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AUSNET SERVICES AND
JEMENA ELECTRICITY
NETWORKS

ECONOMIC OPTIONS TO MAINTAIN REFCL COMPLIANCE AT KALKALLO AND COOLAROO ZONE SUBSTATIONS

JOINT PLANNING
REPORT

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Economic options to maintain REFCL compliance at Kalkallo and Coolaroo Zone Substations
Joint Planning Report

AusNet Service and Jemena Electricity Networks

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ABBREVIATIONS

AER	Australian Energy Regulator
COO	Coolaroo Zone Substation
CBN	Craigieburn Zone Substation (proposed new substation)
DAPR	Distribution Annual Planning Report
DELWP	Department of Environment, Land, Water and Planning
DRN	Doreen Zone Substation
ESV	Energy Safe Victoria
GVE	Greenvale Zone Substation (proposed new substation)
HBRA	High Bushfire Risk Area
KLN	Kalkallo North Zone Substation (proposed new substation)
KLO	Kalkallo Zone Substation
KLW	Kalkallo West Zone Substation (proposed new substation)
KMS	Kilmore South Zone Substation
LBRA	Low Bushfire Risk Area
MHM	Mickleham Zone Substation (proposed new substation)
REFCL	Rapid Earth Fault Current Limiter
SBY	Sunbury Zone Substation
SMTS	South Morang Terminal Station
ST	Somerton Zone Substation
TTS	Thomastown Terminal Station
VCO	Visy Coolaroo Zone Substation
ZSS	Zone Substation

EXECUTIVE SUMMARY

WSP was engaged by AusNet Services and Jemena Electricity Networks to undertake an area planning study for the Kalkallo and Coolaroo distribution areas to determine the most economical solution to achieve compliance with the requirements of the Electricity Safety (Bushfire Mitigation) Regulations 2013 and the Electricity Safety Amendment (Bushfire Mitigation Civil Penalties Scheme) Act 2017 (the Act).

In 2016, the Victorian Government introduced the Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016 to amend the Electricity Safety (Bushfire Mitigation) Regulations 2013 (the Regulations). These regulations set challenging performance standards for fault clearance times that apply to the selected 45 zone substations. The only approach to meet these requirements is to install Rapid Earth Fault Current Limiters (REFCLs) or obtain an exemption from the Act and Regulations.

The Regulations requires Kalkallo (KLO) and Coolaroo (COO) Zone Substations (ZSS) to be compliant by 1 May 2023 at the latest. KLO ZSS is owned by AusNet Services but currently supplies three feeders that are owned by Jemena Electricity Networks. COO ZSS is adjacent to KLO ZSS and is owned by Jemena Electricity Networks. Both zone substations have significant underground distribution networks which cause the technical threshold of the REFCLs to be exceeded, preventing the straight forward implementation of REFCLs at these zone substations. Due to the interrelationship between these two zone substations, the solution must be suitable for the long-term operation and compliance at both zone substations.

WSP assessed a broad range of options that had been developed separately by AusNet Services and Jemena Electricity Networks as well as additional options identified and developed by WSP, using the combined network information from both businesses. In total, 24 options were identified of which 15 were quickly excluded on either a technical feasibility basis or as a result of initial cost analysis that indicated they were unlikely to be cost effective (i.e. significantly more expensive than other options).

High level technical, compliance and cost assessments were undertaken for the remaining nine options. Out of the nine options, only one option (i.e. Option 15) did not require exemptions from the Act and Regulations. However, this option has the highest estimated cost at approximately $120M (in real 2019 dollars), which is at least 50% ($40M) more expensive than the other options without providing any additional benefits to the network or customers.

Hence, in the best interest of customers, AusNet Services and Jemena Electricity Networks sought guidance on the acceptability of options requiring exemptions from Australian Energy Regulator (AER), Energy Safe Victoria (ESV) and Department of Environment, Land, Water and Planning (DELWP) in a meeting on 2 August 2019.

Based on the high-level assessment of the nine options and guidance gained from the meeting on 2 August 2019, three of these nine options were shortlisted for further detailed option assessment. The three final options are:

- Option 7 which entails installing isolation transformers on underground feeders and REFCLs at both KLO and COO ZSSs.
- Option 11 which entails:
  - building a new REFCL Kalkallo North (KLN) ZSS with two supply transformers and installation of an isolation transformer on the KLN network,
  - retaining the existing KLO ZSS to not be REFCL protected,
  - installation of REFCLs at COO ZSS and transferring its underground 22kV feeders from COO ZSS to its neighbouring Somerton (ST) ZSS.
- Option 15 which entails:
  - building a new REFCL Kalkallo North (KLN) ZSS with two supply transformers,
  - building a new REFCL Greenvale (GVE) ZSS with two supply transformers

— installation of two REFCLs at KLO ZSS and two REFCLs at COO ZSS

Further detailed assessments were conducted on the three final options because:

— Option 7 has the lowest upfront cost but may require significant future expenditure and complicated network management into the future.

— Option 11 is simpler from a network management perspective and may have low future expenditure. However, it requires higher upfront expenditure compared to Option 7.

— Option 15 is the reference case to demonstrate the cost difference with an option that does not require exemptions.

The detailed assessment involved a detailed technical, compliance, risk and economic analysis of each final option:

1 **Technical feasibility** ensured the option did not exceed any limitation of the REFCL, load flow studies of the 66kV and 22kV networks, whether the option proposed proven technology and implementation of the REFCLs. The technical feasibility studies found that all three final options were technically feasible.

2 **Compliance requirements** evaluated the extent of the exemptions required from the Act and Regulations and any precedents set by exemptions already granted.

Only Option 15 did not require exemption from the Act and Regulations. Option 7 requires exemptions that are similar to precedent exemptions of underground cables and are expected to be granted on this basis. Option 11 requires an exemption for an entire zone substation (i.e. KLO ZSS), which does not have a precedent exemption at the time of issuing this report although an entire zone substation exemption is being sought by Powercor at the time of issuing this report. The lack of precedence for the type of exemption increases the compliance risk of Option 11.

3 **Risks assessment** evaluated the risk associated with each option in comparison with other options. One of the key risks is deliverability. Deliverability risk was assessed with respect to the likelihood the option could be installed and commissioned to meet the 1 May 2023 compliance deadline. This does not consider the ability to obtain a time extension through the exemption process.

Option 11 was found to have the lowest overall risk compared to Options 7 and 15. Hence, Option 11 is the preferred option from a risk perspective.

4 **Cost assessment** calculated and compared the expenditure required to achieve compliance by 2023 and the indicative whole of lifecycle costs. The cost to comply by 2023 demonstrates the expenditure required to achieve regulatory compliance by 1 May 2023. The whole of lifecycle costs evaluation identifies the long term least cost option. The costs of each option were based on a high level scope and unit costs (informed by historical costs) provided by AusNet Services and Jemena Electricity Networks.

Option 11 has the lowest whole of lifecycle cost compared to Options 7 and 15, but Option 7 has the lowest cost to comply by 2023. The costs to be incurred in order to comply by 1 May 2023 are shown in the table elbow. The table shows the split of costs between Jemena Electricity Networks and Ausnet Services.

OPTION	OPTION DESCRIPTION	AUSNET SERVICES	JEMENA ELECTRICITY NETWORKS	TOTAL COST TO COMPLY BY 2023[1]
7	Install isolation transformers on underground feeders and REFCLs at ZSS	$33.8M	$26.8M	$60.6M

[1] Options 7 and 11 are only compliant once the exemption from the Act and Regulations has been granted

OPTION	OPTION DESCRIPTION	AUSNET SERVICES	JEMENA ELECTRICITY NETWORKS	TOTAL COST TO COMPLY BY 2023[1]
11	Build a new REFCL KLN ZSS with two transformers	$46.7M	$24.5M	$71.2M
15	4 REFCL ZSS – Build a new REFCL GVE ZSS and KLN ZSS	$69.9M	$51.3M	$121M

The table below shows the net present cost of each option to maintain compliance to 2050.

OPTION	OPTION DESCRIPTION	NET PRESENT COST (NPC)
7	Install isolation transformers on underground feeders and REFCLs at ZSS	$77.7M[1]
11	Build a new REFCL KLN ZSS with two transformers	$67.1M
15	4 REFCL ZSS – Build a new REFCL GVE ZSS and KLN ZSS	$163.7M[2]

(1) This is a conservative estimate as future isolation transformer quantities are underestimated and electrical losses and maintenance costs of the isolation transformers have not been included

(2) This assessment assumes the Jemena forecast continues at a constant trend based on linear regression. This aligns with the growth rate forecast by AusNet and is therefore considered reasonable

Subject to the exemption being granted, **WSP recommends Option 11 as the preferred option** as it presents the best long term interest of customers by:

- Lower whole of lifecycle cost
- Presenting a lower deliverability risk which is key to enabling the timely implementation of REFCLs to reduce bushfire risks for the community
- Future proofing by:
  - Reducing the risk of future additional costs
  - Lower future maintenance costs, including electrical losses from isolation transformers (impact was not costed)
  - Fewer constraints on future network operation such as back feeding
  - Providing capacity to meet the expected demand growth from Melbourne's northern growth corridor near KLO ZSS

However, should an exemption not be granted, then Option 15 is the only technically feasible option that will enable Jemena and AusNet Services to achieve compliance with the Regulations.

1 PROJECT BACKGROUND

1.1 PURPOSE OF THIS REPORT

This report develops a joint network planning solution for AusNet Services and Jemena Electricity Networks by identifying the most economic and technically feasible option to maintain the long-term compliance of Kalkallo and Coolaroo Zone Substations with the Electricity Safety Amendment (Bushfire Mitigation Civil Penalties Scheme) Act 2017 (the Act), the Electricity Safety (Bushfire Mitigation) Regulations 2013 and the Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016 (the Regulations).

1.2 THE NEED

AusNet Services' Kalkallo (KLO) zone substation (ZSS) and Jemena Electricity Networks' Coolaroo (COO) ZSS are two of the 45 zone substations that are identified in Schedule 2 of the Electricity Safety (Bushfire Mitigation) Regulations and must be compliant with the Regulations by 1 May 2023.

These zone substations supply neighbouring areas and are interdependent, such that feeders originating from KLO ZSS are owned by Jemena Electricity Networks and supply Jemena Electricity Networks' distribution area. Both zone substations have extensive underground cable networks as well as overhead feeders that extend into high bushfire risk areas (HBRA).

Due to the interdependence of these two zone substations, the area they supply needs to be looked at holistically to find a technically and economically feasible solution that will enable Jemena Electricity Networks and AusNet Services to be compliant with the Regulations.

1.3 SCOPE

The scope of this analysis is a desktop assessment of credible options to address the need by either complying with the Acts and Regulations or obtaining an exemption from the Acts and Regulations. It entails the following:

- Identifying options to address the need
- Shortlisting technically feasible options, which may require network modelling to assess technical feasibility
- Least cost analysis of options based on unit cost estimates provided by AusNet Services and Jemena Electricity Networks
- Identifying the most economic and technically feasible option that addresses the need within the required timeframe
- Report on the above findings (i.e. this report)

The assessment takes into account the following:

- Compliance with, or exemption from, the Act and Regulations at both AusNet Services' KLO ZSS and Jemena Electricity Networks' COO ZSS to ensure the best outcome for the network and customers, regardless of network boundaries
- Existing KLO and COO ZSS networks
- Implication of options on the future network growth in the KLO and COO ZSS area
- Regulation exemptions required

- Options independently developed by AusNet Services and Jemena Electricity Networks for compliance at KLO ZSS and COO ZSS
- Risk of each option from a technical, regulation compliance and deliverability perspective.

1.4 STRUCTURE OF DOCUMENT

This document sets out the requirements for the zone substations, considers the current constraints and future requirements of the network, sets out the options identified by AusNet Services and Jemena Electricity Networks, and considers if there are any additional options that should be considered when assessing the constraints from a whole of network perspective.

The full suite of options is assessed to exclude non-credible options and the remaining shortlist of credible options is given an assessment against technical feasibility, ability to be implemented within the specified timeframe, ability to achieve compliance or get an exemption, and cost.

The sections for the remainder of the report are:

- Compliance requirements
- Compliance constraints
- Network overview
- Basis of the study
- Options identification
- Options assessment
- Recommendation

2 COMPLIANCE OBLIGATION

The Victorian Government has mandated, through the Electricity Safety (Bushfire Mitigation) Regulations 2013 and the amendments in 2016 (the Regulations), that electricity companies increase safety standards on specific components of their networks to reduce bushfire risks. The Regulations set challenging performance standards (the Required Capacity) for 45 zone substations in Victoria. The dates for compliance are separated into three tranches based on a points system (described in section 2.1 below) which occur on 1 May 2019, 1 May 2021 and 1 May 2023. In addition, the Victorian Government has enforced timely compliance of the Regulations by introducing significant financial penalties through the Electricity Safety Amendment (Bushfire Mitigation Civil Penalties Scheme) Act 2017 (the Act).

The Required Capacity can only be met by installing Rapid Earth Fault Current Limiters (REFCLs) in zone substations, which have not previously been implemented for bushfire reduction anywhere in the world. The Regulations allow for an exemption to the Required Capacity or the dates of compliance. A process to obtain an exemption has been established.

2.1 THE REGULATION STIPULATES REQUIREMENTS

The voltage reduction and fault current limiting performance of each polyphase feeder is imposed by the Regulations under the definition of Required Capacity:

> ***required capacity*** *means, in the event of a phase-to-ground fault on a polyphase electric line, the ability:*
>
> **a** *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*
>
> **b** *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:*
>
> **i** *1900 volts within 85 milliseconds; and*
>
> **ii** *750 volts within 500 milliseconds; and*
>
> **iii** *250 volts within 2 seconds;*
>
> **c** *during diagnostic tests for high impedance faults, to limit:*
>
> **i** *fault current to 0·5 amps or less; and*
>
> **ii** *the thermal energy on the electric line to a maximum I^2t value of 0.10;*

A polyphase electric line is defined as an electric line that is comprised of more than one phase of electricity with a nominal voltage of between 1kV and 22kV.

Clause 6(1) imposes the obligation that all substations in Schedule 2 must meet the criteria of the 'required capacity' with all feeders, based on the configuration on 1 May 2016, complying by 1 May 2023. Schedule 2 of the Regulations sets out the selected 45 substations and allocates points to each substation. It lists KLO ZSS at item 24 with 3 points and COO ZSS at item 41 with 1 point.

Clause 6(4) sets out the timing to reach compliance by requiring the electricity business to plan the order of upgrading the substations within a set timeframe, as determined by the number of points: 30 points by 1 May 2019, 55 points by 1 May 2021 and all remaining substations by 1 May 2023. The points assigned to each ZSS in Schedule 2 are used by electricity businesses to determine the schedule to meet compliance.

This has led to AusNet Services and Jemena Electricity Networks setting up 'Tranches' of substations to be addressed by specific dates. KLO and COO ZSS are both allocated to Tranche 3 which are to be compliant prior to 1 May 2023.

2.2 THE ACT STIPULATES NON-COMPLIANCE PENALTIES

The penalties for not complying with the requirements set out in the Regulations are set out in the Act. The Act states that there will be a fine of up to $2 million for each point less than the prescribed number of points that must be achieved at each of the three specified dates and an ongoing fine of $5,500 per day that compliance is not achieved.

The detail of the fines is set out in Clause 120M (3) which states a major electricity company is liable to pay:

a *if subsection (1)(a) or (b) [(1)(a) - A major electricity company must ensure that for the initial period, a sufficient number of zone substations in its supply network are complying substations so that the total number of allocated substation points prescribed in respect of all of the complying substations is not less than 30 (the period 1 minimum points); and (1)(b) for the intermediate period, a sufficient number of zone substations I its supply network are complying substations so that the total number of allocated substation points prescribed in respect of all of the complying substation is not less than 55 (the period 2 minimum points)] is contravened, a pecuniary penalty not exceeding $2 000 000 for every point forming the difference between the total number of allocated substation points prescribed in respect of all of the complying substations and, as the case require:*

- **i** *the period 1 minimum points; or*
- **ii** *the period 2 minimum points; and*

b *if subsection (1)(c) [on or after 1 May 2023, of if Energy Safe Victoria specifies a later date under section 120X, that date, all zone substations in its supply network are complying substations] is contravened, a pecuniary penalty not exceeding $2 000 000 for every allocated substation point prescribed in respect of each zone substation that is not a complying substation; and*

c *if there is a continuing contravention of subsection (1)(a), (b) or (c), a pecuniary penalty that is a daily amount not exceeding $5500 for each day that contravention continues after service on the major electricity company by Energy Safe Victoria of notice of that contravention.*

2.3 EXEMPTIONS

Electricity businesses can seek an exemption from both the Act and Regulations.

Exemption from the Act can be sought under section 120W of the Act from the requirements under section 120M of the Act. An exemption requires the Director of ESV to consult with the Minister for Energy, Environment & Climate Change and Order Council approval. The process can take up to 6 months.

Clause 13 of the Regulations allows for the electricity businesses to apply for exemptions from complying with the requirements of (7)(1)(ha) and (7)(1)(hb).

13 Exemptions

1. *Energy Safe Victoria may, in writing, exempt a specified operator or major electricity company from any of the requirements of these Regulations.*
2. *An exemption under subregulation (1) may specify conditions to which the exemption is subject.*

2.4 RAPID EARTH FAULT CURRENT LIMITER (REFCL)

The REFCL is a protection device that reduces the risk of fires caused by powerlines. It does this by rapidly limiting the current that is released in a phase to ground earth fault only. As it is installed on the zone substation transformer 22kV neutral, it is only effective for 22kV phase to ground earth faults.

There are various types of technologies that fall under the REFCL umbrella. However, the only type of REFCL currently proven by the Victorian Electric Supply Industry (VESI) suitable to meet the performance criteria specified in the Regulations is a proprietary product by Swedish Neutral.

The REFCL consists of four main components, which are housed within a ZSS:

- Arc Suppression Coil (ASC)
- Residual Current Compensator (RCC)
- Grid Balancing Unit
- Control System

The following network configuration is required to accommodate the installation of a REFCL:

- Capacitance balancing of the network is required for the REFCL to operate correctly (i.e. network balancing)
- Ensuring the network capacitive current does not exceed the limit of the ASC
- Replacing equipment with insufficient insulation ratings to ensure no equipment failure when the REFCL operates as the operation raises the phase to ground voltage of the non-faulted phases (i.e. network hardening)

3 COMPLIANCE CONSTRAINTS

Compliance constraints are grouped into the following categories:

- Regulatory constraints
- REFCL limitations
- Network constraints

This section details the regulatory and REFCL constraints. Section 4.4 will describe the network constraints.

3.1 REGULATORY CONSTRAINTS

The need can be addressed either by complying with the Act and Regulations or obtaining an exemption from the Act and Regulations. However, both paths have constraints due to the governing rules and processes.

3.1.1 COMPLIANCE CONSTRAINTS

The Regulations apply to the network supplied by the 45 ZSS listed in Schedule 2 when it came to effect on 1 May 2016. This encompasses all the polyphase 22kV lines originating from the 45 substations as of 1 May 2016, and has the following implications:

- Transferring any 22kV feeders that originated on 1 May 2016 from any of the 45 ZSS to another ZSS will require the other ZSS to become compliant with the Regulations.
- New ZSS built to supply any 22kV feeders that originated on 1 May 2016 from any of the 45 ZSS must be compliant with the Regulations.

3.1.2 EXEMPTION CONSTRAINTS

Exemption from the Act and Regulations requires an application to Energy Safe Victoria (ESV). The application must be:

- Specific to a ZSS or polyphase electric line(s), or part thereof, originating from a single ZSS.
- Isolation of underground cables require an exemption application.

3.2 TECHNOLOGY LIMITATIONS

The current REFCL technology applies the following constraints:

- There is one ASC per bus
- A limit of 100A network capacitive current (Co) for a single ASC. The limit of an ASC is dependent on the damping characteristics of the network at each individual zone substation. However, the actual damping characteristics specific to the network can only be measured once a REFCL is operating. Experience with the Tranche 1 REFCLs has indicated that a limit of 100A is prudent for planning purposes.
- A limit of 80A Co per feeder as the REFCL is unable to correctly identify the faulted feeder due to a combination of CT error, high network capacitive current and software algorithm (advised by AusNet Services on 23 July 2019 based on their REFCL experience with Tranche 1).
- A maximum of 2 REFCLs per ZSS as no software solution has been developed for a 3 REFCL ZSS.

These constraints may be resolved in the future. However, to ensure that KLO and COO ZSS meet the legislative compliance timeline of 1 May 2023, these limitations have been accounted for in the options assessment.

4 NETWORK OVERVIEW

4.1 OVERVIEW OF KLO ZSS

KLO 66/22kV ZSS is owned by AusNet Services. It has two 66/22kV 20/33 MVA transformers. KLO ZSS is supplied by two 66kV lines from South Morang Terminal Station (SMTS) – one directly from SMTS while the other 66kV line is via Doreen (DRN) ZSS. The 66kV overhead lines are cabled for a short distance for entry into the zone substation.

KLO ZSS currently supplies four AusNet Services and three Jemena Electricity Networks 22kV feeders. See Figure 4.1 for KLO ZSS configuration.

Figure 4.1: KLO ZSS single line diagram

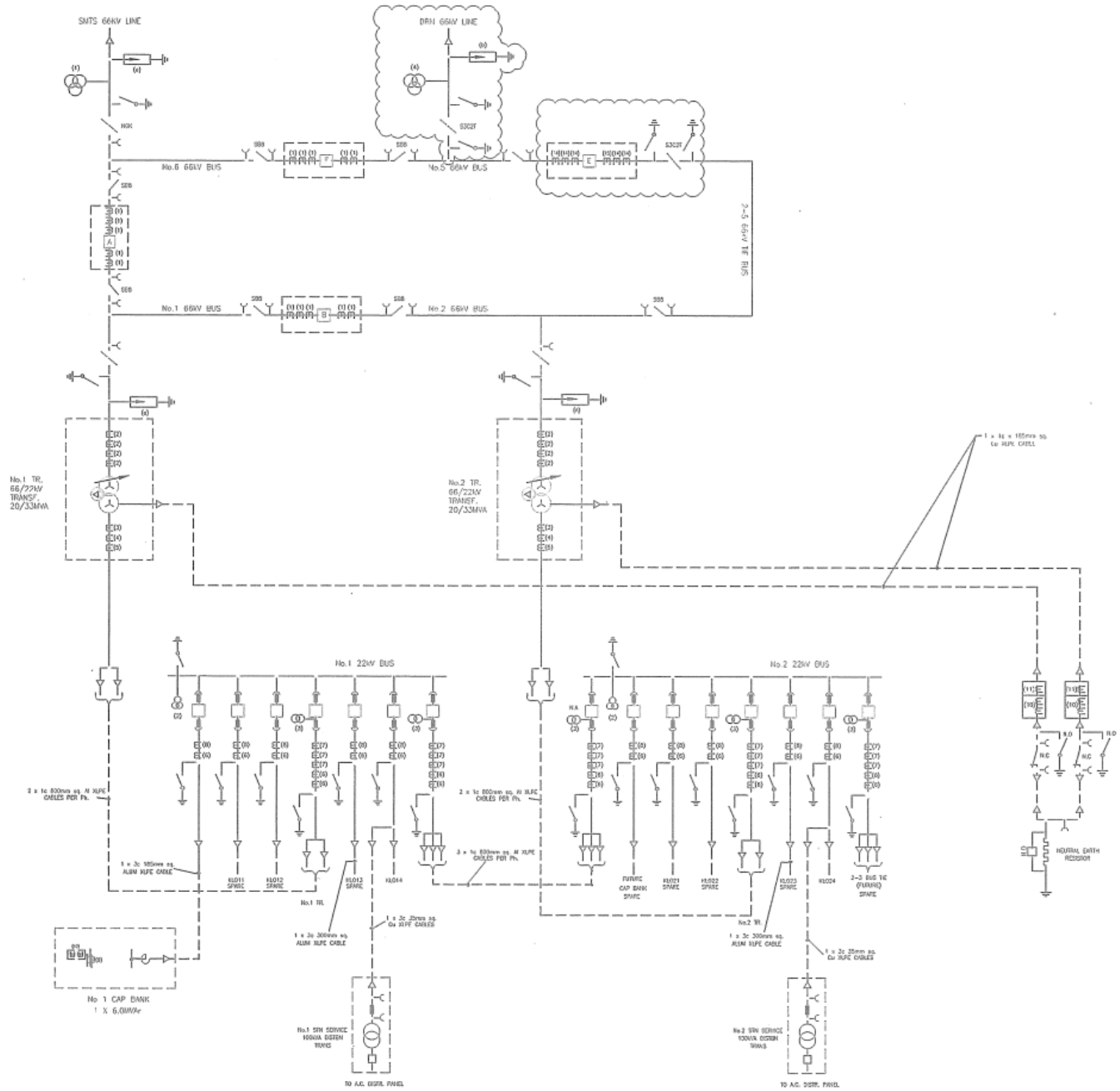


Figure 4.2 shows the network area of KLO ZSS. The grey areas in Figure 4.2 represent low bushfire risk area (LBRA). It is evident from Figure 4.2 that most of KLO is in high bushfire risk area (HBRA). The dotted lines represent underground cables while the solid lines represent overhead conductors which are predominately bare conductors.

