Jemena Electricity Networks (Vic) Ltd

JEN – RIN – Support – 66kV Bushing Replacement Program – Business Case – 20250131

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1. Executive Summary

Synopsis

- This program is required to mitigate the risk of power transformer failure at Jemena Electricity Network (JEN) zone substations.
- Many 66kV transformer bushings contribute towards or cause power transformer failure due to their inherent design, age and condition issues.
- Our approach has identified a prudent, cost effective and efficient risk mitigation program to test and replace at-risk bushings.
- The program involves the testing of approximately 60% of the JEN 66kV bushing population, covering 17 zone substations.
- The program recommends completion by 30 June 2031, with an estimated total capital expenditure of A$7.5 million (nominal) with a positive NPV.

1.1 Business need

Power transformers play an important role in ensuring the reliable and efficient operation of electrical grids. They are a critical asset installed in zone substations to transform sub-transmission voltages (66kV) to local area distribution voltages (<22kV), providing the electricity supply to customers within JEN.

The 66kV bushings of a transformer are a critical component as they provide safe connection of the sub-transmission network to the high voltage (HV) terminals of the transformer. A failure of this connection results in an inoperable transformer.

Analysis suggests an ongoing increase in the risk of failure or adverse performance of power transformers unless at-risk bushings are validated and replaced.

The known issues associated with aging 66kV Transformer Bushing assets are described below in Table 1-1.

Table 1-1: Current Issues with 66kV Transformer Bushings

Issue No.	Description of Issue
1	**Safety risk** – Due to the catastrophic risk of failure for this sub-asset class, there continues to be an increased safety risk to people onsite when in the vicinity of affected assets.
2	**Asset risk** – A previously unidentified design fault in specific bushings has seen their operating life shortened, placing the power transformers they are installed on at risk of failure.
3	**Supply risk** - Ensuring customer obligations are met requires supply and network reliability. Catastrophic failure of a power transformer has major implications and can lead to financial, operational and reputational issues on top of unacceptable supply risk. This risk must be treated to ensure there are no adverse supply capacity, network reliability, and regulatory and compliance obligation outcomes.

The following options addressing these issues have been considered:

1. **Do nothing**
2. **Test and assess at-risk bushings and replace as required**
3. **Replace all potential bushings at risk**
4. **Non-network solution**

As per the Risk Assessment at Appendix B, the untreated risk ratings are High or Significant for the risks identified. This business case forms the rationale to initiate a project addressing the issues and risks associated with at-risk 66kV transformer bushings.

1.2 Recommendation

It is recommended that Option 2 (test and assess at-risk bushings and replace as required) is adopted. This option provides the most financially and operationally viable option to mitigate the risks of power transformer failure due to the poor bushing condition.

This option also involves a targeted test and assessment process ensuring that only bad condition bushings with a high probability of failure are replaced. Based on this, a forecast investment of $7.5M is required. This investment provides a customer net benefit of $10.8M. This option best meets the long-term interests of JEN customers and is consistent with the National Electricity Objective.

1.3 Regulatory considerations

The objective of the project is to determine the most appropriate strategy for the nominated assets to maintain customer supply reliability across the JEN network given their current condition.

Two options were explored in the options analysis outlined in Section 3.3 of this document to identify a recommendation. The options have been benchmarked against the risk assessment in Appendix B to ensure that health, safety and reliability issues are addressed. Risks, costs and economic values remain primary drivers.

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 as discussed and outlined in Section 2.3.2.

1.4 Financial information

1.4.1 Forecast expenditure and budget summary

This business case proposes a total capital investment of $7.5 million.

The program is proposed for completed by 30 June 2031. Table 1–2 provides the Project budget by calendar year.

Table 1–2: Project Budget by Year, $2024

Year	Budget ($M)
2027	0.29
2028	1.21
2029	1.87
2030	1.98
2031	2.14
Total Budget	**7.5**

Results of the economic evaluation for the preferred option is provided below.

Table 1-3: Economic Analysis Results Summary, $2024

Recommended option	($M)
Total Project Cost:	7.5
NPV of Net Financial Benefit:	10.8

2. Background

Power transformers play an important role in ensuring the reliable and efficient operation of electrical grids. Power transformers are a critical asset installed in zone substations. Their role is to transform sub-transmission voltages (66kV) to local area distribution voltages (<22kV), thereby providing electricity supply to JEN customers.

The 66kV bushings of a transformer are a critical component as they provide safe connection of the sub-transmission network to the high voltage (HV) terminals of the transformer. A failure of this connection results in an inoperable transformer.

