Jemena Electricity Networks (Vic) Ltd

2026-31 Electricity Distribution Price Review - Revised Regulatory Proposal

Supporting justification document

Distribution Transformer Replacement - Business Case

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1. Executive Summary

Key highlights

- This replacement program is required to mitigate risk of Pole type and Non-Pole type distribution transformer failure on the Jemena Electricity Network (JEN).
- Our approach has identified a prudent, cost-effective program of replacements to ensure that we maintain network performance and also address JEN compliance requirements.
- One component of this program includes replacing pole mounted and ground/indoor distribution transformers, indoor/kiosk switchgear (and fault replacement), transformer/substation kiosk replacement and kiosk replacement (outdoor).
- Another component of this program includes replacement of distribution zone substation low voltage (LV) switchgear and associated hardware consisting of LV boards (J type fuses) for indoor substations (indoor).
- The replacement program recommends completion by 30 June 2031, with an estimated total capital expenditure of $10.18M ($2024) with a positive NPV.

1.1 Purpose

- This document provides the business case to implement distribution transformer replacement activities during the 2026-31 regulatory period. The proposed program, with a total capital expenditure of $10.18M, is part of our forecast replacement capital expenditure.

1.2 Identified need

Distribution transformers fall under two separate asset classes:

- Pole type transformers and their associated circuits are the principal asset at the overhead networks interface with domestic, commercial and industrial customers. These facilitate the customers energy supply and export requirements. JEN operates 4,238 pole type transformers. The number of customers supplied by these individual transformers ranges between 1 and 370 customers.
- Non-Pole type distribution substations as a group includes several types of distribution substations, including - Indoor, Kiosk, Ground-type, Underground, Cubicle, HV metering cubicles and Switching cubicles. JEN operates 2,681 non-pole type distribution substations and the number of customers supplied by each of these substations ranges between 1 and 322 customers.

The key issues associated with these assets are risk of failure, as well as changing demand dynamics resulting in poor performance. Distribution transformer performance is directly related to customer energy consumption. The ability to deliver the required level of supply quality and reliability is compromised when either a customer's load or export energy levels exceed the transformer rating.

An overview of risks is described below:

Issue	Description of Issues
1	• **Asset failure** – failure modes for distribution transformers can include thermal failure, insultation failure, winding failure, deterioration/corrosion and external factor failure. The consequences of this can include the operation of protections including blown fuses and trips, excessive heat, molten materials/fire, internal/external flashover, oil spills, and distortions of other equipment. In addition, particular kiosk and switch risks exist for certain pieces of equipment on the JEN, with heightened risk of failure.

2	• **Current demand dynamics -** The ability to deliver the required level of supply quality and reliability is compromised when either a customer's load or export energy levels exceed the transformer rating. The current uptake of solar generation by customers is rapidly increasing the level of energy being exported into the distribution network. As it grows in capacity it is creating conditions which have never been experienced or planned for when designing the network. Under current conditions, the supply voltage experienced by a customer is capable of rising above the VEDCoP requirements. There is also an increase in the amount of non-linear, power electronics and generation from customers' equipment that affects the ability of distribution substations to deliver a clean, distortion free supply.
3	• **Future demand dynamics** - There is likely to be an overall increase in the demand for energy, and that this increase will need to be diversified to avoid excessive increases in maximum demands. Rising off peak and peak usage will have an impact on the cyclic rating of transformers.
4	• **Regulatory risk** – Apart from transformer failures, poor performance has credible regulatory compliance risks. The primary purpose of a substation is to provide a supply of electrical energy to the connected customers that complies with the Victorian Electricity Distribution Code of Practice (VEDCoP) with respect to Quality of Supply (QOS) and Reliability of Supply (ROS) requirements. The challenge for JEN is to remain compliant with the QOS and ROS parameters by efficiently matching the networks capacity to the varying requirements of its customer loads.

JEN also recognises its responsibility to act prudently and efficiently when investing in the distribution network to meet customer and community needs. One way we do this is by adopting asset management practices that put controls in place to test the investment need. Our best practice asset management activities involve balancing costs, opportunities and risks against performance.

In preparing our proposed expenditure, we followed capital expenditure objectives that reflect our customers' expectations, the capital expenditure drivers and capital expenditure objectives and criteria contained in the NER. Our objectives are to:

- Meet customers' expectations that we should maintain our current levels of network reliability at the most efficient cost over the long term;
- Meet our customers' expectations that our network and communities are able to withstand and recover from extreme weather events;
- Manage safety, environmental, electrical system and security risks to as low as practicable and comply with all applicable regulatory obligations efficiently over the long term;
- Connect new customers to the electricity network and meet the changing energy needs of existing customers, ensuring we can meet or manage expected demand for all customers; and
- Optimise exports and imports from distributed energy resources and CER to the distribution network.

1.3 Credible options considered

Table 1: Credible options and summary of economic analysis, $2024

Option	Total capital expenditure ($m)	Value of Customer Reliability ($m over 5 years)	Ranking
Option 1 – Do nothing	-	-	3
Option 2 - Replacement levels to maintain network performance and reliability and meet compliance obligations	10.18	11.32	1
Option 3 - Replacement levels to increase network performance and reliability	12.22	11.85	2

1.4 Recommendation

It is recommended that Option 2 is adopted. This option provides the most financially and operationally viable option to mitigate the risks of distribution transformer failure due to associated risks.

Based on this, a forecast investment of $10.18M is required. The VCR calculated was determined to be $11.32M over 5 years. This option best meets the long-term interests of JEN customers and is consistent with the National Electricity Objective and other regulatory and compliance obligations.

1.5 Regulatory considerations

The objective of the replacement program is to undertake replacement activities to ensure network performance and to meet compliance obligations, to maintain customer supply reliability and quality of supply across the JEN network given current and future demand risks.

JEN's investment decisions are ultimately guided by the National Electricity Objective (NEO). Additionally, JEN is required to meet the requirements of the National Electricity Rules (NER), Victorian Electricity Distribution Code of Practice (EDCoP), and public and industry expectations for distribution system performance, which require capital expenditure objectives to be achieved.

1.6 Financial information

This business case proposes a total capital investment of $10.18M.

This project proposed to be completed by FY31. Table 2 provides the project budget by calendar year.

Table 2: Proposed expenditure by regulatory year, $2024

Regulatory Year	Proposed Expenditure ($M)
FY27	$1.95M
FY28	$2.06M
FY29	$2.06M
FY30	$2.06M
FY31	$2.06M
Total proposed expenditure	**$10.18M**

2. Identified need

2.1 Business and socio-economic context

Distribution transformers fall under two separate asset classes.

2.1.1 Pole type transformers

Pole type transformers and their associated circuits are the principal asset at the overhead networks interface with domestic, commercial and industrial customers. These facilitate the customers energy supply and export requirements.

The transformers' principal purpose is to convert High Voltage (HV) of 22kV, 11kV or 6.6kV to a nominal supply voltage of 400/230V. These voltages are then delivered to our customers through the low voltage distribution network.

