Jemena Electricity Networks (Vic) Ltd

2021-26 Electricity Distribution Price Review
Revised Proposal

Attachment 04-03

Network Development Strategy - Comply with Bushfire Mitigation Obligations at Coolaroo Zone Substation

Authorisation

Name	Job Title	Date	Signature
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History

Rev No	Date	Description of changes	Author
1	03/12/2020	First issue	

Owning Functional Area

Business Function Owner:	ED Asset Management

Review Details

Review Period:	Not Applicable
NEXT Review Due:	Not Applicable

Table of contents

Glossary

Amperes (A)	Refers to a unit of measurement for the current flowing through an electrical circuit. Also referred to as Amps.
Capital expenditure (CAPEX)	Expenditure to buy fixed assets or to add to the value of existing fixed assets to create future benefits.
Constraint	Refers to a constraint on network power transfers that affects customer service.
Contingency condition (or event)	Refers to the loss or failure of part of the network. An event affecting the power system that is likely to involve the failure or removal from operational service of one or more generating units and/or network elements.
Contingency probability	The probability that a contingency condition (or event) will occur, and typically approximated by multiplying the number of times a contingency condition occurs (usually in a year) by its duration, normalised by the total available time (in this case, a year).
Energy-at-risk	The total energy at risk of not being supplied if a contingency occurs.
Expected unserved energy (EUSE)	Refers to an estimate of the long-term, probability weighted, average annual energy demanded (by customers) but not supplied. The EUSE measure is transformed into an economic value, suitable for cost-benefit analysis, using the value of customer reliability (VCR), which reflects the economic cost per unit of unserved energy.
Jemena Electricity Networks (JEN)	One of five licensed electricity distribution networks in Victoria, the JEN is 100% owned by Jemena and services over 360,000 customers via an 11,000 kilometre distribution system covering north-west greater Melbourne.
Limitation	Refers to a limitation on a network asset's capacity to transfer power.
Maximum demand (MD)	The highest amount of electrical power delivered (or forecast to be delivered) for a particular season (summer and/or winter) and year.
Megavolt ampere (MVA)	Refers to a unit of measurement for the apparent power in an electrical circuit. Also million volt-amperes.
Network	Refers to the physical assets required to transfer electricity to customers.
Network augmentation	An investment that increases network capacity to prudently and efficiently manage customer service levels and power quality requirements. Augmentation usually results from growing customer demand.
Network capacity	Refers to the network's ability to transfer electricity to customers.
Non-network	Refers to anything potentially affecting the transfer of electricity to customers that does not involve the network.
Non-network alternative	A response to growing customer demand that does not involve network augmentation.
Operations & Maintenance expenditure (O&M)	Expenditure (ongoing) for running a product, business or system.
Peak or maximum demand	The highest amount of electrical power delivered (or forecast to be delivered) for a particular period of time.

Probability of exceedance (POE)	The likelihood that a given level of maximum demand forecast will be met or exceeded in any given year:
10% POE condition (summer)	Refers to an average daily ambient temperature of 32.9ºC derived by NIEIR and adopted by JEN, with a typical maximum ambient temperature of 42ºC and an overnight ambient temperature of 23.8ºC.
50% POE condition (summer)	Refers to an average daily ambient temperature of 29.4ºC derived by NIEIR and adopted by JEN, with a typical maximum ambient temperature of 38.0ºC and an overnight ambient temperature of 20.8ºC.
Probabilistic method	A planning methodology applied to network types with the most significant constraints and associated augmentation costs. It involves estimating the cost of a network limitation with consideration of the likelihood and severity of network outages and operating conditions.
Rapid Earth Fault Current Limiter (REFCL)	Rapid Earth Fault Current Limiter or REFCL means any plant, equipment or technology (excluding neutral earthing resistor) which is: (a) designed to reduce the effect of distribution system faults and when operating as intended may lead to a REFCL condition; and approved by Energy Safe Victoria in an electricity safety management scheme or bushfire mitigation plan pursuant to the Electricity Safety Act 1998 (Vic).
Regulatory Investment Test for Distribution (RIT-D)	A test administered by the Australian Energy Regulator (AER) that establishes consistent, clear and efficient planning processes for distribution network investments in the National Electricity Market (NEM).
Reliability of supply	The measure of the ability of the distribution system to provide supply to customers.
Required Capacity	As prescribed by the Electricity Safety (Bushfire Mitigation Duties) Regulations 2018, means that in the event of a phase-to-ground fault on a polyphase electric line, then network must have the ability: • to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for high impedance faults to 250 volts within 2 seconds; and • to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for low impedance faults to: – 1900 volts within 85 milliseconds; and – 750 volts within 500 milliseconds; and – 250 volts within 2 seconds; and • during diagnostic tests for high impedance faults, to limit: – fault current to 0.5 amps or less; and – the thermal energy on the electric line to a maximum I^2t value of 0.10; where:

	• high impedance faults means a resistance value in ohms that is equal to twice the nominal phase-to-ground network voltage in volts; • I^2t means a measure of the thermal energy associated with the current flow, where I is the current flow in amps and t is the duration of current flow in seconds; • low impedance faults means a resistance value in ohms that is equal to the nominal phase-to-ground network voltage in volts divided by 31.75; and • polyphase electric line means an electric line comprised of more than one phase of electricity with a nominal voltage between 1 kV and 22 kV.
REFCL condition	An operating condition on the 22kV distribution system arising from the proper operation of a REFCL which results in the neutral reference of the distribution system moving to allow the un-faulted Phase to Earth voltage magnitude to approach a value close to the Phase to Phase voltage magnitude. The term "operating condition on the 22kV distribution system" in this term extends up to, but not beyond any device or plant which is functionally equivalent to an isolating transformer.
System normal	The condition where no network assets are under maintenance or forced outage, and the network is operating according to normal daily network operation practices.
value of customer reliability (VCR)	Represents the dollar value customers place on a reliable electricity supply (and can also indicate customer willingness to pay for not having supply interrupted).
zone substation	Refers to the location of transformers, ancillary equipment and other supporting infrastructure that facilitate the electrical supply to a particular zone in the Jemena Electricity Network (JEN).

Abbreviations

Act	Electricity Safety Act 1998
ASC	Arc Suppression Coil
BD	Broadmeadows Zone Substation
Co	Network capacitive current
COO	Coolaroo Zone Substation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DELWP	Department of Environment, Land, Water and Planning
ESV	Energy Safe Victoria
EUE	Expected Unserved Energy
GVE	Greenvale Zone Substation
HBRA	Hazardous Bushfire Risk Area
HV	High Voltage
JEN	Jemena Electricity Networks (Vic) Ltd
KLO	Kalkallo Zone Substation
kV	Kilo-Volts
LBRA	Low Bushfire Risk Area
MVA	Mega Volt Ampere
MVAr	Mega Volt Ampere Reactive
MW	Mega Watt
MWh	Megawatt hour
NEM	National Electricity Market
NPV	Net Present Value
O&M	Operations and Maintenance
REFCL	Rapid Earth Fault Current Limiters
Regulations	Electricity Safety (Bushfire Mitigation) Regulations 2013
ST	Somerton Zone Substation
VCR	Value of Customer Reliability
VEDC	Victorian Electricity Distribution Code

Executive Summary

Jemena is the licensed electricity distributor for the northwest of Melbourne's greater metropolitan area. The network service area ranges from Gisborne South, Clarkefield and Mickleham in the north to Williamstown and Footscray in the south and from Hillside, Sydenham and Brooklyn in the west to Yallambie and Heidelberg in the east.

Our customers expect us to deliver and maintain a reliable electricity supply at the lowest possible cost over the long-term. To do this, we must choose the most efficient solution to address emerging network issues. This means choosing the solution that maximises the present value of net economic benefit to all those who produce, consume and transport electricity in the National Electricity Market (**NEM**).

Identified need

Under the Electricity Safety Act 1998 (the **Act**) and the Electricity Safety (Bushfire Mitigation) Regulations 2013 (the **Regulations**), Jemena Electricity Networks (Vic) Ltd (**JEN**) is obliged to ensure all 22 kV feeders originating from its Coolaroo Zone Substation (**COO**) meet certain specified technical performance requirements by 1 May 2023, effectively requiring these feeders to be protected by Rapid Earth Fault Current Limiters (**REFCL**) or otherwise requiring these feeders to be the subject of exemptions under the Act and the Regulations. Additionally, JEN takes supply for three of its feeders in the nearby area from the Kalkallo Zone Substation (**KLO**), which is owned by AusNet Services, and JEN must also meet the Required Capacity for its KLO feeders by 1 May 2023.

In the process of assessing and identifying viable options to provide the most economic and technically feasible solution to maintain the long-term compliance with the Act and Regulations, JEN is also obliged to consider the customer reliability impact (unserved energy) associated with the technical limitations of the REFCL technology, the costs to High Voltage (**HV**) customers to upgrade their equipment (to enable them to continue to take supply safely from a REFCL protected feeder in accordance with Clause 16 (c)[1] of the Victorian Electricity Distribution Code (**VEDC**)), and the long-term load growth and associated network augmentation requirements.

