to inadequate fault clearance times or failure to operate.
- Severe network equipment damage resulting from slow fault clearance times in areas where there are very high fault levels.
- Limitation on larger load connections to some parts of the network due to inability to provide proper protection as load/fault ratios are inadequate.

As per the *'ESS_3 Growth – Fault Level Model',* the annualised risk associated with deferral of the planned works from the customer connection portfolio has been approximated as shown below in Table 11.

Table 11 – Fault Level Annualised Risk Forecast

PIP	ESS_3
Name	Fault Level
Growth Portfolio Annualised Budget	$7,869,854
Annualised Safety Risk Estimate	$632,821
Annualised Network Risk Estimate	$2,709,768
Annualised Financial Risk Estimate	$0
Annualised Reputation Risk Estimate	$0
Annualised Environment Risk Estimate	$1,868,684

4.5 Growth – Demand Management (Capital Deferral)

Network load growth has two major drivers: new customer connections and increased loading of existing customers.

Demand growth can lead to augmenting the existing network to restore adequate levels of supply performance. However, the construction or augmentation of network assets may not be the optimum method of delivering network services. If the reason for augmentation is to increase capacity, an alternative is to modify the electrical loading or demand side of the network, so the existing electrical infrastructure can supply customers' requirements, hence deferring capital.

This can be achieved by using non-network alternatives (NNA) or applying a demand management (DM) approach.

NNA involves investigating alternatives to network augmentations and offers substantial potential to achieve the power quality and capacity levels required at reduced costs.

DM aims to reduce network demand though conscious activity that alters the level or pattern of energy consumption, energy source or use of the network. Traditional DM methods are switching controllable load or transferring time of peak usage. DM can also involve promoting or facilitating external implementations.

For further information on DM processes and types, refer to the Essential Energy *Demand Management Strategy*.

4.6 Growth – Network Technology Strategy

4.6.1 Overview

Electricity businesses around the world face a common challenge: how to effectively supply electricity through an ageing infrastructure while meeting growing community and government calls for more reliable, environmentally sustainable and affordable energy supply.

The Growth – Network Technology Strategy subcategory covers the implementation of network technology initiatives over the medium- to long-term to provide increased network surveillance, monitoring and control capabilities. With this investment, the network will improve utilisation and performance, lower costs, and achieve greater customer responsiveness.

Ongoing monitoring will confirm that the network is operating within acceptable tolerances and enable us to identify and analyse thermal and voltage constraints, resulting in improved investment forecasting. It will assist in maximising network usage, so we can defer some augmentation projects, and will provide sufficient lead time to implement more DM solutions.

Network monitoring will also help us to identify load and performance trends and allow for more thorough and accurate reporting, as required by the AER’s Regulatory Information Notices.

The future, widespread adoption of distributed and renewable electricity generation, energy storage technologies and electric vehicles will help to reduce Australia’s carbon emissions. However, the large-scale connection of these intermittent power sources could adversely affect network performance, so we will need responsive networks to ensure the reliability and quality of electricity supply is not diminished.

Another challenge is increasing customer and regulatory authority demands for more information about energy consumption and supply outages, and their increased awareness of, and expectations around, power quality.

Essential Energy is meeting these challenges by changing the way we operate and gradually modernising our networks with smarter technologies. We are integrating information and communications technologies into new and existing network infrastructure and business systems to create a more responsive network.

By optimising network operations and facilitating customer responses, new network technology investments support more efficient network management in the short periods of increased load than the traditional and expensive approach of augmenting network assets.

4.6.2 Power Quality and Network Technology Strategies

Essential Energy's network is largely rural, with large numbers of overhead feeders that traverse significant distances across harsh terrain and environments. Maintaining power quality within the required standards under these conditions is difficult and expensive. The network impact of embedded generation and storage device connections is exacerbating this challenge.

To meet new obligations and Licence requirements, we have developed a power quality monitoring and control program to target these issues.

Power quality issues include voltage sags and swells, momentary outages, and power factor. Presently, we manage these reactively after customers report them. By improving our voltage and load monitoring capabilities through field monitoring equipment, and systematically storing the data (e.g. in the proposed Engineering Data Repository described in the Business Integration section), we plan to increase Essential Energy's active power quality management and reporting capabilities.

4.6.3 Network Technology Strategy Objectives

Essential Energy's network technology and monitoring objectives derive from customer, economic and business needs and are shaped by our corporate strategy. We will achieve them by increasing our network surveillance and monitoring capabilities, which will lead to greater understanding of network performance. The objectives are:

> Power Quality:
  - More efficient and effective management of network power quality, which will ultimately drive improvements in customers' supply quality.

> Asset Management Support:
  - Optimise asset renewal, replacement, and growth by providing network performance data that enhances management decisions related to asset condition, longevity, performance and capacity (rating).

> Demand and Load Management:
  - Manage network capacity and peak loads through additional network configuration management and control capability.
  - Enable the deferral of augmentation expenditure.

> Network Reporting:
  - As required by the AER.

> Sustainability Support:
  - Provide the network management capability to enable the connection of new and future technologies (including embedded generation and storage technologies e.g. electric vehicles) without adverse network performance impacts.
  - Support network efficiency, utilisation and power quality management by providing performance data.

> Reliability:
  - Enable improved outage management by assisting with fault location information and monitoring network performance and parameters following contingency network reconfigurations.
  - Drive improvements in average $/Customer Minutes Lost (CML).

4.6.4 Network Technology Deployment

With network technology deployment, we target the areas of greatest business and network need and benefit and prioritise sites in consultation with regional Distribution Network Planning Managers. We will achieve network technology objectives through three program deployment streams, which are depicted in Figure **27**:

> Voltage Monitoring and Control.

> Load Monitoring and Control.

> Fault Monitoring and Control.

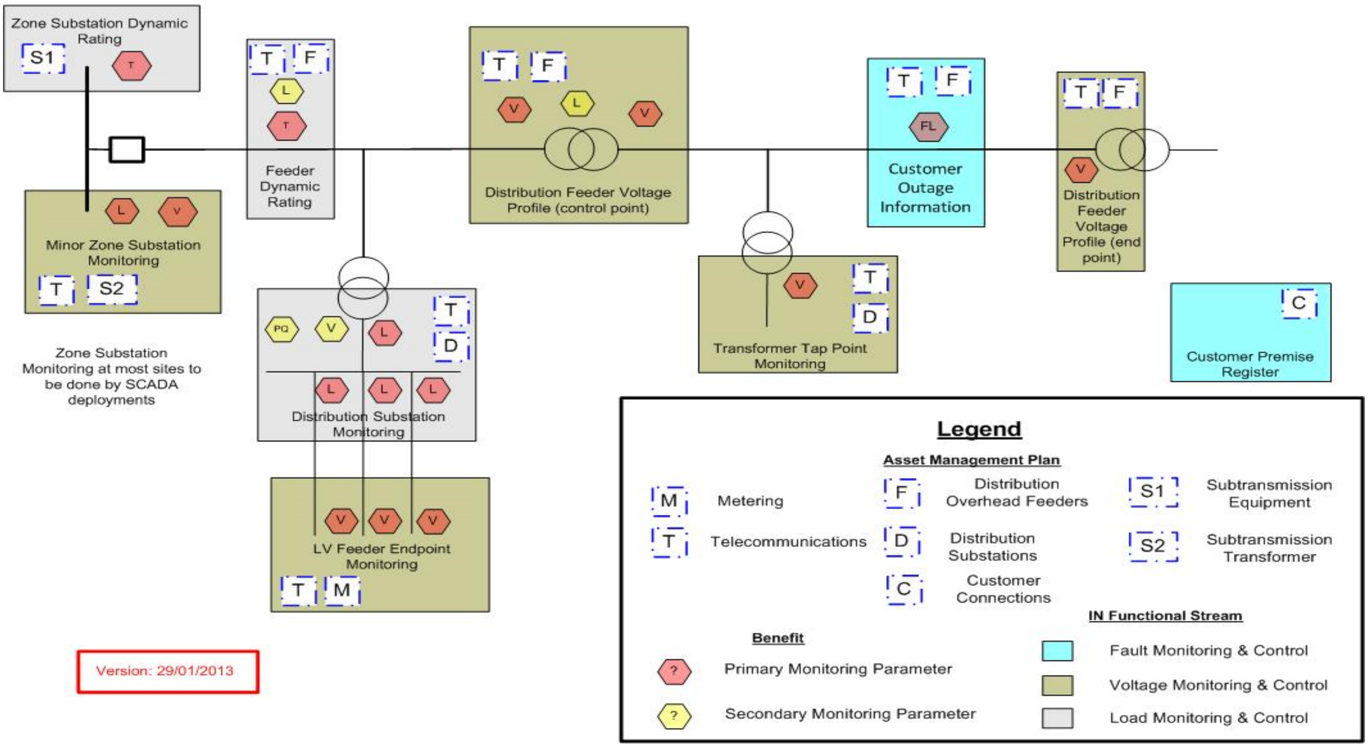

Figure 27 **– Monitoring Equipment Deployment Model**

Voltage Monitoring and Control

With approximately 1,450 overhead feeders traversing significant distances, a diverse range of geographically dispersed customers and limited visibility of network voltage performance, maintaining network voltages within the specified limits is problematic across Essential Energy's footprint. Over the next 15 years, the rapid proliferation of intermittent embedded PV generation and the connection of high volumes of energy storage devices to the network will significantly exacerbate this issue, especially as we have no real-time visibility of electricity generation or storage import/export.

We use diversified equipment ratings as a proxy for loading when modelling network voltage performance. Consequently, our network utilisation and voltage profile management is based on broad approximations, conservative management criteria and a reactive approach to addressing supply performance problems.

We have developed the Voltage Monitoring and Control program to target and support our management of these issues.

Improving the visibility of network voltage levels will help us to move towards a more proactive approach to managing customer power quality and, ultimately, minimising power quality issues.

Monitoring feeder voltage profiles will allow more efficient operation and management of the network within tighter tolerances We plan to deploy voltage monitoring devices at strategic locations on the network, as shown in Figure 27.

HV distribution feeder endpoint monitoring

Essential Energy plans to deploy HV feeder voltage profile monitoring at the electrical endpoints of the HV distribution feeders so we can monitor end-of-feeder voltages to support and validate network models and business and operational decisions. We will deploy this monitoring to 500 sites during 2019–2024. Over the long-term, our aim is monitor two or more feeder endpoints on all Essential Energy's distribution feeders.

We believe these initiatives will provide us with greater confidence that voltage levels are being maintained within acceptable tolerances and will facilitate a more active approach to identifying and managing potential voltage problems.