JEN operates 4,238 pole type transformers. The number of customers supplied by these individual transformers ranges between 1 and 370 customers.

2.1.2 Non-pole type transformers

Non-Pole Type Distribution Substations as a group includes the following types of distribution substations:

- Indoor substations – These are substations installed within a building, either in a free-standing structure or in one or more rooms incorporated in a larger building.
- Kiosk or padmount substations – These are self-contained prefabricated substations housed in a weatherproof metal enclosure and installed on a preprepared foundation or slab.
- Ground type substations – These are substations installed in fenced compounds and fed at HV by overhead conductors.
- Underground substations – These types of substations are installed in underground vaults normally accessed via dedicated stairwells or hatch overs and ladders.
- Cubicle substations – These types of substations are comprised of individual interconnected cubicles mounted side by side. Each cubicle contains the different components of a substation.
- HV metering cubicles – These cubicles are weatherproof prefabricated metal enclosures containing the HV current transformers and voltage transformers required to provide the energy metering requirements of HV customers; and
- Switching cubicles – These are self-contained prefabricated weatherproof enclosures housing HV ring main type switchgear. They are used to facilitate the operation of the HV underground distribution network.

Substations that supply LV customers convert High Voltage (HV) at either 22kV, 11kV or 6.6kV to a nominal supply voltage of 400/230V. Supply is provided either directly to customers via dedicated consumers mains cables or via the low voltage distribution network. Substations can be comprised of one or multiple transformers to supply individual customer supplies.

JEN operates 2,681 non-pole type distribution substations and the number of customers supplied by each of these substations ranges between 1 and 322 customers. There are HV switching devices contained within these substations. They include SF6, oil and air insulated switching devices with various current making and interrupting capabilities.

2.2 The identified need and key drivers

2.2.1 Identified need

2.2.1.1 Life expectancy

As prescribed in *ELE PR 0012 – Network Asset Useful Lives Procedure*,[1] the applicable useful life for pole and non-pole type transformers are as follows in Table 3:

Table 3: Useful life of distribution transformers

Description	Useful Life
Pole	
Pole type transformers	50
Non-Pole	
Kiosk/pad mount substations	40
Ground/indoor substations	50
Distribution switchgear	40

- The above considers asset lives based on good industry practice and specific JEN experience and represents the lives of assets at which end-of-life replacement will be considered. JEN has undertaken several reviews of asset useful lives with consulting agencies and held discussions with other Distribution Businesses to ensure assigned asset lives are realistic.

2.2.1.2 Age profile

There is a total of 4,238 single and two pole transformers in service within JEN. The chart below shows the age distribution of pole type transformers. This shows that the majority of transformers are less than 50 years old with only 6.3% of the transformer population older than 50 years.

The population of non-pole type distribution substations can be characterised as follows:[2]

- 162 ground type substations;
- 498 indoor substations;
- 5 underground substations;
- 104 HV metering cubicles;
- 5 cubicle type substations; and
- 1,907 kiosk substations.

The population of distribution switchgear can be characterised as follows:

- 1,925 Ring Main Units; and
- 235 indoor air break switches.
- 24 HV Disconnectors.

[1] JEN - RP - Support - ELE-999-PR-IN-012 Network Asset Useful Lives Procedure - 20251201 – Public.

[2] JEN – RIN – Support – Electricity Distribution Asset Class Strategy – 20250131 – Public.

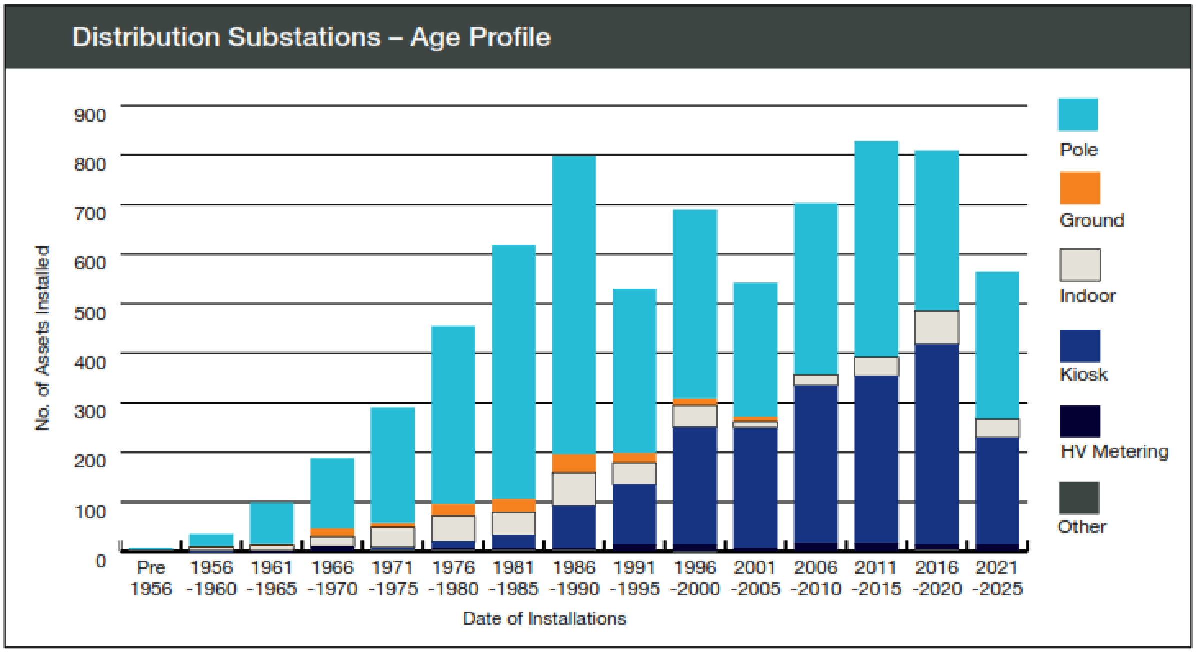
- 19 Gas switches
- 416 Circuit Breakers

The age profile for non-pole distribution substations is presented two ways as follows:[3]

- By site, the date when the substation site was first established; and
- By transformer age.

Figure 1 includes all substation types installed on the JEN. The chart indicates that the installation of new non-pole type substations has consistently increased and now exceeds the number of pole type substations installed year on year. This is reflective of the growth in the JEN underground distribution network.

Figure 1: All Substations by Type Age Profile



2.2.2 Key drivers

2.2.2.1 Failure and quality of supply

Failure modes for distribution transformers include:

- Thermal failure - due to overload, out-of-balance load, and deteriorated or high resistance connections;
- Insulation failure - due to loss of insulation medium (oil leak), heat and age-related winding insulation deterioration, lightning strikes, high voltage injections, switching events, or water penetration;
- Winding failure – winding distortion due to a through-fault;
- Deterioration or corrosion – age and environmental related deterioration of seals, paint, insulation, connections; and
- Failure due to external factors – such as vehicle strikes, animals, vandalism and weather.