Figure 4.2: KLO ZSS 22kV network area

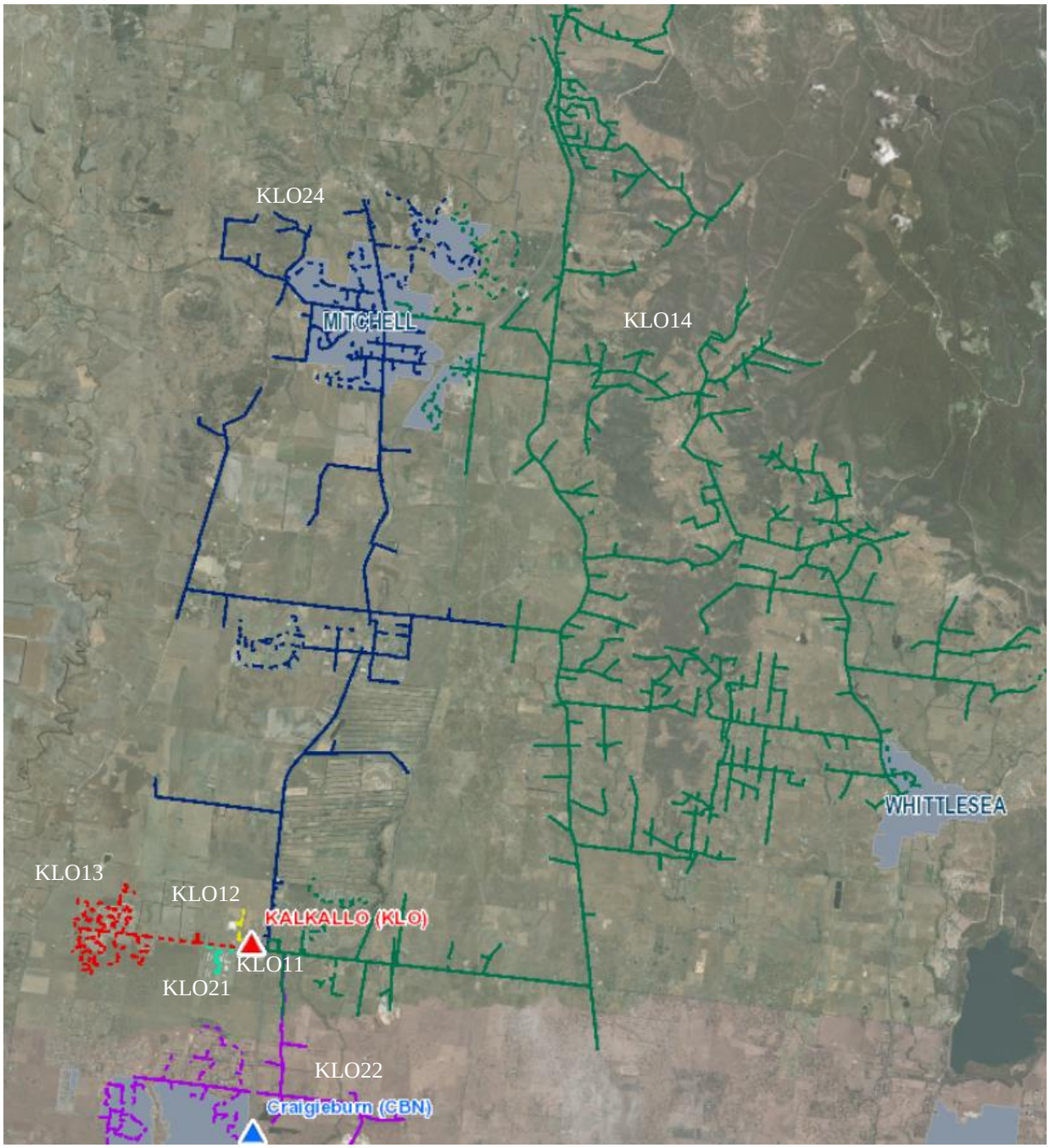


Table 4.1 shows the capacitance of each 22kV KLO feeder as per information received from Jemena Electricity Networks and AusNet Services.

Table 4.1: 2019 Co of KLO ZSS 22kV feeders

Feeder	Co (A)	Underground (km)	Overhead (km)	Network owner
KLO-11	0.5	0.13	0.003	AusNet Services
KLO-12	0.0	1.4	0.003	AusNet Services
KLO-13	83.5	22.3	0.17	Jemena
KLO-14	75.6	29.0	248.8	AusNet Services
KLO-21	10.2	2.9	0	Jemena
KLO-22	61.3	21.2	12.6	Jemena
KLO-23	0.0	0	0	Spare
KLO-24	89.8	35.4	75.1	AusNet Services
TOTAL	**321**	**112.3**	**336.6**	

It is evident from Table 4.1 that the existing 321A Co at KLO ZSS cannot be accommodated by two REFCLs which can at maximum accommodate 200A Co. In addition, the following future works will increase the Co and further exacerbate the high Co issue:

- Jemena's new 15MVA HV customer is expected to connect to KLO-23 by the end of 2019
- Network Co is forecasted to increase to 367A and 424A by 2025 and 2030 respectively due to network growth required to supply the Melbourne northern growth corridor near KLO ZSS. See Figure 4.6 for the growth areas.

4.2 OVERVIEW OF COO ZSS

COO 66/22kV ZSS is owned by Jemena. It has two 66/22kV 20/33 MVA transformers. COO ZSS is supplied by two 66kV lines from Thomastown Terminal Station (TTS) – one directly from TTS while the other 66kV line is via Visy Coolaroo Zone Substation (VCO).

It currently supplies six Jemena Electricity Networks 22kV feeders. See Figure 4.3 for COO ZSS configuration.

Figure 4.3: COO ZSS single line diagram

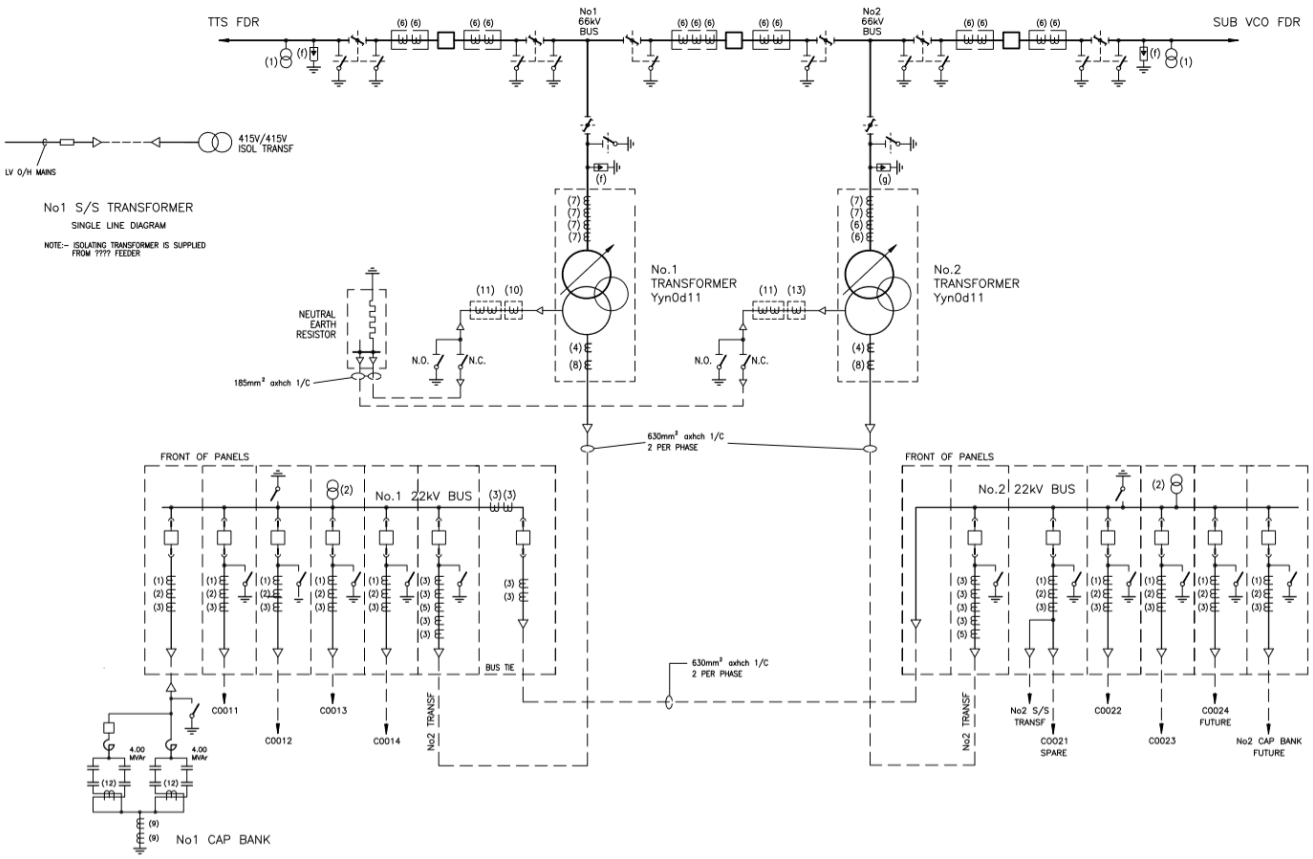


Figure 4.4 shows the network area of COO ZSS. The grey areas in Figure 4.4 represent LBRA. It is evident that all of COO 22kV feeders are in LBRA urban areas, except for COO-11 and short sections of COO-21. The dotted lines represent underground cables while the solid lines represent overhead conductors which are predominately bare conductors.

Figure 4.4: COO ZSS 22kV network area

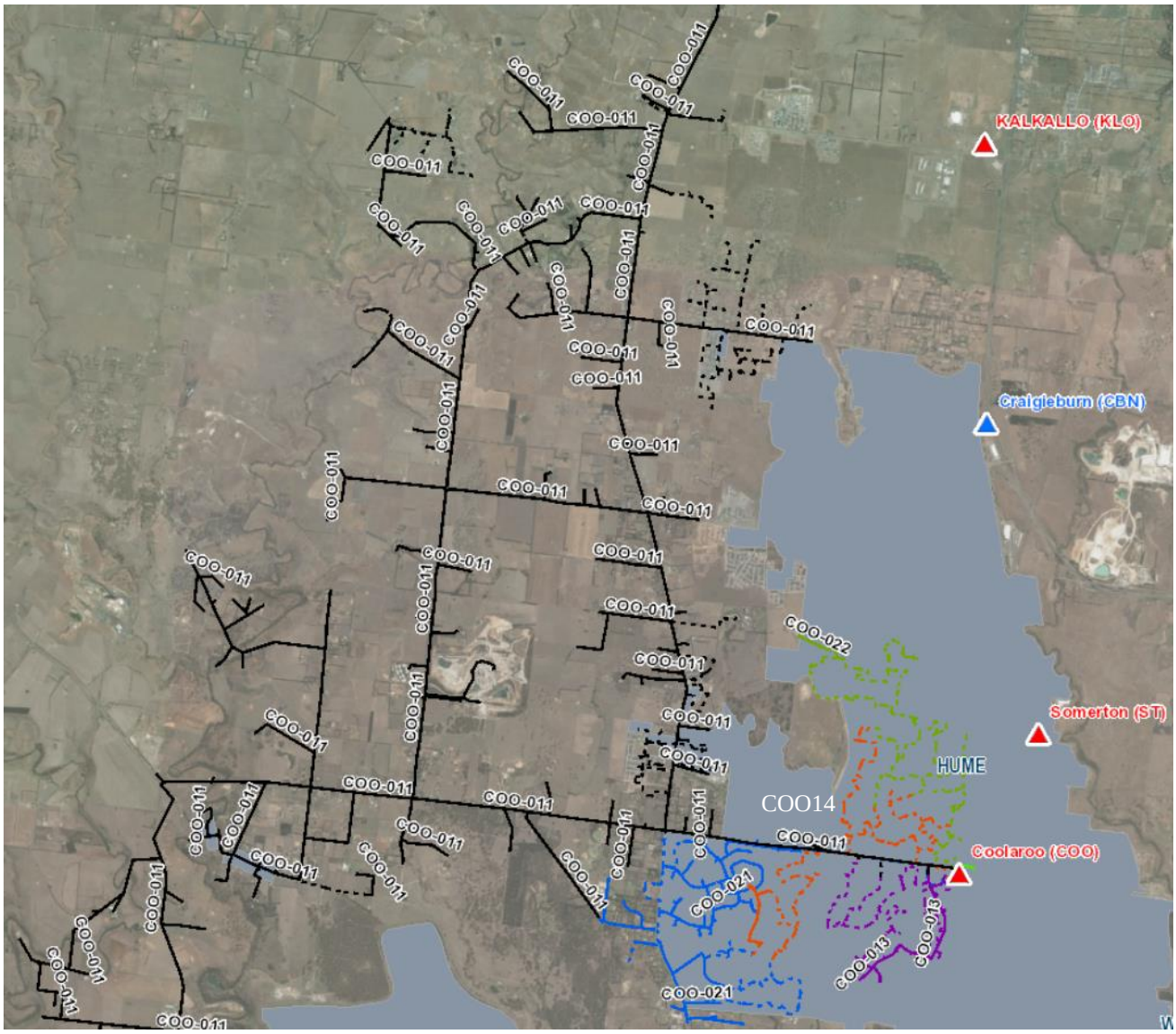


Table 4.2 shows the capacitance of each 22kV COO feeder as per information received from Jemena.

Table 4.2: 2019 Co of COO ZSS 22kV feeders

Feeder	Co (A)	Underground (km)	Overhead (km)	Comments
COO-11	105	36.7	133.3	Heavily loaded
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
COO-23	0	0	0	Future
COO-24	0	0	0	Future
TOTAL	**320**	**99.8**	**156.7**	

It is evident from Table 4.2 that the existing 320A Co at COO ZSS cannot be accommodated by two REFCLs which can at maximum accommodate 200A Co. In addition, network Co is forecasted to increase to 410A by 2029 due to network growth required to supply the Melbourne northern growth corridor, which will further exacerbate the high Co issue. See Figure 4.6 for the growth areas.

We note that there are three HV customers supplied from COO ZSS, two in HBRA and one in LBRA. These customers are also required to be compliant with the Regulations. All options considered in this report will facilitate the HV customers to be compliant (REFCL protected or covered by an exemption). Costs that may be incurred by these customers, i.e. to harden their network, have not been included in the options assessment.

4.3 OVERVIEW OF BOTH KLO AND COO ZSS NETWORKS

Both networks need to be considered holistically to ensure the selected option addresses the need at KLO and COO ZSS which:

- is in the best interest of customers
- does not result in unintended consequences
- is the lowest cost of compliance for both AusNet Services and Jemena Electricity Networks by capitalising on synergies
- addresses challenges at both ZSS such as high Co issues, future network growth and land constraints.

Figure 4.5 shows the existing COO and KLO ZSS network areas with the grey areas representing LBRA. Notably:

- COO-11 feeder (represented by the black line) supplies a wide area which extends to KLO-22 (represented by the purple line) and KLO-13 (represented by the red line).
- KLO-14 (represented by the green line) is a long overhead line that extends into hilly and forested HBRA area.

Figure 4.5: COO and KLO ZSS 22kV network area

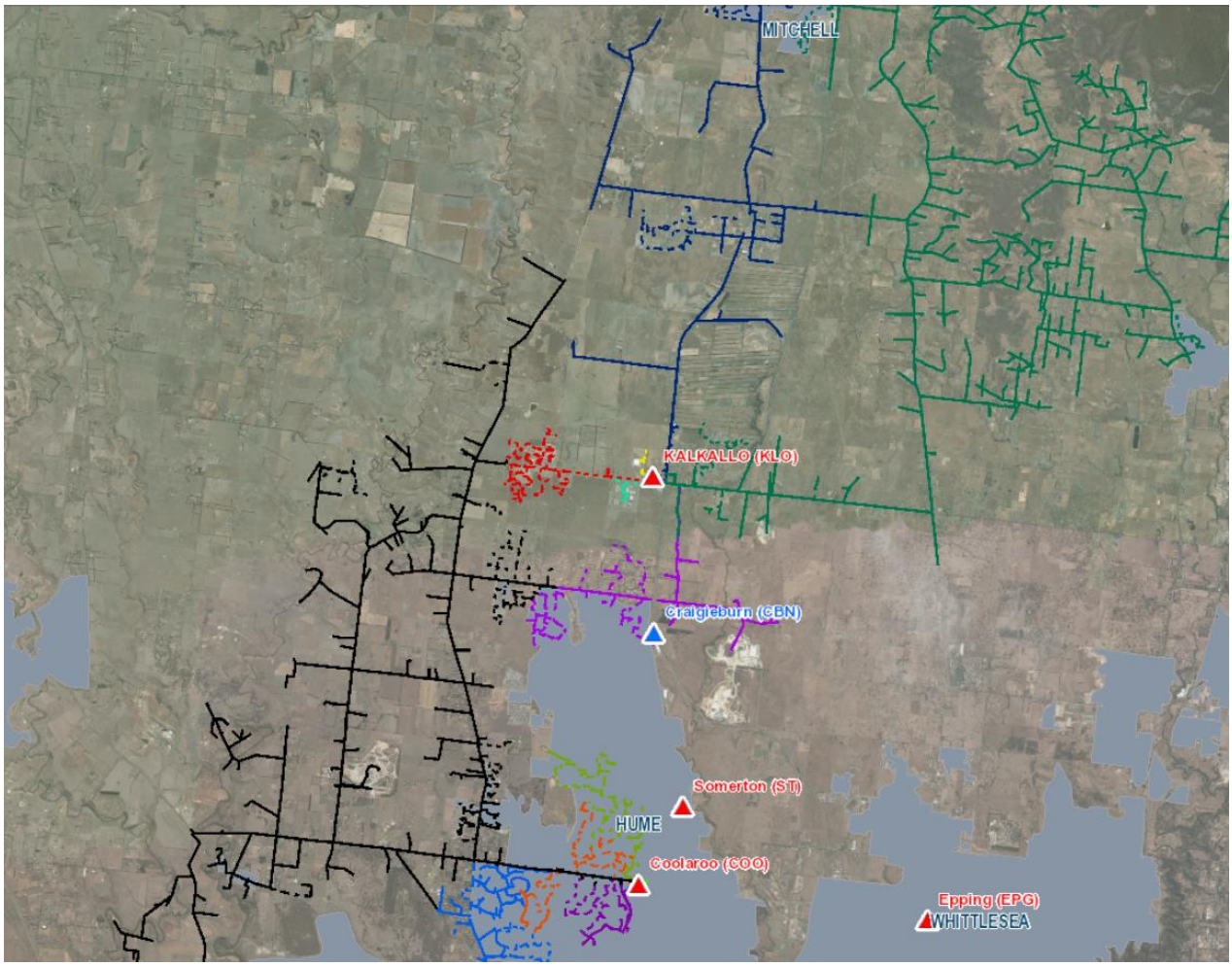


Figure 4.6: Growth areas in KLO and COO ZSS areas

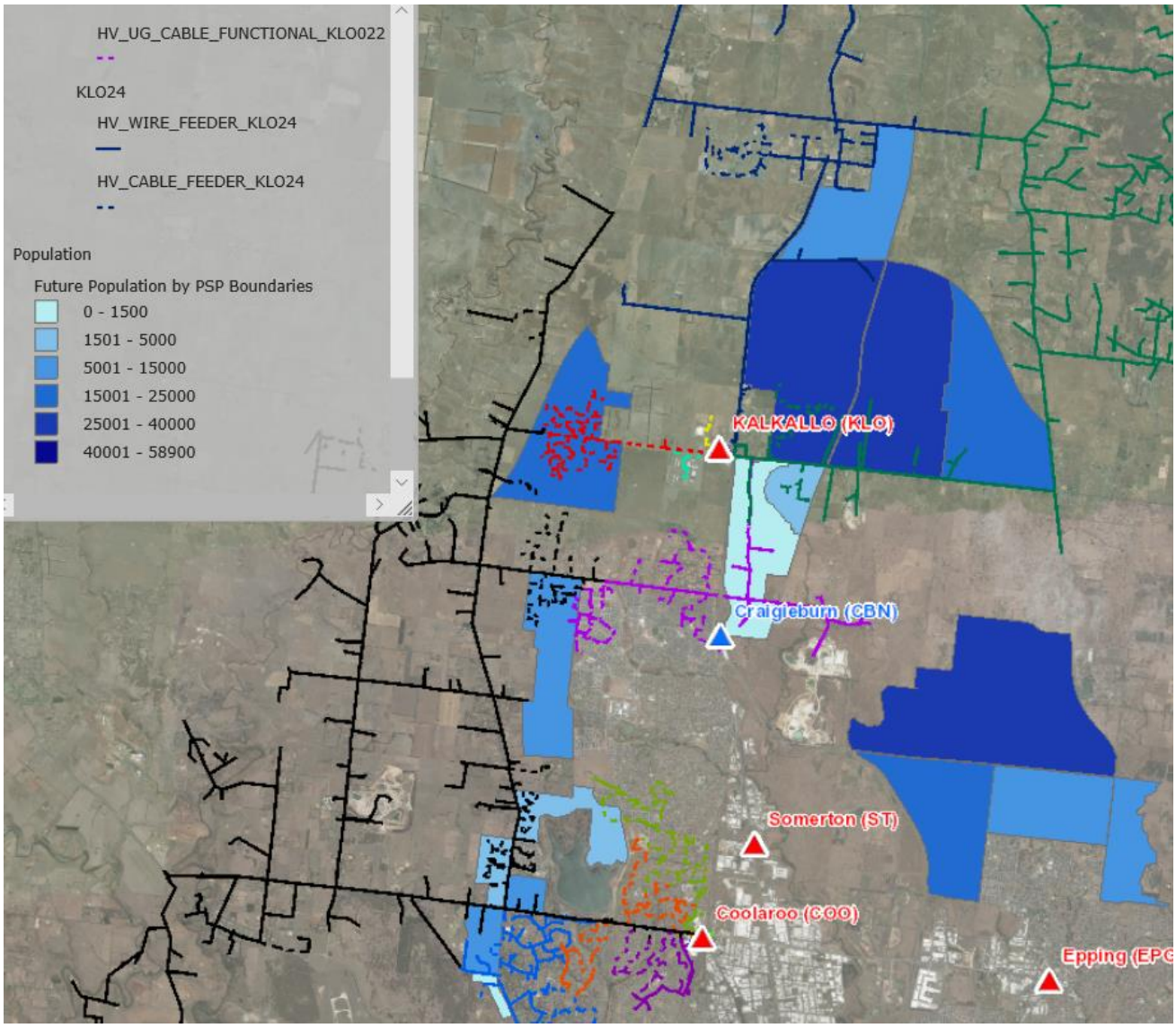


Figure 4.6 shows the forecast growth in the COO and KLO areas. The deeper the blue, the higher the expected growth. It is evident from Figure 4.6 that the area surrounding KLO ZSS, particularly areas supplied by KLO-13 (represented by red lines), KLO-14 (represented by green lines) and KLO-24 (represented by blue lines), will face significant growth.