Options Considered

Recognising the interrelationships between COO and KLO, in 2019, JEN and AusNet Services engaged the consultant WSP to assist in a joint planning exercise to examine a number of technical design options and determine the most efficient cost of meeting the requirements of the Act and Regulations across both COO and KLO supply areas over the long-term. This exercise identified 26 options. Through this process, we identified that there was only one option (Option 15) which did not require any exemptions from the requirements of the Act and Regulations. However this option involved significantly higher expenditure than other options due to significant technical limitations of the REFCL technology.

For the reasons identified above, JEN has investigated alternative solutions to the installation of a REFCL at COO and proposed an approach which will result in a level of residual bushfire risk that we consider is commensurate with that which was originally intended by the Act and Regulations, but at a lower cost to customers than if no exemptions to the Act or Regulations were granted. We considered that such alternative options would likely be more preferable in customers' long-term interests than Option 15 described above.

This document is based on outputs of previous joint planning report[2] prepared by the engineering consultant WSP in December 2019 (and published as part of JEN's regulatory proposal on 31 January 2020), and further works undertaken by JEN since then. For the purpose of evaluating the option that maximises net market benefits, only four credible options[3] have been considered and assessed, with each option providing a commensurate level of bushfire risk mitigation:

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1 Clause 16 (c) of VEDC states that "*A **business customer** must take reasonable precautions to minimise the risk of loss or damage to any equipment, premises or business of the **business customer** which may result from poor quality or reliability of electricity **supply** or the **distribution system** operating under the **REFCL condition** in accordance with clause 4.2.2A*"

2 Refer to "Economic Options to Maintain REFCL Compliance at Kalkallo and Coolaroo Zone Substations, Joint Planning Report, December 2019" report.

3 Options 7, 11 and 15 are extracted from "Economic Options to Maintain REFCL Compliance at Kalkallo and Coolaroo Zone Substations, Joint Planning Report, December 2019" report, and re-produced in this document for information that are relevant to JEN only.

- Option 7 – Install Isolation Transformers On Underground Feeders and REFCLs at COO;
- Option 11 – Install REFCLs at COO;
- Option 15 – Two REFCL Zone Substations in JEN; and
- Option 27 – Build a New REFCL Zone Substation ('GVE')

A summary of the NPV cost analysis assessed for each option is presented in Table ES–1-1

Table ES–1-1: Summary of NPV Cost Analysis (real, $2020)

Option	NPV of Project Cost ($M)	NPV of O&M ($M)	NPV of Cost of Expected Unserved Energy ($M)	NPV of HV Customer Cost ($M)	Total Costs ($M)	Ranking
Option 7	25.8	2.2	60.8	9.1	97.8	4
Option 11	23.6	2.2	60.2	9.1	95.1	3
Option 15	49.5	2.2	12.9	9.1	73.7	2
Option 27	35.2[4]	2.2	13.0	1.3	51.6	1

Preferred Option

The assessment shows that the preferred solution is Option 27, as by representing the lowest total cost, this option maximises the net economic benefit to all those who produce, consume and transport electricity in the NEM.

Option 27 includes the following works:

- Construct a new zone substation with REFCL capability in the Greenvale area and transfer those sections of the existing COO 22 kV network with high bushfire risk, mainly COO11, to the new zone substation – thereby providing REFCL protection to those 22 kV feeders in compliance with the Act and Regulations; and
- Undertake various bushfire mitigation activities to reduce the bushfire risk for those polyphase electric lines of an overhead construction within an urban environment that pose some risk to a fire ignition that could propagate to a bushfire – therefore resulting in a bushfire risk-neutral outcome – and obtain exemptions under the Act and Regulations in respect of these lines.[5].

Option 27 provides a bushfire risk-neutral outcome when compared to the installation of REFCL protection at COO.

JEN has lodged its exemption applications to both Energy Safe Victoria (**ESV**) and Department of Environment, Land, Water and Planning (**DELWP**) for the above alternative solution at COO, and the exemptions from the Act and the Regulations have been granted in November 2020.

[4] Project cost for option 27 is $37.3M (real, $2021).

[5] Additionally, JEN would rely on exemptions already granted under the Act and Regulations in respect of polyphase electric lines originating from COO which are of a fully underground construction.

1. Introduction

1.1 Purpose

This document describes the network development strategy adopted by JEN to comply with Section 120M of the Electricity Safety Act 1998 together with sub-regulation 7(1)(ha) of the Electricity Safety (Bushfire Mitigation) Regulations 2013 for the COO supply area.

It describes our process of identifying viable options to provide the most economic and technically feasible solution to maintain the long-term compliance of COO with the Act and Regulations. It also considers the customer supply reliability impacts associated with REFCL technical limitations, the costs to HV customers to upgrade their equipment (to enable them to continue to take supply safely from a REFCL protected feeder in accordance with Clause 16 (c)[6] of VEDC, and the long-term load growth and associated network augmentation requirements.

The document is based on outputs of previous joint planning report[7] prepared by WSP in December 2019, and further works undertaken by JEN since that time.

1.2 Background

The Act and Regulations requires JEN to ensure that all polyphase electric lines (22kV feeders) originating from COO zone substation meet specified technical performance requirements in regard to conductor voltage, current and thermal energy dissipation limits, referred to as "**Required Capacity**" by 1 May 2023. Additionally, JEN takes supply for three of its feeders in the nearby area from KLO, which is owned by AusNet Services, and JEN must also meet the Required Capacity on its KLO feeders by 1 May 2023.

In practical terms, generally, these performance requirements can be achieved through the installation of REFCLs at the zone substation.

However, there are inherent technical limitations of REFCL that prevent a simple REFCL installation at COO, including:

- A limit of only one Arc Suppression Coil (**ASC**) per 22 kV bus;
- A limit of 100A of network capacitive current (**Co**) per ASC due to network damping ratios. This means that the Co for each 22 kV bus must not exceed 100A;
- A limit of 80A Co per 22 kV feeder; and
- A limit of two REFCLs per zone substation (i.e maximum zone substation Co of 200A).

COO is a two-transformer zone substation with 6 feeders, the network capacitance (Co) of each are as tabulated in

6 Clause 16 (c) of VEDC states that "*A **business customer** must take reasonable precautions to minimise the risk of loss or damage to any equipment, premises or business of the **business customer** which may result from poor quality or reliability of electricity **supply** or the **distribution system** operating under the **REFCL condition** in accordance with clause 4.2.2A*"

7 Refer to "Economic Options to Maintain REFCL Compliance at Kalkallo and Coolaroo Zone Substations, Joint Planning Report, December 2019" report.

Table 1-1.

Table 1-1: 2019 Co of COO Zone Substation 22 kV feeders

Feeder	Co (A)	Underground (km)	Overhead (km)	Comments
COO-11	105	36.7	133.3	Exceeds maximum feeder Co of 80A.
COO-12	2	0.5	0.3	
COO-13	52	11.4	3.9	
COO-14	51	16.5	1.4	
COO-21	45	13.5	17.1	
COO-22	65	21.2	0.7	Heavily loaded
TOTAL	**320**	**99.8**	**156.7**	

It is clear from Table 1-1 that the existing 320A of Co cannot be accommodated with a simple configuration of two REFCLs at COO zone substation, without some form of network rearrangement and significant augmentation. Furthermore, the COO supply area forms part of the Melbourne northern growth corridor, and network Co is forecast to increase to 410A by 2029 due to network growth, which will further exacerbate the high Co issue.

JEN and AusNet Services engaged the consultant WSP in 2019 to assist in a joint planning exercise to examine a number of technical design options and determine the most efficient cost of meeting the requirements of the Act and Regulations across both COO and KLO supply areas over the long-term. This exercise identified 26 options. Through this process, we identified that there was only one option (Option 15) which did not require any exemptions from the requirements of the Act and Regulations. However this option involved significantly higher expenditure than other options due to significant technical limitations of the REFCL technology.

For the reasons identified above, JEN has investigated alternative solutions to the installation of a REFCL at COO and proposed an approach which will result in a level of residual bushfire risk that we consider is commensurate with that which was originally intended by the Act and Regulations (referred to below as a bushfire risk-neutral outcome), but at a lower cost to customers than if no exemptions to the Act or Regulations were granted. JEN's proposed approach is to:

- Construct a new zone substation with REFCL capability in the Greenvale area and transfer those sections of the existing COO 22 kV network with high bushfire risk, mainly COO11, to the new zone substation – thereby providing REFCL protection to those 22 kV feeders in compliance with the Act and the Regulations, and
- Engage the Commonwealth Scientific and Industrial Research Organisation (**CSIRO**) to assess the bushfire risk associated with those sections of the COO 22 kV feeder network that will remain supplied by COO (as a non-REFCL zone substation) and obtain exemptions from the Act and the Regulations for these network sections on the basis that:
  - For those polyphase electric lines (or parts thereof) of an underground construction, which pose an insignificant bushfire risk, the implementation of REFCL protection would not reduce the bushfire risk associated with these lines – and therefore not implementing REFCL protection for these lines represents a bushfire risk-neutral outcome;
  - For those polyphase electric lines of an overhead construction within an urban environment that, following expert assessment by CSIRO, pose no risk of a fire ignition that could propagate to a bushfire – that not implementing REFCL protection for these lines represents a bushfire risk-neutral outcome; and
  - For those polyphase electric lines of an overhead construction that pose some risk of a fire ignition that could propagate to a bushfire, that JEN would undertake various alternative bushfire mitigation activities to reduce this risk – therefore resulting in a bushfire risk-neutral outcome.