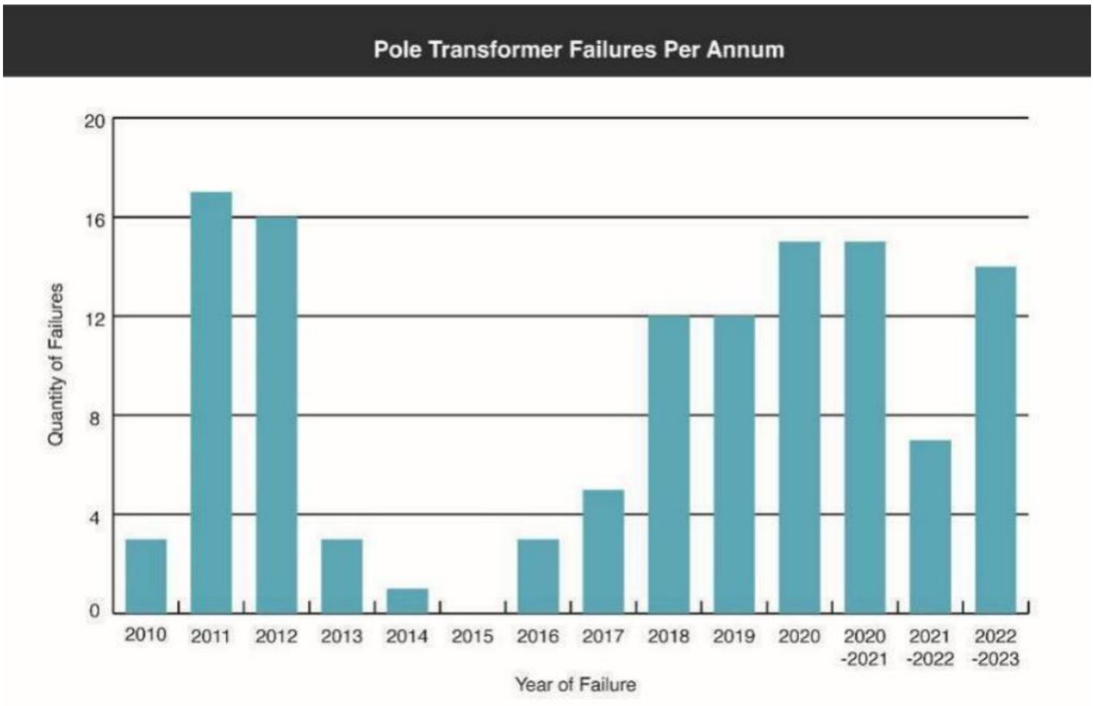
The possible consequences of the above failures include:

[3] JEN – RIN – Support – Electricity Distribution Asset Class Strategy – 20250131 – Public

- Operation of protective devices including blown fuses and circuit breaker trips;
- Excessive heat, hot spots and annealing;
- Molten material and possible fire;
- Internal or external flashover between HV to LV, HV to earth, LV to earth and inter-turn;
- Oil spill and possible environmental impacts; and
- Distortion of tank, winding, lead supports.

- The operational performance of the distribution transformer population is assessed through transformer failure rates, supply quality complaints and substation load profiling. Transformer failures generally result in customer supply outages and can lead to public and operational risks, including oil spills and fire starts.
- Between 2010 and 2022 pole top transformer in-service failures that require transformer replacement have averaged approximately 11 failures per annum and the failure rate trend line is flat. Figure 2 below indicates the annual failure rates. In addition to these in service failures, several transformers will be replaced based on condition assessments to address issues such as oil leaks or corrosion related defects.
- There have been numerous failures because of transformer overloads, faulty connections and external factors such as lightning, but the transformers themselves are generally very reliable with no evidence of systemic problems affecting reliability.

Figure 2: Pole Type Transformer Failures



Quality of supply issues directly caused by transformers generally occur as a result of overload. An overload occurs when there is an excess of customer load or reverse energy flow due to embedded generation, relative to the transformers rating.

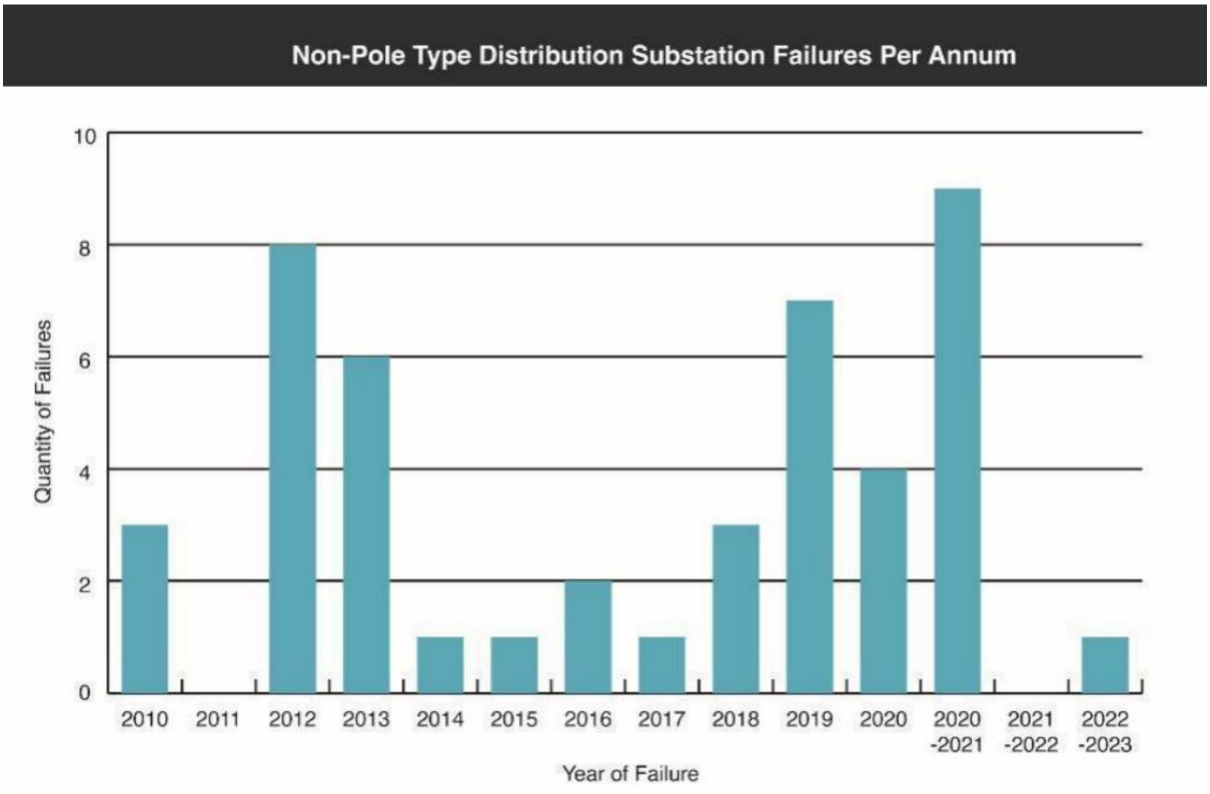
Table 4: Verified QOS Issues (RIN 3.6)

Performance Indicator	2013	2014	2015	2016	2017	2018	2019	2020	FY 20/21	FY 21/22

Low voltage supply	30	29	23	29	20	30	13	10	5	15
Voltage dips	9	10	6	18	15	20	12	8	6	0
Voltage swell	1	1	0	2	0	5	23	37	39	0
Voltage spike (impulsive transient)	1	1	1	1	0	2	10	1	1	0
Waveform distortion	0	0	0	0	0	1	1	0	0	0
TV or radio interference	-	-	-	-	-	-	0	0	0	0
Solar related*	-	-	19	28	73	89	161	125	118	70
Noise from appliances	-	-	-	-	-	-	0	1	1	0
Other	125	102	61	48	47	27	19	98	56	30

Annual non-pole type distribution substation failure rates compiled between 2010 and 2022 indicate that on average approximately 4-5 substations fail catastrophically per annum, see Figure 3 below. In addition to these failures a number of substations or their major components will be replaced based on their condition.