4.4 NETWORK CONSTRAINTS

4.4.1 HIGH FUTURE NETWORK CAPACITIVE CURRENT

Significant residential development is driving the forecast growth in the KLO ZSS area. These new residential estates will have a predominately underground cable reticulation system. As underground cables typically have a higher capacitance than overhead lines by an order of approximately 100 times, the increase in underground cables will significantly increase the Co experienced at KLO ZSS in the future.

Table 4.3 shows the total existing Co and 2030 forecast Co for KLO and COO ZSS as estimated by Jemena Electricity Networks and AusNet Services. It demonstrates the challenge in meeting the regulatory compliance with both the existing and forecast Co at KLO and COO ZSS.

The existing Co requires the installation of 7 REFCLs across 4 ZSSs due to the limitations imposed by the REFCL technology. This means two new ZSSs would need to be built to meet this requirement if alternative network configurations were not considered. The installation of 9 REFCLs across 5 ZSSs in 2030 is driven by Co rather than demand (i.e. capacitance limit of REFCL is reached before transformer capacity is exceeded). The continued residential growth is forecast to continue through to 2050, which would result in additional new REFCL protected zone substations being required. This is clearly not in the best interest of customers from an economic perspective. Hence, an innovative solution is required across both AusNet Services and Jemena Electricity Networks' networks.

Table 4.3: Overview of KLO and COO ZSS

ZSS	Existing Co (A)	2030 forecast Co (A)	% UG	% OH
KLO	321	424	25%	75%
COO	320	410	39%	61%
Total	641	834		
No. of REFCLs required (100A Co per REFCL)	7	9		
No. of ZSS (2 REFCLs per ZSS)	4	5		

4.4.2 LIMITED ABILITY TO TRANSFER TO NEIGHBOURING ZSS

AusNet Services' Kilmore South (KMS) ZSS and Jemena Electricity Networks' Sunbury (SBY) ZSS are the two zone substations that are immediately adjacent to KLO and COO ZSS respectively. Both zone substations have limited capacity to accept KLO and COO feeder transfers.

KMS ZSS is a single transformer substation with a REFCL installed. KMS ZSS has an existing Co of 70A. Thus, KMS ZSS can only accept a maximum of 30A Co to avoid exceeding its ASC limit. In addition, the significant distance of KMS ZSS from the load centre of KLO ZSS may present loading issues if KLO feeders are transferred to KMS ZSS.

Based on Jemena Electricity Networks' 2018 Distribution Annual Planning Report (DAPR), SBY ZSS has insufficient back-up transfer capacity due to the vast supply area. It has exceeded its N rating on maximum demand days and requires load to be transferred away to other zone substations to ensure no loss of supply to customers. In addition, SBY is not a Scheduled zone substation, hence, transferring any COO feeders to SBY ZSS is not feasible due to capacity constraints and the Regulations.

The neighbouring zone substations of Somerton (ST) and Broadmeadows (BD) are not Scheduled and hence cannot be used to transfer load to manage capacitive current.

4.4.3 LIMITED AVAILABILITY OF LAND

There is limited availability of land in the areas surrounding KLO and COO ZSS for acquisition to install equipment to meet the compliance requirement. It is evident from Figure 4.6 that large areas surrounding KLO ZSS have been earmarked for development which limits potential locations for equipment installation. The urban area surrounding COO ZSS also presents similar land availability issue.

The actual locations that have been identified for isolation transformers in order to achieve the required capacitive current reduction are shown on maps in section 7.2. There is very limited ability to change the locations without significantly increasing cost through the need for additional underground cable or preventing the required capacitive current reduction from being achieved.

Land acquisition in these areas would require significant negotiation and community consultation, particularly in the residential areas which are a significant part of the COO and KLO supply areas. This will increase risk to the project cost and ability to implement the project to achieve compliance within the timeframe required by the Regulations.

4.4.4 66KV SUB-TRANSMISSION LINE CAPACITY CONSTRAINTS

The area surrounding KLO ZSS and west of COO ZSS are supplied from AusNet Services' 66kV sub-transmission lines, which are represented by the brown and cyan line in Figure 4.7.

AusNet Services advised on 18 July 2019 that the SMTS-KMS 66kV line (which is represented by the brown line west of COO ZSS heading north past KLO ZSS) is reaching its capacity limit and suffers from voltage collapse issues. This means the SMTS-KMS 66kV line cannot accommodate any additional load.

Based on advice from AusNet Services, WSP has assumed the 66kV lines supplying KLO ZSS – the SMTS-KLO 66kV line (represented by the cyan line) and the KLO-DRN 66kV (represented by the maroon line east of KLO ZSS) have adequate capacity to supply a new ZSS.

Figure 4.7: 66kV sub-transmission network in KLO and COO ZSS area

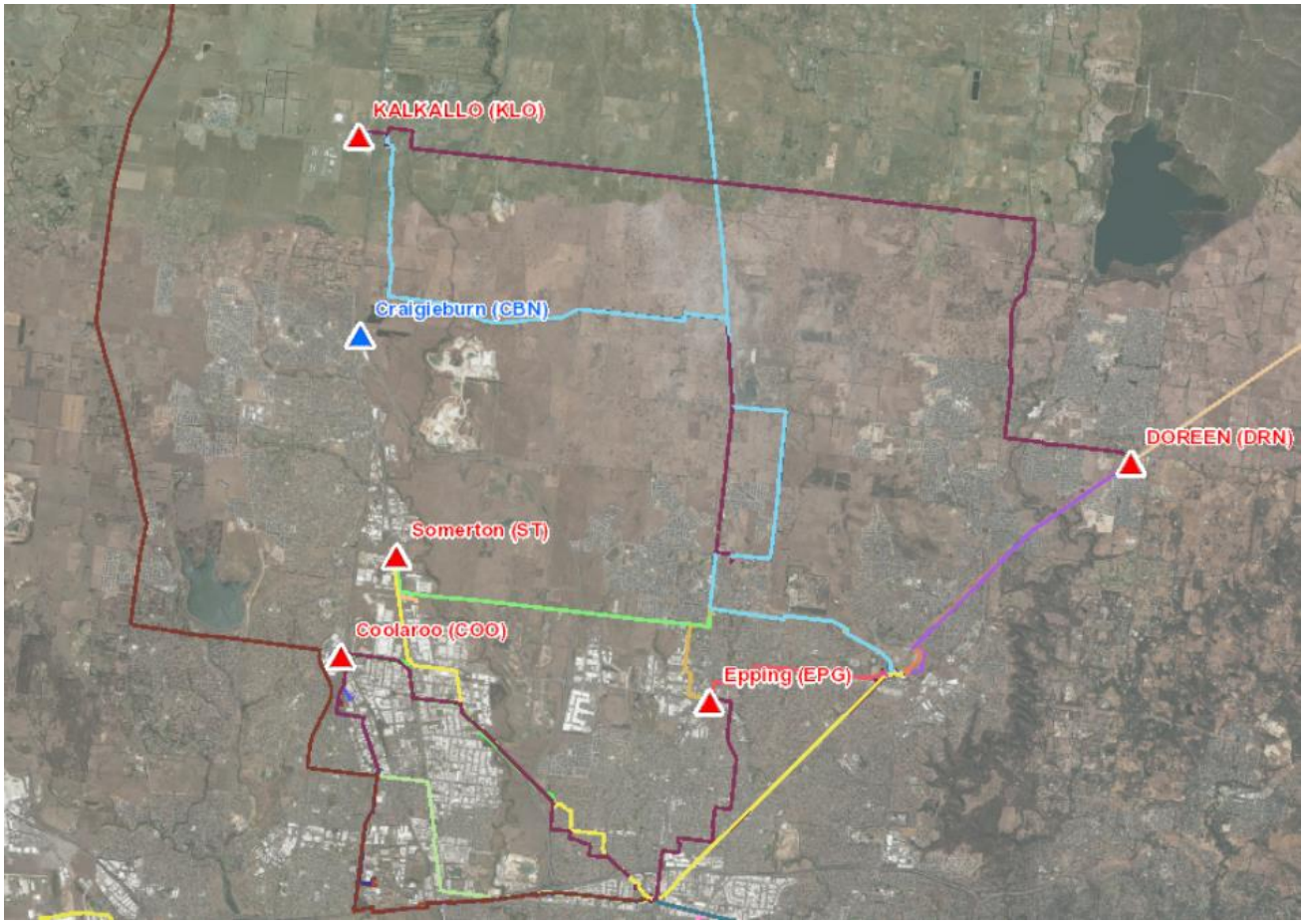
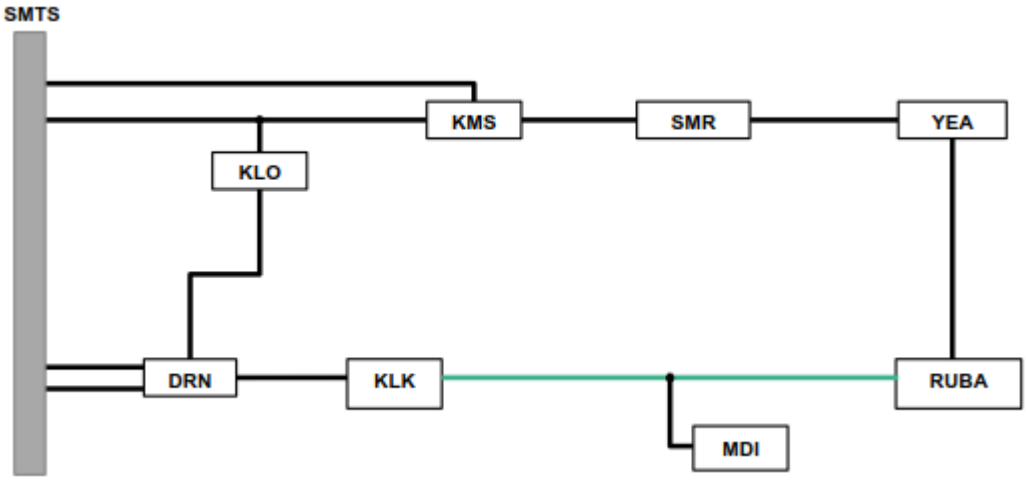


Figure 4.8 shows the single line diagram schematic of the AusNet Services 66kV sub-transmission line loop supplying the area. It shows that there are 8 zone substations on the loop. The 2018 DAPR states that the capacity issues will result in voltage collapse in the loop if the line between KMS and SMR is out of service. WSP has validated this with the PSSE model provided by AusNet Services. Connecting an additional zone substation on this loop will exacerbate the issues and will increase the supply risk to customer.

Figure 4.8: 66kV sub-transmission line loop (extracted from Figure 21 of AusNet Services Distribution Annual Planning Report 2019 -2023)



5 BASIS OF THE STUDY

This section describes the methodology used to complete this study, the input information received from AusNet Services and Jemena Electricity Networks or sourced from publicly available sources, and the key assumptions made.

5.1 METHODOLOGY

WSP undertook the following steps to identify the preferred technically and economically feasible option to address the regulatory obligation at KLO and COO ZSS:

1. Gathered all potential options from AusNet Services and Jemena Electricity Networks
2. Developed additional potential options not yet considered based on holistic consideration of the network area
3. Assessed the credibility of each potential option

   National Electricity Rules chapter 5.15.2 defines a credible option as an option that

   - addresses the identified need;
   - is commercially and technically feasible; and
   - can be implemented in sufficient time to meet the identified need.
4. Shortlist the credible options
5. High level assessment of the shortlisted credible options to identify the final options
6. Assess the final options based on the option assessment framework described in section 7.1
7. Perform multicriteria analysis of the final options
8. Select the preferred option based on results of the multicriteria analysis

5.2 INPUTS

This study was based on technical and cost inputs from AusNet Services and Jemena Electricity Networks. A complete list of data provided is set out in Appendix A.

5.3 ASSUMPTIONS

The study has been underpinned by the following key assumptions. The assumptions were based on information provided and WSPs experience with distribution network assets:

- System studies were conducted for AusNet Services' 66kV network for all new ZSS's proposed to be supplied from AusNet Services' 66kV network.
- Jemena's 2018 DAPR shows that there is sufficient capacity on their existing 66kV loop to supply new ZSS's proposed to be connected to their network.
- 22kV system modelling were not conducted for feeder transfers. However, voltage drop calculations for new long feeder trunks were undertaken.
- For balancing the capacitive current while performing feeder transfer, we have assumed capacitive currents for underground cable sections and overhead lines as 3.36A/km and 0.072A/km respectively based on Jemena's inputs
- Economic analysis was based on least cost

- All cost estimates are shown in 2019 dollars
- AusNet Services advised remote REFCL technology is feasible and will be able to meet the Required Capacity requirements.
- AusNet Services advised the Tyree 22kV 7.5MVA isolation transformer with dimensions 6m (L) × 3.4m (W) × 3.1m (H) will be able to isolate underground 22kV feeder sections from the ZSS. The footprint of this isolation transformer is 11.5m (L) × 5.5m (W) × 3.1m (H).
- Our analysis excludes REFCL operation under zone substation N-1 conditions. It assumes that should a bus or ZSS power transformer be out of service, the feeders supplied by that bus will be offline. This is due to Co constraints of the REFCL not allowing for one transformer/REFCL pair to supply more than one bus
- The analysis included consideration of reliability of the network and the ability to backfeed to resupply customers in the different options.
- The average unit costs provided by AusNet Services and Jemena Electricity Networks were used, except for REFCL and isolation transformer costs which were based on AusNet Services' experience with REFCLs.
- The unit cost for 22kV covered conductors was assumed to be $400/m.
- The unit cost for HV aerial bundled conductors (ABC) was assumed to be $500/m.

6 OPTIONS IDENTIFICATION

This section lists all the options identified by AusNet Services, Jemena Electricity Networks and WSP and shortlists the credible options for further evaluation.

6.1 AUSNET SERVICES OPTIONS

Table 6.1 summarises the options provided by AusNet Services.

Table 6.1: AusNet Services' options

Option number	Option description	Detailed description
1	Build a new REFCL Craigieburn (CBN) ZSS with two transformers	Build a new REFCL CBN ZSS with two transformers and offload KLO and COO feeders to CBN ZSS. Install 2 REFCLs at KLO, COO and CBN ZSS
2	Build a new REFCL Mickleham (MHM) ZSS with two transformers	Build a new REFCL MHM ZSS with two transformers and offload KLO and COO feeders to MHM ZSS. Install 2 REFCLs at KLO, COO and MHM ZSS.
3	Build a new non-REFCL single transformer KLO West (KLW) ZSS	Build a new non-REFCL Kalkallo West (KLW) ZSS with one transformer and transfer KLO-13 and KLO-21 to KLW ZSS. Install 6 isolation transformers on the 22kV network. Install 2 REFCLs at each KLO and COO ZSS. Seek exemption for KLW ZSS.
4	Build a new REFCL KLW ZSS with two transformers	Build a new REFCL KLW ZSS and transfer KLO-14 and KLO-24 to this ZSS. Install 2 REFCLs at each KLW and COO ZSS. Install 5 isolation transformers. KLO is a non-REFCL ZSS. Seek exemption for KLO ZSS.
5	Install third transformer and 3 REFCLs at ZSS	Install a third transformer and 3 REFCLs at both KLO and COO ZSS
6	Install remote REFCLs in HBRA	Install isolation transformers with REFCL functionality for each high bushfire risk feeder.
7	Install isolation transformers on underground feeders and REFCLs at ZSS	Install an isolation transformer for each underground feeder and predominately underground feeder. This will require undergrounding of the short overhead sections of predominately underground feeders. Seek exemption for underground feeders. Install 2 REFCLs at both KLO and COO ZSS
8	Split ZSS bus to REFCL and non-REFCL bus	Split the two buses at both ZSS's into a REFCL and non-REFCL protected bus. Transfer all overhead feeders to the REFCL bus. Transfer all underground feeders and predominately underground feeders to the non-REFCL bus. This will require undergrounding of the short overhead sections of predominately underground feeders. Seek exemption for underground feeders.
9	Offload KLO ZSS Co to COO ZSS	Transfer some KLO feeders to COO ZSS and install REFCLs at KLO and COO
10a	Cover all overhead conductors	Cover all overhead sections of KLO and COO feeders and seek exemption.
10b	Replace all overhead conductors with HV ABC	Replace all overhead sections of KLO and COO feeders with HV aerial bundled conductors (ABC) and seek exemption.

6.2 JEMENA ELECTRICITY NETWORKS OPTIONS

Table 6.2 summarises the options provided by Jemena Electricity Networks.

Table 6.2: Jemena Electricity Networks options

Option number	Option description	Detailed description
11	Build a new REFCL Kalkallo North (KLN) ZSS with two transformers	Build a new REFCL KLN ZSS with two transformers and two REFCL. Transfer KLO-14, KLO-22 and KLO-24 to KLN ZSS. Seek REFCL exemption for KLO ZSS which will supply only underground feeders. Install 2 REFCLs at COO ZSS. Transfer underground sections of COO-11, COO-13, COO-14, COO-21 and COO-22 to ST ZSS. Seek exemption for all underground feeders.
12	Install third transformer and 3 REFCLs at ZSS	Install a third transformer and 3 REFCLs at COO ZSS. Build a new REFCL KLN ZSS. KLO is a non-REFCL ZSS with only underground feeders. Install a third transformer at KLO in the future to accommodate load growth. Seek exemption for KLO ZSS.
13	Build a new non-REFCL MHM ZSS with two transformers	Build a new non-REFCL MHM ZSS with two transformers. MHM ZSS will be supplied from ST ZSS. Transfer KLO-21 and underground sections of COO-11, KLO-13 and KLO-22 to MHM ZSS. Install 2 REFCLs at KLO ZSS. Install 2REFCLs at COO ZSS. Transfer underground section of COO-11, COO-13, COO-14, COO-21 and COO-22 to ST ZSS. Seek exemption for all underground feeders.
14	Build a new non-REFCL CBN ZSS with transfers to ST ZSS	Build a new non-REFCL CBN ZSS with two transformers. Transfer KLO-13 and KLO-21 and underground sections of COO-11 and KLO-22 to CBN ZSS. Install 2 REFCLs at KLO ZSS. Install 2 REFCLs at COO ZSS. Transfer underground section of COO-11, COO-13, COO-14, COO-21 and COO-22 to ST ZSS. Seek exemption for all underground feeders.
15	4 REFCL ZSS - Build a new REFCL Greenvale (GVE) ZSS and KLN ZSS	Build a new REFCL Greenvale (GVE) ZSS with two transformers and 2 REFCLs. GVE ZSS will be supplied by extending the 66kV lines from COO ZSS. Transfer COO-11, and COO-21 to GVE. Install 2 REFCLs at KLO ZSS. Install 2 REFCLs at COO ZSS. Build a new REFCL KLN ZSS with two transformers and 2 REFCLs. KLN ZSS will be supplied from the SMTS-KLO-KMS 66kV line. Transfer KLO-14 and part of KLO-24 to KLN
16	2 REFCL ZSS - Build a new REFCL GVE ZSS and KLN ZSS	Build a new REFCL Greenvale (GVE) ZSS with a single transformer and single REFCL. GVE ZSS will be supplied by extending the 66kV lines from COO ZSS. Transfer COO-11, overhead section of COO-21 and KLO-22 to GVE. Seek exemption of COO ZSS as feeders supplied by COO ZSS are in LBRA. Build a new REFCL KLN ZSS with two transformers and two REFCL. KLN will be supplied from the KLO-DRN 66kV line. Transfer KLO-14 and KLO-24 to KLN. Seek exemption of KLO ZSS as it supplies all underground feeders.
17	Underground all HV overhead conductors in HBRA	Underground all HBRA HV overhead conductors and pole top substations to kiosks. Seek exemption for all LBRA HV overhead conductors and underground cables in HBRA and LBRA.

6.3 WSP OPTIONS

WSP also considered the following additional options in Table 6.3.

Table 6.3: WSP's options

Option number	Option description	Detailed description
21	Build a new non-REFCL CBN ZSS with isolation transformers	Build a new non-REFCL CBN ZSS with two transformers. Transfer all KLO and COO underground and predominately underground feeders to CBN. Underground all overhead sections on feeders transferred to CBN. Install 2 REFCLs at KLO and COO ZSS. Seek exemption for CBN ZSS.
22	Build a new REFCL MHM ZSS	Build a new REFCL MHM ZSS with two transformers. MHM ZSS is supplied by SMTS-KMS 66kV line. Install 2 REFCLs at each KLO and MHM ZSS. Transfer KLO-22, COO-21 and most of COO-11 to MHM ZSS. Transfer underground feeders KLO-13 and KLO-21 to COO ZSS. COO is a non-REFCL ZSS and supplies only underground feeders. Seek exemption for COO ZSS.
23	Transfer feeders to KMS and SBY ZSS	Transfer KLO-14 and KLO-24 to KMS ZSS. Transfer COO-11 and COO-21 to SBY ZSS. Install REFCLs at SBY ZSS. KMS already has a REFCL. Seek exemption for KLO and COO ZSS.
24	Targeted installation of isolation transformers and remote REFCLs.	Install isolation transformer for KLO-13. Install isolation transformer and remote REFCL for KLO-24 and COO-11. Install 2 REFCLs at KLO ZSS. Seek exemption for COO ZSS as the rest of COO feeders are in LBRA.
25	Exemption for KLO and COO ZSS	Seek exemption for KLO and COO ZSS due to urban locality and network similarity with SBY ZSS. SBY ZSS is not mandated to be REFCL protected.
26	Underground all KLO and COO feeders	Underground all overhead KLO and COO feeders and seek exemption for KLO and COO ZSS.