This solution (**Option 27**) provides a bushfire risk-neutral outcome when compared to the installation of REFCL protection at COO.

JEN has lodged its exemption applications to both the ESV and DELWP for the above alternative solution at COO, and the exemptions from the Act and the Regulations have been granted in November 2020.

For the purpose of demonstrating the above option (Option 27) that maximises the net market benefits (measured in terms of total project cost, cost of expected unserved energy and HV customers cost to upgrade their equipment to continue to take supply safely), this document only considers Options 7, 11 , 15[8] and 27 for COO supply area. All other options assessed by WSP previously were considered non-credible and the proposed solutions at KLO are independent to that of COO, thereby those ‘non-credible’ options are excluded from this assessment.

1.3 Network Overview

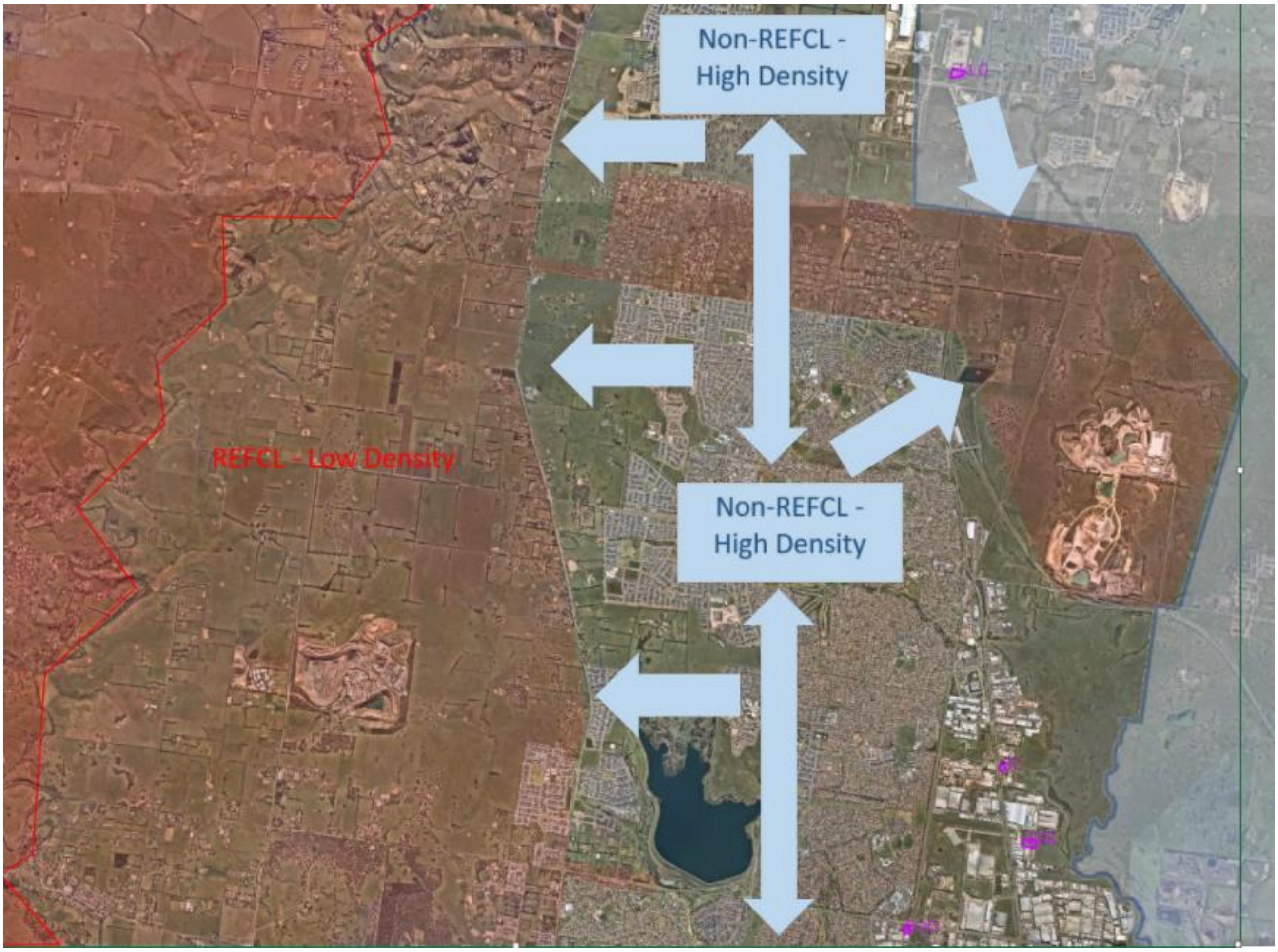
1.3.1 General Network Strategy

JEN has identified the areas of the COO supply network which are expected to experience urban growth in the near future. Meanwhile, other areas are expected to remain rural and will experience low levels of growth in the short to medium term. These differences are highlighted in Figure 1-1, where the high density non-REFCL areas are indicated as pushing out in the direction of the blue arrows.

JEN’s overall REFCL strategy must not inhibit this future network topology.

[8] Options 7, 11 and 15 are extracted from “AusNet Services and Jemena Electricity Networks, Economic Options to Maintain REFCL Compliance at Kalkallo and Coolaroo Zone Substations, Joint Planning Report, December 2019” report, and re-produced in this paper.

Figure 1-1: Network Growth Strategy

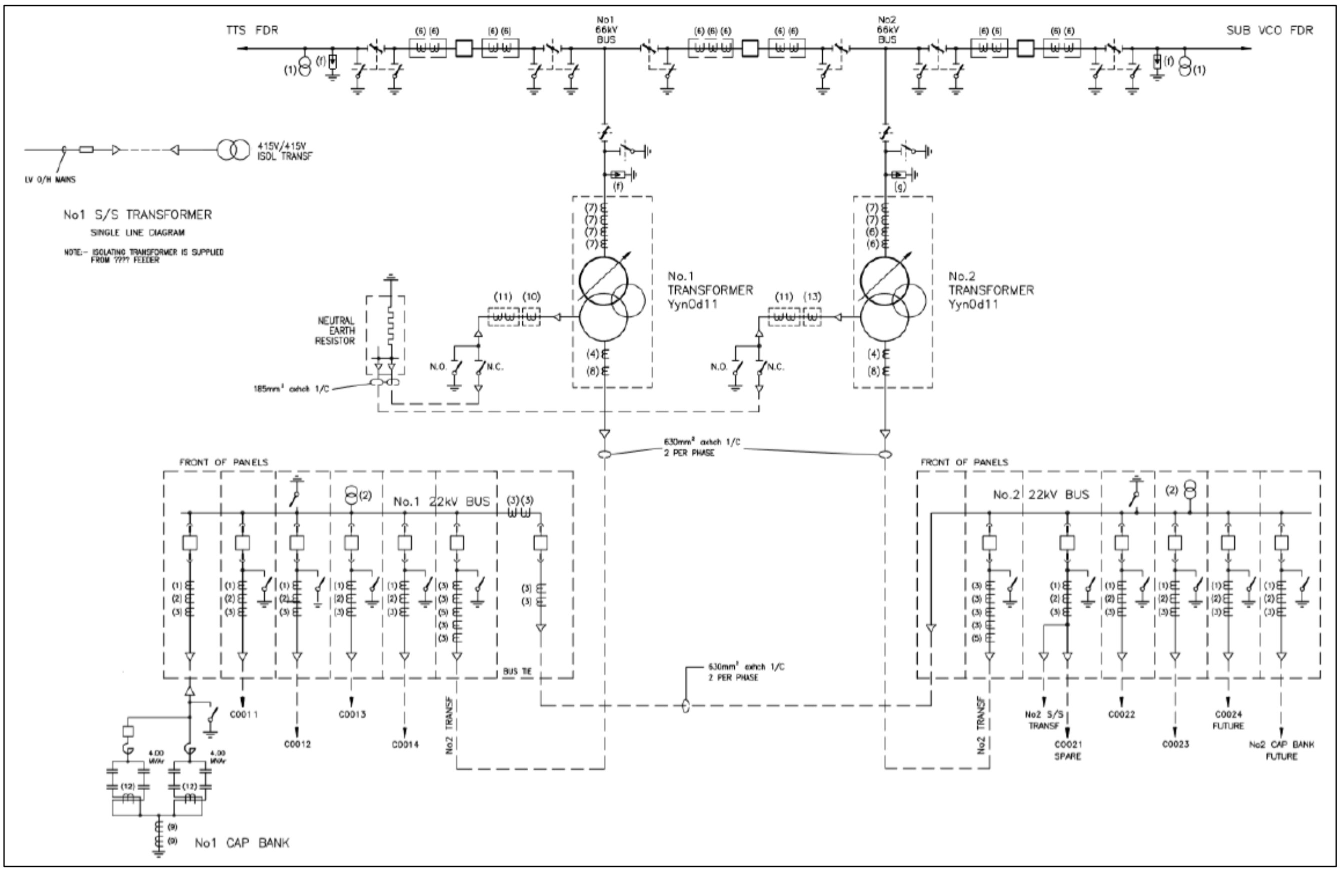


1.3.2 COO Network

Single line diagrams and network area maps of COO existing network is provided below.

COO is fed from two 66 kV incoming lines and includes two 66/22kV 20/33MVA Yyn0d11 transformers, that supply six JEN 22 kV feeders (refer to Figure 1-2).