The key benefits include:

- Identifying situations where Essential Energy may be in breach of Licence Conditions and enabling remedial work to obtain compliance and mitigate possible penalties.
- Improving identification of parts of network that are voltage constrained so we can actively plan timely network upgrades and improve network voltage performance.
- Helping us to identify potentially hazardous over-voltage situations so we can act before an incident occurs.
- Identifying deferral opportunities for network augmentation expenditure, including costly feeder upgrades.
- Reducing the need for, and cost of, remote and on-site voltage reads associated with power quality investigations and model verification.
- Mitigating the risk of damage to customer equipment resulting from network voltage issues.
- Providing data that facilitates more accurate reporting and assists with our five-yearly regulatory review submission process.

Distribution substation load monitoring

With limited visibility of distribution substations and connected LV distributor loading patterns, Essential Energy has limited ability to actively monitor and manage LV distribution network capacity, utilisation, or quality of supply. Monitoring localised load peaks and profiles will improve our understanding of load flows, enabling better management of our capital augmentation needs and extending asset life by limiting overload situations.

We plan to deploy load monitoring equipment to distribution transformers with a capacity of 300kVA or more and their associated LV circuits. Substations and underground LV cables supplying multiple loads in commercial and CBD areas will be specifically targeted, to minimise prolonged and costly equipment failures caused by overloads that could critically impact commercial customer precincts.

The deployment will involve around 3,390 distribution substations over 15 years, with 500 sites to be completed during 2019-2024.

The key benefits include:

- Assisting with identifying parts of the network (particularly underground cables and equipment) that may be overloaded or load constrained, so we can actively plan timely network upgrades and minimise equipment failures and degradation.
- Reducing faults by improving our identification of network equipment that is load constrained.
- Identifying investment deferral opportunities for network augmentation projects.
- Reducing the need for, and the cost of, remote and on-site load reads associated with customer connection investigations and model verification.
- Providing data that facilitates more accurate reporting and assists with our five-yearly regulatory review submission process.
- Identifying areas where Essential Energy may be in breach of Licence Conditions and enabling remedial work to obtain compliance and mitigate possible penalties.
- Assisting with the identification of neutral integrity issues.

Table 12 – Voltage and Load Monitoring Deployment Model

Overview of Voltage Monitoring & Control	Network Initiative	Description	5-Year Cost
Voltage profile monitoring will be strategically deployed across the network. It will provide a topological view of voltage conditions and could also provide indication for loss of supply decisions.	**ESS_5** Distribution Feeder Voltage Profile Monitoring (Endpoint)	HV feeder profile monitoring is applied at the electrical endpoints of the HV feeders.	$2.44M
Strategic load and thermal monitoring will enable the identification of localised peaks, load flows and thermal loadings, providing the ability to actively manage network utilisation, capacity or quality of supply.	**ESS_36** Distribution Substation Monitoring	Distribution substations and individual LV circuit load monitoring devices are deployed at targeted ground-mounted distribution transformers with a capacity of 300kVA or more. Note: new pad mount substations will come pre-equipped with voltage/load monitoring equipment and communications.	$2.44M

4.6.5 Business Deployment Strategy

Provide monitoring and communications for existing equipment

We will prioritise providing communications and, where necessary, upgrading data monitoring hardware capabilities for existing voltage regulators, reclosers, switchgear and substations. This is a low cost/high benefit strategy for extracting performance information from our existing assets.

Integrate network technology capability into equipment specifications

While we recognise that targeted deployment of network technology capability is needed to maximise the value and minimise the cost of this technology, on a day-to-day basis, our business as usual asset management practices involve augmenting, replacing and refurbishing areas of the network.

However, where these activities continue to use equipment that is largely based on old technologies, it likely to become obsolete due to the rapid changes in power system equipment technologies. This also represents a lost opportunity to develop our technology capabilities incrementally and organically more broadly across the network. Moreover, as the demand for technology-enabled equipment increases globally, it is becoming increasingly difficult, and may soon be impossible, to purchase equipment that is not.

Consequently, we are progressively integrating technology capability into all Essential Energy's standard equipment specifications.

Use standard deployment models

We have developed a standard deployment and functionality model to further target the specific location and monitoring and/or control capability at a model feeder or substation. These standardised network capability footprints optimise deployment by minimising the number of devices needed to achieve capability that will deliver value.

Evaluate and build on deployment outcomes

A key element of our annual review of this Distribution Growth Strategy is to assess progress in delivering the network monitoring objectives. We may modify this Strategy to build on its learnings and align the outcomes achieved with the network performance objectives, or to take advantage of changes such as technology advances, revised costs, or new regulatory conditions.

4.6.6 Business Integration

We view network technology and monitoring as a whole-of-business/whole-of-network enabling concept.

To extract maximum value, Essential Energy needs to embrace, adapt to, and exploit our network technology capability by progressively incorporating it into normal business activities over the next 15 years. This will enable us to operate our distribution network efficiently for the long-term interests of customers, the regional economy, and our business.

Two business integration elements are crucial to the success and realisation of network monitoring benefits:

- Network performance data is captured and managed.
- Business processes are enhanced to capture network monitoring technology capability value.

Network performance data is captured and managed

Historically, Essential Energy's network performance data has been either very limited or unavailable.

By capturing network performance data in real time and providing broad access to this information, Essential Energy and our customers will be able to make efficient decisions about the management and use of the network.

To achieve this, we plan to capture and manage network performance data through the Engineering Data Repository (EDR). The EDR will provide a warehouse of all network performance data to enhance a range of business processes, from network planning to operations. It will provide the foundation for capturing and managing the volume of network data we need to extract full value from the network.

Figure 28 shows the key links between three core elements of effective network monitoring:

- **Field devices** – installed at appropriate locations to provide network performance and operation information.
- **Telecommunications** – ensure the information is retrieved from the field and presented to operators, planners, and designers in a timely and cost-effective fashion.
- **IT system** – the EDR, which will be a repository for the data and facilitate efficient data dissemination across the organisation in a way that supports effective information visualisation, analytics, event monitoring and trending.

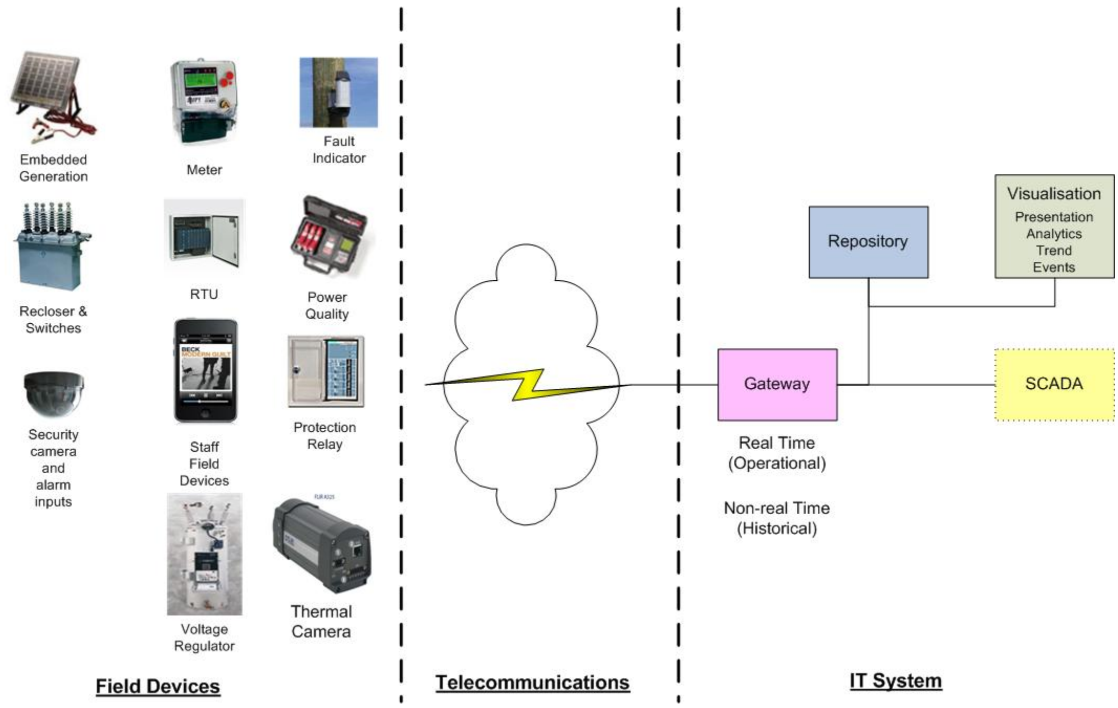

Figure 28 – Network Technology Key Components

Business processes are enhanced to capture network technology capability value

Incorporating network technology capabilities into business as usual asset management practices is key to realising the value of network monitoring initiatives. To capture this value, we will need to enhance our business processes and practices.

> **Planning processes and standards** will need to evolve to use the information from enhanced network monitoring, then progressively develop to accommodate network control and automation. The required changes will include: revised network modelling and performance analysis practices; capacity planning practices; and a shift towards a reliance operational contingency management capability.
> **Design standards** will need to accommodate changing equipment standards, communications needs, maintenance needs and works practices.
> **Field works practices and procedures** will need to include managing communications needs, IT needs and asset data management needs.
> **Network operations, fault finding, switching, isolation and network access procedures** will be impacted by: increased availability of real-time fault location information; a growing ability to inform customers of outage durations; and the operational impacts of both dynamic rating capability and growing control and automation capability.
> **Asset installation and replacement practices** will be impacted by improved asset performance data that will enable improved analysis of asset and network performance and risks.
> **Asset management data and network control systems** will alter to accommodate new information about network state and performance. This will underpin enhanced network performance analysis to better support targeted power quality management, demand-side management, reliability management, asset management, risk management and network operations activities.

These changes will be supported by aligning them with our overall IT strategy so that data, functionality and capabilities are delivered to critical areas of the business (e.g. network operations, network planning) and, ultimately, to all relevant areas of the business.

For further details, refer to Essential Energy's *Information Technology Business Plan.*

4.6.7 Network Technology Forecast Capital Investment Plan

Table 13 summarises the annual investment required to implement network monitoring initiatives over the 2019-2014 regulatory period. While network technology deployment is a long-term strategy that extends over 15 years or more, for the purposes of the regulatory submission, the plan focuses on 2019-2024.