Figure 3: Non-Pole Type Distribution Substation Failures



Condition monitoring of these substations is conducted as part of the Enclosed Distribution Substation Inspection Program (EDSIP) on a 3 and 4 yearly basis dependent upon their location. Since the creation of the Enclosed Distribution Substation Inspection Program in 2012, many maintenance notifications have been raised against non-pole substations with issues such as overgrown vegetation, subsidence of cable trenches, missing signs, graffiti, and access issues with only a small number of all notifications relating to electrical asset integrity issues such as low oil, low gas and missing or damaged insulation.

Quality of supply issues related to these types of substations generally occur as a result of overload. An overload occurs when there is an excess of customer load or reverse energy flow due to embedded generation relative to the substations rating.

Table 5: Verified Quality of Supply Issues (RIN A 3.6)

Performance Indicator	2013	2014	2015	2016	2017	2018	2019	2020	FY 20/21	FY 21/22
Low voltage supply	30	29	23	29	20	30	13	10	5	15
Voltage dips	9	10	6	18	15	20	12	8	6	0
Voltage swell	1	1	0	2	0	5	23	37	39	0
Voltage spike (impulsive transient)	1	1	1	1	0	2	10	1	1	0
Waveform distortion	0	0	0	0	0	1	1	0	0	0
TV or radio interference	-	-	-	-	-	-	0	0	0	0
Solar related	-	-	19	28	73	89	161	125	118	70
Noise from appliances	-	-	-	-	-	-	0	1	1	0
Other	125	102	61	48	47	27	19	98	56	30

2.2.2.2 Regulatory compliance

Quality and reliability of supply

The primary purpose of a substation is to provide a supply of electrical energy to the connected customers that complies with the Victorian Electricity Distribution Code of Practice (VEDCoP) with respect to Quality of Supply (QOS) and Reliability of Supply (ROS) requirements.

- QOS and ROS issues are dynamic in nature; they develop as a result of the localised and cumulative effects of increasing demand and diversity that customers load and customers generation places on the LV networks. As customers electrical equipment is modernised, its impact and reliance on the networks compliance with the regulated QOS and ROS requirements increases. Reduced supply quality can have perceived and/or real impacts on the operation and lifecycle of connected electrical equipment. Substations play a vital role in maintaining a stable and reliable supply. The challenge for JEN is to remain compliant with the QOS and ROS parameters by efficiently matching the networks capacity to the varying requirements of its customer loads.

Investment decisions

In line with the NEO, JEN's investment decisions aim to maximise the NPV to electricity consumers. The objective of this project is to maintain the reliability of supply to customers, given the current condition of the assets. This strategy must align with other JEN strategies and plans, and the project must comply with associated regulatory requirements.

JEN's investment decisions are ultimately guided by the NEO. Additionally, considerations such as the capital expenditure objectives set out in the NER (clause 6.5.7) are particularly relevant to JEN's investment decisions:

> *a) A building block proposal must include the total forecast capital expenditure for the relevant regulatory control period which the Distribution Network Service Provider considers is required in order to achieve each of the following (the capital expenditure objectives):*
>
> > *(1) Meet or manage the expected demand for standard control services over that period*
> >
> > *(2) Comply with all applicable regulatory obligations or requirements associated with the provision of standard control services*
> >
> > *(3) To the extent that there is no applicable regulatory obligation or requirement in relation to:*
> >
> > > *(i) The quality, reliability or security of supply of standard control services; or*

(ii) The reliability or security of the distribution system through the supply of standard control services,

to the relevant extent:

(iii) Maintain the quality, reliability and security of supply of standard control services

(iv) Maintain the reliability and security of the distribution system through the supply of standard control services.

(4) Maintain the safety of the distribution system through the supply of standard control services.[4]

Additionally, the EDCoP sets out provisions relevant to JEN's planning, design, maintenance, and operation of its network, most notably section 19.2 (Good Asset Management) and section 13.3 (Reliability of Supply):

Section 19.2 – Good Asset Management

A distributor must use best endeavours to:

a) Assess and record the nature, location, condition and performance of its distribution system assets

b) Develop and implement plans for the acquisition, creation, maintenance, operation, refurbishment, repair and disposal of its distribution system assets and plans for the establishment and augmentation of transmission connections:

- *To comply with the laws and other performance obligations which apply to the provision of distribution services including those contained in this Code*
- *To minimise the risks associated with the failure or reduced performance of assets*
- *In a way which minimises costs to customers taking into account distribution losses.*

c) Develop, test or simulate and implement contingency plans (including where relevant plans to strengthen the security of supply) to deal with events which have a low probability of occurring, but are realistic and would have a substantial impact on customers.

Section 13.3 – Reliability of Supply

A distributor must use best endeavours to meet targets determined by the AER in the current distribution determination and targets published under clause 13.2.1 and otherwise meet reasonable customer expectations of reliability of supply.

When making decisions to invest, JEN must comply with these obligations.

2.2.3 Proposed replacement programs and activities

Our proposed expenditure is informed by specific activities, each assigned to service codes (in brackets):

Program & Service Code	• Activities

Transformer Pole Mounted (RHA)	• Replacement of an existing transformer due to failure.
	• Includes, but not limited to:
	  • Installation and commissioning of new transformer
	  • Fitting of bird covers or animal proofing to a structure
	  • Moving and securing displaced covers back into position

[4] NER, cll 6.5.6(a), 6.5.7(a).