Figure 1-2 COO Single Line Diagram

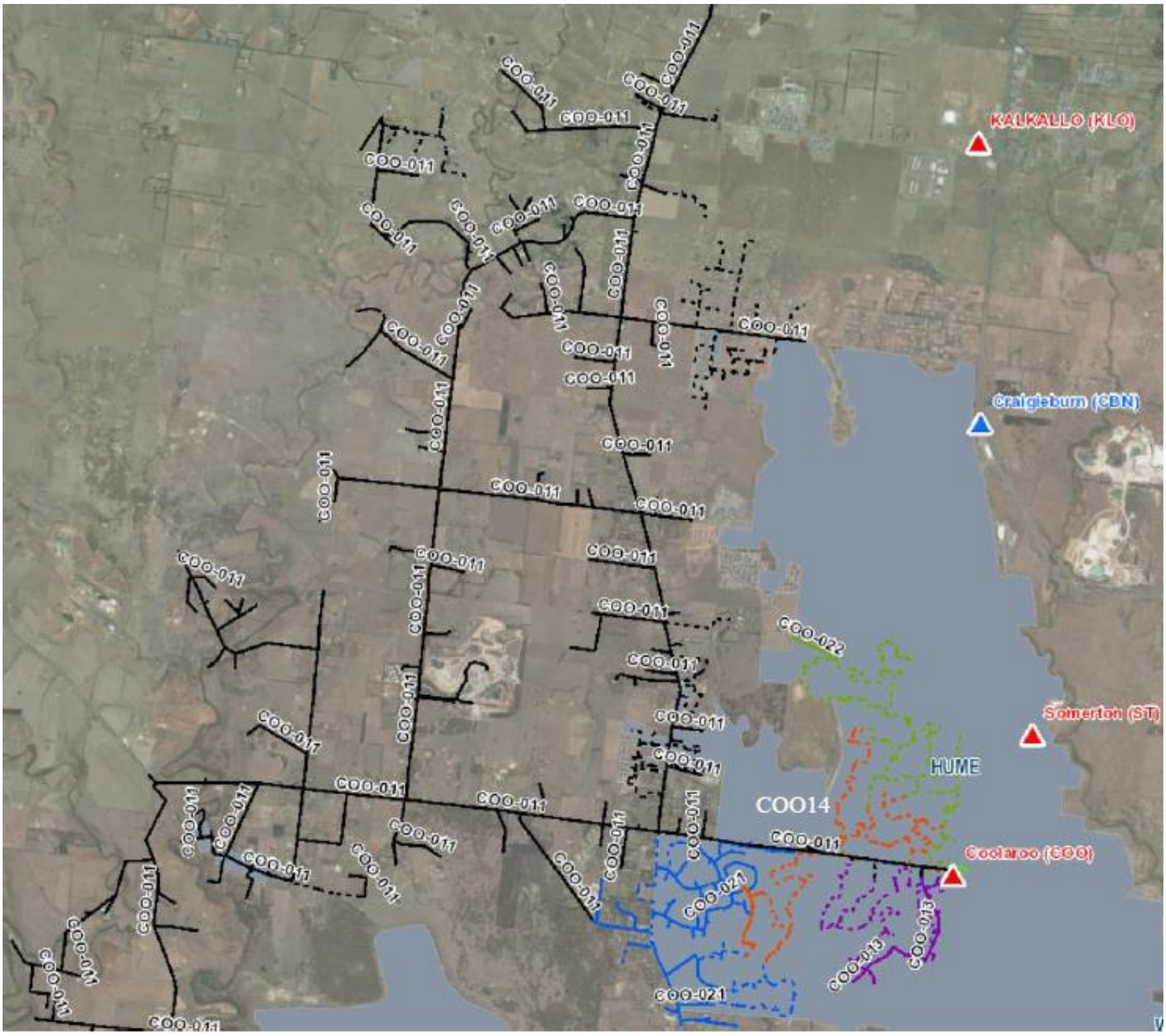


Source: "AusNet Services and Jemena Electricity Networks, Economic Options to Maintain REFCL Compliance at Kalkallo and Coolaroo Zone Substations, Joint Planning Report, December 2019" report

The network area fed by COO is a mix of underground and overhead feeders (Figure 1-3). The underground feeder areas are urban and are all within the Low Bushfire Risk Area (**LBRA**), as depicted by the greyed areas. COO11 represents the vast majority of the COO 22 kV network and has 36.7km of underground cable and 133.3km of overhead network, where COO 22 kV network totals are 99.8km and 156.7km respectively.

There are two HV customers within the COO LBRA, located on COO12 and BD14 (ex. COO13), and one in the COO Hazardous Bushfire Risk Area (**HBRA**), on COO 11. These customers or 'substation points' are still subject to the requirements of the Act and Regulations due to having been part of the COO network on the date as specified within the Act & Regulations.

Figure 1-3: COO 22 kV Network Area



Source: "AusNet Services and Jemena Electricity Networks, Economic Options to Maintain REFCL Compliance at Kalkallo and Coolaroo Zone Substations, Joint Planning Report, December 2019" report

2. Identified Need

As outlined in Section 1.2, the primary driver of this network development strategy is to comply with the Bushfire Mitigation Act and Regulations for the COO network area. Under section 120M of the Electricity Safety Act 1998 and Regulation 7(1)(ha) of the Electricity Safety (Bushfire Mitigation) Regulations 2013, JEN is obliged to ensure all 22 kV feeders originating from COO have the Required Capacity by 1 May 2023.

In the process of identifying viable options to provide the most economic and technically feasible solution to maintain the long-term compliance of COO, JEN is also obliged to consider the customer reliability impact due to the technical limitations of the REFCL technology, costs to HV customers to upgrade their equipment to continue to take supply safely, and the long-term load growth and associated network augmentation requirements.

3. Assessment Methodology and Assumptions

This section outlines the methodology that JEN applies in assessing its network supply risks and limitations for each of the feasible option that complies or has the potential to comply with the Act and Regulations. It presents key assumptions and input information applied to the assessments described in this document.

3.1 Probabilistic Economic Planning

In accordance with clause 5.17.1(b) of the National Electricity Rules, JEN's augmentation investment decisions aim to maximise the present value of the net economic benefit to all those who produce, consume and transport electricity in the NEM.

To achieve this objective, JEN applies a probabilistic planning methodology that considers the likelihood and severity of critical network conditions and outages. The methodology compares the forecast cost to consumers of losing energy supply (e.g. when there is a feeder outage and it can't be transferred to an adjacent feeder due to the REFCL technical limitations) against the proposed augmentation cost to mitigate the energy supply risk. The annual cost to consumers is calculated by multiplying the expected unserved energy (the expected energy not supplied based on the probability of the supply constraint occurring in a year) by the value of customer reliability (**VCR**). This expected benefit is then compared with the costs of the feasible options.

In essence, the total cost for each option would cover the following:

- Project cost to comply with the Act and Regulations by 1 May 2023;
- Annual on-going operating and maintenance expenditure (**O&M**) to maintain compliance;
- Present value of the annual cost of expected unserved energy over 10-year period; and
- HV customer cost to comply with the Act and Regulations by 1 May 2023.

As this strategy is developed to meet the safety regulation as the primary focus, future network augmentation costs due to load growth under each option have not been specifically quantified, however the impacts of load growth are factored into the annual cost of expected unserved energy considered in our analysis.

All options considered would result in the same bushfire risk-neutral safety outcome. Therefore, the option that has the least overall cost would be considered to be the option that maximises the net economic benefit to all those who produce, consume and transport electricity in the NEM.

JEN has not considered any non-network alternatives in this paper as a non-network solution is unlikely to be considered sufficient to mitigate the bushfire risk.

3.2 Assessment Assumptions

In evaluating net economic benefits, the following assumptions are used to calculate the annualised value of expected unserved energy (**EUE**) for all the options analysed in this paper:

- Value of Customer Reliability of $41,738 per MWh;
- Average feeder outage rate is calculated based on JEN historic data;
- Average feeder outage repair time (or supply restoration time) for underground assets is 8 hours and overhead assets is 4 hours;
- Average feeder operational response time to perform load transfers to adjacent feeders is 1 hour;

- Feeder average demand is used to determine expected unserved energy at risk for a feeder outage that cannot be transferred to adjacent feeders due to REFCL technical limitations;
- Feeder load factor of 0.55 is assumed;
- NPV is calculated over 10 years, using a real discount rate of 2.5%;
- Options 7, 11 and 15 have the same assessment outcomes in terms of technical feasibility, compliance, risk and costs as documented in the "AusNet Services and Jemena Electricity Networks, Economic Options to Maintain REFCL Compliance at Kalkallo and Coolaroo Zone Substations, Joint Planning Report, December 2019" report; and
- Option 27 is technically feasible, is compliant with the Act and Regulations, and results in an acceptable risk outcome (bushfire risk-neutral outcome).

4. Options Analysis

4.1 Options Description

This section provides a summary of the scope of works for Options 7, 11, 15 and 27.

Options 7, 11 and 15 are extracted from “Economic Options to Maintain REFCL Compliance at Kalkallo and Coolaroo Zone Substations, Joint Planning Report, December 2019” report, and re-produced in this document to reflect the information relevant to JEN only.