Table 13 – Network Technology: Forecast Capital Investment Plan

Network Monitoring Program	2019/20	2020/21	2021/22	2022/23	2023/24	Total $M
Feeder Voltage Profile - End of Feeder	$.51	$.5	$.49	$.48	$.48	$2.44
Dist. Substation Monitoring	$.51	$.5	$.49	$.48	$.48	$2.44
Total, $M	**$1.02**	**$.99**	**$.97**	**$.96**	**$.95**	**$4.89**

Investment justification

> Reduce future expenditure (investment deferral) by enabling DM and providing data that supports more informed decision-making.
> Assist with the reporting required by the AER's Regulatory Information Notices.
> Mitigate risks for the network and customers from mal-operation, damage or premature equipment ageing due to varying or exceeding steady state voltage levels, voltage unbalances or excessive loads.
> Facilitate effective compliance with the power quality requirements of the NER, Australian Standards and other statutory requirements.

- Ensure voltage levels are maintained within acceptable tolerances and identify present and emerging voltage constraints.
- Assist with planning and decision-making for future augmentation needs, refurbishment and maintenance works for distribution feeders, substations, and LV mains, including protection reviews.
- Expose the potential to defer capital expenditure through better understanding of feeder voltages profiles and optimising feeder utilisation.
- Assist with network operation, control, and management through improved visibility of network voltages and loads.
- Monitor the impacts of, and assist in managing, embedded generation connections.
- Improve provision of customer information and service.
- Identify present distribution transformer load cycles and identify overload conditions and emerging load constraints that will help prevent equipment degradation, damage, and potential failure.
- Assist with actively identifying and managing emerging supply quality issues.

Risks of deferring or cancelling investment

- Reduced ability to implement cost-effective network asset management owing to lack of information about network infrastructure performance.
- Reduced ability to assess the impact on our network of adverse weather, increased take-up of embedded generation and the expectation for increased storage devices, because we lack relevant network performance data.
- Breaching Licence Conditions by being unable to complete the required Regulatory Information Notice with accurate measured data.
- Increased difficulty in efficiently planning for future distribution equipment needs due to lack of network information.
- Difficulty in assessing the potential for deferral of distribution capital projects and expenditure due to lack of network information.
- Potential damage and degradation to network equipment due to unknown abnormal loads and voltages, with the risk of failure, fire or explosion resulting in outages and high costs.
- Increased difficulty in maintaining network voltages within required Licence limits without better visibility of our 1500 overhead feeders.
- Inability to verify network modelling information with real data.
- Inability to confirm voltage performance following complaints.
- Inability to meet increasing demands for more detailed data in network performance reports.

5. Distribution Network Growth Strategy Investment Summary

This section summarises the capital investment plan for implementing Essential Energy's Network Growth Strategy, as shown in Table 15. These plans are aligned with Essential Energy's investment programs.

We have based the predicted volumes of work on the analysis, needs and forecasts in section 4.

Growth-related investments for the distribution network are primarily reactionary. Accurately forecasting defined and specific projects over the medium- to long-term is problematic due to the localisation and variability of load growth and Essential Energy's lack of network monitoring capability.

However, our capacity forecasting for distribution network feeders and substations in regional cities is more advanced. Also, forecasting investments for the subtransmission network is more precise as constraints are most likely to involve more predictable singular or point-to-point assets that have more performance monitoring and data availability.

Each growth-related project undergoes a rigorous assessment process, including a peer review for >$1.0M projects. This includes investigation of alternative traditional network or non-network solutions by local Network Planners.

Every project is subject to an individual Investment Case approval to ensure all capital expenditure is technically appropriate, prudent, and efficient. Part of this investment case approval process involves approximating the value of risk associated with the projects deferral.

5.1 Capital Investment Drivers

Six main component streams of capital network investment are associated with implementing the Distribution Growth Strategy.

Connections

Shared distribution assets work funded and constructed by Essential Energy to facilitate and provide capacity for connecting new or additional customer loads or generation. Typical works include:

- New or augmented transformers and substations (includes transformer upgrades to minimum size 16kVA because of increased customer lifestyle loads - not power quality related).
- New or reconductoring of HV and LV lines to increase capacity, including associated line equipment, protection equipment or setting upgrades where these assets are part of the shared network and required to supply customer loads.
- Shared padmount substations and HV cables/switches for Underground Residential Distribution (URD) estates and multi-occupancy developments in accordance with Essential Energy's *Connection Policy* CEOP 2513.06.

Thermal

Upgrading the load-carrying capacity of HV and LV cables, conductors, transformers and other network equipment (e.g. switches, reclosers, fuse links, regulators) where the currents being carried are exceeding, or expected to exceed, their safe thermal capacity rating because of general and incremental load growth. Typical works include:

- New or augmented HV distribution feeders or subtransmission lines and zone substations to cater for incremental network load growth, new or additional loads, or to address wider network reliability/power quality issues.
- Installing new, or augmenting existing, distribution substations to relieve overloaded substations.
- New HV mains to facilitate load redistribution, feeder reconfiguration flexibility and spare feeder capacity for contingency conditions.
- Increasing ground clearances of overhead conductors to maintain/increase thermal rating.

Voltage

Upgrading the distribution network infrastructure to improve voltage capacity and performance; maintaining adequate voltage regulation and bandwidths; and restricting voltage swings to within the prescribed limits while carrying existing and expected loads. Typical works include:

- Reducing system impedance and improving voltage regulation by upgrading HV or LV conductors.
- Upgrading undersized transformers if they are a contributing factor to voltage constraints.
- Reducing network loads by redistributing and optimising loads on the network, including:
  - Improving power factor to reduce the reactive component of load current.
  - Installing a third wire on single-phase lines to distribute existing loads across the phases and upgrading system voltage to reduce current proportionally.
  - Reducing peak current through DM strategies.
- Installing or upgrading voltage regulator equipment on the HV network.
- Installing invertor and energy storage initiatives, particularly on remote lines.

Fault

Reducing system impedances (i.e. increasing fault levels) on the network to ensure safe and proper operation of network electrical protection systems and protect customer installations. Typical works include:

- Installing larger cables and conductors to reduce network supply impedance and increase fault levels.
- Installing switching equipment and interconnections on the network to maintain efficient and flexible operation (e.g. gas switches for sectionalising/switching feeders and loads), which becomes necessary following growth of network load at risk and peak demand.
- Installing new reclosers/sectionalisers and relocating existing reclosers to ensure adequate protection, sectionalising and grading margins exist, including communications to such equipment.
- Installing network load, voltage and fault monitoring devices e.g. fault indicators.
- Installing high fault level capacity protection devices e.g. boric fuses in high fault level areas.

Demand management

Deferring traditional network augmentation expenditure by implementing:

- Power factor correction – Installing power factor correction equipment (capacitors) on the network to reduce peak demand and losses and improve voltage profiles.
- Advanced load control – Targeted engagement of Essential Energy customers with load control products for air conditioning, pool pumps and hot water to reduce peak demand.

Network technology

Installing voltage monitoring, load monitoring and control equipment on Essential Energy's network to give real-time visibility of network voltages and loads. This will provide us with a topological view of voltage and load conditions, indicate loss of supply and assist with restoration decisions. It is also part of our strategy for modernising and extracting more from Essential Energy's ageing network. Programs include:

- Installing dedicated voltage monitoring meters/equipment at the electrical endpoints of HV distribution feeders to provide high voltage feeder profile monitoring.
- Deploying load monitoring and/or metering devices at targeted padmount and chamber substations and their associated individual LV circuits where transformers have a capacity of 300kVA or more and are in commercial load precincts.

5.2 Capital Investment Plan

Table 14**Error! Reference source not found.** summarises our forecast capital investments for the 2019-2024 regulatory period. We have based this forecast on the historical expenditure patterns for each growth driver category over the 2016/17 to 2018/19 period.

We consider this historic expenditure approach to be appropriate and prudent, given the uncertainty and variability of demand growth or decline across localised areas of Essential Energy's network.

Most of Essential Energy's medium-term distribution growth investment needs are driven by growth in customer numbers and the need to manage risks associated with pre-existing network voltage and thermal constraints, which result from past incremental demand growth. This is a common situation, as distribution growth expenditure generally addresses demand growth constraints after they have been identified. Therefore, most of our medium-and long-term demand growth projects will remain largely unknown until specific constraints either emerge or are identified, and will tend to be area-specific.

Our customer growth has been around 0.55 per cent p.a. over the past five years. NIEIR predicts it will continue at 0.57 per cent p.a. through to 2022. NIEIR has forecast combined summer/winter demand growth to be around 1.3 per cent p.a. after accounting for the impact of economics, customers, policies, and weather.

Despite these growth indicators, we have not applied an annual growth rate index to our forecast investments. This is because we recognise the role of changing customer energy usage patterns, network management efficiency improvements, DM initiatives, improved network utilisation, and the need to contain capital investment increases. We also recognise the uncertainties when forecasting macro network and localised demand growth, particularly the impact of increased PV generation.

In addition to historically-based distribution growth investments, we have included new investment for network monitoring initiatives. These will provide investment deferral opportunities, efficiency gains, network management cost reductions and better customer service and information and will facilitate more accurate performance reporting.