	◦ Removal of old transformer and de-commissioning works ◦ Replacement of LV leads and connections to comply with current construction standards ◦ Testing of HV and LV earth while onsite ◦ Earth repair / maintenance ◦ Visual check and tightening of loose hardware on the same structure ◦ Electrical pre-testing of transformers ◦ Testing of retired transformer's oil for PCB prior to refurbishment or disposal ◦ Waste disposal generated from the replacement of the transformer connections ◦ Moving platform mount to pole mount if required • The activity excludes: ◦ Replacement of surge arrestors ◦ Replacement of HV fuse unit ◦ Replacement of LV isolators; and ◦ Replacement of ampact connectors
Transformer Ground/Indoor (RHD)	• Replacement of an existing ground/indoor transformer due to failure. • Includes, but not limited to: ◦ Installation and commissioning of new transformer ◦ Fitting of bird covers or animal proofing to a structure ◦ Moving and securing displaced covers back into position ◦ Removal of old transformer and de-commissioning works ◦ Load testing and replacement of HV/LV fuses ◦ All connections, lugs and brackets (as current construction design and standards) ◦ Testing of HV and LV earth while onsite ◦ Electrical pre-testing of transformers ◦ Testing of retired transformer's oil for PCB prior to refurbishment of disposal ◦ Site clean-up and any associated civil works ◦ Waste disposal generated from the replacement of the transformer ◦ Replacement of ground surface with 100mm depth using 20mm washed rock • The activity excludes: ◦ HV cables and termination ◦ LV cables and terminations ◦ Replacement of surge arrestors ◦ Replacement of HV fuse units ◦ Replacement of LV isolators ◦ Replacement of ampact connectors; and ◦ Replacement of HV and LV switchgears
Indoor/Kiosk Switchgear RMU Age and Fault Replacement (RHE)	• Replacement of HV switchgear due to failure or that can no longer be maintained. • Includes, but not limited to: ◦ Removal of all wall mounted HV equipment, brackets and fittings ◦ Installation & replacement of HV switch or Circuit Breaker ◦ Replacement of HV fuses ◦ Labels, signage and locks ◦ Testing CB setting ◦ Testing of HV and LV earth while onsite ◦ LV distribution board ◦ Polycarbonate barriers ◦ LV fuses ◦ Brackets and fittings ◦ Connection to earthing

	• Cut and refit existing trench covers
	• Electrical inspection as required
	• Mechanical and flash protection cover around base of switch
	• Fitting and alterations of all cables and earths
	• Associated civil works to remove and install the replacement switchgear
	• De-commissioning and disposal of defective switchgear and SF6
	• The activity excludes:
	  • HV cables and terminations
	  • LV cables and terminations
	  • The replacement of enclosures
	  • Prescribed or non-prescribed waste disposal (SF6, asbestos)
	  • Cable joints
	  • New trench covers

LV Switchgear Replacement (RHF)	• Replacement of LV switchgear and all associated hardware, on a single structure, as a result of:
	  • A fault or operational damage
	  • Erection of new isolators to facilitate network requirements
	  • New LV distribution board
	  • LV Bus
	  • LV fuse switches disconnectors and isolators
	  • Cable extensions, luging and connections
	  • Polycarbonate barriers
	  • LV fuses
	  • Labels signage and locks
	  • Brackets and fittings
	  • Fitting and alterations of all cables and earths
	  • Cut and refit existing or replace trench covers
	  • Electrical inspection as required
	  • Disposal of asbestos including environmental reporting if required
	  • De-commissioning and disposal of defective switchgear
	• The activity excludes:
	  • The installation of ampact stork lugs/connectors

Transformer/Substation Kiosk (RHK)	• Replacement of a kiosk substation due to failure. Includes, but not limited to:
	  • Replacement of a kiosk substation as a result of fault or operational damage
	  • Site re-establishment to required standard
	  • Installation of new or refurbished kiosk transformer
	  • Removal of old transformer
	  • All associated civil works
	  • Replacement of ground surface with 100mm depth using 20mm washed rock
	  • Installation, replacement or reinstatement of plinth to required standard, where required
	  • Refitting of all HV & LV cable connections, cable extensions and re-lugging if required
	  • Labels, signage, locks and commissioning of new Transformer
	  • Replacement of HV/LV fuses where required
	  • Testing of HV/LV earth while onsite
	  • Electrical pre-testing of transformers
	  • Testing of retired transformer's oil for PCB prior to refurbishment or disposal
	  • De-commissioning and disposal of defective switchgear
	  • Waste disposal generated from the replacement of the transformer

	• The activity excludes: • New cable joints/terminations • Site establishment and foundation to new construction standard • HV cable lengths over 10m and terminations • LV cable lengths over 10m • Civil works for prescribed or non-prescribed waste including recovery and site re-establishment (arising from significant environmental issues • Prescribed or non-prescribed waste disposal
Kiosk Refurbishment (RHM)	• Major refurbishment of kiosks for the hold of these as part of the overall transformer stock. • The suitability of a transformer for refurbishment will be based on the approved refurbishment policy. The activity shall include as required: • Cleaning, painting, tighten all gaskets • Maintain external items (taps, valves, sight glass, plugs) • Maintain or replace internal items including transformer core • Supply and install LV board • Re-gasket transformer, oil test dielectric • Maintain or install signs and locks • Electrical pre test • PCB oil sampling and oil test • Final electrical test • Checking and tightening all hardware on the same structure

2.3 Asset risk (or opportunity) analysis

2.3.1 Short description of the affected Jemena assets

2.3.1.1 Current risks

Apart from transformer failures, poor performance has credible regulatory compliance risks. Distribution transformer performance is directly related to customer energy consumption. The ability to deliver the required level of supply quality and reliability is compromised when either a customer's load or export energy levels exceed the transformer rating.

The uptake of solar generation by customers is rapidly increasing the level of energy being exported into the distribution network. As it grows in capacity it is creating conditions which have never been experienced or planned for when designing the network. The main impact is on the level of voltage being supplied to customers.

Under current conditions, the supply voltage experienced by a customer is capable of rising above the VEDCoP requirements at the customer's Point of Common Coupling (POCC). At a localised level the excessive voltage causes inverters to shut down and/or adversely affect QOS limits at both the customer's premise and neighbouring properties. At the network level the cumulative export capacity can potentially exceed the rating of the transformer and its associated components leading to possible asset failure.

Energy export doesn't always align with energy usage patterns. At the domestic level, peak energy demand typically occurs in the evening, whereas solar systems predominantly export energy during daylight hours when the sun is shining. Consequently, distribution substations must be equipped to handle the peak energy demands of customers in the evening, independent of embedded generation, while also maintaining acceptable voltage levels during the day when embedded generation is at its peak. Meeting the demands for supply quality in these fluctuating operating conditions poses challenges with the current static network infrastructure.

In addition, there is an increase in the amount of non-linear, power electronics and generation from customers' equipment that affects the ability of distribution substations to deliver a clean, distortion free supply. Non-linear loads produce harmonics which inherently distort supply voltages creating a dirty supply. The cumulative impact of these types of loads increases the base levels of harmonic distortion which increase the impact of individual localised harmonic distortion. Experience indicates that localised harmonic distortion can exceed the 5% supply voltage VEDCoP distortion limit, leading to the overheating of transformers.

For Non-Pole type transformers, particular kiosk risks also exist. For example:

- During 2013, several kiosks manufactured between 2005 and 2009 failed catastrophically. An investigation by the manufacturer found no root cause for the failures but hypothesised that there could have been internal clearance issues causing partial discharge which eventually led to the failures; and
- Another iteration of kiosks have suffered two bushing failures. These issues have been taken up with the manufacturer to identify possible remedies.