4.1.1 Option 7 – Install Isolation Transformers On Underground Feeders and REFCLs at COO

This option is technically feasible and entails installing isolation transformers on underground feeders and installing REFCLs at COO zone substation.

Option objective

This option aims to provide REFCL protection for all overhead conductors and seek exemption for all underground cables, particularly for the sections of isolated underground cables.

Scope of works by 2023

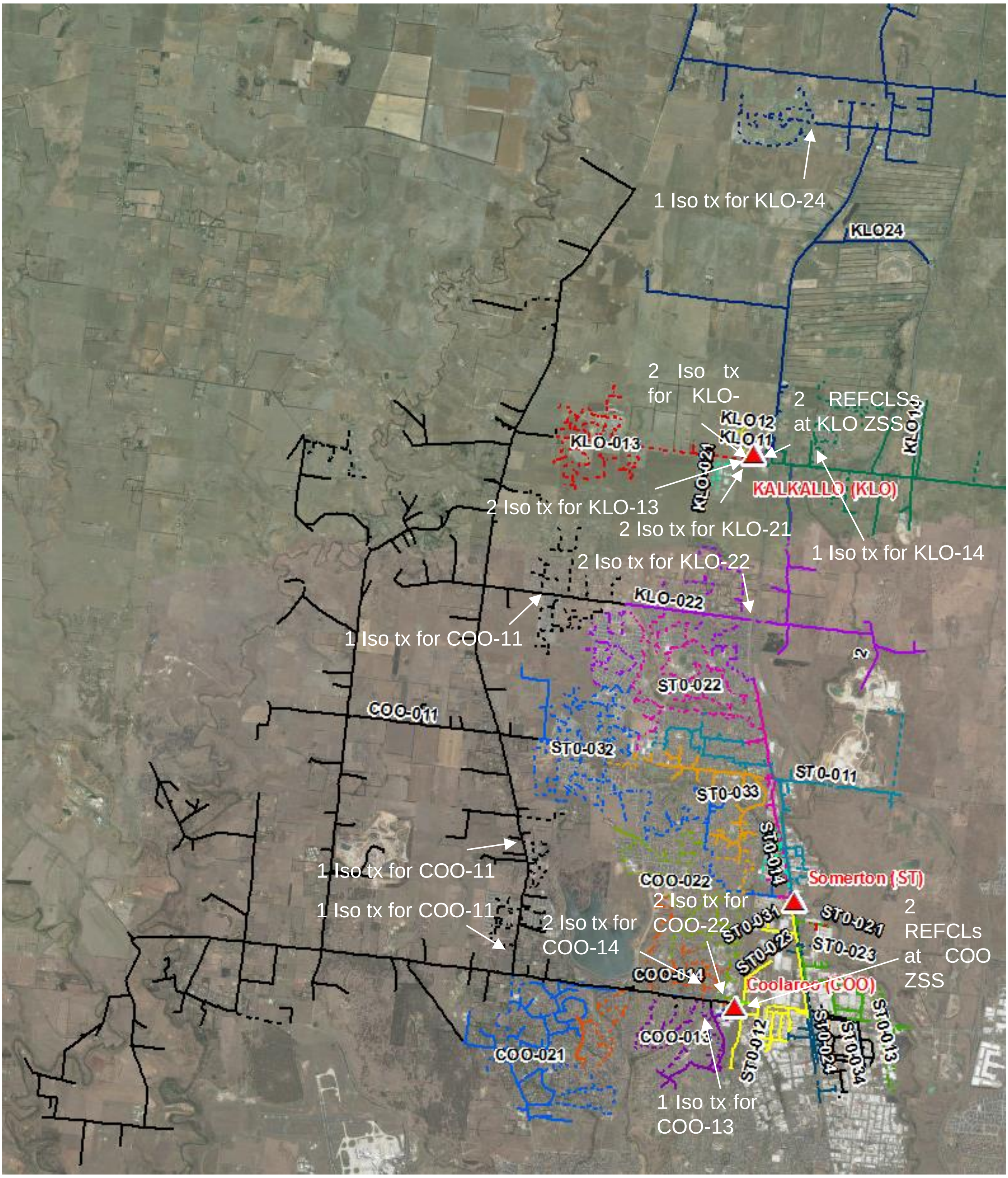
Figure 4-1 provides a high-level overview of the scope of works.

The high level scope of works required by JEN are:

- Install 2 REFCLs at COO zone substation, including network hardening and balancing
- For COO-11 feeder:
  - Underground 1.8km of overhead line on Mt Ridley Road
  - Install one isolation transformer, 5 kiosks and one Ring Main Unit on Mt Ridley Road
  - Install 370m of 22 kV cable
  - Install two isolation transformers at the start of the underground section on Mickleham Road
- For COO-13 feeder,
  - Install 2 x 170m 22 kV cable and one Ring Main Unit
  - Install one isolation transformer at the start of an underground section of the feeder
- For COO-14 feeder,
  - Transfer 1.4km of overhead conductor on COO-14 to COO-21
  - Install two isolation transformers at the start of an underground section of the feeder
  - Transfer the entire feeder to spare COO-23 CB to balance the capacitance on the COO zone substation bus so that the REFCL constraint limits are maintained
- For COO-22 feeder,
  - Underground 0.7km of overhead conductor

  - Install 2 kiosks
  - Install two isolation transformers at the start of the feeder
- Seek exemptions under the Act and Regulations for all isolated underground cables.

Figure 4-1: Option 7 High Level Scope of Works



4.1.2 Option 11 – Install REFCLs at COO

This option is technically feasible and entails installation of REFCLs at COO and transferring its underground 22 kV feeders from COO to its neighbouring Somerton Zone Substation (**ST**).

Option objective

This option aims to provide REFCL protection for all overhead conductors and seek exemption for all underground cables.

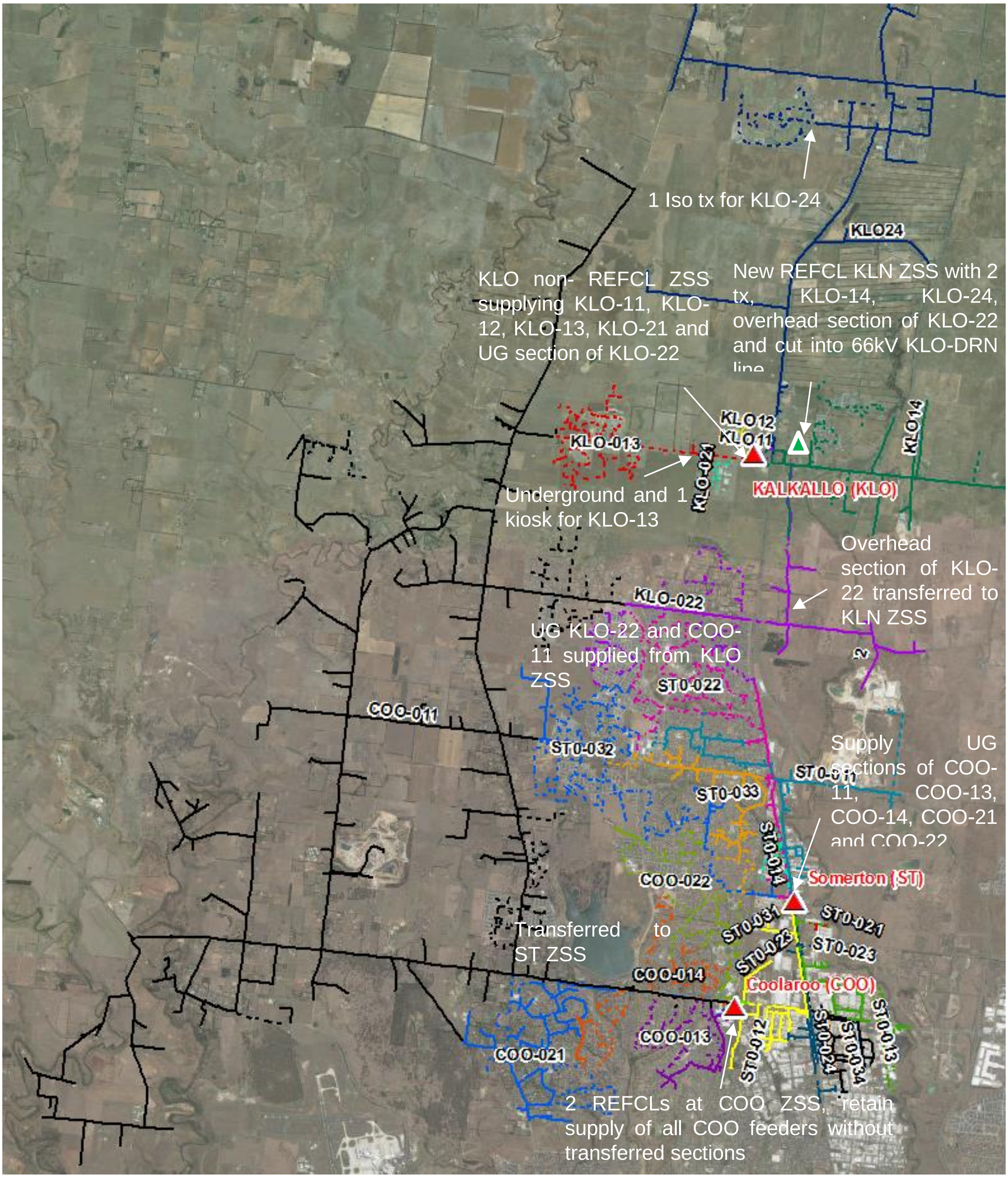
Scope of works by 2023

The high level scope of works required by JEN are:

- 1.06km of new 22 kV cables to connect underground sections of COO-11 on Mt Ridley Road to KLO-22 and one Ring Main Unit. This will transfer the supply of this underground section from COO to KLO and will assist COO in meeting REFCL compliance by reducing the capacitance at the zone substation.
- Install 2 REFCLs at COO, including network hardening and balancing
- Transfer underground sections of COO-11, COO-13, COO-14, COO-21 and COO-22 to ST zone substation.
- Seek exemptions under the Act and Regulations for the COO feeders transferred to ST on the basis that they are all underground cables.