Table 14 – Summary of Growth Investments

Financial Year ($M)	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**5 Year Total**
Distribution Growth Investment	$23.67	$22.49	$21.99	$21.71	$21.62	**$111.48**
Network Technology Investment	$1.02	$.99	$.97	$.96	$.95	**$4.89**
Total	**$24.69**	**$23.48**	**$22.96**	**$22.67**	**$22.57**	**$116.37**

Table 15 – Growth Investments by AER Drivers and Essential Energy PIP Codes

Distribution Growth Category ($M)	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**5 Year Total**	**PIP**
Growth - Voltage	$5.44	$5.09	$4.94	$4.84	$4.81	**$25.11**	ESS_1
Growth - Thermal	$4.72	$4.42	$4.29	$4.21	$4.18	**$21.82**	ESS_2
Growth - Fault	$8.73	$8.17	$7.93	$7.78	$7.72	**$40.33**	ESS_3
Growth - Connections	$4.77	$4.81	$4.84	$4.88	$4.91	**$24.21**	ESS_4
NT - Feeder Voltage Profile	$.51	$.5	$.49	$.48	$.48	**$2.44**	ESS_5
NT - Substation Monitoring	$.51	$.5	$.49	$.48	$.48	**$2.44**	ESS_36
Total	**$22.7M**	**$22.7M**	**$22.7M**	**$22.7M**	**$22.7M**	**$113.6M**	

Table 16 – Annualised Deferral Risk Estimate Summary

Distribution Growth Category ($M)	**Annualised Safety Risk Value**	**Annualised Network Risk Value**	**Annualised Financial Risk Value**	**Annualised Reputation Risk Value**	**Annualised Environment Risk Value**	**PIP**
Growth - Voltage	$0.0M	$0.0M	$1.9M	$0.0M	$0.0M	ESS_1
Growth - Thermal	$0.0M	$29.8M	$0.0M	$0.0M	$0.0M	ESS_2
Growth - Fault	$0.6M	$2.7M	$0.0M	$0.0M	$1.9M	ESS_3
Growth - Connections	$0.0M	$59.3M	$0.0M	$0.1M	$0.0M	ESS_4
Total	**$0.6M**	**$91.8M**	**$2.0M**	**$0.1M**	**$1.9M**	

Appendix A - Examples of Growth - Connections Projects in 2016/17

Example 1 – Low Voltage Extension in Coonabarabran

Full Project Approval

APPROVED 08/07/2016

Independent Project, Planning ID: 1230141 WASP: 729084 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 214663

Total Approval: $66,006
Est Overheads: @47.79% $21,344

Approval Direct: $44,662
Variance from previous approval: $44,662
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L2 <slot 305> Distribution Planning Mgr $100,000

IO Region: Northern
Works Area: NTH Castlereagh
FSC: Coonabarabran Depot
Local Gov't Area: Warrumbungle Shire Council
State Seat: Barwon

Project Name:
LV New - Extend LV 0.145km, 46 Barker Street, Coonabarabran (CC)

Project Description:
This project will see a low voltage extension along Barker Street Coonabarabran to cater for a new connection.

Planning Project ID:	1230141	WASP ID:	729084
Primavera No.:		WASP Program:	NC Dist LV lines and Cables
Urban/Rural:	Urban	Asset type:	LVOH LV Distn OH Line-Incl Services
Target Completion Date:	07/10/16	Primary AER Cat.:	Growth (GRI)

Full Project Approval

APPROVED 08/07/2016

Independent Project, Planning ID: 1230141 WASP: 729084 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Connections-	100%	GRI: Connections: Loads LV OH - New	132	metres

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_4	Distribution Growth - Customer Co	High	$890

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_4	Distribution Growth - Customer Co	High	$44,662

Constraint Summary:

The constraints for this project are:

- A customer has applied for and been granted a basic connection offer.
- No electrical infrastructure is present at the property boundary.

Background:

A customer has applied for and been granted a Basic Connection Offer for 46 Barker Street Coonabarabran. At present there is no electrical infrastructure to the boundary of the property for the customer to take supply.
Essential Energy is obligated to provide the shared network assets as per CEOM2513.06a (3.2 Individual Retail Customer).

Non Network Options:

Options Considered But Ruled Out:

Options Considered:

Financial Implications:

Funding for the option as outlined in this report has been made available, via the funding wizard, from the Northern Regions Power Quality/ Customer Connections budget for construction during the 2016/17 financial year.

Reference Documents (if any):

Nil

Project Benefits:

The benefits of this project are: - A new customer can take supply from Essential Energy's network.

Peer Review:

Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:

It is recommended that this project proceed as identified in this report in the 2016/17

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Example 2 – Transformer Installation Tarago Town

Full Project Approval

APPROVED 21/07/2016

Independent Project, Planning ID: 1241001 WASP: 732003 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 215803

Total Approval: $30,371
Est Overheads: @47.79% $9,821

Approval Direct: $20,550
Variance from previous approval: $20,550
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L2 <slot 305> Distribution Planning Mgr $100,000

IO Region:	Southern
Works Area:	STH Eurobodalla Tablelands
FSC:	Goulburn Depot
Local Gov't Area:	Goulburn Mulwaree Council
State Seat:	Goulburn

Project Name:
Install transformer to supply lots within Tarago Town

Project Description:
Installation of 25 kva transformer Application for connection to multiple Lots within defined town boundary pre 1960. As per Capital Contributions policy 3.3.6 asset will be a shared asset and requires EE funding Lots 126 and 127 DP793043.

Planning Project ID:	1241001	WASP ID:	732003
Primavera No.:		WASP Program:	NC Dist HV Lines and Cables
Urban/Rural:	Urban	Asset type:	11OH 11kV Distribution OH Lines
Target Completion Date:	30/11/16	Primary AER Cat.:	Growth (GRI)

Approval Overview

Installation of 25 kva transformer
Application for connection to multiple Lots within defined town boundary pre 1960.
As per Capital Contributions policy 3.3.6 asset will be a shared asset and requires EE funding
Lots 126 and 127 DP793043.

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1241001	1	$3,600	07/06/2016

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Full Project Approval

APPROVED 21/07/2016

Independent Project, Planning ID: 1241001 WASP: 732003 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Connections-	100%	GRI: Connections: Loads Dist Transformers/S	1	Transformer

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_4	Distribution Growth - Customer Co	High	$730

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_4	Distribution Growth - Customer Co	High	$20,550

Constraint Summary:

Installation of 25 kva transformer required for shared asset customer connection.
Application for connection to multiple Lots within defined town boundary pre 1960.
As per Capital Contributions policy 3.3.6 asset will be a shared asset and requires EE funding
Lots 126 and 127 DP793043.

Background:

Installation of 25 kva transformer
Application for connection to multiple Lots within defined town boundary pre 1960.
As per Capital Contributions policy 3.3.6 asset will be a shared asset and requires EE funding
Lots 126 and 127 DP793043.

Non Network Options:

Options Considered But Ruled Out:

Options Considered:

Financial Implications:

This project has been included in the 15-16 and 16-17 Fys budget for design and construct

Reference Documents (if any):

Nil

Project Benefits:

Installation of 25 kva transformer Application for connection to multiple Lots within defined town boundary pre 1960. As per Capital Contributions policy 3.3.6 asset will be a shared asset and requires EE funding Lots 126 and 127 DP793043.

Peer Review:

Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:

Full Project Approval

APPROVED 21/07/2016

Independent Project, Planning ID: 1241001 WASP: 732003 Primavera:

It is recommended that the project to install a 25 kVA transformer at a cost of $20,550 be approved.
EE has an application for connection to multiple Lots within defined town boundary pre 1960.
As per Capital Contributions policy 3.3.6 asset will be a shared asset and requires EE funding
Lots 126 and 127 DP793043.

Example 3 – New Overhead Substation Coffs Harbour

Full Project Approval

APPROVED 23/08/2016

Independent Project, Planning ID: 1248842 WASP: Primavera:

PROJECT APPROVAL REPORT

Approval ID: 218183

Total Approval: $63,961
Est Overheads: @47.79% $20,683

Approval Direct: $43,278
Variance from previous approval: $43,278
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L2 <slot 305> Distribution Planning Mgr $100,000

IO Region:	North Coast
Works Area:	NC Coffs Coast
FSC:	Coffs Harbour Depot
Local Gov't Area:	Coffs Harbour City Council
State Seat:	Coffs Harbour

Project Name:
ASP- install new CDB OH sub cnr McLean Meadow St Coffs Harb CW 110190

Project Description:
EE contributed to CBD sub near corner of McLean and Meadow Srt Coffs Harbour. Extend HV and LV 1 span, contribute to 200kVA to 300kVA Tx size increase and cut in new LV links. CW 110190

Planning Project ID:	1248842	WASP ID:	
Primavera No.:		WASP Program:	NC Dist HV Lines and Cables
Urban/Rural:	Urban	Asset type:	11OH 11kV Distribution OH Lines
Target Completion Date:	17/08/16	Primary AER Cat.:	Growth (GRI)

Approval Overview

Funded under Connection Policy OM2513.06a Section 5 Prorata Calculations for Urban Customers.

Works includes extending the HV and LV 1 span, contribute to 200 kVA to 300 kVA transformer size increase, and cut in new LV links. These works increase network capacity and flexibility for Essential Energy in the CBD area.

Project approval history: #### NIL ####

Design (CAP2) approval history: ####

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Full Project Approval

APPROVED 23/08/2016

Independent Project, Planning ID: 1248842 WASP: Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units
Connections-	100%	GRI: Connections: Loads ASP/Cust Reimburse	0

Portfolio Investment Plan:

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_4	Distribution Growth - Customer Co	High	$43,278

Constraint Summary:
Augmentation to shared asset portion of Network required to facilitate new load.

Background:
Connection Policy requires Essential Energy to fund augmentation works on shared assets.

Non Network Options:

Options Considered But Ruled Out:

Options Considered:
No alternative. Work is being carried out by the customers ASP.

Financial Implications:
Funded from network Funded Portion of Shared Assets Allocation.

Reference Documents (if any):
The following documents are filed with the project and form part of this investment approval: Quote:<2016-05-18_110190_Revised Q0026191.pdf>
Drawing:<2016-05-19_11019_ Certified Construction Drawing_McLean St Oval Coffs.pdf>

Project Benefits:
Funded under Connection Policy OM2513.06a Section 5 Prorata Calculations for Urban Customers

Peer Review:
Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:
It is recommended Essential Energy invest $43,278 (direct) / $63,961 (onCost) as an ASP payment for the upgrade of a substation and lines to address network capacity and flexibility issues in the vicinity of Meadow St, Coffs Harbour.

Appendix B – Examples of Growth - Thermal Projects in 2016/17

Example 1 – 11kV Overhead Conductor Replacement Byron Bay

Full Project Approval

APPROVED 23/12/2015

Independent Project, Planning ID:1179781 WASP: 709862 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 195923

Total Approval: $202,549
Est Overheads: @44.69% $62,561

Approval Direct: $139,988
Variance from previous approval: $139,988
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L4 <slot 401> MG Asset & Network Planning $250,000

IO Region: North Coast
Works Area: NC Coastal
FSC: Ewingsdale Depot
Local Gov't Area: Byron Shire Council
State Seat: Ballina

Project Name:
OH - reconduct 11kV Bangalow Rd Byron Bay - 800m

Project Description:
Reconduct 11kV 7/3.00AAC @ 19/3.75AAAC from pole 84129 to pole 74335, along Bangalow Rd, Byron Bay - 800m

Planning Project ID:	1179781	WASP ID:	709862
Primavera No.:		WASP Program:	NC Dist HV Lines and Cables
Urban/Rural:	Urban	Asset type:	11OHU 11kV Dist OH Lines Urban
Target Completion Date:	30/06/17	Primary AER Cat.:	Growth (GRI)

Approval Overview

Byron Bay has two primary supply points being Ewingsdale zone substation, and more recently Suffolk Park zone substation.
Suffolk Park has one primary feeder to the east and southern portions of Byron Bay, with Ewingsdale providing 3 primary feeders to the west and central parts of Byron Bay.
A limitation in distribution switching flexibility exists because of only one feeder supply from the Suffolk Park zone. With reconductoring a 800m section of 11kV along Bangalow rd, a second primary feeder can supply Byron Bay from Suffolk Park zone substation.
With this additional capacity a significant increase in switching flexibility is available , which will minimise risk of customer outage, and also cater for ongoing load increasing in the Byron CBD and surrounds.