The following HV switch types also have known issues specific to their design. These switches are either being maintained or are targeted for replacement:

- Schneider RM6s RMU's (manufactured between 1983 and 1987)
- Schneider RM6 units (manufactured between 1983 and 1987)
- Early versions of the Merlin Gerin gas insulated RMU
- F & G RMU's (purchased in the 1990's for use in indoor distribution substations at both 22kV and 11kV)
- Calor Emag 22kV air break switchgear
- Siemens 3AC-20N Minimum Oil Breaker
- A number of different types of air break switches have been identified as having high maintenance costs and a probability of failure.

2.3.1.2 Future risks

Changes in load profiles due to both changing usage patterns and embedded generation are occurring, and the outcomes of these changes are currently being assessed and modelled. The initial indicators are that there will be an overall increase in the demand for energy and that the increase will need to be diversified to avoid excessive increases in maximum demands. The most significant impacts will come from Electric Vehicle (EV) charging and electrification.

As Victoria is moving towards a lower carbon footprint there will be a push towards EV's away from the traditional fossil fuelled vehicles. The energy demands for EV's will have to be met by the current electricity infrastructure in conjunction with non-network generation. Their demands will add to the daily load profiles and if they follow a similar pattern will increase usage in peak demand periods. Usage will therefore need to be managed to limit their impact on network maximum demands.

Off peak and peak usage will have an impact on the cyclic rating of transformers. Off peak usage will result in load being diversified across a 24-hour period thus reducing the transformer cooling time and as a result, require a reduction in the cyclic ratings to manage the transformers performance. An increase in peak usage will require more capacity to be added to the network increasing the network cyclic rating.

2.3.2 Asset condition and risk assessment

Asset criticality is a measure of the risk of specified undesired events faced when utilising equipment. An asset criticality assessment was conducted at sub-asset class level by following the Asset Criticality Assessment Procedure (ELE-999-PR-RM-003, formerly JEM AM PR 0016). The asset criticality score is then utilised to rank critical assets which have the potential to significantly impact on the achievement of JEN's operational objectives.

The pole-type transformer asset class has an asset criticality score of AC2 (Moderate) due to the consequence of a pole type transformer failure having the potential to cause third party damage and injury to JEN personnel and members of the public. Pole-type distribution substations influence JEN's overall network performance in terms of reliability and quality of customer supply. The JEN is configured such that in the majority of cases the impact of customer outages associated with a substation can be minimised through HV switching and LV parallels so that supply to customers can be restored promptly.

The non-pole type distribution substation asset class has an asset criticality score of AC2 (Moderate). This is due to the potential for failure of a non-pole substation to cause third party damage and injury to JEN personnel and members of the public. Non-pole type distribution substations contribute to the JEN overall service level performance through reliability and quality of customer supply.

2.4 Consistency with Jemena strategy and plans

This section describes how this project is consistent with JEN's objectives and strategies:

- **Provision of Service Levels and Reliability:** Ensuring service levels and reliability meet customer expectations.
- **Modern Capabilities:** Deployment of modern equivalent capabilities in the network to remain relevant to customers in the longer term.
- **Prudent and Efficient Expenditure:** Ensuring expenditure is prudent and efficient, aligning with customer expectations regarding affordability.

JEN seeks to ensure that lifecycle costs are both efficient and effective. This business case is consistent with this requirement and aligns with the long term vision of the network, as set out in the Asset Management Plan (AMP) and annual planning reports.

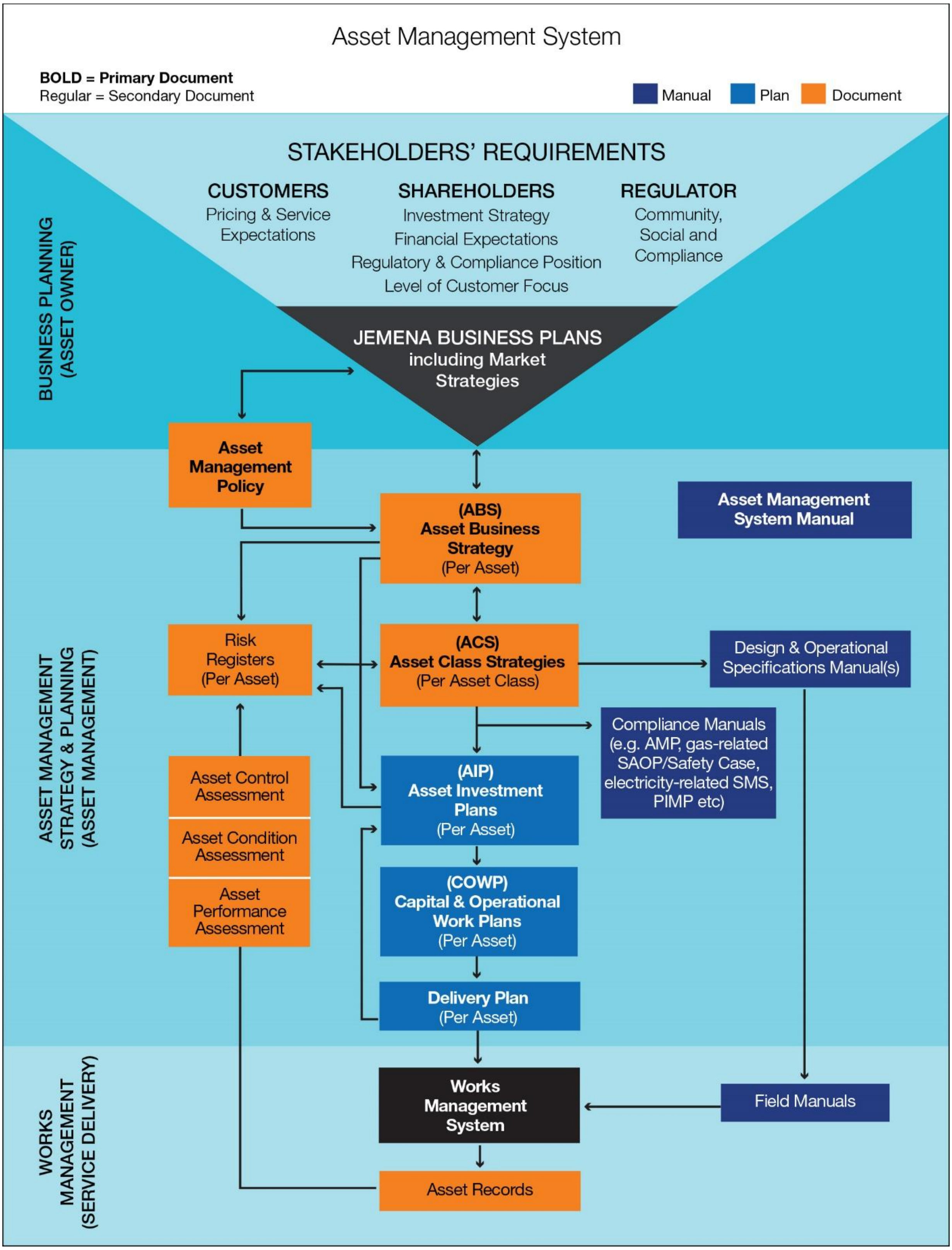
This proposal aligns with Asset Management Strategies, Plans and Policies contributing to a safe workplace for JEN employees and contractors. By addressing identified issues, JEN can reduce the risk of injury or environmental incident.