Figure 4-2 provides a high-level overview of this option.

Figure 4-2: Option 11 High Level Scope of Works



4.1.3 Option 15 – Two REFCL Zone Substations in JEN

This option is technically feasible and does not require any exemption to the Act and Regulations. It entails two REFCL Zone Substations, COO and Greenvale Zone Substation (**GVE**) in JEN supply area. This requires one new REFCL Zone Substation to be built in the Greenvale area.

Option objective

This option aims to provide REFCL protection for all overhead conductors and underground cables.

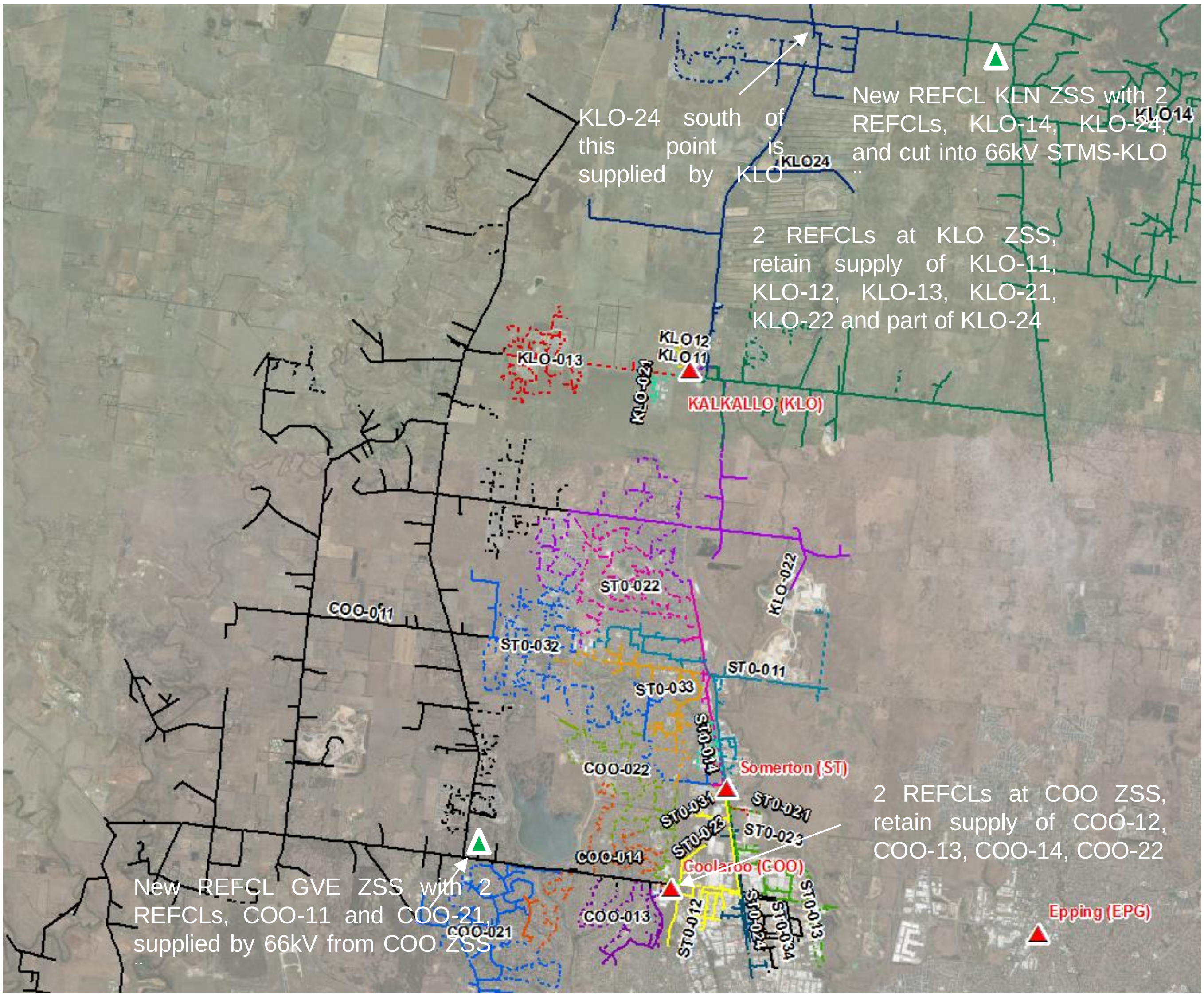
Scope of works by 2023

The high level scope of works required by JEN are:

1. GVE REFCL zone substation scope of works
   - Build a new REFCL GVE zone substation with two transformers and 2 REFCLs which will supply COO-11 and COO-21
   - New 10km of 66 kV overhead lines to supply GVE zone substation from COO
   - Short sections of 22 kV underground cable and overhead line to connect COO-11 and COO-21 to GVE zone substation
2. COO REFCL zone substation scope of works
   - Install 2 REFCLs at existing COO, including network hardening and balancing
   - COO retains supply to COO-12, COO-13, COO-14 and COO-22
   - Transfer 4km of underground cable from COO-14 to COO-22 to balance Co on both COO 22 kV buses within the 100A Co bus limit

Figure 4-3 provides a high level overview of this option.

Figure 4-3: Option 15 High Level Scope of Works



4.1.4 Option 27 – Build a New REFCL Zone Substation ('GVE')

Option objective

This option aims to:

- provide REFCL protection for all overhead conductors and some underground cables in the HBRA from the new GVE zone substation; and
- seek exemption for all underground cables and overhead conductors within an urban environment supplied by COO (as a non-REFCL zone substation) and undertake various bushfire mitigation activities for the remaining overhead conductors (supplied by COO) that pose some risk to a fire ignition that could propagate to a bushfire.

By separating the current COO supply area into a low density rural area (or HBRA) to be REFCL protected and a high density area within an urban environment to be a non-REFCL network, the capacity of COO can be fully utilised and provide supply back-up to its neighbouring ST zone substation and Broadmeadows Zone Substation (**BD**) – the reverse also applies. This arrangement would allow JEN to avoid a decrease in network reliability levels for customers in the COO and neighbouring ST and BD supply areas.

Scope of works by 2023

This option is technically feasible and includes the following works:

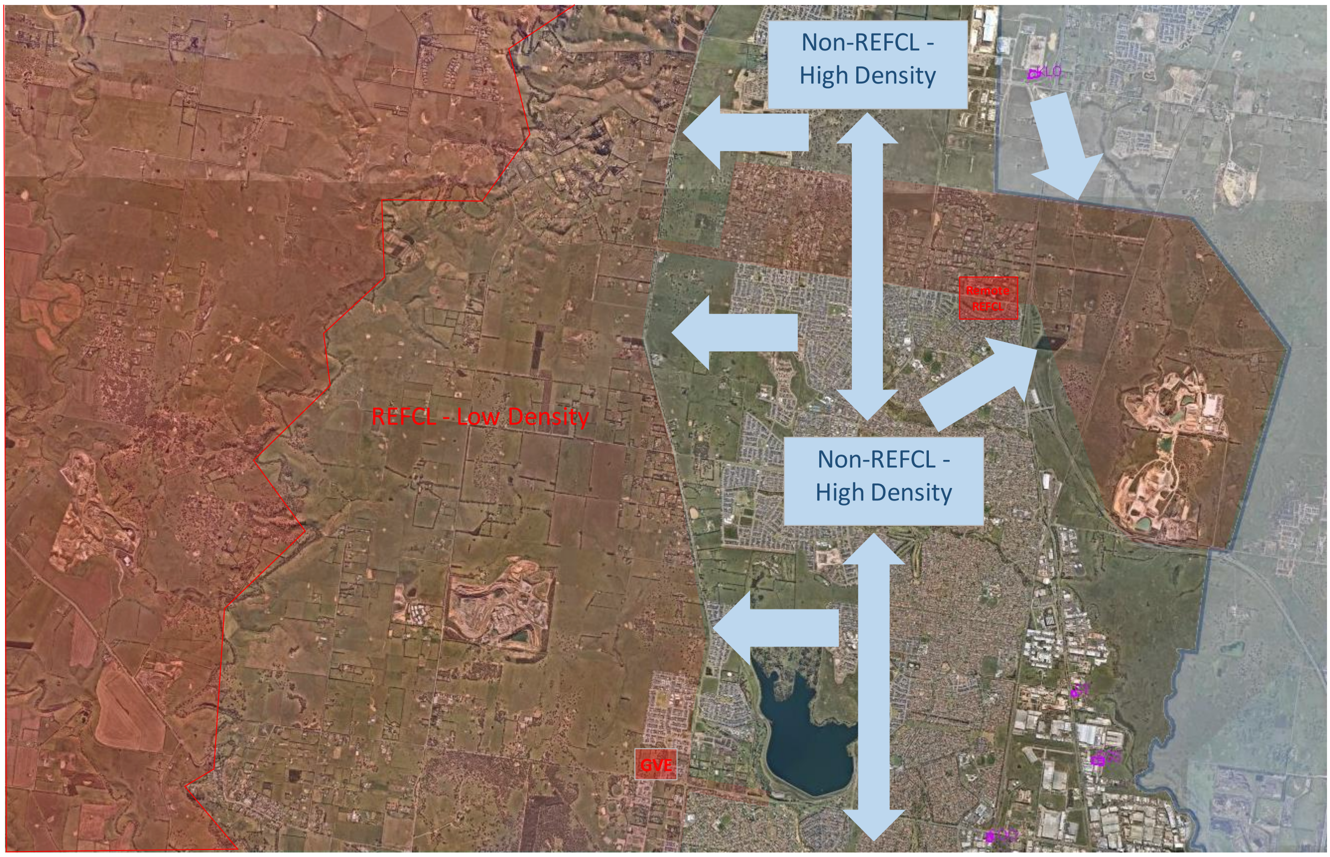
- Construct a new zone substation with REFCL capability in the Greenvale area and transfer those sections of the existing COO 22 kV network with high bushfire risk, mainly COO11, to the new zone substation – thereby providing REFCL protection to those 22 kV feeders in compliance with the Act and the Regulations, and
- Engage CSIRO to assess the bushfire risk associated with those sections of the COO 22 kV feeder network that will remain supplied by COO (as a non-REFCL zone substation) and obtain exemptions from the Act and Regulations for these network sections on the basis that:
  - For those polyphase electric lines (or parts thereof) of an underground construction, which pose an insignificant bushfire risk, the implementation of REFCL protection would not reduce the bushfire risk associated with these lines – and therefore not implementing REFCL protection for these lines represents a bushfire risk-neutral outcome;
  - For those polyphase electric lines of an overhead construction within an urban environment that, following expert assessment by CSIRO, pose no risk of a fire ignition that could propagate to a bushfire – that not implementing REFCL protection for these lines represents a bushfire risk-neutral outcome; and
  - For those polyphase electric lines of an overhead construction that pose some risk to a fire ignition that could propagate to a bushfire, that JEN would undertake various alternative bushfire mitigation activities to reduce this risk – therefore resulting in a bushfire risk-neutral outcome.

This solution therefore provides a bushfire risk-neutral outcome when compared to the installation of REFCL protection at COO.

JEN has lodged its exemption applications in May 2020 to both the ESV and DELWP for the above alternative solution at COO, and the exemptions from the Act and the Regulations have been granted in November 2020.

This proposed option is most aligned with JEN's general network strategy for the area detailed in Section 1.3.1 and as provided in Figure 4-4.

Figure 4-4: Option 27 – Proposed GVE Zone Substation



4.2 Load Forecast

This section presents the maximum demand forecast at COO, neighbouring ST and the new GVE zone substations prior-to- and post- REFCL augmentation work under each option and compares them to the station ratings. In doing so, it indicates whether the proposed REFCL augmentation under each option caters for the load growth requirement over the next 10 years or whether it requires further augmentation to meet the projected growth in the area.

This assessment supports us in determining the most efficient outcome in the long-term interests of JEN's customers.

Table 4-1 and Table 4-2 present the ratings of existing COO and ST zone substations respectively – these ratings remain the same prior-to- and post- REFCL augmentation work.

Table 4-1: COO Zone Substation Ratings

	Summer	Winter
Substation N Secure Rating (MVA)	47.6	47.6
Substation N-1 Rating (MVA)	38.0	39.6

Table 4-2: ST Zone Substation Ratings

	Summer	Winter
Substation N Secure Rating (MVA)	95.2	95.2
Substation N-1 Rating (MVA)	79.7	89.3

Table 4-3 presents the maximum demand forecast for COO zone substation for the forward 10-year planning period.

Table 4-3: COO Zone Substation Demand Forecast Prior to REFCL Augmentation

	2020 (actual)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Summer – 10% POE (MVA)	43.7	49.4	51.0	52.1	52.7	53.2	53.5	53.5	53.9	54.2	54.2
Summer – 50% POE (MVA)	43.7	43.0	44.4	45.3	46.0	46.5	46.4	46.7	46.9	47.2	47.4

Based on the above forecast, there is insufficient capacity at COO zone substation to supply the area in the forward 10-year planning period, meaning action (most likely augmentation work given the size of this constraint) will be required to alleviate the emerging capacity constraint to meet on-going load growth.

Table 4-4: ST Zone Substation Demand Forecast Prior to REFCL Augmentation

	2020 (actual)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Summer – 10% POE (MVA)	76.4	82.0	83.4	83.9	83.3	83.3	84.1	84.3	85.2	85.9	86.1
Summer – 50% POE (MVA)	76.4	75.1	76.6	77.0	76.6	76.7	76.9	77.6	78.2	78.8	79.5

Based on the above forecast, there is sufficient capacity at ST zone substation to supply the area in the forward 10-year planning period. However, it should be noted that the station is fully utilised. Beyond 2030, JEN will likely need to consider some form of augmentation or alternative non-network solution to alleviate the emerging capacity constraint to meet on-going load growth.

4.2.1 Load Forecast for Option 7

Under Option 7, the maximum demand forecasts for COO and ST zone substations over the forward 10-year planning period remain the same. Based on this outcome, there is likely a need for further augmentation at COO to meet the load growth requirement within the forward planning period.

Due to the complexity in the REFCL technical limitations and supply arrangements between REFCL and non-REFCL supply areas, the future network augmentation scope and cost for load growth have not been quantified. However, we have factored this load growth impact in the annual cost of expected unserved energy in Section 4.5.

4.2.2 Load Forecast for Option 11

Under Option 11, it is expected that there will be a net load transfer from COO to ST of approximately 11MVA from summer 2024 onwards. This results in the demand reduction at COO, which will likely mean avoiding any augmentation work to meet load growth requirement within the forward 10-year planning period. However, the increase in demand at ST would necessitate augmentation work or alternative non-network solution to address the emerging capacity constraint within the forward planning period.

Due to the complexity in the REFCL technical limitations and supply arrangements between REFCL and non-REFCL supply areas, the future network augmentation scope and cost for load growth have not been quantified. However, we have factored this load growth impact in the annual cost of expected unserved energy in Section 4.5.

Table 4-5 presents the maximum demand forecast for COO zone substation for the forward 10-year planning period.

Table 4-5: COO Zone Substation Demand Forecast Post REFCL Augmentation (Option 11)

	2020 (actual)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Summer – 10% POE (MVA)	43.7	49.4	51	52.1	41.7	42.2	42.5	42.5	42.9	43.2	43.2
Summer – 50% POE (MVA)	43.7	43	44.4	45.3	36.4	36.9	36.8	37.1	37.3	37.6	37.8

Table 4-6 presents the maximum demand forecast for ST zone substation for the forward 10-year planning period.

Table 4-6: ST Zone Substation Demand Forecast Post REFCL Augmentation (Option 11)

	2020 (actual)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Summer – 10% POE (MVA)	76.4	82	83.4	83.9	94.3	94.3	95.1	95.3	96.2	96.9	97.1
Summer – 50% POE (MVA)	76.4	75.1	76.6	77	86.2	86.3	86.5	87.2	87.8	88.4	89.1

4.2.3 Load Forecast for Options 15 and 27

Under Options 15 and 27, it is expected that there will be a net load transfer from COO to the new GVE of approximately 15MVA from summer 2024 onwards. This results in the demand reduction at COO, which will avoid any augmentation work to meet the load growth requirement. The new GVE zone substation will also have sufficient capacity to meet the on-going load growth over the forward 10-year planning period.

There is no change to ST demand forecast.

Table 4-7 presents the maximum demand forecast for COO zone substation for the forward 10-year planning period.

Table 4-7: COO Zone Substation Demand Forecast Post REFCL Augmentation (Options 15 & 27)

	2020 (actual)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Summer – 10% POE (MVA)	43.7	49.4	51	52.1	37.7	38.2	38.5	38.5	38.9	39.2	39.2
Summer – 50% POE (MVA)	43.7	43	44.4	45.3	32.9	33.4	33.4	33.6	33.8	34.1	34.3

Table 4-8 presents the maximum demand forecast for GVE zone substation for the forward 10-year planning period.

Table 4-8: GVE Zone Substation Demand Forecast Post REFCL Augmentation (Options 15 & 27)

	2020 (actual)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Summer – 10% POE (MVA)	0	0	0	0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Summer – 50% POE (MVA)	0	0	0	0	13.1	13.1	13.0	13.1	13.1	13.1	13.1

4.3 Project and On-going Operational Costs

Based on the scope of works provided in Section 4.1, the project costs for each option is summarised in Table 4-9 below.

Table 4-9: Project Costs (real, $2020)

	Option 7	Option 11	Option 15	Option 27
Project capital cost ($M)	27.1	24.7	51.9	36.9
NPV of project capital cost ($M)	25.8	23.6	49.5	35.2

The on-going annual O&M expenditure of REFCL compliance testing for each option is estimated at $306.2 thousand per annum (real, $2020). Applying the real discount rate of 2.5% per year, the present value of this expenditure over the ten-year assessment period equates to $2.2M.