The Value of Customer Reliability Report (VCR - attached) indicates that $249,769 can be spent on augmentation.

Prime drivers:
- Increase in switching flexibility in Byron Bay.
- Increasing loads in Byron Bay

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1179781	1	$13,440	19/12/2014

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Full Project Approval

APPROVED 23/12/2015

Independent Project, Planning ID: 1179781 WASP: 709862 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Thermal	100%	GRI: Thermal: HV reconductoring	789	metres

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_9998	Major Project PIP Unallocated (Cap	Medium	$9,560

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_2	Distribution Growth - Thermal Cons	Medium	$130,428

Constraint Summary:
Thermal capacity of existing 7/3.00 AAC 11kV conductor, and resulting voltage constraints limits ability to supply additional load into Byron Bay

Background:
Byron Bay was experiencing significant voltage problems prior to the establishment of the new zone substation at Suffolk Park in 2011. The additional feeder capacity afforded by this project will allow further improvements to supply, and reliability in Byron Bay

Non Network Options:

Options Considered But Ruled Out:

Options Considered:
Option 1 is the preferred option as this is the least cost option that satisfies the prime drivers for the project.

Option No: **1** OH reconduct 800m of 11kV - Bangalow Rd **Preferred Optio**

This option reconducts the existing 7/3.00 AAAC with 19/3.75 AAAC. - 789m, and replaces 7 poles .

NPV Result: $139,988

Option No: **2** UG - replace O/H with UG 11kV cable - 800m

This optiion involves installing 240mm XLPE 11kV cable - 800m, along Bangalow rd. The existing overhead poles remain in place for the LV network.

NPV Result: $336,000

Financial Implications:
This project is funded in the 15/16 and 16/17 FY's

Reference Documents (if any):
The following documents are filed with the project and form part of this investment approval: CAPEX:<CapexNotification_709862_1_0.pdf> Design:<709862_CAPEXPlan_56.pdf> VCR Report:<1179781 - Alternate supply SFP3B5 SFP3B1 VCR calculator V0.2.xlsm>

Project Benefits:

Full Project Approval

APPROVED 23/12/2015

Independent Project, Planning ID: 1179781 WASP: 709862 Primavera:

Will increase capacity to supply Byron Bay from Suffolk Park Zone Susbstation

Peer Review:
Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:
It is recommended that Essential Energy invest $139,988 (direct) / $202,549 (on-cost) and 925 man-hours in 2016/17 to reconduct 789m of the 11kV feeder in the vicinity of Bangalow Rd Byron Bay to 19/3.75 AAAC to address identified network capacity and alternate supply flexibility constraints.

Example 2 – LV Tie and Load Transfer Queanbeyan

Full Project Approval

essential energy

APPROVED 06/05/2016

Independent Project, Planning ID: 1206601 WASP: 722029 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 210023

Total Approval: $25,416
Est Overheads: @44.69% $7,850

Approval Direct: $17,566
Variance from previous approval: $17,566
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L1 <slot 205> Planner Distribution $50,000

IO Region:	Southern
Works Area:	STH Lower Alpine
FSC:	Queanbeyan Depot
Local Gov't Area:	Queanbeyan City Council
State Seat:	Monaro

Project Name:
Rutledge St LV Tie & Load Transfer - Queanbeyan

Project Description:
Transfer load off the overloaded LV cables that run between SUB33-13574 and LVP10598 in Rutledge St by repairing the faulted LV cable in Crawford St and relocating normally open points. Load will be transferred to substations 33-16868 in Crawford St and 33-241 in Isabella St.

Planning Project ID:	1206601	WASP ID:	722029
Primavera No.:		WASP Program:	NC Dist LV lines and Cables
Urban/Rural:	Urban	Asset type:	LVOHU LV OH line including services -Urban
Target Completion Date:	30/06/17	Primary AER Cat.:	Growth (GRI)

Approval Overview

Transfer load off the overloaded LV cables that run between SUB33-13574 and LVP10598 in Rutledge St by repairing the faulted LV cable in Crawford St and relocating normally open points at a cost of $17,566 to be funded in the 2016/17 financial year budget.

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1206601	1	$4,000	30/09/2015

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Full Project Approval

APPROVED 06/05/2016

Independent Project, Planning ID: 1206601 WASP: 722029 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Thermal	100%	GRI: Thermal: LV reconductoring / relocation	5	metres

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_2	Distribution Growth - Thermal Cons	Medium	$3,132

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_2	Distribution Growth - Thermal Cons	Medium	$14,434

Constraint Summary:

- The twin 240mm cables that run from substation 33-13574 to LVP33-10598 in Rutledge St are overloaded with 820A measured on the cables in July 2015 (cables rated at 700A). The high load is damaging the cable insulation with cable vibration now occurring.
- The low voltage pillar in Rutledge St (LVP33-10598) supplies two 240mm circuits that then supply four 150mm ABC LV OH circuits in Rutledge St adjacent to the pillar (with two 150mm ABC circuits connected to each cable). These two 240mm circuits are protected by 400A fuses. The 400A fuses that supply the circuit heading east along Rutledge St have blown due to excessive load. The overload is confirmed by the LV log results that indicate that the load is expected to reach close to 500A (well in excess of the 400A fuse rating and the 330A cable rating.
- One of the 150mm ABC circuits in Rutledge St (rated at 280A) is overloaded with 339A measured in September 2015. The load on this circuit is expected to reach 410A at peak load which is well in excess of the rated load.

Background:

The LV UG cable in Crawford St adjacent to substation 33-16868 is damaged and isolated. With this cable damaged the Crawford St load was transferred to one of the 150mm ABC LV circuits in Rutledge St (supplied from substation 33-13574). This load transfer has resulted in the overload of the LV cables and fuses along Rutledge St.

The peak load on the Oleria St feeder during the second log period was 165A. During 2015 the peak load on the feeder was 202A. A factor of 1.22 (=202/165) was used to determine the peak load on the 150mm circuit along Rutledge St that supplies the transferred Crawford St load.

Non Network Options:

There are no non network options available.

Options Considered But Ruled Out:

The option of only relocating the LV OH open points along Crawford St was considered but ruled out as there is a significant amount of load (at least 87A based on instantaneous reads) on the underground network along Crawford St which can be taken off the overloaded cable with the relocation of LV UG open points.

Options Considered:

Two Options were considered:

Full Project Approval

APPROVED 06/05/2016

Independent Project, Planning ID: 1206601 WASP: 722029 Primavera:

- Install a 3rd 240mm cable and an additional 150mm ABC circuit to accommodate the overload.
- Repair the LV UG in Crawford St and relocate OH & UG LV open points

Repairing the LV UG in Crawford St and relocate OH & UG LV open points was selected as the least cost option.

Option No: **1** Install additional LV cables

Install a 3rd 240mm cable (80m) and an additional 150mm ABC circuit (128m) to accommodate the overload. Replace the 400A LV fuses with 630A fuses.

NPV Result: wacc 6.18% = $ -130000

Option No: **2** Repair the LV cable and relocate LV open points **Preferred Optio**

Repair the LV UG in Crawford St and relocate OH & UG LV open points along Crawford St to reduce the number of customers on the overloaded circuits by 15. The open point relocation will take at least 177A off the overloaded cables (based on instantaneous reads of the circuits in Crawford St)

NPV Result: wacc 6.18% = $ -17566

Financial Implications:
$17,566 to be funded in the 2016/17 financial year budget.

Reference Documents (if any):
The following documents are filed with the project and form part of this investment approval: Measured load profile of 150mm ABC circuit in Rutledge St that supplies Crawford St:<Rutledge St Top East Circuit Load Profile.JPG> Scaled load profile of 150mm ABC circuit in Rutledge St that supplies Crawford St:<Scaled Rutledge St Top East Circuit Load Profile.JPG> Twin 240mm UG Cable load Profile:<Rutledge St Twin 240mm UG Cable Load Profile.JPG> Load on each of the 400A fuses in the LV pillar in Rutledge St:<Rutledge St LV Pillar 400A Fused Circuit Loads.JPG>
Rutledge St Circuit Layout & Loadings:<Rutledge St Circuit Layout & Loadings.pdf>
Scope of Works:<Rutledge St Circuit Scope of Works.pdf>

Project Benefits:
- Repair damaged LV cable in Crawford St - Reduce the load on the overloaded UG 240mm LV cables in Rutledge St - Reduce the load on the overloaded OH 150mm ABC LV cable in Rutledge St

Peer Review:
Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:
Transfer load off the overloaded LV cables that run between SUB33-13574 and LVP10598 in Rutledge St by repairing the faulted LV cable in Crawford St and relocating normally open points at a cost of $17,566 to be funded in the 2016/17 financial year budget.

Example 3 – Substation Load Balance Mudgee

Full Project Approval

APPROVED 29/06/2016

Independent Project, Planning ID: 1208042 WASP: 722583 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 213843

Total Approval: $58,948
Est Overheads: @44.69% $18,207

Approval Direct: $40,741
Variance from previous approval: $40,741
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L2 <slot 305> Distribution Planning Mgr $100,000

IO Region:	Northern
Works Area:	NTH Macquarie
FSC:	Mudgee Depot
Local Gov't Area:	Mid-Western Regional Council
State Seat:	Orange

Project Name:
Substation load balance_50-1224_Lawson St Mudgee

Project Description:
This project will see a thermally overloaded substation site in Farnell Street Mendooran have it's phases rebalanced to evenly distribute the load across all three phases. This will ensure the substation is no longer thermally overloaded and reduce the neutral current.

Planning Project ID:	1208042	WASP ID:	722583
Primavera No.:		WASP Program:	NC Dist HV Lines and Cables
Urban/Rural:	Urban	Asset type:	22OHU 22/33kV Dist OH lines Urban
Target Completion Date:	30/12/16	Primary AER Cat.:	Growth (GRI)

Approval Overview

The purpose of this project is to balance substation 50-1224 located in Lawson Street Mudgee. The substation was logged and it was found that phase 'A' of the transformer was out of balance compared to the 'B' and 'C' phase by around 100 Amps.