6.4 NON FEASIBLE OPTIONS

WSP undertook a first pass feasibility assessment of all identified options to shortlist potentially feasible options for further technical, economic, compliance and deliverability assessment. As per the RIT-D guidelines, appropriate levels of analysis were undertaken in this first pass feasibility assessment. This means if an option was either found to be non-credible for a criterion or clearly unlikely to be cost competitive compared with other options, the option was discarded and not considered further. Table 6.4 shows non feasible options and the reasons why the option was deemed non feasible.

Table 6.4: Non-credible options

Option number	Option description	Not feasible aspect	Reason option is non feasible
1 and 2	Build a new REFCL CBN or MHM two transformer ZSS	Not technically feasible	Existing Co at KLO and COO ZSS requires 7 REFCLs across 4 ZSS. These options only provide 6 REFCLs and does not consider future load requirements.
5 and 12	Install third transformer and 3 REFCLs at KLO and/or COO ZSS	Not technically feasible	Currently not feasible to synchronise 3 REFCLs at a ZSS as a software solution for a 3 REFCLs ZSS is currently unavailable.
6	Install remote REFCLs in HBRA	Does not address need	High bushfire risk feeders are overhead feeders which, generally has lower Co than underground feeders. Hence, this option does not address current Co issues and future Co growth from future underground feeders.
8	Split ZSS bus to REFCL and non-REFCL bus	Not technically feasible	The shared earth at ZSS makes this option not feasible. In addition, the loss of one transformer will result in either the REFCL bus not being protected or the REFCL

Option number	Option description	Not feasible aspect	Reason option is non feasible
			experiencing the whole ZSS Co of over 300A with the bus tie closed.
9	Offload KLO ZSS Co to COO ZSS	Not technically feasible	Based on Jemena's 2018 Distribution Annual Planning Report (DAPR), COO ZSS is overloaded with 10% POE and 50% POE summer maximum demand conditions already exceeding the substation N-1 capacity. In addition, COO ZS has Co issues (i.e. too high Co for 2 REFCLs at the ZSS). Hence, KLO feeders cannot be transferred to COO ZSS.
10a	Cover all overhead conductors	Not commercially feasible	At an assumed unit rate of $400/m, it will cost $197M to replace 493km of bare overhead conductors with covered conductor in KLO and COO area. This is not economical.
10b	Replace all overhead conductors with HV ABC	Not commercially feasible	At an assumed unit rate of $500/m, it will cost $247M to replace 493km of overhead conductors with ABC in KLO and COO area. This is not economical.
13	Build a new non-REFCL two transformers MHM ZSS	Not commercially feasible	Although MHM ZSS is located close to SMTS-KMS 66kV line, it cannot be supplied from this 66kV line due to the capacity issue. Hence, MHM ZSS has to be supplied from ST ZSS. It entails two new 11km 66kV overhead lines to be built, which is forecast to cost $19M. This results in total cost of $83.5M (in 2019 dollars) makes this option not economical. In addition, the lengthy process to build these 66kV lines (i.e. easement approval, design and build) makes this option less likely to be compliant by 1 May 2023.
17	Underground all HV overhead conductors in HBRA	Not commercially feasible	At a unit rate of $1,000/m, it will cost $471M to underground 471km of HBRA overhead conductors in KLO and COO area. This is not economical.
22	Build a new REFCL MHM ZSS	Not technically feasible	SMTS-KMS 66kV line is unable to supply MHM ZSS due to capacity issue.
23	Transfer feeders to KMS and SBY ZSS	Not technically feasible	Based on Jemena's DAPR, SBY ZSS has insufficient back-up transfer capacity due to the vast supply area. It has exceeded its N rating on maximum demand days and requires load transfers to ensure no load reduction. In addition, SBY ZSS is not a Scheduled zone substation, hence, transferring COO-11 to SBY ZSS is not feasible. KMS can only accept at maximum of 30A Co which is less than the sum of KLO-14 and KLO-24 Co and will not significantly reduce the Co at KLO ZSS. There may be load issues with KMS supplying KLO-14 as KLO-14 feeder load is predominately located closer to KLO.
25	Exemption for KLO and COO ZSS	Unacceptable from regulatory perspective	This will require exemption from the Victorian government and ESV. It will mostly likely not be accepted.
26	Underground all KLO and COO feeders	Not commercially feasible	At a unit rate of $1,000/m, it will cost $493M to underground 493km of overhead conductors in KLO and COO area. This is not economical. Cost to underground KLO-14, which is a high bushfire risk feeder as it supplies the area near a national park, is $249M.

6.5 SUMMARY OF OPTIONS

Table 6.5 summarises all the identified potentially credible options based on the initial feasibility assessment. Only potentially feasible options will be taken forward for assessment in section 7.

Table 6.5: Summary of all options

AusNet Services options	Jemena Electricity Networks options	WSP options
✗ Option 1: Build a new REFCL two transformer CBN ZSS	✓ Option 11: Build a new REFCL two transformers KLN ZSS	✓ Option 21: Build a new non-REFCL CBN ZSS with isolation transformers
✗ Option 2: Build a new REFCL two transformer MHM ZSS	✗ Option 12: Install third transformer and 3 REFCLs at ZSS	✗ Option 22: Build a new REFCL MHM ZSS supplied
✓ Option 3: Build a new non-REFCL single transformer KLW ZSS	✗ Option 13: Build a new non-REFCL two transformer MHM ZSS	✗ Option 23: Transfer feeders to KMS and SBY ZSS
✓ Option 4: Build a new REFCL two transformer KLW ZSS	✓ Option 14: Build a new non-REFCL CBN ZSS with transfers to ST ZSS	✓ Option 24: Targeted installation of isolation transformers and remote REFCLs
✗ Option 5: Install third transformer and 3 REFCLs at ZSS	✓ Option 15: 4 REFCL ZSS - Build a new REFCL GVE ZSS and KLN ZSS	✗ Option 25: Exemption for KLO and COO ZSS
✗ Option 6: Install remote REFCLs in HBRA	✓ Option 16: 2 REFCL ZSS - Build a new REFCL GVE ZSS and KLN ZSS	✗ Option 26: Underground all KLO and COO feeders
✓ Option 7: Install isolation transformers on underground feeders and REFCLs at ZSS	✗ Option 17: Underground all HV overhead conductors in HBRA	
✗ Option 8: Split ZSS bus to REFCL and non-REFCL bus		
✗ Option 9: Offload KLO ZSS Co to COO ZSS		
✗ Option 10a: Cover all overhead conductors		
✗ Option 10b: Replace all overhead conductors with HV ABC		

Legend:

✓ Credible option

✗ Not credible option

7 OPTIONS ASSESSMENT

The nine potentially feasible options identified in Table 6.5 were short-listed for a high level technical, compliance and cost assessment. This high level assessment is summarised in Table 7.1. All nine options were found to be technically feasible with approximate estimated high level costs shown in Table 7.1.

Table 7.1: Short-listed feasible option

Option no.	Option description	New ZSS	KLO ZSS	COO ZSS	Isolation transformer	Objective of option	Require exemption	Approx. costs
3	Build a new non-REFCL single transformer KLW ZSS	KLW – Non-REFCL	2 REFCLs	2 REFCLs	13	REFCL protection for all overhead conductors. Seek exemption for all underground cables.	Yes	$70 - $80M
4	Build a new REFCL KLW ZSS with two transformers	KLW – 2 REFCLs	Non-REFCL	2 REFCLs	9	REFCL protection for all overhead conductors. Seek exemption for all underground cables.	Yes	$70 - $80M
7	Install isolation transformers on underground feeders and REFCLs at ZSS	N/A	2 REFCLs	2 REFCLs	18	REFCL protection for all overhead conductors and sections of underground cables. Seek exemption for all isolated underground cables.	Yes	$55 – $65M
11	Build a new REFCL KLN ZSS with two transformers	KLN – 2 REFCLs	Non-REFCL	2 REFCLs	1	REFCL protection for all overhead conductors. Seek exemption for all underground cables.	Yes	$70 - $80M
14	Build a new non-REFCL CBN ZSS with transfers to ST ZSS	CBN – Non-REFCL	2 REFCLs	2 REFCLs	4	REFCL protection for all overhead conductors. Seek exemption for all underground cables.	Yes	$70 - $80M
15	4 REFCL ZSS - Build a new REFCL GVE ZSS and KLN ZSS	GVE – 2 REFCLs KLN – 2 REFCLs	2 REFCLs	2 REFCLs	0	REFCL protection for all overhead conductors and underground cables. No exemption required.	No	$121M
16	2 REFCL ZSS - Build a new REFCL GVE ZSS and KLN ZSS	GVE – 1 REFCL KLN – 2 REFCLs	Non-REFCL	Non-REFCL	1	REFCL protection for all HBRA overhead conductors. Seek exemption for all LBRA overhead conductors. Seek exemption for all underground cables.	Yes	$75 - $85M
21	Build a new non-REFCL CBN ZSS with isolation transformers	CBN – Non-REFCL	2 REFCLs	2 REFCLs	8	REFCL protection for all overhead conductors. Seek exemption for all underground cables.	Yes	$70 - $80M
24	Targeted installation of isolation transformers and remote REFCLs	N/A	2 REFCLs 1 remote REFCL	1 remote REFCL	7	REFCL protection for all HBRA overhead conductors and sections of underground cables. Seek exemption for all LBRA overhead conductors and completely cabled feeders.	Yes	$50 – $60M

To be deemed compliant, all options except Option 15 require exemptions from the Act and Regulations. However, Option 15 has the highest estimated cost at approximately $120M, which is at least 50% ($40M) more expensive than the other options without providing any additional benefits to the network or customers.

Hence, in the best interest of customers, AusNet Services and Jemena Electricity Networks sought guidance on the acceptability of options requiring exemptions from Australian Energy Regulator (AER), Energy Safe Victoria (ESV) and Department of Environment, Land, Water and Planning (DELWP) in a meeting on 2 August 2019. AER is responsible for approving funding for the selected option. ESV and DELWP are responsible for assessing compliance and granting exemption to the Act and Regulations.

The meeting identified the following concerns:

1. The AER may consider options that require exemptions (based on precedent exemptions), however, in the absence of an exemption, the number of solutions available to AusNet Services and Jemena Electricity Networks is significantly reduced.
2. There is existing precedence for underground cable exemptions
3. Powercor is currently applying for an exemption for a ZSS nominated in Schedule 2 of the Regulations but has not been granted the exemption at the time of issuing this report.
4. Exemptions for bare overhead line in LBRA would need to be individually assessed, the process would be lengthy and are unlikely to be accepted.
5. The ESV indicated possible issues with an excessive number of isolation transformers scattered around the network from the perspective of long term maintainability, increased electrical losses, operational constraints, introduction of an additional reliability risk, and deteriorated visual amenity.
6. The AER is seeking justification from the perspective of whole lifecycle costs and/or prudent engineering practices for why the least cost option is not selected

Based on Energy Safe Victoria's (ESV) verbal feedback during the meeting on 2 August 2019 in regards to the operational constraints posed by isolation transformers, the options have been reviewed to take into account back feeding requirements to maintain existing operational configuration under contingency events (which is consistent with the network planning standards). This has resulted in an increase in the number of isolation transformers required for all options.

Based on the disadvantages of options and the high level guidance from the meeting, Options 3, 4, 14, 16, 21 and 24 were not taken forward for further detailed assessment. The reasons are set out below.

- Options 3 and 4 require a high number of isolation transformers (i.e. 13 and 9 respectively) which is not desirable based on guidance from the ESV (item 5 above). Both options are not the least cost options at approximately $79M and $78M respectively. In addition, land applications and land subdivision processes are currently underway in the KLW ZSS area. This increases land acquisition risk and visual amenity issues for KLW ZSS. Hence, both options have been discarded.
- Options 14 and 21 entail the building of a new non-REFCL CBN ZSS which will supply existing and future underground cables. CBN ZSS, which is located south of KLO ZSS, is further from the future underground growth area which will be located north-east and west of KLO ZSS. This will result in higher future 22kV cabling costs. Although the CBN site has already been acquired by Jemena Electricity Networks, these options are not expected to be the least cost options at $77M for Option 14 and $79M for Option 21 and have been discarded on this basis.
- Option 16 entails the building of two new ZSSs (a Greenvale ZSS and Kalkallo North ZSS) and requires the exemption of all LBRA overhead conductors which is unlikely to be accepted based on guidance from the ESV (item 4 above). This option poses high land acquisition risk as it requires the acquisition of two large parcels of land. In addition, this option is not the least cost option at $83M as it is expected to be approximately $12

million higher than Option 11 involving the construction of only one new ZSS. Hence, this option has been discarded.

- Option 24 requires the exemption of all LBRA overhead conductors and is unlikely to be accepted based on guidance from the ESV (item 4 above). In addition, the remote REFCL proposed in this option presents additional risks as it is unproven technology. Hence, this option has been discarded.

These considerations have resulted in the shortlisting of the final Options 7, 11 and 15 for further detailed assessment because:

- Option 7 has the lowest upfront cost but may require significant future expenditure and complicated network management into the future.
- Option 11 is simpler from a network management perspective and may have low future expenditure. However, it requires higher upfront expenditure.
- Option 15 is the reference case to demonstrate the cost difference with an option that does not require exemptions.

The rest of the section is dedicated to the detailed assessment of Options 7, 11 and 15. Refer to Appendix C for details of the high level assessment of Options 3, 4, 14, 16, 21 and 24.

7.1 OPTION ASSESSMENT FRAMEWORK

A multicriteria analysis was utilised to provide rigour and transparency in the selection of the preferred option. The final three options were assessed against each of the following criteria. The preferred option is the option that consistently ranks the best compared to other options across the following criteria.

1. **Technical feasibility -** assesses whether the option is technically feasible and proposes proven existing technologies/implementations.
2. **Compliance –** assesses the requirements of the option to be deemed compliant such as required exemptions from the Act and Regulations.
3. **Risk** – qualitatively evaluates the risk associated with each option based on the risk posed by the option in comparison to other options. The higher the risk rating, the higher the risk exposure of the option.
4. **Costs** – evaluated on a least cost basis using unit costs provided by AusNet Services and Jemena Electricity Networks and scope of works required to meet the compliance requirements. It assesses both cost to comply by 2023 and whole of lifecycle costs.

These criteria are discussed in the following sections.

7.1.1 TECHNICAL FEASIBILITY ASSESSMENT

This section details the approach to the technical assessment of the final three options. Refer to Appendix B for details of the technical assessment of the original nine shortlisted options.

The technical assessment of the final three options entailed:

- Validating the 66kV sub-transmission line has adequate capacity and voltages are within limits in the model of the current AusNet Services' 66kV system.
- Jemena Electricity Networks 2018 DAPR was relied upon to confirm adequate capacity for zone substations connected to their network.
- Validating the voltage drop on transferred 22kV feeders are within statutory voltage drop limits (as specified in Victorian Electricity Distributors Service & Installation Rules 2014) based on high level calculations,
- Validating transformer capacities are not exceeded based on the 2023 feeder load forecast

- Ensuring the 80A Co per feeder and 100A Co per bus limitations are met. This can be addressed by either installing an isolation transformer at the start of an underground section of the feeder to reduce the feeder Co experienced by the ZSS REFCL or transferring a section of the feeder to reduce feeder Co.
- Whether the option uses proven or unproven technology or configurations.

Two technical feasibility assessments were undertaken for the final three options to ensure compliance is met by 2023 and compliance is maintained until 2026 (the end of the next regulatory period). The outcomes of these technical feasibility assessments are described in the scope of works of each option (i.e. scope of works to comply by 2023 and scope of works to maintain compliance until 2026). Refer to section 7.2 for the scope of works of the three options.

7.1.2 COMPLIANCE ASSESSMENT

Each technically feasible option was assessed for compliance with the Regulations, and the expectation that the required exemptions from the Act and Regulations will be obtained from ESV and Minister for Energy, Environment & Climate Change.

Compliance assessment is based on the exemptions required by the option to be deemed compliant. The compliance risk is based on whether there are precedent cases for the exemptions being sought by the option. Compliance risk is lower for exemptions that have precedent cases. Currently, only underground cable exemptions have been approved. Powercor is currently seeking an exemption for a REFCL nominated ZSS, however, it has not been granted at the time of issuing this report.

This compliance assessment is incorporated in the scope of works of each final option. Refer to section 7.2 for the scope of works of each final option.

7.1.3 RISK ASSESSMENT

Each final option is qualitatively compared against the other options for each risk category. The option that has the lowest total risk or minimises issues compared to the other options will be the preferred option from a risk perspective.

One of the key risks is deliverability risks. Deliverability risk was assessed with respect to the likelihood the option could be installed and commissioned to meet the 1 May 2023 compliance deadline. This does not consider the ability to obtain a time extension through the exemption process. This risk considers factors such as:

- The ability to obtain land in appropriate locations
- Acceptance by the community. For example, residents may oppose infrastructure, particularly the isolation transformers, being installed in the vicinity of their homes. This has been denoted as community risk.

Refer to section 7.3 for details of the risk assessment.

7.1.4 COST ASSESSMENT

In addition to the qualitative assessment of each option on compliance and deliverability risks, a high-level cost assessment for the three final options were undertaken to enable a quantitative approach to ranking the options.

The final three options were evaluated for:

- whole of lifecycle costs; and
- expenditure required to achieve compliance by 2023

To determine the option that is in the long term interest of customers, the whole of lifecycle cost of each option needs to be evaluated to identify the long term least cost to customers. The cost to comply by 2023 demonstrates the expenditure required to achieve regulatory compliance by 1 May 2023. However, the whole of lifecycle cost provides a better comparison between options to maintain compliance as the network grows as it includes future costs which are option dependent and compares the options on a like for like basis. Refer to section 7.4 for details of the whole of lifecycle costs and cost to comply by 2023 of the final options.

7.2 SCOPE OF WORKS ASSESSMENT

This section details and compares the complexity of the scope of works for Options 7, 11 and 15, including the scope of works to comply by 2023 and to maintain compliance until 2026.

7.2.1 OPTION 7 – INSTALL ISOLATION TRANSFORMERS ON UNDERGROUND FEEDERS AND REFCLS AT ZSS

This option is technically feasible and entails installing isolation transformers on underground feeders and installing REFCLs at both KLO and COO ZSS .

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.

Dependency between KLO and COO REFCL-related works

There is no dependency between REFCL-related works required on the KLO and COO networks.

Scope of works by 2023

Based on Energy Safe Victoria's (ESV) verbal feedback during the meeting on 2 August 2019 in regards to the operational constraints posed by isolation transformers, the options have been reviewed to take into account back feeding requirements to maintain existing operational configuration under contingency events (which is consistent with the network planning standards). This has resulted in an increase in the number of isolation transformers required.

Figure 7.1 provides a high-level overview of the scope of works. Refer to Appendix B for details of the technical assessment.

The high level scope of works required by each network area and business are:

1 KLO REFCL ZSS scope of works (undertaken by AusNet Services)

- Install 2 REFCLs at KLO ZSS, including network hardening and balancing
- For Jemena Electricity Network's KLO-13 feeder:
  - Underground 0.17km of overhead lines
  - Install a kiosk
  - Install two isolation transformers at the start of the feeder
- Install one isolation transformer at the start of an underground section on Dwyer Street for AusNet Services' KLO-14 feeder
- Install two isolation transformers at the start of Jemena Electricity Network's KLO-21 feeder
- For Jemena Electricity Network's KLO-22 feeder:
  - Underground 2.5km of overhead lines
  - Install 12 kiosks and one Ring Main Unit
  - Install two isolation transformers at the start of the underground section on Mt Ridley Road
- Install two isolation transformers at the start of Jemena Electricity Network's new KLO-23 feeder, which is a dedicated feeder for a new 15MVA high voltage customer that is expected to connect by the end of 2019
- Install one isolation transformer at the start of an underground section of AusNet Services's KLO-24 feeder

- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

2 COO REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

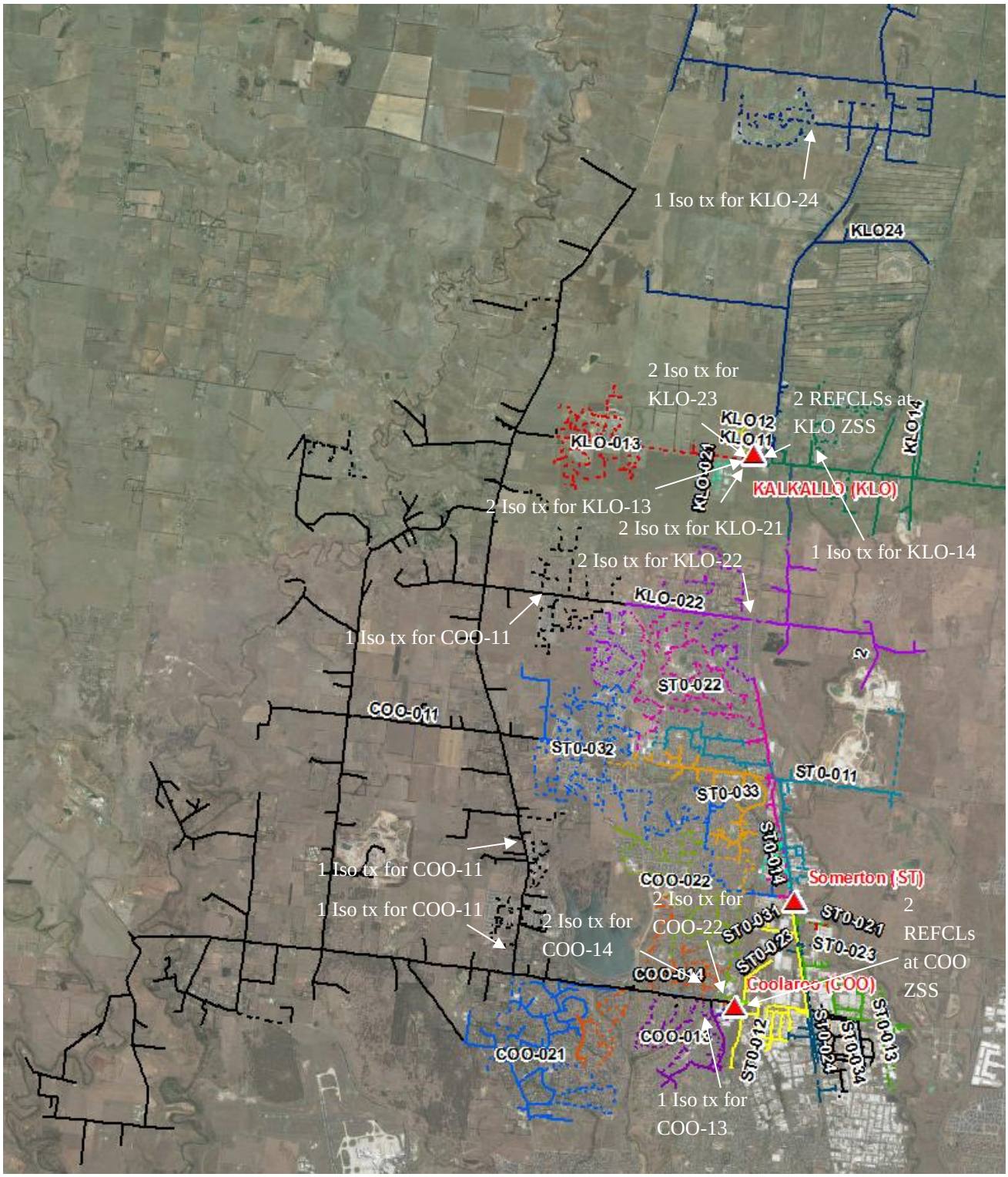
- Install 2 REFCLs at COO ZSS, including network hardening and balancing
- For Jemena Electricity Network's COO-11 feeder:
  - Underground 1.8km of overhead line on Mt Ridley Road
  - Install one isolation transformer, 5 kiosks and one Ring Main Unit on Mt Ridley Road
  - Install 370m of 22kV cable
  - Install two isolation transformers at the start of the underground section on Mickleham Road
- For Jemena Electricity Network's COO-13 feeder,
  - Install 2 x 170m 22kV cable and one Ring Main Unit
  - Install one isolation transformers at the start of an underground section of the feeder
- For Jemena Electricity Network's 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 bay to balance the capacitance on the COO ZSS bus so that the REFCL constraint limits are maintained
- For Jemena Electricity Network's COO-22 feeder,
  - Underground 0.7km of overhead conductor
  - Install 2 kiosks
  - Install two isolation transformers at the start of the feeder
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

Scope of works by 2026

This option requires at least 2 additional isolation transformers, one on each of AusNet Service's KLO-14 and KLO-24 by 2026, to isolate the expected increase in underground cables to be installed due to residential growth areas near KLO ZSS.