4.4 HV Customer Cost to Comply

In determining the option that maximises the net economic benefit to all those who produce, consume and transport electricity in the NEM, JEN also considers the cost to HV customers within COO supply area required to upgrade their equipment to continue to take supply safely[9].

Following our discussions with a HV customer connected to COO in early 2020, they've indicated that the total cost to upgrade both their HV substations in Roxburgh Park and Coolaroo to the Required Capacity is estimated at $8M. JEN also has a third HV customer connected within the COO supply area that also require to meet the Required Capacity. For this HV customer, we assume that an isolation transformer will be used to meet the compliance and is estimated at $1.3M.

Table 4-10 presents a summary of the HV customers cost under each option.

Table 4-10: HV Customer Cost to Comply within COO Supply Area ($M, real 2020)

HV Customer Cost to Comply	Option 7	Option 11	Option 15	Option 27
HV Customers 1 & 2	8	8	8	0
HV Customer 3	1.3	1.3	1.3	1.3
Total HV Customers Cost	9.3	9.3	9.3	1.3
Total NPV of HV Customers Cost	**9.1**	**9.1**	**9.1**	**1.3**

4.5 Network Reliability and Capacity Assessment (Unserved Energy)

The complexities and technical limitations associated with REFCL equipment can introduce a number of constraints during network operations—for example, by limiting our ability to undertake emergency load transfers between feeders—that may lead to significant supply interruptions under some circumstances. The following table summarises an assessment of the impact on the affected feeders for each proposed option, in terms of prolonged customer supply interruptions (unserved energy) during unplanned outages affecting customer supplies reliability. It also summarises the impact on network capacity for COO, where significant urban growth is expected in the mid-term.

[9] Clause 16 (c) of VEDC states that "*A **business customer** must take reasonable precautions to minimise the risk of loss or damage to any equipment, premises or business of the **business customer** which may result from poor quality or reliability of electricity **supply** or the **distribution system** operating under the **REFCL condition** in accordance with clause 4.2.2A*"

Table 4-11: Prolonged customer supply interruptions (unserved energy) summary for each option

Single Contingency Event	Option 7	Option 11	Option 15	Option 25
Feeder COO-11	100% of customers cannot be transferred to COO-21 because of COO Bus #2 capacitance limit, until fault is repaired	100% of customers cannot be transferred to COO-21 because of COO Bus #2 capacitance limit, until fault is repaired	Reliability risk reduced to 1/3 compares with Options 7 & 11 because COO-11 is split into 3 feeders, reducing exposure by 2/3	Reliability risk reduced to 1/3 compares with Options 7 & 11 because COO-11 is split into 3 feeders, reducing exposure by 2/3
Feeder COO-12	100% of customers cannot be transferred to COO-11 due to thermal capacity limit	100% of customers cannot be transferred to COO-11 due to thermal capacity limit	100% of customers can be transferred to COO-11	100% of customers can be transferred to COO-11 or ST-12
Feeder COO-13	70% of customers cannot be transferred to COO-11 or ST-31 because of capacitance limit (80A) on COO-11 and thermal capacity limit on ST-31, until fault is repaired	70% of customers cannot be transferred to COO-11 or ST-31 because of capacitance limit (80A) on COO-11 and thermal capacity limit on ST-31, until fault is repaired	100% of customers can be transferred to COO-11	100% of customers can be transferred to COO-11 or BD-14
Feeder COO-14	25% of customers cannot be transferred to adjacent feeders. Isolation transformer provides 75% of customer transfer to COO-22 and ST-32	50% of customers cannot be transferred to COO-22, ST-31 or ST-32 because of capacitance limit on COO Bus #2 and thermal capacity limit on ST-31 and ST-32, until fault is repaired	No customer is at risk with prolonged outage, as there are likely to be transfers to adjacent feeders on the same bus.	No customer is at risk with prolonged outage, as there are transfers to COO-21, COO-22, GVE-12 and GVE-13.
Feeder COO-21	100% of customers cannot be transferred to adjacent feeders COO-11 or COO-14, due to capacitance limit on COO-11 or COO-14 as non-REFCL via isolation transformer	100% of customers cannot be transferred to adjacent feeders COO-11 or ST-31, due to capacitance limit on COO-11 or ST-31 being a non-REFCL feeder	No customer is at risk with prolonged outage, as there are likely to be transfers available to adjacent feeders on the same bus.	No customer is at risk with prolonged outage, as there are transfers available to COO-11, COO-14, GVE-11, GVE-12 and GVE-13
Feeder COO-22	25% of customers cannot be transferred to adjacent feeders. Isolation transformer provides 75% of	50% of customers cannot be transferred to adjacent feeders due to capacity limit on ST-31 and ST-32.	No customer is at risk with prolonged outage, as there are likely to be transfers available to adjacent	25% of customers cannot be transferred to adjacent feeders – 75% transfers available to COO-14 and ST-32, and indirect transfers to

	customer transfer to COO-14 and ST-32		feeders on the same bus.	COO-21, GVE-12 and GVE-13.
Unplanned outage of one COO transformer	0MVA of load transfer from COO zone substation to ST zone substation.	Approximately 11MVA of load transfer from COO zone substation to ST zone substation.	Approximately 15MVA of load transfer from COO zone substation to GVE zone substation.	Approximately 15MVA of load transfer from COO zone substation to GVE zone substation.

Based on the impact on network supply reliability summarised in Table 4-11, the cost of expected unserved energy is determined using the VCR and other assumptions listed in Section 3.2. The NPV of the cost of expected unserved energy over the 10-year period is determined for each option, and the results for each option is summarised in Table 4-12.

Table 4-12: NPV of Cost of Expected Unserved Energy ($M, real 2020)

Single Contingency Event	Option 7	Option 11	Option 15	Option 27
Feeder COO-11	38.59	38.59	12.92	12.92
Feeder COO-12	0.31	0.31	0.00	0.00
Feeder COO-13	2.15	2.15	0.00	0.00
Feeder COO-14	0.03	0.17	0.00	0.00
Feeder COO-21	18.37	18.37	0.00	0.00
Feeder COO-22	0.04	0.44	0.00	0.04
Unplanned outage of one COO transformer	1.30	0.20	0.01	0.01
Total NPV of Cost of Expected Unserved Energy ($M)	**60.8**	**60.2**	**12.9**	**13.0**

4.6 Summary of Cost Analysis

A summary of the cost analysis assessed for each option is present in Table 4-13.

Table 4-13: Summary of NPV Cost Analysis (real, $2020)

Option	NPV of Project Cost ($M)	NPV of O&M ($M)	NPV of Cost of Expected Unserved Energy ($M)	NPV of HV Customer Cost ($M)	Total Costs ($M)	Ranking
Option 7	25.8	2.2	60.8	9.1	97.8	4
Option 11	23.6	2.2	60.2	9.1	95.1	3
Option 15	49.5	2.2	12.9	9.1	73.7	2
Option 27	35.2	2.2	13.0	1.3	51.6	1

5. Recommendation and Next Steps

The assessment outlined within this document shows that the identified need associated with this strategy comprises:

- The compliance with the Act and Regulations for the COO network area;
- The level of reliability in the COO supply area must be maintained and managed in light of the REFCL technical limitations; and
- Long-term load growth must be considered and catered for. In essence, the proposed solution needs to align with the network growth strategy.

5.1 Recommended Solution

In line with the assessment, the recommended solution is Option 27, as this option maximises the net economic benefit to all those who produce, consume and transport electricity in the NEM. The results of this analysis is summarised in Table 4-13. This solution will deliver a bushfire risk-neutral outcome and is in the long-term interests of JEN's customers.

Option 27 includes the following works:

- Construct a new zone substation with REFCL capability in the Greenvale area and transfer those sections of the existing COO 22 kV network with high bushfire risk, mainly COO11, to the new zone substation – thereby providing REFCL protection to those 22 kV feeders in compliance with the Act and the Regulations; and
- Undertake various bushfire mitigation activities to reduce the bushfire risk for those polyphase electric lines of an overhead construction within an urban environment that pose some risk to a fire ignition that could propagate to a bushfire – therefore resulting in a bushfire risk-neutral outcome.

The JEN capital expenditure required for the recommended solution is $37.3M[10] (real $2021, including overheads).

5.2 Next Steps

In accordance with Clause 5.17 of the National Electricity Rules and as per the process defined in the AER's RIT-D Application Guidelines, JEN will undertake a RIT-D for this project.

JEN is currently working through this process, however, a non-network solution is unlikely to be considered sufficient to address the identified need in relation to this project—namely to mitigate bushfire risk.

Given the timeframes imposed by the Act and Regulations and the very low likelihood that a non-network alternative solution would address the identified need, JEN has initiated a land search activities for the proposed GVE site. JEN will continue to focus on a location that it considers to be optimal in terms of meeting the compliance obligation, and supporting the network growth strategy for the wider area with the ultimate aim of achieving the lowest whole life cost.

Initiation of landowner discussions and refining of a proposed REFCL zone substation requirements and footprint will inform the next steps.

10 This figure includes expenditure prior to the commencement of JEN's 2021-26 regulatory period.