The proposed works include:

- Ensure service connections are configured as per the N.S.W Service and Installation Rules.
- Reconductor 120m of existing single phase 95mm to three phase 95mm ABC bundle in Honey Lane.
- Change 9 single phase road crossings to three phase.
- Replace 20 services.

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1208042	1	$2,000	06/10/2015

printed 29/06/2016 11:47:31 AM Planning Project ID 1208042 **Page 1 of 3**

Full Project Approval

APPROVED 29/06/2016

Independent Project, Planning ID: 1208042 WASP: 722583 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Thermal	100%	GRI: Thermal: LV reconductoring / relocation	60	metres

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_2	Distribution Growth - Thermal Cons	Medium	$517

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_2	Distribution Growth - Thermal Cons	Medium	$40,000

Constraint Summary:
The constraints of this project are:

- Phase 'A' of the transformer is out of balance by about 100 Amps compared to 'B' and 'C' phases.
- High neutral currents experianced due to an out of balance load.

Background:
Substation 50-1224 is located in Lawson Street Mudgee. It was selected to be monitored due a small housing development taking supply from the substation and the number of customers connected.
The load profile of the substation indicated that phase 'A' is out of balance when compared the phases 'B' and 'C' by approximately 100 Amps.
A project was created to confirm that service connections are configured as per the N.S.W. Service and Installation Rules.

Non Network Options:

Options Considered But Ruled Out:

Options Considered:

Financial Implications:
Funding for this project has been allocated in the 16/17 capital works program.

Reference Documents (if any):
The following documents are filed with the project and form part of this investment approval: Load Profile:<Load Profile 50-1224.pdf>

Project Benefits:
The benefits of this project are: - Phase 'A' on substation 50-1224 will no longer be thermally overloaded. - Phase currents will be closer to each other resulting in a lower neutral current.

Peer Review:
Project cost is < $1,000,000 - Peer Review NOT required

Full Project Approval

APPROVED 29/06/2016

Independent Project, Planning ID: 1208042 WASP: 722583 Primavera:

Recommendation:
It is recommended that this project proceed as identified in this report in the 2016/17 FY at a Direct Cost of $40,741.

Appendix C – Examples of Growth - Voltage Projects in 2016/17

Example 1 – Install New Regulators Failford

Full Project Approval

APPROVED 04/07/2016

essential energy

Independent Project, Planning ID: 1072541 WASP: 722824 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 213043

Total Approval: $238,589
Est Overheads: @44.69% $73,692

Approval Direct: $164,897
Variance from previous approval: $164,897
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L4 <slot 401> MG Asset & Network Planning $250,000

IO Region: North Coast
Works Area: NC Hastings/Hunter
FSC: Forster Depot
Local Gov't Area: Great Lakes Council
State Seat: Upper Hunter

Project Name:
OH - Install new regulator site Failford Rd Failford pole 12463

Project Description:
PIP1 Install new regulator site Failford Rd Failford pole 12463 or pole 12462. 300 amp closed delta. Reg to provide boost to Failford Rd feeder for supply to Nabiac once Failford Zn is removed

Planning Project ID:	1072541	WASP ID:	722824
Primavera No.:		WASP Program:	NC Dist HV Lines and Cables
Urban/Rural:	Rural	Asset type:	11OH 11kV Distribution OH Lines
Target Completion Date:	31/12/16	Primary AER Cat.:	Growth (GRI)

Approval Overview

To gain approval for the installation of a new 300amp 11kv closed delta regulator at Failford Rd under PIP1

Base $164,897
Oncost $238,589

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1072541	1	$14,359	13/10/2015

printed 4/07/2016 9:17:51 AM Planning Project ID 1072541 **Page 1 of 3**

Full Project Approval

APPROVED 04/07/2016

Independent Project, Planning ID: 1072541 WASP: 722824 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Voltage	100%	GRI: Voltage: Voltage Regulators	3	Regulators

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_1	Distribution Growth - Voltage Const	Medium	$6,000

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_1	Distribution Growth - Voltage Const	Medium	$162,194

Constraint Summary:

The existing Nabiac feeder will be supplied from Hallidays Point ZS in late 2016, as Failford ZS will be retired.
A new regulator is required to maintain system voltage out to Nabiac, and the next downstream regulator. This regulator is to be located near the existing ZS site, and also is positioned to support the new MCW Borefield project (>500kVA).
Feeder peak load is expected to be in excess of 3.5MVA, therefore a 300amp site is required.
System voltage without the VR will fall below minimum standard over a wide area between the existing zone site, and Nabiac
See sincal screenshots attached

Background:

Hallidays Point ZS was commissioned in 2015 to permit the retirement of Failford ZS.
A group of projects are included in the 1617 budget to permit load transfer so Failford can be taken offline and dismantled.
Installation of a new regulator site is integral to allow this transfer to occur

Non Network Options:

Options Considered But Ruled Out:

Options Considered:

Installation of a new VR site is the most practical option for maintaining system voltage

Option No: **1** Install new VR site at Failford Rd **Preferred Optio**

NPV Result: wacc 6.18% = $ -164897

Financial Implications:

Project is budgeted for 1617 financial year

Reference Documents (if any):

The following documents are filed with the project and form part of this investment approval: con plan:<722824_FPLAN_A_ee.pdf> Sincal with VR:<Proposed VR sincal.pdf> capex:<CapexNotification_722824_1_0.pdf> sincal without VR:<Without proposed VR sincal.pdf>

Full Project Approval

APPROVED 04/07/2016

Independent Project, Planning ID: 1072541 WASP: 722824 Primavera:

Project Benefits:
Required for voltage regulation to Nabiac area after removal of Failford ZS

Peer Review:
Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:
It is recommend that Essential Energy invest $164,897 (direct) / $238,589 (Oncost) and 356 manhours in 2016/17 to install a new closed delta voltage regulator site at Failford Rd, Failford.

Example 2 – LV OH Rebuild, O'Neill Street Broken Hill

Full Project Approval

APPROVED 14/03/2016

Independent Project, Planning ID: 1139123 WASP: 711471 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 206764

Total Approval: $103,763
Est Overheads: @44.69% $32,049

Approval Direct: $71,714
Variance from previous approval: $71,714
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L3 <slot 307> Mgr Distribution Planning $150,000

IO Region: Northern
Works Area: NTH Far Western
FSC: Broken Hill Depot
Local Gov't Area: Broken Hill City Council
State Seat: Murray Darling

Project Name:
LVOH Rebuild, replace HDcu, O'Neill Street, between McCulloch-Brooks Sts, BH

Project Description:
LVOH Rebuild, replace hard drawn copper, O'Neill Street, between McCulloch-Brooks Sts, BH Replace OHLV replace hard drawn copper conductor with 95 mm sq ABC [aerial bundled conductor]. In O'Neill Street, Broken Hill between McCulloch and Brooks Sts, supplied from Willyama High sub 6 - 16054. Pole # 4718 to # 4783 [295 metres] Leave LV configuration as is, LV Open Point on pole 4718.

Planning Project ID:	1139123	WASP ID:	711471
Primavera No.:		WASP Program:	NC Dist LV lines and Cables
Urban/Rural:	Urban	Asset type:	LVOHU LV OH line including services -Urban
Target Completion Date:	30/06/17	Primary AER Cat.:	Refurbishment (REF)

Approval Overview

The main intention of these works is to replace the existing 7/064 hard drawn copper conductor with 95 mm sq. aerial bundled conductor in order to address the voltage and LV protection constraints existing in this area of Broken Hill.

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1139123	1	$14,000	25/11/2015

printed 14/03/2016 9:33:51 AM Planning Project ID 1139123 **Page 1 of 4**

Full Project Approval

APPROVED 14/03/2016

Independent Project, Planning ID: 1139123   WASP: 711471   Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Voltage	100%	GRI: Voltage: LV reconductoring / relocation	136	metres

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_1	Distribution Growth - Voltage Const	Medium	$14,227

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_1	Distribution Growth - Voltage Const	Medium	$71,714

Constraint Summary:

Primary Constraint-Voltage-Out of range voltage recorded at premises in this section of line.
The tap voltage of the transformer needs to be lowered, but this would make the voltage on the end of this section of LV further outside the range.

Secondary Constraint-Protection-The fault level at the end of this LV section would not be adequate to clear a bolted fault in less than 10seconds as required by CEOM7097.

Background:

Generally, there is evidence that there are a number of issues associated with existing small hard drawn copper conductor existing in LV distribution.

They include but are not limited to:-
*out of range voltage recorded at customer's premises
*Protection reach/fault levels not compliant,
*voltage rise in LV distribution, caused by PV/Solar Embedded Customer Generation
*voltage drop in LV distribution, caused by long runs of hard drawn copper conductor
*Unable to reduce the Standard voltage to near 230 volt due to end of line voltage range.

Non Network Options:

Options Considered But Ruled Out:

**Supply from Regional Aquatic Centre substation, #6-15113
This was ruled out as there was very little improvement in the voltages, by switching supply to sub 6-15113.

**Install Voltage regulator instead of rebuilding conductor.
This was ruled out, as installing a regulator will not address the protection constraint.

Options Considered:

Options IN

Rebuild LVOH with 150 mm sq. ABC aluminium conductor in O'Neill Street.
This was ruled out as there is very little effect , other than a slight increase in fault levels vs. extra cost to rebuild with 150 mm sq. ABC aluminium conductor.
Estimated cost=$85,000--655 hours

Full Project Approval

APPROVED 14/03/2016

Independent Project, Planning ID: 1139123 WASP: 711471 Primavera:

Option No: **1** Rebuild LVOH with 150 mm sq. ABC

Rebuild LVOH with 150 mm sq. ABC aluminium conductor in ONeill Street.
This was ruled out as there is very little effect , other than a slight increase in fault levels vs extra cost to rebuild with 150 mm sq. ABC aluminium conductor.
Estimated cost=$85,000--655 hours

NPV Result: wacc 6.18% = $ -85,000

Option No: **2** Rebuild LVOH with 95 mm sq. ABC **Preferred Optio**

Rebuild LVOH with 95 mm sq. ABC

NPV Result: wacc 6.18% = $ -71714

Option No: **3**

NPV Result:

Financial Implications:

Sufficient funding and hours were allowed for in the 15/16 capital program for Design Only and the 16/17 capital program for Standard Delivery.