This estimated number of isolation transformers required by Option 7 is **most likely an underestimation.** The required number of future isolation transformers depends on the location of the future underground network growth, which is currently unknown (i.e. number and distribution of underground connections along the feeders). Since a REFCL does not detect and protect against faults beyond an isolation transformer, isolation transformers cannot be installed upstream of a feeder that has bare overhead conductor. This constraint is described in Appendix D.

Figure 7.1: Option 7 high level scope of works



7.2.2 OPTION 11 – BUILD A NEW REFCL KLN ZSS

This option is technically feasible and entails building a new REFCL Kalkallo North (KLN) Zone Substation (ZSS) with two transformers, retaining existing KLO ZSS without REFCL protection, installation of REFCLs at COO ZSS and transferring its underground 22kV feeders from COO ZSS to its neighbouring Somerton (ST) ZSS.

Option objective

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

Dependency between KLO and COO REFCL-related works

There is a dependency between REFCL-related works required on the KLO and COO networks that will assist COO ZSS in meeting REFCL compliance by reducing the capacitance at COO ZSS. This dependency requires transferring the underground section of Jemena Electricity Network's COO-11 on Mt Ridley Road (near KLO-22) to Jemena Electricity Network's KLO-22, which will be supplied by KLO non-REFCL protected ZSS.

Scope of works by 2023

The high level scope of works required by each network area and business are:

1 KLN REFCL ZSS scope of works (undertaken by AusNet Services)

- Build a new REFCL KLN ZSS with two transformers and two REFCLs which will supply AusNet Services feeders KLO-14 and KLO-24 and overhead section of Jemena Electricity Network's feeder KLO-22
- Install 1 km of 66kV overhead lines to supply KLN ZSS by cutting into AusNet Services' KLO-DRN 66kV line
- Network hardening/balancing on KLO14, KLO24 and KLO-22
- Install one isolation transformer at AusNet Services' KLO-24 to reduce capacitance seen by the KLN REFCL
- 1km of new 22kV cables to connect AusNet Services' KLO-14 to KLN ZSS
- 1km of new 22kV cables to connect AusNet Services' KLO-24 to KLN ZSS and one Ring Main Unit
- 1.3km of new 22kV overhead line to connect overhead section of Jemena Electricity Network's KLO-22 to KLN ZSS

2 KLO non-REFCL ZSS scope of works (undertaken by AusNet Services)

- Underground 0.17km of overhead lines and install a kiosk for Jemena Electricity Network's KLO-13 feeder
- 4.4km of new 22kV cables to connect underground section of Jemena Electricity Network's KLO-22 to KLO ZSS and one Ring Main Unit (RMU)
- Seek exemption from the Act and Regulations for KLO ZSS on the basis that it supplies only underground cables and all overhead feeders are transferred from KLO to the new REFCL-protected KLN ZSS. Although an entire zone substation exemption is being sought by Powercor, it has not been granted at the time of issuing this report. Hence, the lack of precedence for this exemption type increases the compliance risk of Option 11.

3 COO REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- 1.06km of new 22kV cables to connect underground sections of Jemena Electricity Network's 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 ZSS to KLO ZSS and will assist COO ZSS in meeting REFCL compliance by reducing the capacitance at COO ZSS.

- Install 2 REFCLs at COO ZSS, including network hardening and balancing
- Transfer underground sections of COO-11, COO-13, COO-14, COO-21 and COO-22 to ST ZSS.
- Seek exemption from the Act and Regulations for the COO feeders transferred to ST ZSS on the basis that they are all underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

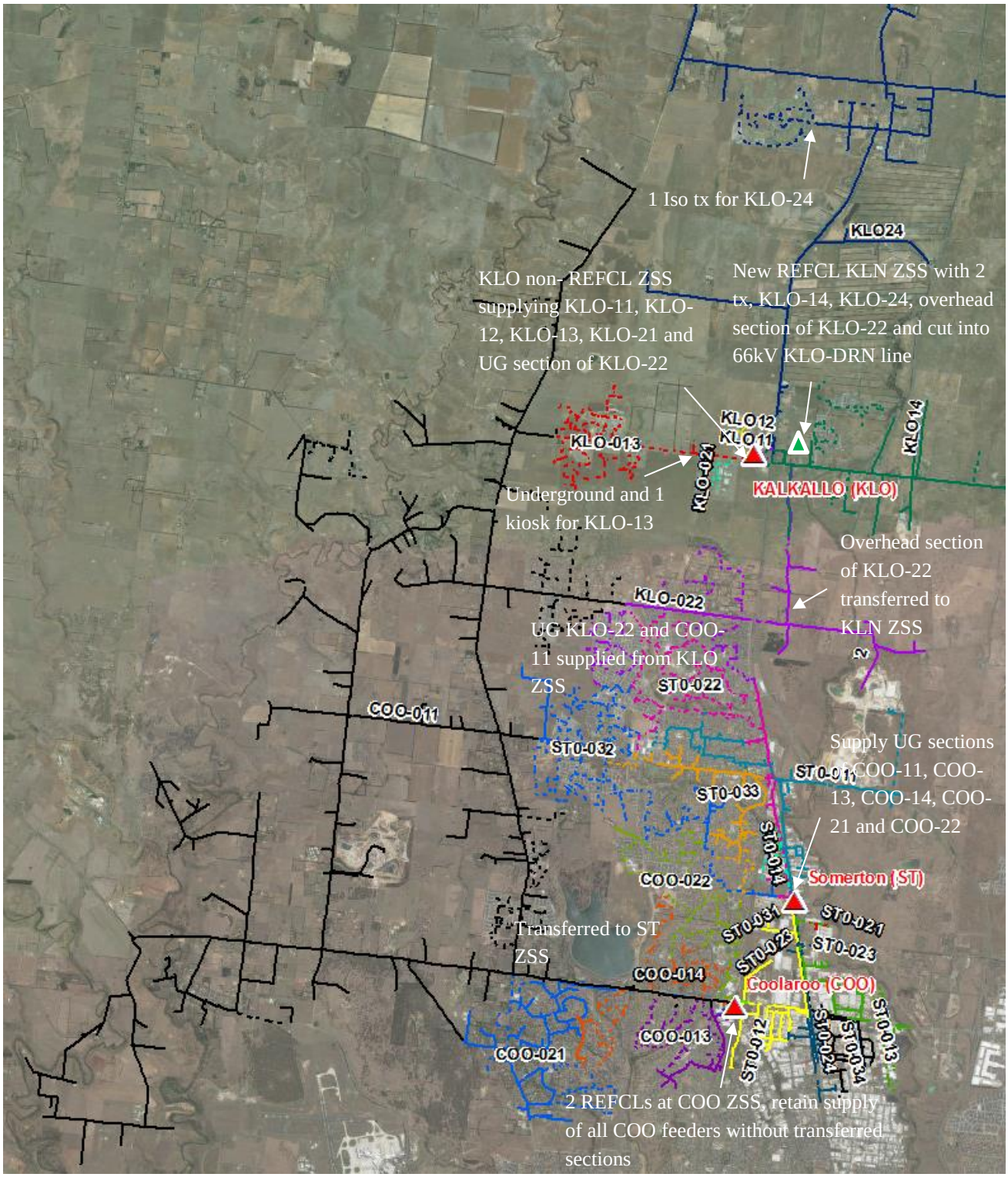
Figure 7.2 provides a high-level overview of this option. Refer to Appendix B for details of the technical assessment.

Scope of works by 2026

The proposed works provide sufficient capacity with respect to demand and Co to meet all requirements up to 2026. No additional works are required for this option as:

- Future underground growth in the KLO area will be supplied by KLO non-REFCL ZSS
- Future Co growth on COO-11 feeders are on the underground sections of COO-11, which have been transferred to KLO ZSS and ST ZSS
- Future Co growth of approximately 12A on COO-21 and COO-22 can be accommodated by the existing REFCL in COO ZSS.

Figure 7.2: Option 11 high level scope of works



7.2.3 OPTION 15 – 4 REFCL ZSS – BUILD A NEW REFCL GVE ZSS AND KLN ZSS

This option is technically feasible and does not require any Regulation exemption. It entails 4 REFCL ZSS (i.e. KLO, COO, GVE and KLN). This requires two new REFCL ZSS to be built (i.e. GVE and KLN).

Option objective

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

Dependency between KLO and COO REFCL-related works

There is no dependency between REFCL-related works required on the KLO and COO networks

Scope of works by 2023

The high level scope of works required by each network area and business are:

1 KLN REFCL ZSS scope of works (undertaken by AusNet Services)

- Build a new REFCL KLN ZSS with two transformers and two REFCLs which will supply AusNet Services feeders KLO-14 and part of KLO-24 (with transferred section of KLO-24 with a Co below 80A)
- New 1km of 66kV overhead lines to supply KLN ZSS by cutting into AusNet Services's STMS-KLO-KMS 66kV line.
- 0.5km of KLO-14 line from the KLN ZSS to KLO-14 trunk is to be upgraded
- 4km of KLO-24 line from the KLN ZSS to KLO-24 trunk is currently two phases and is to be upgraded

2 KLO REFCL ZSS scope of works (undertaken by AusNet Services)

- Install 2 REFCLs at KLO ZSS, including network hardening and balancing
- KLO ZSS retains supply of KLO-11, KLO-12, KLO-13. KLO-21, KLO-22 and part of KLO-24
- Transfer KLO-21 to KLO-12 to balance Co on both KLO buses within the 100A Co bus limit

3 GVE REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- Build a new REFCL GVE ZSS with two transformers and 2 REFCLs which will supply COO-11 and COO-21
- New 10km of 66kV overhead lines to supply GVE ZSS from COO ZSS
- Short sections of 22kV underground cable and overhead line to connect COO-11 and COO-21 to GVE ZSS

4 COO REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

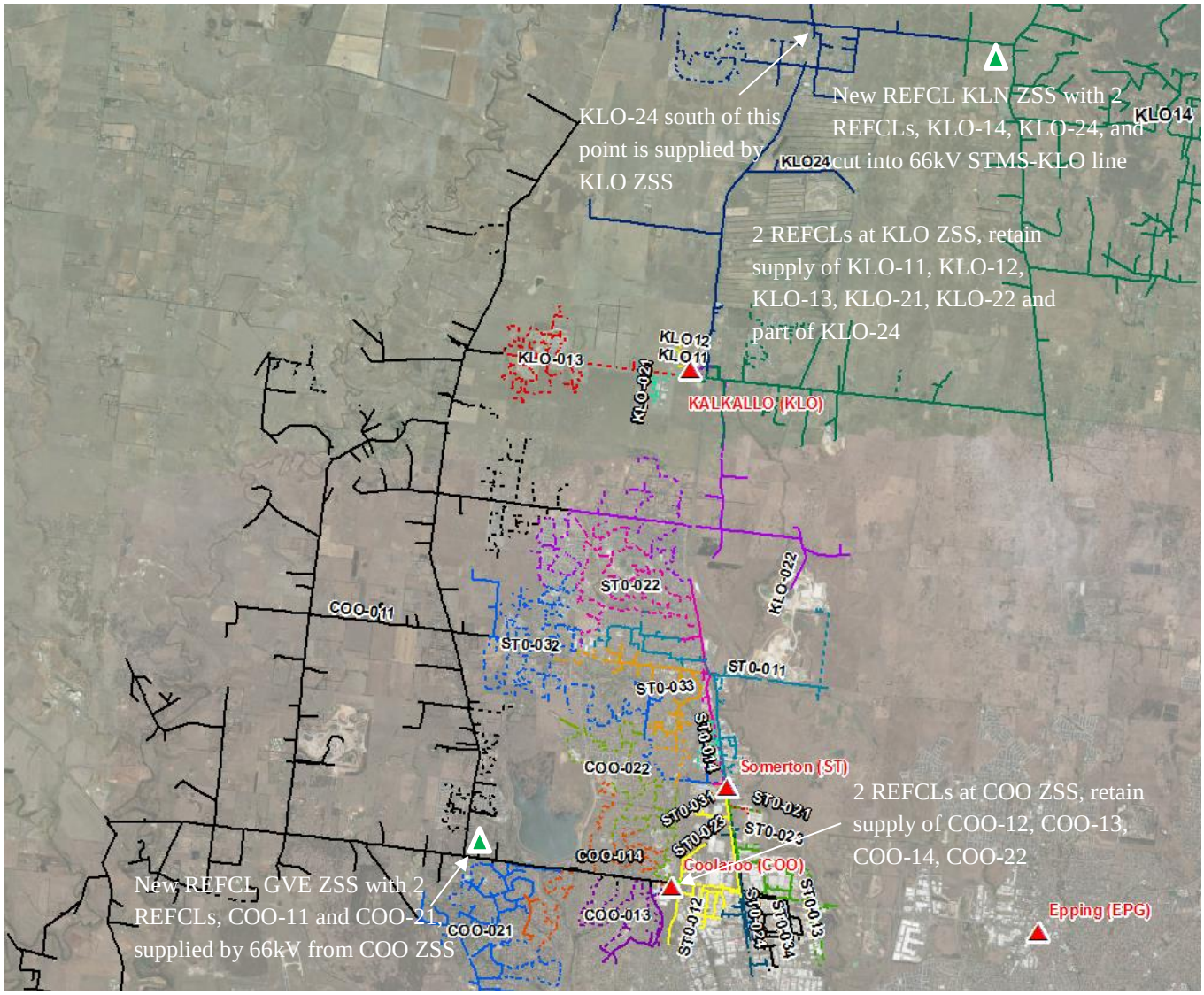
- Install 2 REFCLs at COO ZSS, including network hardening and balancing
- COO ZSS retains supply to COO-12, COO-13, COO-14 and COO-22
- Transfer 4km of underground from COO-14 to COO-22 to balance Co on both COO buses within the 100A Co bus limit

Figure 7.3 provides a high level overview of this option. Refer to Appendix B for details of the technical assessment.

Scope of works by 2026

The proposed works provide sufficient capacity with respect to demand and Co to meet all requirements up to 2026. However, should the capacitive current increase more quickly than forecast, this approach will result in significantly more cost as more REFCL protected zone substations are required.

Figure 7.3: Option 15 high level scope of works



7.2.4 SUMMARY OF SCOPE OF WORKS

Table 7.2 summarises the scope of works required to meet compliance till 2026 for Options 7, 11 and 15.

Table 7.2 Scope of works for options 7, 11 and 15

OPTION	OPTION DESCRIPTION	SCOPE OF WORK BY 2023						SCOPE OF WORK FROM 2023 TO 2026
		NEW ZSS	KLO ZSS	COO ZSS	ISOLATION TRANSFOMER	KIOSK	RING MAIN UNIT	
7	Install isolation transformers on underground feeders and REFCLs at ZSS	N/A	2 REFCLs	2 REFCLs	18 (AusNet KLO feeders: 2 Jemena KLO feeders: 8 Jemena COO feeders: 8)	20 (Jemena KLO feeders: 13 Jemena COO feeders: 7)	3 (Jemena KLO feeders: 1 Jemena COO feeders: 2)	Minimum of 2 Isolation transformers
11	Build a new REFCL KLN ZSS with two transformers	KLN – 2 REFCLs	Non-REFCL	2 REFCLs	1 (AusNet KLN feeder: 1)	1 (Jemena KLO feeder: 1)	1 (AusNet KLN feeder: 1)	Nil
15	4 REFCL ZSS – Build a new REFCL GVE ZSS and KLN ZSS	KLN – 2 REFCLs GVE – 2 REFCLs	2 REFCLs	2 REFCLs	0	0	0	Nil

Key observations from Table 7.2 are:

- **Option 11 is the preferred option in terms of scope of works**. It is less complex than both Options 7 and 15 as it requires less equipment to be distributed across the network and less REFCLs and ZSS.
- Two REFCLs in Option 11 will be installed in the new KLN ZSS (a greenfield site) which reduces the complexity of the REFCL installation, whereas Options 7 and 15 require the installation of all 4 REFCLs at the existing KLO and COO ZSS's (i.e. brownfield sites) which increases complexity of REFCL installation such as interfacing with existing equipment and working in an energised zone substation.
- Option 7 requires significantly more isolation transformers and kiosks (as well as the land for the equipment), which will be located across the network and in close vicinity to the public. Risks associated with the equipment are described in section 7.3.
- Option 15 requires more REFCLs and an additional new REFCL ZSS compared to option 11 by 2023.

7.3 RISKS AND ISSUES ASSESSMENT

This section provides a qualitatively comparison of the three options based on the risks and issues identified. The option that has the lower total risk or minimises the issues compared to the other option will be the preferred option from a risk perspective.

It is evident from Table 7.3 that Option 11 provides less risk and issues compared to both Options 7 and 15. Hence, **Option 11 is the preferred option from a risk perspective**.

Table 7.3 Risks and issues comparison of Options 7, 11 and15

ITEM	RISK OR ISSUE CATEGORY	OPTION 7	OPTION 11	OPTION 15	PREFERRED OPTION
1	Equipment risk	A total of 4 REFCLs, at least 18 isolation transformers, 20 kiosks and 3 ring main units are required as shown in Table 7.2. This presents a higher risk in terms of equipment procurement and installation.	A total of 4 REFCLs, 1 new ZSS, 1 isolation transformer and 1 kiosk are required as shown in Table 7.2. This presents a lower risk in terms of equipment procurement and installation.	A total of 8 REFCLs, 2 new ZSSs are required as shown in Table 7.2. This presents a medium risk in terms of equipment procurement and installation.	Option 11
2	Land acquisition risk	Highest land acquisition risk as at least 36 individual parcels of land are required and most of these parcels of land are in densely populated areas. 11 parcels of land to house the 18 isolation transformers required by 2023.	Lowest land acquisition risk as only 3 individual parcels of land are required and the area around the proposed KLN ZSS is currently not densely populated.	Higher land acquisition risk as two large parcels of land are required and the area around the proposed GVE ZSS is currently densely populated.	Option 11
3	Community risk	Highest risk of community resistance with at least 36 parcels of land and most of these parcels of land are in densely populated areas.	Lowest risk of community resistance with 3 parcels of land. In addition, the area around the proposed KLN ZSS is currently not densely populated.	Higher risk of community resistance as the area around the proposed GVE ZSS is currently densely populated.	Option 11
4	Deliverability risks (i.e. delay in meeting compliance by 1 May 2023)	Highest deliverability risk based on the above items 1 to 3.	Lowest deliverability risk based on the above items 1 to 3 and the businesses familiarity with building ZSS.	Higher deliverability risk based on the above items 1 to 3.	Option 11

ITEM	RISK OR ISSUE CATEGORY	OPTION 7	OPTION 11	OPTION 15	PREFERRED OPTION
5	Visual amenity	High impact on visual amenity with at least 218 isolation transformers and 20 kiosks. Isolation transformers have footprint of 11.5m (L) x 5.5m (W) x 3.1m (H) and are therefore not a discrete asset and will impact visual amenity of the locations.	Better visual amenity with only 1 ZSS, 1 isolation transformer and 1 kiosk, noting that the area around the proposed KLN ZSS is currently not densely populated.	Medium impact visual amenity with 2 ZSSs and the area around the proposed GVE ZSS is currently densely populated.	Option 11
6	Long term maintenance	May present maintenance issues (with respect to access and requirements) as most of the equipment are distributed across the network.	Unlikely to present maintenance issues (with respect to access and requirements) as most of the equipment are in a ZSS (i.e. a centralised location) and the businesses are familiar with maintaining ZSS	Unlikely to present maintenance issues (with respect to access and requirements) as most of the equipment are in a ZSS (i.e. a centralised location) and the businesses are familiar with maintaining ZSS. However, has higher number of equipment to maintain compared to Option 11.	Option 11
7	Isolation transformer electrical losses (which introduces an additional losses)	High electrical losses from at least 18 isolation transformers	Low electrical losses from 1 isolation transformer	No electrical losses as isolation transformers are not required for Option 15	Option 15

ITEM	RISK OR ISSUE CATEGORY	OPTION 7	OPTION 11	OPTION 15	PREFERRED OPTION
8	Isolation transformer reliability risk (which introduces an additional bushfire and reliability risk)	Higher reliability risk from at least 4 isolation transformers that radially feed customers on KLO-14 and KLO-24 feeders. In the event of an isolation transformer failure, the transformer can either be bypassed, or the downstream customers can be taken off supply. With the isolation transformer bypassed, the REFCL cannot be operated to reduce bushfire risk as the REFCL constraint limits will be exceeded. Whilst low probability, an isolation transformer failure during a bushfire risk period would either present a higher bushfire risk (from the REFCL not operating) or an extended outage for customers downstream of the isolation transformer. With a spare isolation transformer on hand, it would take at least two days to replace the failed isolation transformer.	Low reliability risk from 1 isolation transformer	No reliability risk as isolation transformers are not required for option 15	Option 15

7.4 ECONOMIC ASSESSMENT

This section examines the indicative whole of lifecycle costs and the indicative expenditure required to achieve compliance by 2023. The 2023 cost to comply demonstrates the expenditure required to achieve regulatory compliance by 1 May 2023. The whole of lifecycle costs identify the long term least cost option.

All cost assessments were based on a high level scope and unit rates provided by AusNet Services and Jemena Electricity Networks. The unit rates were based on a combination of actual historical project costs and budget unit rates used by AusNet Services and Jemena Electricity Networks for estimating project costs. WSP considers that these costs meet the accuracy requirements of Class 3 of the Australian Association of Cost Engineers guidelines. This means that the accuracy range has a lower bound of -10% to -20% and an upper bound of +10% to +30% and is appropriate for this type of options analysis.

7.4.1 COST TO COMPLY BY 2023

Table 7.4 shows the indicative expenditure required by AusNet Services and Jemena Electricity Networks businesses to achieve compliance by 1 May 2023. The cost split is based on the scope of works to be undertaken by each business (i.e. KLO area by AusNet Services and COO area by Jemena Electricity Networks). The cost under AusNet Services were segregated based on the cost of works required on AusNet Services feeders and Jemena Electricity Network feeders emanating out of KLO ZSS.