JEN abides by Australian asset and risk management industry standards (ISO 55001 and ISO 31000:2018) which is part of JEN's internal risk and asset management framework documents (ELE PL 0004 and JAA PO 0050).

Figure 4 outlines the Jemena asset management system and where the Asset Management Plan (**AMP**) is positioned within it. The AMP covers the creation, maintenance and disposal of assets including investment planned to augment network capacity to meet increasing demand and to replace degraded assets to maintain reliability of supply to meet Jemena Business Plan requirements.

This strategic framework facilitates the planning and identification of business needs that require network investment documented via business cases.

Figure 4: The Jemena Asset Management System



JEN also recognises its responsibility to act prudently and efficiently when investing in the distribution network to meet customer and community needs. One way we do this is by adopting asset management practices that put controls in place to test the investment need. Our best practice asset management activities involve balancing costs, opportunities and risks against performance.

In preparing our proposed expenditure, we followed capital expenditure objectives that reflect our customers' expectations, the capital expenditure drivers and capital expenditure objectives and criteria contained in the NER. Our objectives are to:

- Meet customers' expectations that we should maintain our current levels of network reliability at the most efficient cost over the long term;
- Meet our customers' expectations that our network and communities are able to withstand and recover from extreme weather events;
- Manage safety, environmental, electrical system and security risks to as low as practicable and comply with all applicable regulatory obligations efficiently over the long term;
- Connect new customers to the electricity network and meet the changing energy needs of existing customers, ensuring we can meet or manage expected demand for all customers; and
- Optimise exports and imports from distributed energy resources and CER to the distribution network.

3. Comparison of credible options

3.1 Identifying credible options

The following feasible options could be executed to address the business need, problem or opportunity.

1. **Option 1 is 'do nothing'**, assumes that as distribution transformers fail they are not replaced and as load distribution alternatives become unavailable customers will be left off supply indefinitely. This option does not address any of the identified condition issues in full nor does it allow us to maintain current levels of network reliability and is not considered a credible option; or
2. **Option 2 is 'replacement levels to maintain network performance, reliability and to meet compliance obligations'**, which invests in replacement of distribution transformer assets based on forecasts using historical trends. Replacing distribution transformer assets as required assists in mitigating issues and risks associated with a failure of this type of asset, as well as accommodating current and future demand dynamics while managing regulatory quality and reliability of supply risks. This option optimises replacement levels to ensure current levels of network reliability whilst responding to our customers who have indicated they value a stable network. This is evidenced by our customer engagement, which highlights 'maintaining the network' being more important to customers than 'improving the network'. When assessing this option, we calculated a value of customer reliability (VCR) metric to determine the average value different types of our customers place on having reliable electricity supply.[5] The VCR calculated was determined to be $11.32M over 5 years; or
3. **Option 3 is 'replacement levels to increase network performance and reliability'**. This approach would focus on proactively replacing the highest risk distribution transformer assets. This option would replace assets at a rate above historical trend forecasts, with the intention of improving network reliability above current levels. As with Option 2, when assessing this option we calculated a value for VCR to determine the average value different types of our customers place on having reliable electricity supply.[6] The VCR calculated was determined to be $11.85M over 5 years.

3.2 Developing credible options

Table 6 shows the extent to which each option addresses the identified issues.

Table 6: Credible Options Analysis

Issue	Option 1	Option 2	Option 3
Asset failure Distribution transformers are subject to a variety of failure modes. Certain kiosk and switch risks also exist, with heightened chance of failure. Risks are exacerbated by demand dynamics.	○	●	◑
Current demand dynamics Current uptake rates of solar are compromising supply quality and reliability, where customer load or export energy exceed transformer ratings. There is also an increase in the amount of non-linear, power electronics and generation which affects the ability of distribution substations to deliver clean, distortion free supply.	○	●	●
Future demand dynamics Rising off peak and peak usage will have an impact on the cyclic rating of transformers.	○	●	●

[5] JEN - RP - Support - Distribution Substation Replacement Model - 20251201 - Public.

[6] More detail on how this has been calculated can be found in 4.1.1.

Regulatory risk Apart from transformer failures, poor performance has credible regulatory compliance risks. Under current conditions, the supply voltage experienced by a customer is capable of rising above the VEDCoP requirements. The challenge for JEN is to remain compliant with the quality and reliability of supply parameters by efficiently matching the networks capacity to the varying requirements of its customer loads.	○	●	◑

●	Fully addressed the issue
◑	Partially addressed the issue
○	Did not address the issue

Each of these options are discussed in detail below.

3.2.1 Option 1: Do nothing

The ‘do nothing’ option assumes that as distribution transformers fail they are not replaced and as load distribution alternatives become unavailable customers will be left off supply indefinitely. This option does not address any of the identified condition issues, given it does not undertake distribution transformer replacement. The probability of failure for this equipment would continue to increase over time, potentially leading to catastrophic failure while in service. Given the criticality of these issues and the lack of risk mitigation, this option is not considered credible.

3.2.2 Option 2: Replacement program to maintain network performance, reliability and to meet compliance obligations

The ‘replacement levels to maintain network performance, reliability and to meet compliance obligations’ is an approach which invests in replacement of pole and non-pole distribution transformers based on forecasts using historical trends. This assists in mitigating issues and risks associated with a failure of this type of asset, as well as alleviating current and future demand risks, while meeting quality and reliability of supply regulatory obligations.

This option would maintain current levels of network reliability, and optimises replacement levels to maintain this reliability whilst responding to our customers who have indicated they value a stable network more so than improvements to the network. This is evidenced by our customer engagement, which highlights ‘maintaining the network’ being more important to customers than ‘improving the network’.[7]

Jemena’s Peoples Panel noted ‘Jemena needs to prioritise investing in reliability by assessing, building, and maintaining the network to meet changes in operating conditions and withstand network failures’.[8] This position was reiterated by the First Nations and Disability Customer Voice Groups.

When assessing this option, we calculated a value of customer reliability (VCR) metric to determine the average value different types of our customers place on having reliable electricity supply.[9] The VCR calculated was determined to be $11.32M over 5 years.

This option resolves all identified issues while aligning with the JEN asset class and business strategies. The

[7] See JEN - Att 02-01 Customer engagement – 20250131.

[8] See JEN - Att 02-01 Customer engagement – 20250131, s.5.1.

[9] More detail on how this has been calculated can be found in 4.1.1.

total capital cost of this option is forecasted at $10.18M based on activities commencing in 2027.

A program has been developed to target for replacement pole top transformers that are overloaded at levels greater than 150% of their nameplate rating. In addition to the replacements proposed for the overloaded family of pole type transformers a number of projects have been identified that are required to ensure that network performance and reliability is maintained at current levels and our compliance requirements are addressed.