Reference Documents (if any):

The following documents are filed with the project and form part of this investment approval: Project summary and justification.:
<NPD 1139123 WASP 711471 Planning Summary 11032016.pdf>
CAPEX Approval Request:<CapexNotification_711471_1_0.pdf>
Final Design Plan:<711471_FPLAN_O'Neil St LV Rebuild.pdf>

Project Benefits:

The project benefits are:- *Address the voltage issues; bring the customer voltages with the required limits *Address the protection constraint by increasing the fault level. *Allow the substation tap voltage to be reduced. *Cater for future load growth and embedded generation connection *Replace an old copper conductor which would be near the end of its life, reducing the risk of failure. *Reduce maintenance costs for the next 20+ years. *Improve load transfer capability.

Peer Review:

Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:

It is recommended that the project, as designed, be approved for construction during 16/17 for a direct cost of $71,714 requiring 595 total hours [construction hrs. =428, Design hrs. =122, Planning hrs. =45].

Example 3 – LV Upgrade, Lucan and North St Harden

Full Project Approval

APPROVED 14/04/2016

Independent Project, Planning ID: 1196281   WASP: 717229   Primavera:

PROJECT APPROVAL REPORT

Approval ID: 204663

Total Approval: $103,980
Est Overheads: @44.69% $32,116

Approval Direct: $71,864
Variance from previous approval: $71,864
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L3 <slot 307> Mgr Distribution Planning $150,000

IO Region:	Southern
Works Area:	STH Lower Alpine
FSC:	Harden Depot
Local Gov't Area:	Harden Shire Council
State Seat:	Burrinjuck

Project Name:
Lucan & North St LV Upgrade

Project Description:
Reconductor 820m of copper LV with 95mm in Lucan & North St due to low volts outside the normal EE supply standard voltages at the end of the LV circuits.

Planning Project ID:	1196281	WASP ID:	717229
Primavera No.:		WASP Program:	NC Dist LV lines and Cables
Urban/Rural:	Urban	Asset type:	LVOHU LV OH line including services -Urban
Target Completion Date:	30/06/17	Primary AER Cat.:	Growth (GRI)

Approval Overview

Reconductor 820m of copper LV with 95mm in Lucan & North St due to low volts outside the normal EE supply standard voltages at the end of the low voltage circuits at a cost of $71,864 to be funded in the 2016/17 financial year budget.

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1196281	1	$25,000	09/10/2015

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Full Project Approval

APPROVED 14/04/2016

Independent Project, Planning ID: 1196281 WASP: 717229 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Voltage	100%	GRI: Voltage: LV reconductoring / relocation	820	metres

Portfolio Investment Plan:

2014/2015

PIP CODE:	PROGRAM	RISK	$
ESS_1	Distribution Growth - Voltage Const	Medium	$454

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_1	Distribution Growth - Voltage Const	Medium	$12,294

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_1	Distribution Growth - Voltage Const	Medium	$58,745

Constraint Summary:

- The voltage at the end of the LV circuit on Lucan St at pole CE106311 is expected to swing from 215V - 258V at peak times which is well outside mandated limits. (Refer voltage charts in the supporting documents folder)
- The voltage at the end of the LV circuit on Neill St at pole CE125304 is expected to swing from 223V - 259V at peak times which is also well outside mandated limits.
- The voltage at the end of the LV circuit on North St at pole CE80125 is expected to swing from 223V - 252V at peak times which is just outside mandated limits.
- Furthermore the voltage at the end of the LV circuit on Lucan St at pole CE106311 exceeds 253V 3% of the time which exceeds the 1% allowed by AS/NZS 60038.
- The voltage swing is expected to worsen on all the LV circuits with the increased penetration of solar installations.

Background:

The voltage at the end of the LV circuit on Lucan St at pole CE106311 was measured to swing from 221V-258V in December 2014. At the same time the voltage swing at sub 26-1168 in Lucan St was 242V-254V. Based on the measurements the voltage drop in the LV along Lucan St is 21V and the voltage rise 4V. During the log period the load on the feeder ranged from 8A-58A. Over a year the load swings from 8A-75A. As a result it is expected that the voltage drop on the LV at peak times (winter) is 21V×(75/58) = 27V. With the 4V voltage rise in the LV circuit and the 10V swing at the substation, the voltage at the end of the circuit is expected to swing from 215V - 258V at peak times which is well outside mandated limits.

The voltage at the end of the LV circuit on Neill St at pole CE125304 was measured to swing from 228V-259V in May 2015. At the same time the voltage swing at sub 26-1168 in Lucan St was 242V-254V. Based on the measurements the voltage drop in the LV along Lucan St is 14V and the voltage rise 5V. During the log period the load on the feeder ranged from 22A-56A. Over a year the load swings from 8A-75A. As a result it is expected that the voltage drop on the LV at peak times (winter) is 14V×(75/56) = 19V. With the 5V voltage rise in the LV circuit and the 10V swing at the substation, the voltage at the end of the circuit is expected to swing from 223V - 259V at peak times which is also well outside mandated limits.

The voltage at the end of the LV circuit on North St at pole CE80125 was measured to swing from 226V-252V in December 2014. At the same time the voltage swing at sub 26-3915 in North St was 236V-248V*. Based on the measurements the voltage drop in the LV along Lucan St is 10V and the voltage rise 4V. During the log period the load on the feeder ranged from 22A-56A. Over a year the load swings from 8A-75A. As a result it is expected that the voltage drop on the LV at peak times (winter) is 10V×(75/56) = 13V. With the 4V voltage rise in the LV circuit and the 10V swing at the substation, the voltage at the end of the circuit is expected to swing from 223V - 252V at peak times which is just outside mandated limits.

Furthermore the voltage at the end of the LV circuit on Lucan St at pole CE106311 exceeds 253V 3% of the time which exceeds the 1% allowed by AS/NZS 60038.

*volts estimated from the volts at adjacent substation 26-1168 (11,000V tap) and the fact that 26-3915 is on the 11,275V tap.

Non Network Options:
There are no viable non network options available.

Options Considered But Ruled Out:
- The option of tapping down substation 26-1157 was considered but ruled out as this would drop the voltage at the end of the line to 209V at peak times which is well outside limits.
- The option of tapping down substation 26-3915 was considered but ruled out as this would drop the voltage at the end of the line to 217V at peak times which is well outside limits.

Options Considered:
Two options were considered:
- Extend HV by 200m and install a 200kVA substation
- Reconductor 820m of copper LV with 95mm ABC

Reconductoring 820m of copper LV with 95mm ABC was selected as the least cost option.

Option No: **1** Extend HV by 200m and install a 200kVA substation

Based on recent projects this option would cost $453/m = $91k

NPV Result: wacc 6.18% = $ -91000

Option No: **2** Reconductor 820m of copper LV with 95mm ABC **Preferred Optio**

Reconductor 820m of 19/0.064, 7/0.104 & 7/0.080 copper LV with 95mm ABC. This option will reduce the end of line voltage by at least 5V on all the LV circuits at peak periods.

NPV Result: wacc 6.18% = $ -71864

Financial Implications:
$71,864 to be funded in the 2016/17 financial year budget.

Reference Documents (if any):
The following documents are filed with the project and form part of this investment approval: Lucan St LVDrop:<Lucan St LVDrop - Existing & Reconductored.JPG> North St LVDrop:<North St LVDrop - Existing & Reconductored.JPG> Sub 26-1157 Lucan St Load Profile:<Substation 26-1157 Lucan St Load Profile - April-May 2015.JPG> Lucan St EOL LV Volts: North St EOL LV Volts: Neill St EOL LV Volts: Lucan & North St Voltage

Full Project Approval

APPROVED 14/04/2016

Independent Project, Planning ID: 1196281 WASP: 717229 Primavera:

Constraints: <Lucan & North St Constraints.pdf> Lucan & North St Options Analysis: <Lucan & North St Options Analysis.pdf> Lucan & North St Solar Connections: <Lucan & North St Solar Connections.pdf>

Project Benefits:

- Resolve voltage issues at Lucan & North Sts in Harden - Reduce maintenance costs with the removal of 14 LV crossarms - Reduce ongoing tree trimming costs with the replacement of bare LV with ABC

Peer Review:

Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:

It is recommended that the project to reconductor 820m of copper LV with 95mm in Lucan & North St due to low volts at the end of the low voltage circuits at a cost of $71,864 to be funded in the 2016/17 financial year budget be approved.

Appendix D – Examples of Growth - Fault Projects in 2016/17

Example 1 – Recloser Relocation Killabakh

Full Project Approval

APPROVED 15/04/2016

essential energy

Independent Project, Planning ID: 1102061 WASP: 686557 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 209383

Total Approval: $39,545
Est Overheads: @44.69% $12,214

Approval Direct: $27,331
Variance from previous approval: $27,331
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L1 <slot 205> Planner Distribution $50,000

IO Region:	North Coast
Works Area:	NC Hastings/Hunter
FSC:	Taree Depot
Local Gov't Area:	Greater Taree City Council
State Seat:	Oxley

Project Name:
OH - Relocate recloser 2-R25475 to links 2-L24345 Mortons Rd Killabakh

Project Description:
Protection upgrade Relocate recloser 2-R25475 to links 2-L24345 Mortons Rd Killabakh. Ensure all weather access and comms are available

Planning Project ID:	1102061	WASP ID:	686557
Primavera No.:		WASP Program:	NC Dist HV Lines and Cables
Urban/Rural:	Rural	Asset type:	11OHR 11kV Dist OH Lines Rural
Target Completion Date:	30/06/17	Primary AER Cat.:	Growth (GRI)

Approval Overview

To gain approval for the relocation of 2-R25475 from existing position to Mortons Rd Killabakh under PIP3

Base $27,331
Oncost $39,545

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1102061	1	$2,735	20/12/2013

printed 15/04/2016 8:31:05 AM Planning Project ID 1102061 **Page 1 of 3**

Full Project Approval

APPROVED 15/04/2016

Independent Project, Planning ID: 1102061 WASP: 686557 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Fault / Opera	100%	GRI: Fault/Operational: Reclosers	0	Reclosers

Portfolio Investment Plan:

PIP CODE:	PROGRAM	RISK	$
2014/2015			
ESS_3	Distribution Growth - Fault Level Co	Risk Top 10	$2,735
2015/2016			
ESS_3	Distribution Growth - Fault Level Co	Risk Top 10	$2,735
2016/2017			
ESS_3	Distribution Growth - Fault Level Co	Risk Top 10	$26,255

Constraint Summary:
There are low fault levels at the end of the feeder. An upstream recloser was installed in 2015 to cover primary protection holes, but it is physically quite close to R25475, and there is difficulty grading these sites. Relocating further along the feeder will allow them to grade and cover protection better. The intention was always to relocate this site.