Table 7.4 Indicative cost to comply by 1 May 2023 (in real 2019 dollars)

OPTION	OPTION DESCRIPTION	AUSNET SERVICES	JEMENA ELECTRICITY NETWORKS	TOTAL COST TO COMPLY BY 2023[2]
7	Install isolation transformers on underground feeders and REFCLs at ZSS	$33.8M (KLO: $33.8M)	$26.8M (COO: $26.8M)	$60.6M
11	Build a new REFCL KLN ZSS with two transformers	$46.7M (KLN: $41.4M KLO: $5.3M)	$24.5M (COO: $24.5M)	$71.2M
15	4 REFCL ZSS – Build a new REFCL GVE ZSS and KLN ZSS	$69.9M (KLN: $54.7M KLO: $15.2M)	$51.3M (COO: $11.8M GVE: $39.4M)	$121M

7.4.2 WHOLE OF LIFECYCLE COSTS

In order to determine the option that is in the long-term interest of customers, whole of lifecycle costings of Options 7, 11 and 15 have been evaluated. A whole of lifecycle cost view provides a better comparison between options, compared to the cost to comply by 2023, as it includes future costs which are option dependent. The comparison of costs to comply by 2023 is not a like for like comparison.

Options 11 and 15 inherently provide additional capacity to meet future load growth at a higher upfront cost, whilst Option 7 does not provide such additional capacity but has a lower upfront cost. Since Options 11 and 15 provide

[2] Options 7 and 11 are only compliant once the exemption from the Act and Regulations has been granted

additional capacity by building a new substation(s), it is necessary to identify when additional capacity will be required to meet load and capacitance growth on the network under Option 7 and include that cost to ensure a like for like comparison of the options.

The cost was assessed over a 30 year horizon (until 2050) and considered the following:

- expenditure required to achieve compliance in 2023
- forecast costs to maintain compliance as network capacitance (Co) increases
- forecast cost for the next step of capacity required.

The timing of the additional capacity was calculated based on the demand forecast compared to the substation capacity with consideration of transformer reliability. This calculated an expected economic timing for additional capacity based on current demand expectations and the zone substation characteristics. This was done using the probability of transformer failure, load duration curves and Value of Customer Reliability (VCR) to calculate the value of energy at risk and compared it to the annualised cost of a new zone substation.

This assessment has utilised a probabilistic approach in determining the need for a new ZSS based on probability of a transformer failure. The assessment found that KLO does not require a new ZSS by 2050 and COO requires a new ZSS in 2045 for Option 7. However, if a deterministic approach is used (i.e. the need for a new ZSS is triggered when demand forecast exceeds N-1 firm capacity of the ZSS), the need for a new ZSS will be required at KLO in 2042 and COO in 2030 for Option 7. Hence, the probabilistic approach used in the assessment is conservative.

A discounted cash flow (using a real discount factor of 3% based on AusNet Services' advice) based on capital cost was used to determine the net present cost (NPC) of each option. Operational expenditure was excluded as it was not material compared to the capex. Benefits were considered equivalent in both options (achieving compliance and reducing bushfire risk) and excluded from the calculation, hence the NPC was the differentiating metric between the options.

Table 7.5 Indicative whole of lifecycle costs to 2050 (discounted to 2019 dollars based on 3% discount rate)

OPTION	OPTION DESCRIPTION	NET PRESENT COST (NPC)
7	Install isolation transformers on underground feeders and REFCLs at ZSS	$77.7M
11	Build a new REFCL KLN ZSS with two transformers	$67.1M
15	4 REFCL ZSS – Build a new REFCL GVE ZSS and KLN ZSS	$163.7M

(1) This is a conservative estimate as future isolation transformer quantities are underestimated and electrical losses and maintenance costs of the isolation transformers have not been included

(2) This assessment assumes the Jemena forecast continues at a constant trend based on linear regression. This aligns with the growth rate forecast by AusNet and is therefore considered reasonable

It is evident from Table 7.5 that **Option 11 has the lowest whole of lifecycle cost compared to Options 7 and 15**.

In addition, there is a higher risk of cost increases for Option 7 due to the need for more isolating transformers or an additional ZSS that may be required earlier than modelled. Hence, Option 11 is the least cost option in the long run compared to Option 7 and is the preferred option from an economic perspective.

7.5 SUMMARY OF OPTIONS

Table 7.6 summarises the scope of works, risks and economic assessments for Options 7, 11 and 15 which was set out in sections 7.2, 7.3 and 7.4. It provides a traffic light (red, amber, green) assessment of all the scope of works, risks and economic assessments. The preferred option is the option with the most number of green lights across all categories.

Table 7.6 Summary of options with traffic light assessment

OPTION	OPTION DESCRIPTION	SCOPE OF WORKS BY 2023	SCOPE OF WORKS BY 2026	COMPLIANCE	RISK LEVEL	INITAL COST (BY 2023)	WHOLE LIFECYCLE COST
7	Install isolation transformers on underground feeders and REFCLs at ZSS	🔴	🟡	🟡	🔴	🟢	🟡
11	Build a new REFCL KLN ZSS with two transformers	🟢	🟢	🔴	🟢	🟡	🟢
15	4 REFCL ZSS – Build a new REFCL GVE ZSS and KLN ZSS	🟡	🔴	🟢	🟡	🔴	🔴

It is evident from Table 7.6 that **Option 11 is the preferred option** as it has the most number of green lights.

8 RECOMMENDATION

WSP undertook an assessment of all 24 potential options to comply with the Regulations at KLO and COO ZSS. These potential options were based on a compilation of studies by Jemena Electricity Networks and AusNet Services as well as additional options identified by WSP.

As per the RIT-D guidelines, appropriate levels of analysis were undertaken based on the credibility of each option. If an option was found to be non-credible for a criterion, it was discarded and not considered further. This initial feasibility assessment resulted in nine technically and economically feasible options.

Based on further assessment of these nine options and guidance gained from the 2 August 2019 meeting with the AER, ESV and DELWP, three of these nine options were shortlisted for detailed option assessment. This involved a detailed technical, compliance, risk and economic analysis of each final option.

Subject to the exemption being granted, **WSP recommends Option 11 as the preferred option** based on the detailed option assessment as described in section 7. Option 11 is the preferred option as it presents the best long term interest of customers by:

- Lower whole of lifecycle cost
- Presenting a lower deliverability risk which is key to enabling the timely implementation of REFCLs to reduce bushfire risks for the community
- Future proofing by:
  - Reducing the risk of future additional costs from additional isolation transformers driven by future underground network growth locations
  - Lower future maintenance costs, including electrical losses from isolation transformers (impact was not costed)
  - Fewer constraints on future network operation such as back feeding
  - Reduced bushfire risk due to isolation transformer failure (which can be mitigated through lower customer reliability)
  - Providing capacity to meet the expected demand growth from Melbourne's northern growth corridor near KLO ZSS

However, should an exemption not be granted, then Option 15 is the only technically feasible option that will enable Jemena and AusNet Services to achieve compliance with the Regulations.

APPENDIX A

INFORMATION RECEIVED

A1 INFORMATION FROM AUSNET SERVICES

Table A.1 Information from AusNet Services

ITEM	DATE RECEIVED	DESCRIPTION
1	1 May 2019	PSSE model
2	1 May 2019	Sincal model for KLO14 and 24
3	28 May 2019	KLO_KMS_DRN_EPG_Shape_files.zip (GIS data for 22kV network)
4	28 May 2019	Methodology and results.pptx (for capacitance forecast)
5	5 June 2019	Capacitance Forecast model May 2019.xls (KLO Co forecast)
6	5 June 2019	Attachment 14 – REF 30-04 REFCL Program – Arc Suppression Coil Sizing Policy – Issue 3 - PUBLIC.pdf
7	5 June 2019	Attachment 21 – KLO overview presentation – confidential.pdf
8	6 June 2019	Estimate – Confidential.docx (cost estimate for REFCL and third transformer)
9	7 June 2019	KLO_KMS_DRN_EPG_ZSS_LOCATIONS (GIS data for zone substations locations)
10	18 June 2019	66kV GIS Data.zip (GIS data for 66kV lines)
11	10 July 2019	A9RCF3.tmp.pdf (Comments on WSP 19 June presentation slides)
12	10 July 2019	PREL_GA_ISOLATION_TX_GFNand SLDvB-Model.pdf (Remote REFCL layout)
13	10 July 2019	Cost estimate.xls (AusNet Services unit costs)
14	10 July 2019	AusNet Services Option Analysis Feedback,msg (email on scope of remote REFCL and details of isolation transformers)
15	15 July 2019	KLO_assessment_ZS_and_Feeder_MD_Forecasts.xls (KLO demand forecast)
16	19 July 2019	Copy of Unite Cost Estimate V2.xls (updated AusNet Services unit costs)
17	23 July 2019	Fw: Joint Planning Report KLO and COO.msg (email on 80A capacitance limit per feeder and land costs)
18	6 Aug 2019	AusNet Services comments on draft report from Hannah Williams, Matthew Chng and Youssef Ali
19	12 Aug 2019	REFCL discounting cost spreadsheet (discount rate of 3%)

A2 INFORMATION FROM JEMENA ELECTRICITY NETWORKS

Table A.2 Information from Jemena Electricity Networks

ITEM	DATE RECEIVED	DESCRIPTION
1	31 May 2019	Capacitive Current of Feeders (Apr 2019).xlsx (2019 capacitance of Jemena feeders)
2	31 May 2019	Capacitance forecast – do nothing option.xlsx (Capacitance forecast for Jemena feeders)
3	31 May 2019	Schematics Ops Diagrams 1 May 2016 (network diagrams on 1 May 2016)
4	3 June 2019	Schematics Ops Diagrams 24 Apr 2019 (network diagrams on 24 April 2019)
5	3 June 2019	Zone Substation SLD (single line diagrams for Jemena ZSS)
6	3 June 2019	2018 JEN Demand Forecast_Reconciled to ACIL 2018 Forecast_Final_For WSP (COO and KLO feeder demand forecast)
7	5 June 2019	GIS data (22kV feeders and ZSS)
8	7 June 2019	Capacitance forecast TB1.xlsx (Co calculation for Jemena Option 1 i.e. Option 11)
9	7 June 2019	Capacitance forecast TB2.xlsx (Co calculation for Jemena Option 2 i.e. Option 12)
10	7 June 2019	Capacitance forecast TB3.xlsx (Co calculation for Jemena Option 3 i.e. Option 13)
11	12 June 2019	Capacitance forecast TB4.xlsx (Co calculation for Jemena Option 4 i.e. Option 14)
12	17 June 2019	Capacitance forecast TB5.xlsx (Co calculation for Jemena Option 5 i.e. Option 15)
13	18 June 2019	Summary of TB options (18062019).xlsx
14	5 July 2019	Capacitance forecast TB6.xlsx (Co calculation for Jemena Option 6 i.e. Option 16)
15	5 July 2019	Final SoW & Cost Estimate (04072019).xlsx
16	11 July 2019	Final SoW & Cost Estimate (11072019).xlsx
17	18 July 2019	Final SoW & Cost Estimate (17072019).xlsx and JEN options clarifications 20190718.doc
18	23 July 2019	Jemena Option 1 – Map of KLO and COO area.docx, Option 1 transfer.docx, Option 1 SOW diagram.pdf
19	23 July 2019	Jemena Option 3 – Map of KLO and COO area.docx, Option 3 SOW diagram.pdf
20	24 July 2019	Jemena Option 6 – Map of KLO and COO area.docx, Option 6 SOW diagram.pdf
21	24 July 2019	Joint Planning Report KLO and COO.msg ($2.8M cost of land around COO)
22	24 July 2019	Jemena Option 4 – Map of KLO and COO area.docx, Option 4 SOW.pdf
23	25 July 2019	Jemena Option 5 – Map of KLO and COO area.docx, Option 5 diagrams.pdf
24	27 July 2019	Final SoW & Cost Estimate (26072019).xlsx

25	31 July 2019	PS113850-ADV-REP-001 REvA_Jemena comments (30-7-19).pdf

A3 UNIT COSTS

The table below sets out the unit costs used in this analysis. The cost estimates were based on:

- Cost to implement the scope of each options as set out in section 7.1.1 in 2019 dollars.
- Average unit costs calculated from data provided by AusNet Services's and Jemena Electricity Networks were used for sub transmission and distribution assets.
- Unit costs for REFCL and isolation transformer were based on AusNet Services' actual historical costs (Jemena Electricity Networks did not have actual historical data).
- Network upgrades for future load growth have been excluded in the costing as per AER's email dated 15/7/2019. Network upgrades (i.e. ZSS and line upgrades) are assumed to be approximately constant across options and thus, can be reasonably excluded for option assessment as we are only concerned with the incremental differences between the options.

	Unit	JEN Unit Rate ($2019)	Ausnet Unit Rate ($2019)	Average unit rate ($2019)	Final Unit Rate used by WSP ($2019)	
22kV feeder costs						
3-way RMU	each					
315kVA Kiosk S/S	each					
New 22kV U/G cable in existing conduit	km					
New 22kV U/G cable in new conduit	km					
New 2 x 22kV U/G cable in new conduit	km					
Railway crossing for 22kV U/G cable	each					
Reconductor existing 22kV overhead conductor	km					
New 22kV overhead conductor	km					
New 22kV feeder CB including prot & control	each					
66kV sub-transmission costs						
New 66kV CB including prot & control	each					
New 66kV CB at COO including prot & control, & zone substation earth grid extension	each					
New 66kV ring bus at ST zone substation	each					
New 66kV underground cable including termination	km					
New 66kV overhead conductor	km					
REFCL costs						
Remote REFCL	each					
Remote REFCL land cost	each					
New REFCL installed into a new zone substation	each					
2 GFNs at the existing KLO	each					
COO network hardening and balancing	each					
KLO network hardening and balancing	each					
Isolation transformer costs						
Isolation transformer installed cost	each					
Isolation transformer land cost	each					
New zone substation costs						
Cost of new zone substation land near KLO	each					
Cost of new zone substation land near COO/MHM	each					
Establish a single transformer zone substation	each					
Establish a two transformers zone substation	each					

APPENDIX B

TECHNICAL FEASIBILITY ASSESSMENT

B1 PSSE MODELLING

PSSE model provided by AusNet Services is modelled down to the 22kV busbar and 66/22kV transformers.

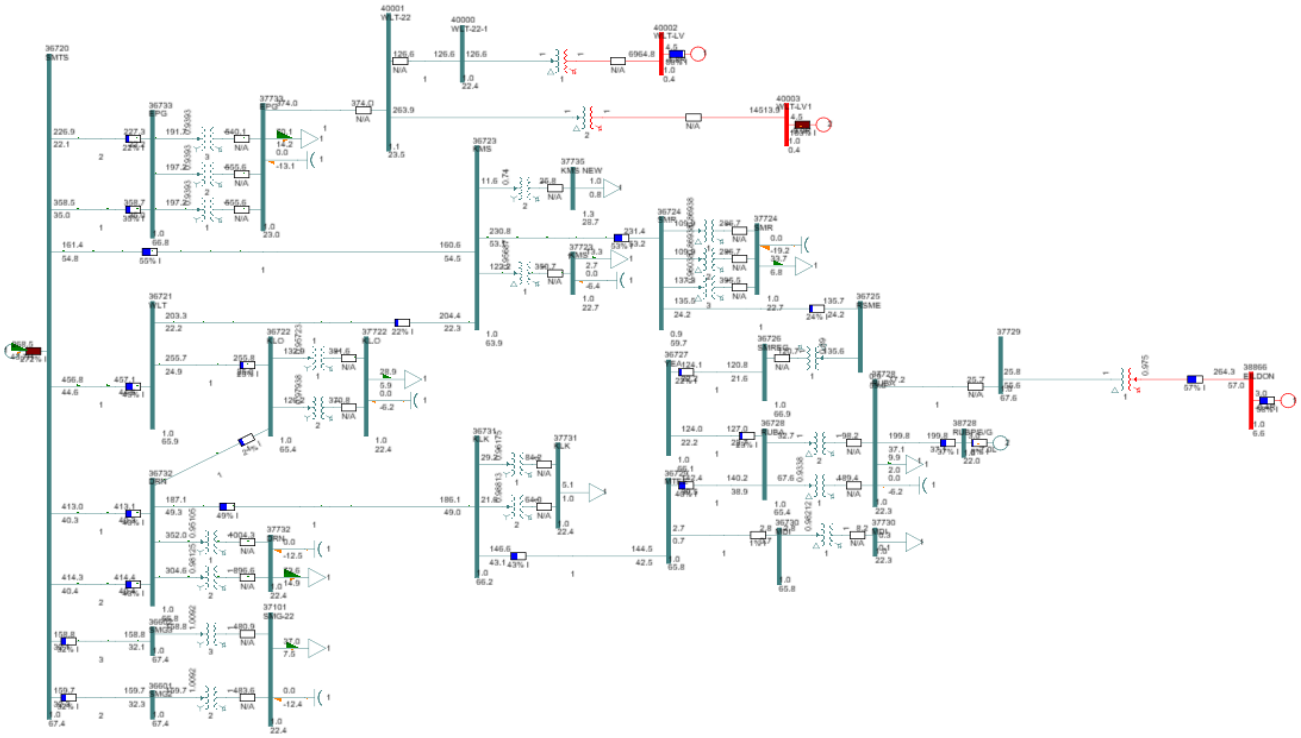


Table B. 1 Voltage variations in 66kV bus when KLN and KLW ZSS is connected to the existing network

Bus	Bus Voltage (KV)	Voltage variations %	
		When KLN is connected	When KLW is connected
SMG2	66	0.0%	0.0%
SMTS	66	0.0%	0.0%
KLO	66	-0.4%	0.2%
SMR	66	0.4%	0.7%
SMREG	66	0.4%	0.8%
RUBA	66	0.9%	1.1%
MDI	66	0.5%	0.7%
DRN	66	0.0%	0.1%
SMG3	66	0.0%	0.0%
WLT	66	-0.2%	0.1%
KMS	66	-0.1%	0.3%
RSME	66	0.4%	0.7%
YEA	66	0.7%	0.9%
MTEE	66	0.5%	0.7%
KLK	66	0.2%	0.4%
EPG	66	0.0%	0.0%

Table B. 2 Change in loading in 66kV lines when KLN and KLW ZSS is connected to the existing network

Line	Bus Voltage (KV)	Loading variations %	
		When KLN is connected	When KLW is connected
SMG2 -SMTS	66	0.0%	0.0%
SMG3 -SMTS	66	0.0%	0.0%
SMTS -WLT	66	22.8%	-0.5%
SMTS -KMS	66	5.8%	-0.6%
SMTS -DRN	66	9.0%	-0.6%
SMTS -DRN	66	9.1%	-0.4%
SMTS -EPG	66	0.0%	0.0%
SMTS -EPG	66	0.0%	0.0%
WLT -KLO	66	65.2%	-
WLT -KMS	66	-4.8%	-0.4%
KLO -DRN	66	-	-0.8%
KMS -SMR	66	-1.5%	-1.1%
SMR -RSME	66	-2.7%	-4.0%
SMREG-YEA	66	-2.9%	-3.6%
YEA -RUBA	66	-2.1%	-3.6%
RUBA -MTEE	66	8.3%	7.1%
MTEE -MDI	66	0.0%	0.0%
MTEE -KLK	66	8.7%	6.8%
KLK -DRN	66	5.3%	4.4%

Table B. 3 Voltage variations in 22kV bus when KLN and KLW ZSS is connected to the existing network

Bus	Bus Voltage (KV)	Voltage variations %	
		When KLN is connected	When KLW is connected
SMG-22	22	0.0%	0.0%
KMS	22	-0.1%	0.3%
RUBA	22	2.0%	2.2%
MDI	22	0.5%	0.7%
DRN	22	0.0%	0.1%
RUBPS/G	22	3.2%	3.4%
WLT-22-1	22	0.0%	0.0%
KLO	22	0.5%	0.9%
SMR	22	0.4%	0.8%
KLK	22	0.2%	0.4%
EPG	22	0.0%	0.0%
WLT-22	22	0.0%	0.0%

Note: Inclusion of ZSS does not cause any thermal overloads or voltage violation on the 66 kV and 22 kV network.

Table B. 4 Voltage variations in 66kV bus when KMS_SMR Line is disconnected from the network

Bus	Bus Voltage (KV)	Voltage variation %
		When KMS_SMR Line Disconnected
SMG2	66	0.0%
SMTS	66	0.0%
KLO	66	0.0%
SMR	66	-54.3%
SMREG	66	-52.0%
RUBA	66	-17.2%
MDI	66	-11.0%
DRN	66	-1.0%
SMG3	66	0.0%
WLT	66	0.5%
KMS	66	3.5%
RSME	66	-52.7%
YEA	66	-34.2%
MTEE	66	-11.0%
KLK	66	-5.3%
EPG	66	0.0%

Table B. 5 Change in loading in 66kV lines when KMS_SMR Line is disconnected from the network

Line	Bus Voltage (KV)	Loading variation %
		When KMS_SMR Line Disconnected
SMG2 -SMTS	66	0.0%
SMG3 -SMTS	66	0.0%
SMTS -WLT	66	-27.5%
SMTS -KMS	66	-54.9%
SMTS -DRN	66	24.7%
SMTS -DRN	66	25.0%
SMTS -EPG	66	0.0%
SMTS -EPG	66	0.0%
WLT -KLO	66	43.0%
WLT -KMS	66	-72.5%
KLO -DRN	66	-46.2%
KMS -SMR	66	-100.0%
SMR -RSME	66	300.0%
SMREG-YEA	66	286.9%
YEA -RUBA	66	277.1%
RUBA -MTEE	66	213.5%
MTEE -MDI	66	33.3%
MTEE -KLK	66	204.3%
KLK -DRN	66	162.6%

Table B. 6 Voltage variations in 22kV bus when KMS_SMR Line is disconnected from the network

Bus	Bus Voltage (KV)	Voltage variation %
		When KMS_SMR Line Disconnected
SMG-22	22	0.0%
KMS	22	3.8%
RUBA	22	-11.6%
MDI	22	-11.0%
DRN	22	-1.1%
RUBPS/G	22	-7.9%
WLT-22-1	22	0.0%
KLO	22	0.1%
SMR	22	-61.8%
KLK	22	-5.4%
EPG	22	0.0%
WLT-22	22	0.0%

Note: When KMS-SMR 66kV line is disconnected, the entire network suffers a voltage collapse issues

APPENDIX C

HIGH LEVEL ASSESSMENT OF OPTIONS 3, 4, 14, 16 AND 21

C1 OPTION 3 – BUILD A NEW NON-REFCL KLW ZSS

This technically feasible option entails installing a new non-REFCL single transformer Kalkallo West (KLW) ZSS which will only supply underground cables and seeks exemptions from the Act and Regulations .

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 each network area and business are:

1 KLW non-REFCL ZSS scope of works (undertaken by AusNet Services)

- Build a new non-REFCL KLW ZSS with a single transformer which will supply Jemena Electricity Networks' underground feeders KLO-13 and KLO-21 as well as an underground section of AusNet Services' KLO-14
- For Jemena Electricity Network's KLO-13 feeder:
  - Underground 0.17km of overhead lines
  - Install a kiosk
  - 0.1km of new 22kV cables to connect Jemena Electricity Networks' KLO-13 to KLW ZSS
- 0.1km of new 22kV cables to connect Jemena Electricity Networks' KLO-21 to KLW ZSS
- 1.5km of new 22kV cables to connect underground section of AusNet Services' KLO-14 to KLW ZSS
- New 2km of 66kV underground cables to develop the ring to supply KLW ZSS from SMTS-KLW and KLW-KLO
- Seek exemption from the Act and Regulations for KLW ZSS on the basis that it supplies only underground cables. Although an entire zone substation exemption is being sought by Powercor, it has not been granted at the time of issuing this report. Hence, the lack of precedence for this exemption type increases the compliance risk of Option 3.