Table 7 lists the replacement volumes for non-pole and pole type distribution transformers from 2027 to 2031 required to, as per the Asset Class Strategy, maintain the performance and reliability of the asset class.

As detailed in this strategy, a number of projects have been identified to ensure that we maintain network performance and also address our compliance requirements.

Table 7: Option 2 Replacement Volumes and Expenditure - Non-Pole and Pole Type Distribution Substations

Unique ID	Service Code	Activity	Forecast Replacement Volumes					Proposed Expenditure ($2024,'000)					
			FY27	FY28	FY29	FY30	FY31	FY27	FY28	FY29	FY30	FY31	Total
A140	RHA	Transformer Pole Mounted	32	32	32	32	32	809	809	809	809	809	**4,045**
A243	RHD	Transformer Ground/Indoor	9	9	9	9	9	401.4	401.4	401.4	401.4	401.4	**2,007**
A143	RHE	Indoor/Kiosk RMU Gas Gauges & Fault Replacement	2	3	3	3	3	204.6	307	307	307	307	**1,432**
A148	RHK	Transformer/Sub station Failure Kiosk	4	4	4	4	4	471.4	471.4	471.4	471.4	471.4	**2,357**
A108	RHM	Kiosk Refurbishment	6	6	6	6	6	68.2	68.2	68.2	68.2	68.2	**341**

3.2.3 Option 3: Replacement levels to increase network reliability

The 'replacement levels to increase network reliability' option is a proactive approach that invests in at-risk replacement of distribution transformer assets over and above historical trend forecasts. This approach would focus on replacing the highest risk distribution transformer assets.

Generally, this option would include a variety of sub-options for determining when replacement occurs:

- **Replacing distribution transformers at a scheduled age**. Although the scheduled replacement age will be based on structured analysis of the functions and potential failures, for assets such as distribution transformers, age-based replacement is not an optimal strategy and not cost effective.

- **Scheduled testing of distribution transformers to ascertain their conditions**. The incremental improvement in network reliability does not outweigh the cost to test the distribution transformers.

This option is likely to resolve most identified issues while aligning with the JEN asset class and business strategies. The total capital cost of this option is $12.22M.

This option would replace assets at a rate above historical trend forecasts, to improve network reliability above current levels. This option does not respond to our customer's needs, who have indicated they value a stable network more so than improvements to the network. This is evidenced by our customer engagement, which highlights 'maintaining the network' being more important to customers than 'improving the network'.[10] Jemena's Peoples Panel noted 'Jemena needs to prioritise investing in reliability by assessing, building, and maintaining the network to meet changes in operating conditions and withstand network failures'.[11] This position was reiterated by the First Nations and Disability Customer Voice Groups.

As with Option 2, when assessing this option we calculated a value for VCR to determine the average value different types of our customers place on having reliable electricity supply.[12] The VCR calculated was determined to be $11.85M over 5 years.

Table 8: Option 3 Replacement Volumes and Expenditure - Non-Pole and Pole Type Distribution Substations

Unique ID	Service Code	Activity	Forecast Replacement Volumes					Proposed Expenditure ($2024, '000)					
			FY27	FY28	FY29	FY30	FY31	FY27	FY28	FY29	FY30	FY31	Total
A140	RHA	Transformer Pole Mounted	38	38	38	38	38	970.8	970.8	970.8	970.8	970.8	**4,854**
A243	RHD	Transformer Ground/Indoor	11	11	11	11	11	481.7	481.7	481.7	481.7	481.7	**2,408**
A143	RHE	Indoor/Kiosk RMU Gas Gauges & Fault Replacement	2	4	4	4	4	245.6	368.4	368.4	368.4	368.4	**1,719**
A148	RHK	Transformer/Substation Failure Kiosk	5	5	5	5	5	565.7	565.7	565.7	565.7	565.7	**2,829**
A108	RHM	Kiosk Refurbishment	7	7	7	7	7	81.8	81.8	81.8	81.8	81.8	**409**

[10] See JEN - Att 02-01 Customer engagement – 20250131.

[11] See JEN - Att 02-01 Customer engagement – 20250131, s.5.1.

[12] More detail on how this has been calculated can be found in 4.1.1.

4. Option analysis

4.1 Economic analysis

In line with the objective of the National Electricity Rules, JEN's capex investment decisions aim to maximise the present value of the net economic benefit to all those who produce, consume and transport electricity in the National Electricity Market.

To assess benefits against this objective, JEN has undertaken a probabilistic cost-benefit assessment of replacement options that considers the likelihood and severity of critical network outages. This methodology assesses the expected impact of asset failures and subsequent network outages on supply delivery and combines this with the value customers place on supply reliability (VCR) and compares the result with the costs required to reduce the likelihood and/or impact of these supply outages. The benefits considered in this economic analysis relate to mitigating the increasing risk of transformer failure within the electricity distribution network. This includes the safety risks associated with Option 1 (do nothing) described earlier. The following table summarises the economic analysis undertaken.

Table 9: Costs of Options, $2024[13]

Option	Total capital expenditure ($m)	Value of Customer Reliability ($m over 5 years)	Ranking
Option 1 – Do nothing	-	-	3
Option 2 - Replacement levels to maintain network performance and reliability and meet compliance obligations	10.18	11.32	1
Option 3 - Replacement levels to increase network performance and reliability	12.22	11.85	2

4.1.1 Assumptions and inputs used

Value of unserved energy analysis

This business case determines the value of unserved energy based on the historical level of replacements for Option 2 and an increase in volumes from historical levels in Option 3. The value of unserved energy is determined by the average duration that customers experience an outage due to a distribution transformer fault converted to consumption and using the 2025 VCR in $/kWh to calculate the monetary value of the unserved energy.

Table 10: Estimate of customer unserved energy per hour

Sector	kW/h
Residential	0.70
Commercial	1.67
Industrial	16.67

[13] JEN - RP - Support - Distribution Substation Replacement Model - 20251201 - Public

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Sector	2025 VCR - $/kWh
Residential	54.41
Agricultural	22.25
Commercial	34.39
Industrial	33.49
>10MVA	70.88

4.2 Financial analysis for the preferred option

4.2.1 Financial analysis

This business case proposes a total capital investment of $10.18M.

This project proposed to be completed by FY31. Table 10 provides the project budget by calendar year.

Table 12: Proposed expenditure by regulatory year, $2024

Regulatory Year	Proposed Expenditure ($M)
FY27	$1.95M
FY28	$2.06M
FY29	$2.06M
FY30	$2.06M
FY31	$2.06M
Total proposed expenditure	**$10.18M**

5. Recommendation

It is recommended that Option 2 is adopted. This option provides the most financially and operationally viable option to mitigate the risks of distribution transformer failure due to associated risks.

Based on this, a forecast investment of $10.18M is required. The VCR calculated was determined to be $11.32M over 5 years. This option best meets the long-term interests of JEN customers and is consistent with the National Electricity Objective and other regulatory and compliance obligations.