Background:
Identified during protection and grading study in 2012. Numerous areas where protection was no existent or limited required an additional recloser but locating them at practical separation was difficult as there was a need to cover protection initially, and then reposition when the opportunity arose

Non Network Options:

Options Considered But Ruled Out:

Options Considered:

Financial Implications:
Project is budgeted for 1617 finance year

Reference Documents (if any):
Nil

Project Benefits:
Improvement in protection coverage and grading

Peer Review:
Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:
Recommend EE invest $27,331 ($39,545 oncost) and 211 manhours to relocate R25475

Full Project Approval

APPROVED 15/04/2016

Independent Project, Planning ID: 1102061 WASP: 686557 Primavera:

under PIP3 to new location

Example 2 – Install New Recloser Wellington Vale

Full Project Approval

APPROVED 22/04/2016

Independent Project, Planning ID: 451980 WASP: 724187 Primavera:

PROJECT APPROVAL REPORT

Approval ID: *209763*

Total Approval: $67,181
Est Overheads: @44.69% $20,750

Approval Direct: $46,431
Variance from previous approval: $46,431
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L2 <slot 305> Distribution Planning Mgr $100,000

IO Region:	Northern
Works Area:	NTH Northern Tablelands
FSC:	Glen Innes Depot
Local Gov't Area:	Glen Innes - Severn Council
State Seat:	Northern Tablelands

Project Name:
ACR New - 82-A783, Wellington Vale Rd, Wellington Vale

Project Description:
Constraints - Protection review indicate protection operating factors are currently not met with the existing network configuration. There is only the ZSS protection and field recloser for the whole feeder. The current back up protection operating factors are not met with only 0.75 times achieved. Solution - Install an electronic recloser 82-A783 (80300483) to meet protection operating factors on this feeder.

Planning Project ID:	451980	WASP ID:	724187
Primavera No.:		WASP Program:	NC Dist HV Lines and Cables
Urban/Rural:	Rural	Asset type:	110HR 11kV Dist OH Lines Rural
Target Completion Date:	30/03/17	Primary AER Cat.:	Growth (GRI)

Approval Overview

This project was initiated after a protection review was carried out on the EME1E10 feeder. It was found that there was back up protection issues as there is only one field recloser and the ZSS protection. This feeder from Emmeville supplies the township of Deepwater and is protected by the ZSS 11kV CB at the Emmaville ZSS. The field recloser is on the other side of Deepwater protecting the outskirts of Deepwater.

Project approval history: #### NIL ####

2 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
451980	1	$5,300	09/12/2015
451980	2	$1	01/04/2016

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Full Project Approval

APPROVED 22/04/2016

Independent Project, Planning ID: 451980 WASP: 724187 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Fault / Opera	100%	GRI: Fault/Operational: Reclosers	1	Reclosers

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_3	Distribution Growth - Fault Level Co	Risk Top 10	$1,750

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_3	Distribution Growth - Fault Level Co	Risk Top 10	$46,431

Constraint Summary:

The constraints associated with project are-

- Back up protection operating factor of 0.75 times with the current configuration. After the installation of the new recloser the back up protection operating factor will increase to 1.63 times.

- At present the Emmaville ZSS protection protects the line supplying all the way to Deepwater and Deepwater township. This will see any faults on the line to Deepwater resulting in outages for Deepwater township.

Background:

With the current back up protection operating factors not met it was decide to install an extra recloser between the ZSS and 82-R11871. This will increase back up protection operating factors to 1.65 times and provide an improved protection scheme for the Deepwater town ship to reduce outages and STIPUS results.

Non Network Options:

Options Considered But Ruled Out:

Option 1 - HV fuse installation Ruled Out

The option to install HV to met back up operating factors was ruled out due to the fact the fuses would have been protecting the Deepwater township and would obviously effect outages and STIPUS results.

Options Considered:

Option 2 Install a new recloser at ABS site 82-A783 - Preferred option

- This option will provide back up protection within EE standards and will reduce the amount of, and length of outages associated with the Deep-water township by reducing the length of line protected by the ZSS 11kV CB and the proposed recloser.

Financial Implications:

The original allocation was for $53,000 and 265 hrs. The Capex approval is for $46,431 and 180hrs.

Full Project Approval

APPROVED 22/04/2016

Independent Project, Planning ID: 451980 WASP: 724187 Primavera:

Reference Documents (if any):
Nil

Project Benefits:
The installation of this recloser will see back up operating factos on the feeder meet Essential Energy's standards.

Peer Review:
Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:
Planning North recommends this project forms part of the 2016/17 financial year and is funded under sub delegation clause 1.8.1.

Example 3 – Lumley Road, Tarago Reconductor - Protection Mitigation

Full Project Approval

APPROVED 06/07/2016

Independent Project, Planning ID: 1070761 WASP: 721891 Primavera:

PROJECT APPROVAL REPORT

Approval ID: 214743

Total Approval: $106,698
Est Overheads: @47.79% $34,502

Approval Direct: $72,196
Variance from previous approval: $72,196
Costs are Direct (excluding Corporate OnCosts & GST)

Final by:
L3 <slot 307> Mgr Distribution Planning $150,000

IO Region:	Southern
Works Area:	STH Eurobodalla Tablelands
FSC:	Goulburn Depot
Local Gov't Area:	Goulburn Mulwaree Council
State Seat:	Goulburn

Project Name:
Lumley Road, Tarago Reconductor - Protection Mitigation

Project Description:
Reconductor 1.8km of 3/2.00 SCGZ with 3/4/2.50 ACSR Lumley road to lift fault levels to provide adquate protection levels (Load to Fault ratio)

Planning Project ID:	1070761	WASP ID:	721891
Primavera No.:		WASP Program:	NC Dist HV Lines and Cables
Urban/Rural:	Rural	Asset type:	11OH 11kV Distribution OH Lines
Target Completion Date:	30/06/17	Primary AER Cat.:	Growth (GRI)

Approval Overview

A full protection review of the Woodlawn feeder revealed some poor fault levels near Tarago. In particular, a spur line with 14 customer s fed off 3/2.00 GZ steel had fault levels below 20 Amps. This project will lift fault levels to around 42 A and allow for fused grading to occur on the line ensuring compliance with our protection standards and improving emerging voltage constraints. Present situation sees a 50kva transformer on the spur fused with 8A elements and spur take off fused with 5A elements due to the poor fault levels.

Project approval history: #### NIL ####

1 Design (CAP2) approval(s) found:

Project type: Independent

Project ID:	PRS Vers:	Value:	Date approved
1070761	1	$13,675	24/09/2015

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Full Project Approval

APPROVED 06/07/2016

Independent Project, Planning ID: 1070761 WASP: 721891 Primavera:

Project Analysis and Justification

Project Driver contributions:

AER Sub-Class	Split	AER Category	Units	
Fault / Opera	100%	GRI: Fault/Operational: HV reconductoring	900	metres

Portfolio Investment Plan:

2015/2016

PIP CODE:	PROGRAM	RISK	$
ESS_3	Distribution Growth - Fault Level Co	Risk Top 10	$2,000

2016/2017

PIP CODE:	PROGRAM	RISK	$
ESS_3	Distribution Growth - Fault Level Co	Risk Top 10	$65,360

Constraint Summary:

Constraint- Validated sincal modelling has shown poor fault levels on the ends of this spur down to 18 Amps. Refer Fault Level snap shot in supporting documents) Voltage levels on a scaled load flow get down to around 92%.

Reconductoring with Raisin lifts levels to 32-34 Amps and voltage levels to 95%. This ensures protection guidelines are met and voltage standards are maintained within acceptable limits on the spur line.

Background:

Strategic review of this feeder has highlighted both existing fault level constraints, and emerging voltage constraints. This project will address these issues allowing for fault clearance times to be maintained in accordance with our standards.

Non Network Options:

No non network options available as constraint is a direct result of high network impedance.

Options Considered But Ruled Out:

Options Considered:

Reconductor 1.8km of 3.2.00 GZ steel conductor with Raisin to lift fault levels and allow grading on the line and compliance with protection guidelines is the most cost effective option to solve the identified constraint

Option No: **1** Reconductor 1.8km of 3/2.00 SCGZ with3/4/2.50 ACSR **Preferred Optio**

NPV Result: wacc 6.18% = $ -72196

Option No: **2** Reconductor 1.8km of 3/2.00 SCGZ with 7/3.00 AAAC

NPV Result: wacc 6.18% = $ -85283

Financial Implications:

Project first budgeted in 2015/16 year for design only and construction in 2016/17. Total budget cost $72193 direct for the entire project $65360 in the 2016/17 budget. Primary Driver GRI; Fault Operational HV reconductoring.

Full Project Approval

APPROVED 06/07/2016

Independent Project, Planning ID: 1070761 WASP: 721891 Primavera:

Reference Documents (if any):

Sincal screenshot showing fault levels end of line.
The following documents are filed with the project and form part of this investment approval: sincal:<Sincal p-p fault levels existing.docx>

Project Benefits:

Project will lift fault levels to enable compliance with CEOP8002. Existing available fault level insufficient to operate 5A fuse under 2 seconds.

Peer Review:

Project cost is < $1,000,000 - Peer Review NOT required

Recommendation:

It is recommended that Option 1 - Project Reconductor 1.8km of 3/2.00 SCGZ with3/4/2.50 ACSR with Raisin in order to lift fault levels be approved at a direct cost of $72,193.
Project first budgeted in 2015/16 year for design only and construction in 2016/17.
Total budget cost $72,193 direct for the entire project, $6,838 in the 2015/16 FY Budget and $65,360 in the 2016/17 budget for construction.
Primary Driver GRI; Fault Operational HV reconductoring.

Appendix F – References

NIEIR	*National Institute of Economic & Industry Research: Electrical Energy & Peak Demand Projections for Essential Energy in NSW to 2021-22*	https://www.aer.gov.au/system/files/Essential%20Energy%20-%20Attachment%204.5_Consumption%20forecasts%20-%202014.pdf
ABS Cat. No. 4602.0.55.001 –	*Australian Bureau of Statistics: Environmental Issues: Energy Use and Conservation*	http://www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.001
Dept. of Planning TPDC R2001	*NSW Government: Population Forecast to 2036*	http://www.planning.nsw.gov.au/Research-and-Demography/Demography/Population-projections
Dept. of Planning TPDC R2006/02	*NSW Statistical Local Area - Population Projections*	http://www.planning.nsw.gov.au/Research-and-Demography/Demography/Population-projections
HIA Economics Group	*Industry & Business Information: Australian Housing Forecasts*	https://hia.com.au/BusinessInfo/economicInfo/housingForecasts