2 KLO REFCL ZSS scope of works (undertaken by AusNet Services)

- Install 2 REFCLs at KLO ZSS, including network hardening and balancing
- For Jemena Electricity Network's KLO-22 feeder:
  - Underground 2.5km of overhead lines
  - Install 12 kiosks and one Ring Main Unit
  - Install two isolation transformers at the start of the underground section on Mt Ridley Road
- Install two isolation transformers at the start of Jemena Electricity Network's new KLO-23 feeder, which is a dedicated feeder for a new 15MVA high voltage customer that is expected to connect by the end of 2019
- Install one isolation transformer at the start of an underground section of AusNet Services' KLO-24 feeder
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

3 COO REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- Install 2 REFCLs at COO ZSS, including network hardening and balancing
- For Jemena Electricity Network's 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 two isolation transformers on Mickleham Road and 0.6km of underground cable to connect underground sections
- Install one isolation transformers at the start of an underground section of COO-13 feeder
- For Jemena Electricity Network's COO-14 feeder,
  - Transfer 1.4km of overhead conductor of COO-14 to COO-21
  - Install two isolation transformers at the start of an underground section of the feeder
  - Transfer the remainder of the feeder to spare COO-23 bay to balance the capacitance on the COO ZSS bus so that the REFCL constraint limits are maintained
- For Jemena Electricity Network's COO-22 feeder,
  - Underground 0.7km of overhead conductor
  - Install 2 kiosks
  - Install two isolation transformers at the start of the feeder
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

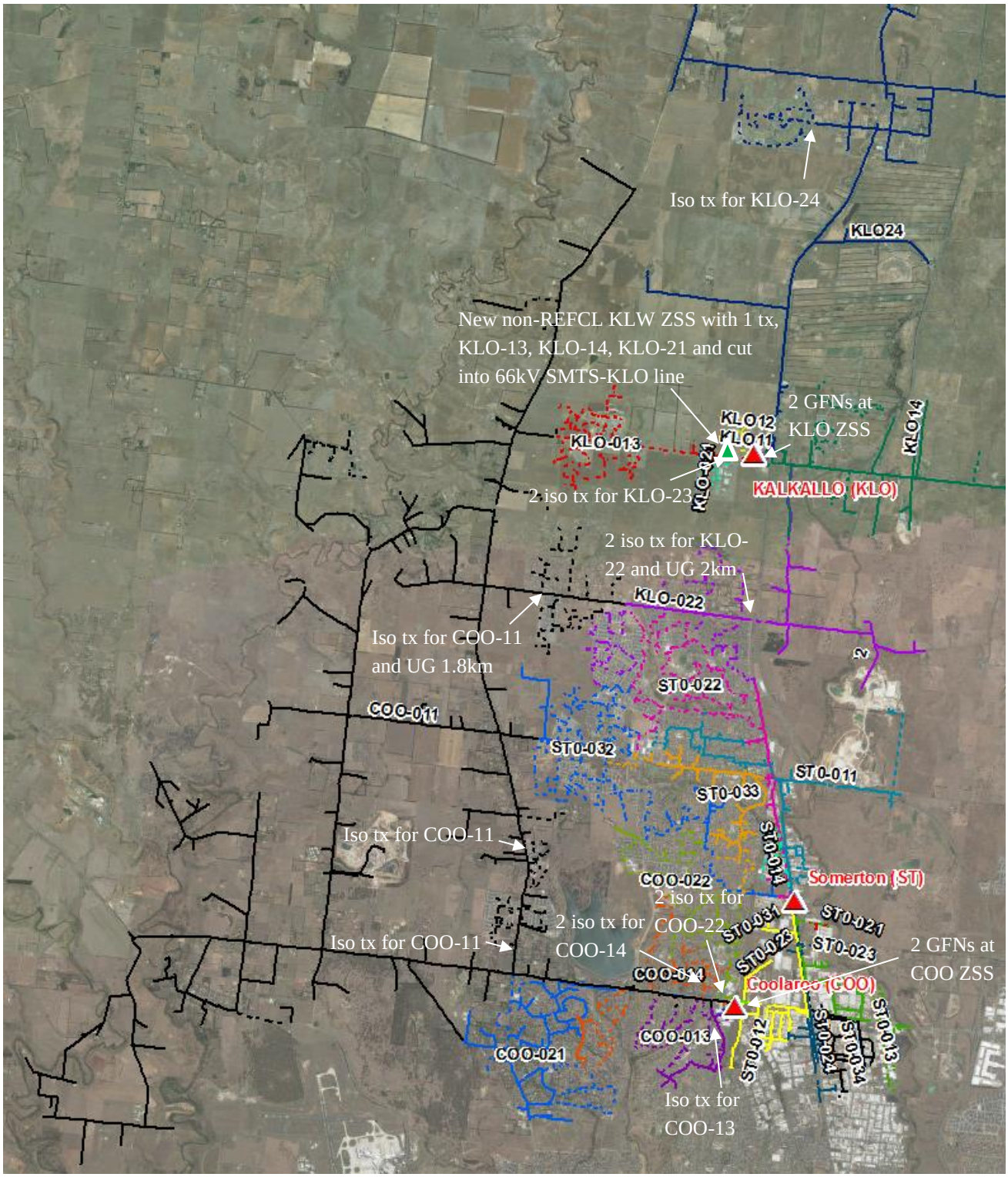
Figure 8.1 provides a high-level overview of this option. Refer to Appendix B for details of the technical assessment.

Risk assessment

This option has the following risk:

- Land acquisition and community risk of 13 isolation transformers and KLW ZSS.
- Land acquisition risk of 8 isolation transformers for COO feeders can be mitigated by transferring these feeders to ST ZSS. Note transferring COO feeders to ST ZSS requires ESV exemption for the transferred underground feeders.

Figure 8.1: Option 3 high level scope of works



C2 OPTION 4 – BUILD A NEW REFCL KLW ZSS

This option is technically feasible and aims to achieve compliance by installing a new REFCL Kalkallo West (KLW) ZSS which will supply all overhead feeders and obtain an exemption from the Act and Regulations for KLO ZSS which will only supply underground cable feeders.

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 each network area and business are:

1 KLW REFCL ZSS scope of works (undertaken by AusNet Services)

- Build a new REFCL KLW ZSS with two transformers which will supply AusNet Services' KLO-24, overhead section of AusNet Services' KLO-14 and overhead section and underground section of Jemena Electricity Networks' KLO-22
- Install 2 REFCLs at KLW ZSS, including network hardening and balancing
- 0.2km of new 22kV cables to connect Jemena Electricity Networks' KLO-22 to KLW ZSS
- 0.2km of new 22kV cables to connect overhead section of AusNet Services' KLO-14 to KLW ZSS
- 0.2km of new 22kV cables to connect overhead section of AusNet Services' KLO-24 to KLW ZSS
- Install one isolation transformer at the start of an underground section of AusNet Services' KLO-24 feeder
- New 2km of 66kV underground cables to develop the ring to supply KLW ZSS from SMTS-KLW and KLW-KLO
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

2 KLO non-REFCL ZSS scope of works (undertaken by AusNet Services)

- For Jemena Electricity Network's KLO-13 feeder:
  - Underground 0.17km of overhead lines
  - Install a kiosk
- 1.5km of new 22kV cables to connect underground section of AusNet Services' KLO-14 to KLO ZSS
- 4.5km of new 22kV cables to connect underground section of Jemena Electricity Network's KLO-22 to KLO ZSS
- Seek exemption from the Act and Regulations for KLO ZSS on the basis that it supplies only underground cables. Although an entire zone substation exemption is being sought by Powercor, it has not been granted at the time of issuing this report. Hence, the lack of precedence for this exemption type increases the compliance risk of Option 4.

3 COO REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- Install 2 REFCLs at COO ZSS, including network hardening and balancing

- For Jemena Electricity Network's 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 two isolation transformers on Mickleham Road and 0.6km of underground cable to connect underground sections
- Install one isolation transformers at the start of an underground section of COO-13 feeder
- For Jemena Electricity Network's COO-14 feeder,
  - Transfer 1.4km of overhead conductor of COO-14 to COO-21
  - Install two isolation transformers at the start of an underground section of the feeder
  - Transfer the remainder of the feeder to spare COO-23 bay to balance the capacitance on the COO ZSS bus so that the REFCL constraint limits are maintained
- For Jemena Electricity Network's COO-22 feeder,
  - Underground 0.7km of overhead conductor
  - Install 2 kiosks
  - Install two isolation transformers at the start of the feeder
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

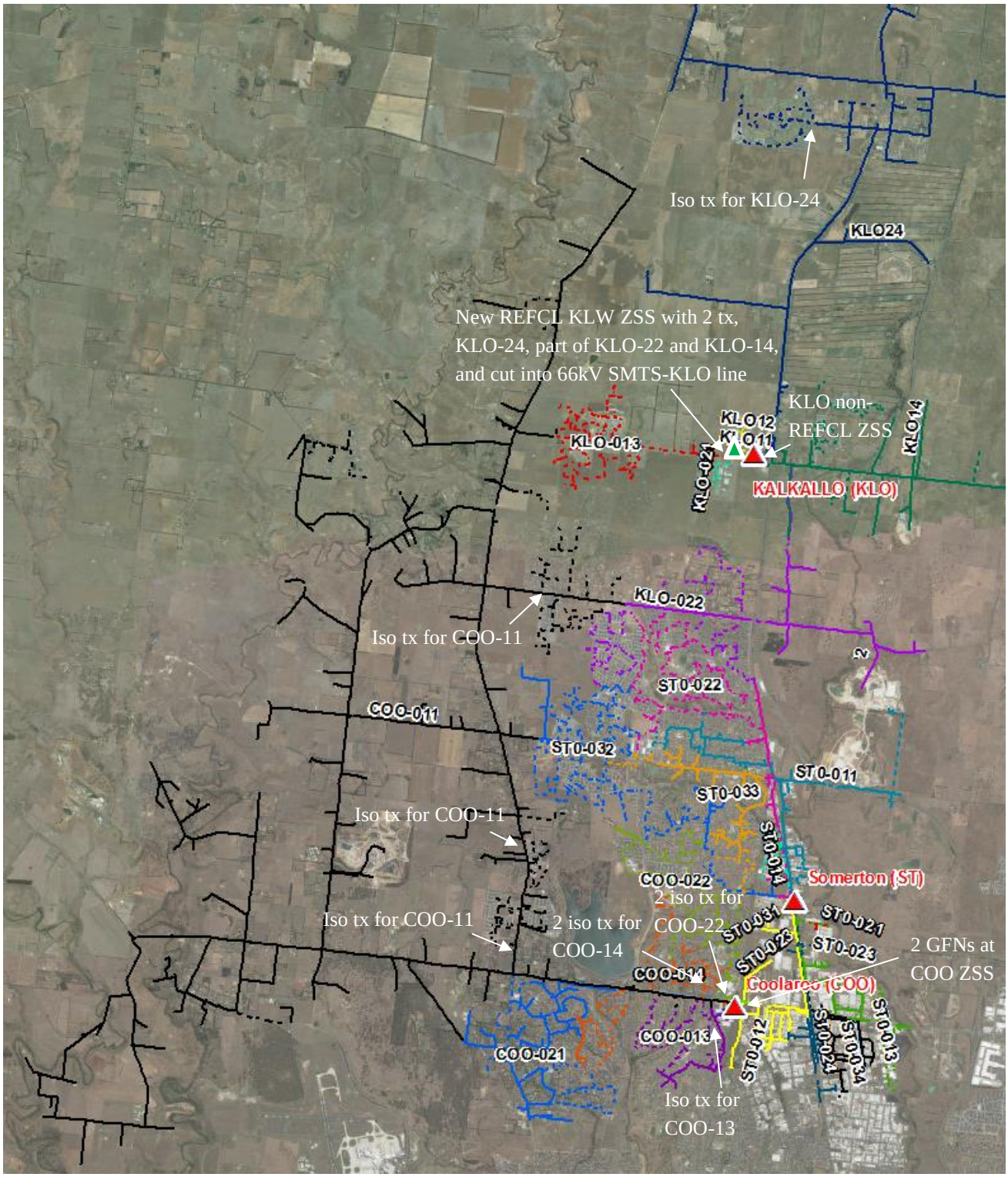
Figure 8.2 provides a high-level overview of this option. Refer to Appendix B for details of the technical assessment.

Risk assessment

This option has the following risk:

- Land acquisition and community risk of the 9 isolation transformers and KLW ZSS.
- Land acquisition risk of 8 isolation transformers for COO feeders can be mitigated by transferring these feeders to ST ZSS. Note transferring COO feeders to ST ZSS requires ESV exemption for the transferred underground feeders.

Figure 8.2: Option 4 high level scope of works



C3 OPTION 14 – BUILD A NEW NON-REFCL CBN ZSS WITH TRANSFERS TO ST ZSS

This option is technically feasible and aims to achieve compliance by installing a new non-REFCL Craigieburn (CBN) ZSS which will supply all underground feeders and get an exemption from the Act and Regulations.

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 each network area and business are:

1 KLO REFCL ZSS scope of works (undertaken by AusNet Services)

- Install 2 REFCLs at KLO ZSS, including network hardening and balancing
- Install one isolation transformer at the start of an underground section on Dwyer Street for AusNet Services' KLO-14 feeder
- Install two isolation transformers at the start of Jemena Electricity Network's new KLO-23 feeder, which is a dedicated feeder for a new 15MVA high voltage customer that is expected to connect by the end of 2019
- Install one isolation transformer at the start of an underground section of AusNet Services' KLO-24 feeder
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

2 CBN non-REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- Build a new non-REFCL CBN ZSS with two transformers which will supply only underground feeders
- New 2.6km of 66kV overhead lines to cut into the SMTS-KLO 66kV line to supply CBN ZSS
- For Jemena Electricity Network's KLO-13 feeder:
  - Underground 0.17km of overhead lines
  - Install a kiosk
  - 5.5km of new 22kV cables to connect to CBN ZSS
- 5.5km of new 22kV cables to connect Jemena Electricity Network's KLO-21 feeder to CBN ZSS
- 0.25km of new 22kV cables to connect Jemena Electricity Network's KLO-22 underground section south of Mt Ridley Road to CBN ZSS
- Seek exemption from the Act and Regulations for CBN ZSS on the basis that it supplies only underground cables. Although an entire zone substation exemption is being sought by Powercor, it has not been granted at the time of issuing this report. Hence, the lack of precedence for this exemption type increases the compliance risk of Option 14.

3 COO REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- Install 2 REFCLs at COO ZSS, including network hardening and balancing

- For Jemena Electricity Network's COO-11 feeder:
  - Transfer underground section south of Mt Ridley Road to CBN ZSS via KLO-22
  - 1.5km of new 22kV cable to connect part of underground section north of Mt Ridley Road to KLO-13
  - 3.5km of new 22kV cables to connect underground section along Mickleham Road to ST-32
- Transfer part of underground section of Jemena Electricity Network's COO-13 to ST-32
- For Jemena Electricity Network's COO-14 feeder:
  - Transfer part of underground section to ST-32
  - Transfer the remainder of the feeder to spare COO-23 bay to balance the capacitance on the COO ZSS bus so that the REFCL constraint limits are maintained
- Transfer part of underground section of Jemena Electricity Network's COO-21 to ST-32
- For Jemena Electricity Network's COO-22 feeder,
  - Underground 0.7km of overhead conductor
  - Install 2 kiosks
  - Transfer underground sections to ST-22, ST-32 and ST-33
- Seek exemption from the Act and Regulations for the COO feeders transferred to ST ZSS on the basis that they are all underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis

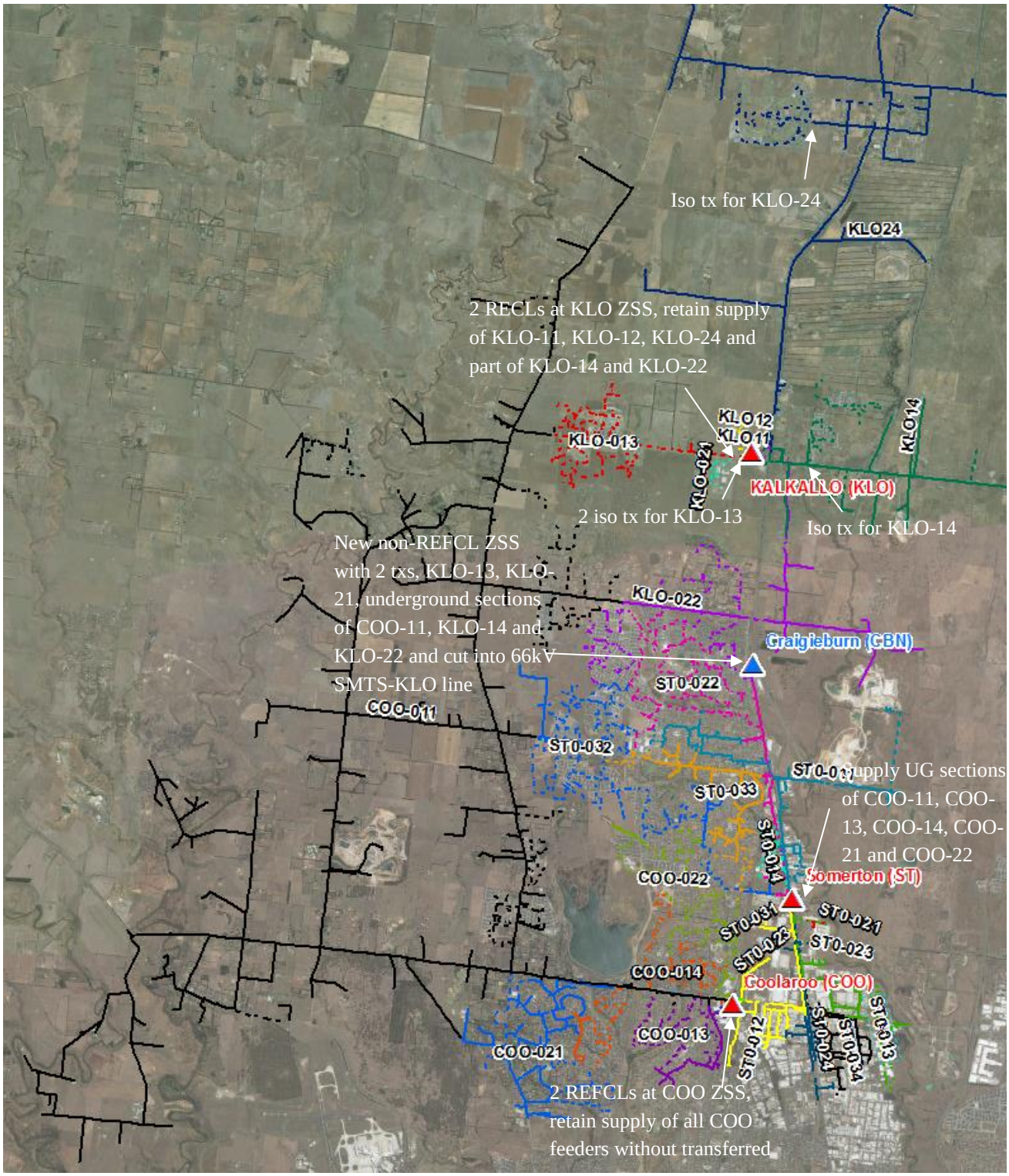
Figure 8.3 provides a high level overview of this option. Refer to Appendix B for details of the technical assessment.

Risk assessment

This option has the following risk:

- Land acquisition and community risk of 4 isolation transformers (CBN site has already been acquired by Jemena)

Figure 8.3: Option 14 high level scope of works



C4 OPTION 16 – 2 REFCL ZSS – BUILD A NEW REFCL GVE ZSS AND KLN ZSS

This option is technically feasible and aims to achieve compliance by installing two new REFCL ZSS (GVE and KLN which will supply all overhead feeders and get an exemption from the Acts and Regulation for KLO and COO ZSS which will only supply underground cable feeders and overhead conductors in LBRA.

Option objective

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

Scope of works by 2023

The high level scope of works required by each network area and business are:

1 KLO non-REFCL ZSS scope of works (undertaken by AusNet Services)

- For Jemena Electricity Network's KLO-13 feeder:
  - Underground 0.17km of overhead lines
  - Install a kiosk
  - 2.6km of new 22kV cables to transfer underground section of COO-11 near KLO-13
- For Jemena Electricity Network's KLO-22 feeder:
  - 4.7km of new 22kV cables to connect underground section of COO-11 and KLO-22 south of Mt Ridley Road to ST ZSS
  - Overhead section of KLO-22 connect to COO-11, which is transferred to GVE ZSS.
- 1km of new 22kV cables to connect underground section of AusNet Services' KLO-14 to KLO ZSS
- Seek exemption from the Act and Regulations for KLO ZSS on the basis that it supplies only underground cables. Although an entire zone substation exemption is being sought by Powercor, it has not been granted at the time of issuing this report. Hence, the lack of precedence for this exemption type increases the compliance risk of Option 16.

2 KLN REFCL ZSS scope of works (undertaken by AusNet Services)

- Build a new REFCL KLN ZSS with two transformers which will supply AusNet Services' KLO-24 and overhead section of AusNet Services' KLO-14
- Install 2 REFCLs at KLN ZSS, including network hardening and balancing
- Install 1 km of 66kV overhead lines to supply KLN ZSS by cutting into AusNet Services' KLO-DRN 66kV line
- 1km of new 22kV cables to connect overhead section of AusNet Services' KLO-14 to KLN ZSS
- 1.5km of new 22kV overhead lines to connect overhead section of AusNet Services' KLO-24 to KLN ZSS
- Install one isolation transformer at the start of an underground section of AusNet Services' KLO-24 feeder
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

3 COO non-REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- For Jemena Electricity Network's COO-11 feeder:
  - Underground section along Mickleham Road to be transferred to COO-21 for supply from COO ZSS
  - 2.8km of new 22kV cable to connect underground section of COO-11 to COO-21 along Somerton Road
  - 1 Ring Main Unit
- Seek exemption from the Act and Regulations for COO ZSS on the basis that it supplies only underground cables and overhead lines in LBRA. Although an entire zone substation exemption is being sought by Powercor, it has not been granted at the time of issuing this report. In addition, there is no precedence in seeking exemption for overhead lines in LBRA. Hence, the lack of precedence for both exemption types significantly increases the compliance risk of Option 16.

4 GVE REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- Build a new REFCL GVE ZSS with one transformer which will supply Jemena Electricity Networks' remaining of COO-11, COO-21 in HBRA and overhead sections of KLO-22
- Install 1 REFCL at GVE ZSS, including network hardening and balancing
- New 10km of 66kV overhead lines to supply GVE ZSS from COO ZSS

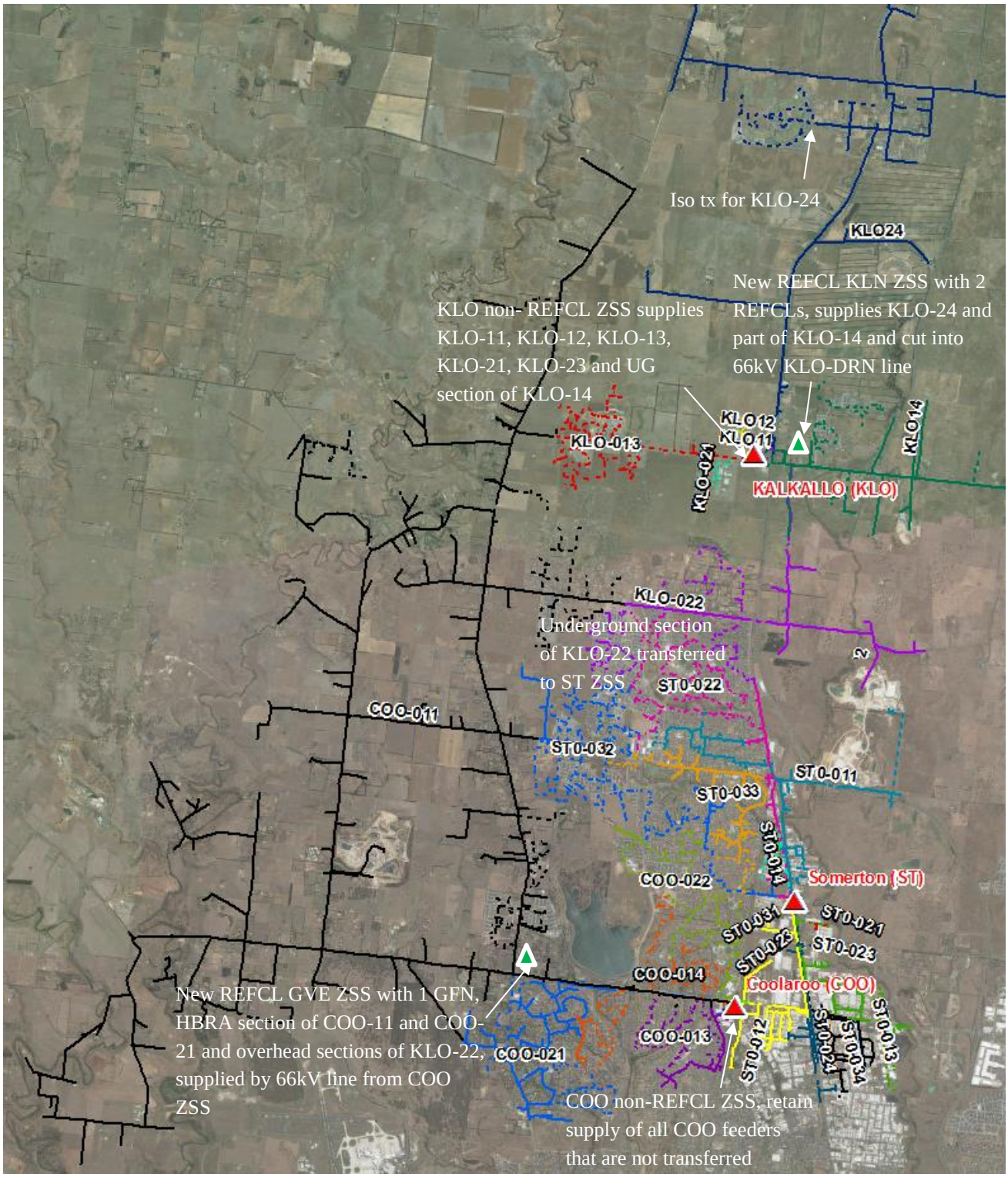
Figure 8.4 provides a high level overview of this option. Refer to Appendix B for details of the technical assessment.

Risk assessment

This option has the following risk:

- Land acquisition and community risk of 1 isolation transformer, KLN ZSS and GVE ZSS

Figure 8.4: Option 16 high level scope of works



C5 OPTION 21 – BUILD A NEW NON-REFCL CBN ZSS WITH ISOLATION TRANSFORMERS

This option is technically feasible and aims to achieve compliance by installing a new non-REFCL Craigieburn (CBN) ZSS which will supply all underground feeders and obtain an exemption from the Acts and Regulation.

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 each network area and business are:

1 KLO REFCL ZSS scope of works (undertaken by AusNet Services)

- Install 2 REFCLs at KLO ZSS, including network hardening and balancing
- Install one isolation transformer at the start of an underground section on Dwyer Street for AusNet Services' KLO-14 feeder
- Install two isolation transformers at the start of Jemena Electricity Network's new KLO-23 feeder, which is a dedicated feeder for a new 15MVA high voltage customer that is expected to connect by the end of 2019
- Install one isolation transformer at the start of an underground section of AusNet Services' KLO-24 feeder
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

2 CBN non-REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- Build a new non-REFCL CBN ZSS with two transformers which will supply only underground feeders
- New 2.6km of 66kV overhead lines to cut into the SMTS-KLO 66kV line to supply CBN ZSS
- For Jemena Electricity Network's KLO-13 feeder:
  - Underground 0.17km of overhead lines
  - Install a kiosk
  - 5.5km of new 22kV cables to connect to CBN ZSS
- 5.5km of new 22kV cables to connect Jemena Electricity Network's KLO-21 feeder to CBN ZSS
- 0.25km of new 22kV cables to connect Jemena Electricity Network's KLO-22 underground section south of Mt Ridley Road to CBN ZSS
- Transfer underground section of Jemena Electricity Network's COO-21 to neighbouring COO-14 feeder
- Transfer underground section of Jemena Electricity Network's COO-14 with the transferred part of COO-21 to neighbouring COO-22 feeder
- Transfer underground section of Jemena Electricity Network's COO-22 with transferred part of COO-14 and COO-21 to CBN ZSS via 5.1km of new 22kV cable.

- Seek exemption from the Act and Regulations for CBN ZSS on the basis that it supplies only underground cables. Although an entire zone substation exemption is being sought by Powercor, it has not been granted at the time of issuing this report. Hence, the lack of precedence for this exemption type increases the compliance risk of Option 21.

3 COO REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- Install 2 REFCLs at COO ZSS, including network hardening and balancing
- For Jemena Electricity Network's 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 two isolation transformers on Mickleham Road and 0.6km of underground cable to connect underground sections
- Install one isolation transformers at the start of an underground section of COO-13 feeder
- Transfer the remainder of Jemena Electricity Network's COO-14 feeder to COO-23 bay to balance the capacitance on the COO ZSS bus so that the REFCL constraint limits are maintained
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

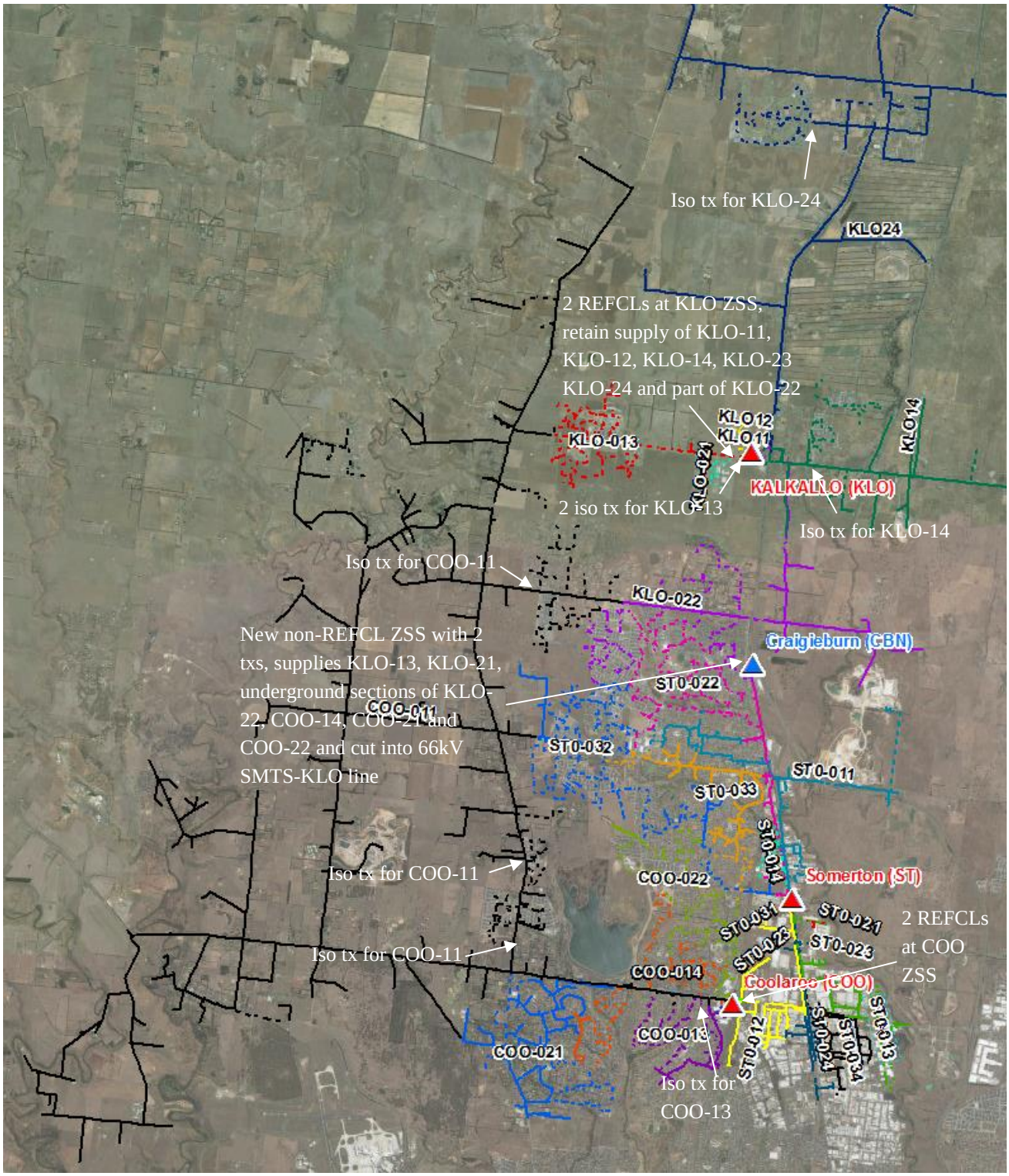
Figure 8.5 provides a high level overview of this option. Refer to Appendix B for details of the technical assessment.

Risk assessment

This option has the following risk:

- Land acquisition and community risk of 8 isolation transformers (CBN site has already been acquired by Jemena)

Figure 8.5: Option 21 high level scope of works



C6 OPTION 24 – TARGETED INSTALLATION OF ISOLATION TRANSFORMERS AND REMOTE REFCL

This option is technically feasible and aims to achieve compliance by reducing Co at the ZSS through installation of isolation transformers and remote REFCLs and obtaining exemptions from the Act and Regulations.

Option objective

This option aims to provide REFCL protection for all HBRA and sections of underground cables. Seek exemption for all LBRA overhead conductors and completely underground feeders.

Scope of works by 2023

The high level scope of works required by each network area and business are:

1 KLO REFCL ZSS scope of works (undertaken by AusNet Services)

- Install 2 REFCLs at KLO ZSS, including network hardening and balancing
- For Jemena Electricity Network's KLO-13 feeder:
  - Underground 0.17km of overhead lines
  - Install a kiosk
  - Install two isolation transformers at the start of the feeder
- Install one isolation transformer at the start of an underground section on Dwyer Street for AusNet Services' KLO-14 feeder
- Install two isolation transformers at the start of Jemena Electricity Network's new KLO-23 feeder, which is a dedicated feeder for a new 15MVA high voltage customer that is expected to connect by the end of 2019
- For AusNet Services' KLO-24 feeder:
  - Install a remote REFCL at the start of the feeder
  - Install one isolation transformer at the start of an underground section of further down the feeder
- Seek exemption from the Act and Regulations for all isolated underground cables. As there are similar precedent exemptions for underground cables, it is expected that these exemptions will be granted on this basis.

2 COO REFCL ZSS scope of works (undertaken by Jemena Electricity Networks)

- For Jemena Electricity Network's COO-11 feeder:
  - Install a remote REFCL at the start of the feeder, including feeder hardening and balancing
  - 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
- For Jemena Electricity Network's COO-21 feeder in HBRA:
  - Underground 4.6km of overhead line on Mickleham Road

- Install 16 kiosks

- Seek exemption from the Act and Regulations for COO ZSS on the basis that it supplies only underground cables and overhead lines in LBRA. Although an entire zone substation exemption is being sought by Powercor, it has not been granted at the time of issuing this report. In addition, there is no precedence in seeking exemption for overhead lines in LBRA. Hence, the lack of precedence for both exemption types significantly increases the compliance risk of Option 24.

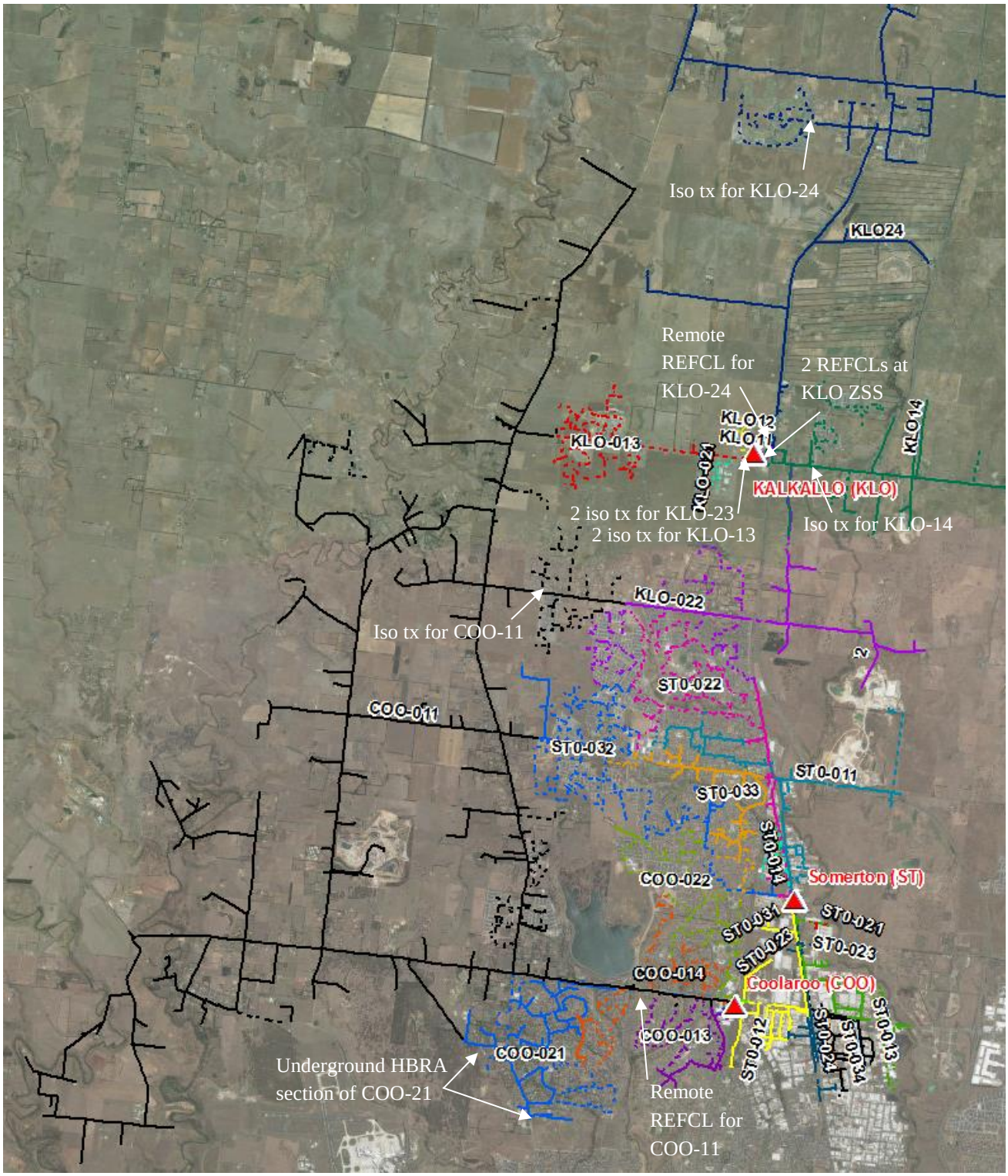
Figure 8.6 provides a high level overview of this option. Refer to Appendix B for details of the technical assessment.

Risk assessment

This option has the following risk:

- Technology risk posed by remote REFCL as it is not a tested and proven technology
- Land acquisition and community risk of 2 remote REFCLs and 7 isolation transformers (Remote REFCLs require substantial land)

Figure 8.6: Option 24 high level scope of works



APPENDIX D

ESTIMATION OF FUTURE ISOLATION TRANSFORMERS

The required number of future isolation transformers depends on the location of the future underground network growth, which is currently unknown (i.e. number and distribution of underground connections along the feeders).

Figure 8.7 and Figure 8.8 illustrate this concept:

- If all the underground network growth is connected at one point on the KLO-14 feeder as shown in Figure 8.7, only one isolation transformer is required at the point of connection to KLO-14 to disconnect this underground capacitance from KLO-14 and hence, from KLO ZSS.
- If underground growth is connected at multiple points along the KLO-14 feeder as shown in Figure 8.8, each underground connection point will require an isolation transformer.

Figure 8.7 Single isolation transformer required

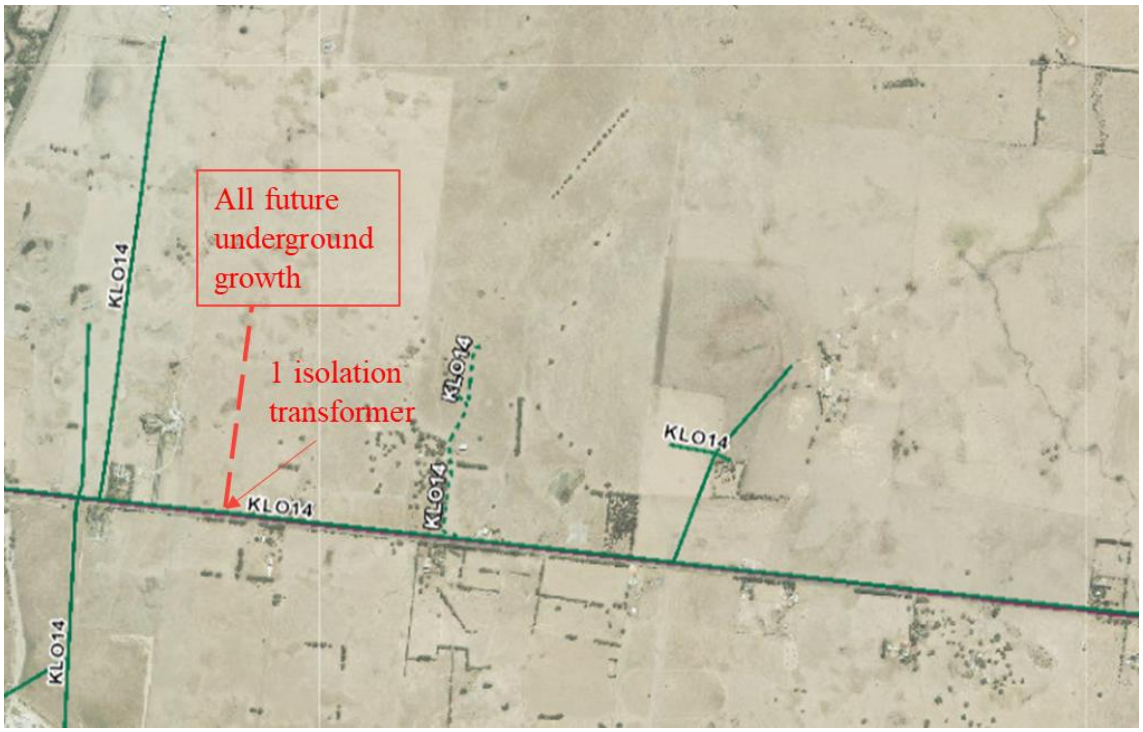
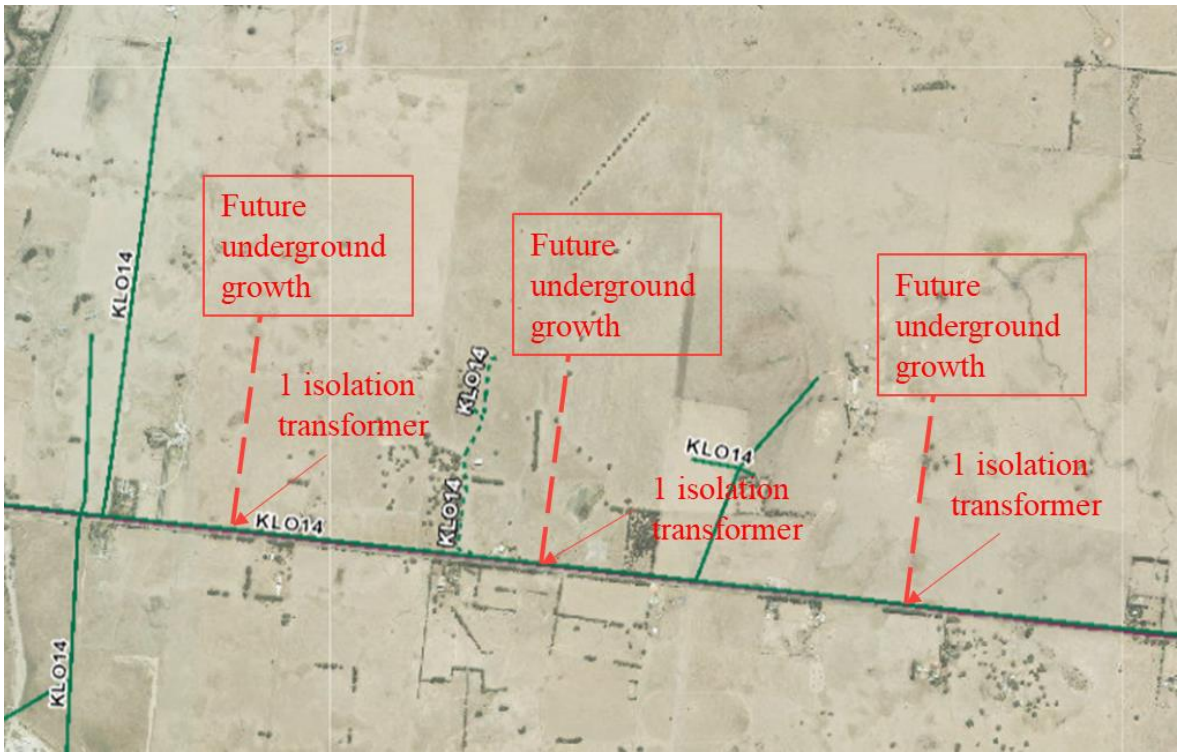


Figure 8.8 Multiple isolation transformers required



The estimated number of future isolation transformers has been based on Figure 8.7 which will most likely yield an underestimation of **both isolation transformer quantities and costs for option 7**. A more accurate estimation can only be conducted once the underground growth locations are known.