The 66kV transformer bushings within JEN can be categorised into three types:

- Synthetic Resin Bonded Paper (SRBP),
- Resin Impregnated Paper (RIP) and
- Oil Impregnated Paper (OIP).

It has recently been established that all three bushing types are susceptible to moisture ingress leading to insulation breakdown and potential catastrophic failure consequences (explosive debris, fire, oil spills, reputation, illness and injury).

In the event of a failure, the cost of asset replacement and unserved energy at risk is dependent on the nature of the failure and load profile of the network on which the failure occurred. Typically, this could be greater than $1M per asset replacement (single event) should the bushing be replaced within four-weeks. The unserved energy at risk could typically be greater than 1,000MWh per annum should no action be taken.

The Project involves completing a targeted program to test 66kV transformer bushings and assess their condition to confirm if replacement is required. Of the 183 individual 66kV bushings in JEN substations, 36 sets (60% of population) across 17 zone substations have been nominated to be tested and condition assessed. The test, analyse and replace (if required) approach ensures that risks are not only treated effectively but also efficiently, with at most, 36 sets of 66kV transformer bushings being replaced.

The Project aims to provide a safer workplace for all JEN staff and contractors who work on site whilst ensuring compliance with the following is achieved:

- JEN business strategies
- JEN internal Asset Class Strategies
- JEN technical standards
- JEN risk governance framework and
- Relevant obligations covered by acts, regulations, codes and rules that apply to JEN assets and practices.

2.1 Business and socio-economic context

The bushings targeted for testing, assessment and potential replacement are spread across the JEN network. This currently includes power transformers at 17 out of 34 zone substations (50% of zone substations). The remaining zone substations either have no transformer bushing affected by the inherent design issue or will be tested and replaced as part of a separate project at that zone substation (separate redevelopment works). The total number of customers supplied from each zone substation nominated is quite large. Any transformer catastrophic failure would require immediate action to mitigate the supply risk.

In surveying 1,000 residential customers across Jemena's electricity network, reliability and the maintenance of the network was the most important priority to customers. Customers surveyed identified network reliability, defined as 'the ability of the electricity network to perform its function adequately for the period of time intended' as of high importance.

The People's Panel, a Citizen's Jury made of up to 50 residential customers, also provided a recommendation for Jemena to focus on network reliability, "Jemena needs to prioritise investing in reliability by assessing, building and maintain the network to meet changes in operating conditions and withstand network failures."

2.2 Asset risk (or opportunity) analysis

2.2.1 Short description of the affected assets

Transformer manufacturers have provided a written investigation report on the condition of 66kV transformer bushings installed on JEN transformers. This investigation report included testing and analysis of samples where previous test results proved suspicious.

The investigation concluded that the bushings were considered defective due to an inherent design issue making them prone to moisture ingress. The suspected bushings were from the 1990's and well out of warranty. The report also noted that if the moisture ingress was left untreated, insulation deterioration could occur quickly leading to catastrophic transformer failure. This potential for catastrophic transformer failure has led to this proactive review of transformer bushing asset management.

Deteriorated operational equipment and infrastructure present serious health and safety hazards to JEN staff and contractors working in JEN zone substations. Due to the consequences of such failures (oil leaks, explosive debris, fire) for this sub-asset class, there continues to be an increased safety risk to people onsite when in the vicinity of affected assets.

It is mandatory for JEN to comply with:

- internal asset class strategies,
- technical standards as stipulated in its Electricity Safety Management Scheme (ESMS)
- the Electricity Safety (General) Regulations 2019 and standards,
- providing a safe workplace for all JEN staff and contractors who work on site.

2.2.2 Risk assessment

A network asset risk assessment has been completed for the 66kV transformer bushings dispersed throughout JEN zone substations. The risk assessment results have highlighted that adverse conditions of any transformer bushings and controls implemented exceed JEN risk appetite leading to further treatment. The current condition of assets are unknown however the consequences of bushing failures due to bad condition are well understood. Failure of a transformer bushing continue to drive safety and business continuity risks. Further details of the network assets risk assessment are shown in Appendix B.

2.3 Project objectives and assessment criteria

2.3.1 Project objective

In line with the NEO, JEN's investment decisions aim to maximise the net present value 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.

The Project also aims to ensure equipment related statutory requirements are satisfied whilst realising the designed operating life of the transformer.

2.3.2 Regulatory considerations

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

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. [1]

Additionally, the Victorian 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.

[1] NER, clause 6.5.6(a), 6.5.7(a).

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.

2.4 Consistency with 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 that 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.

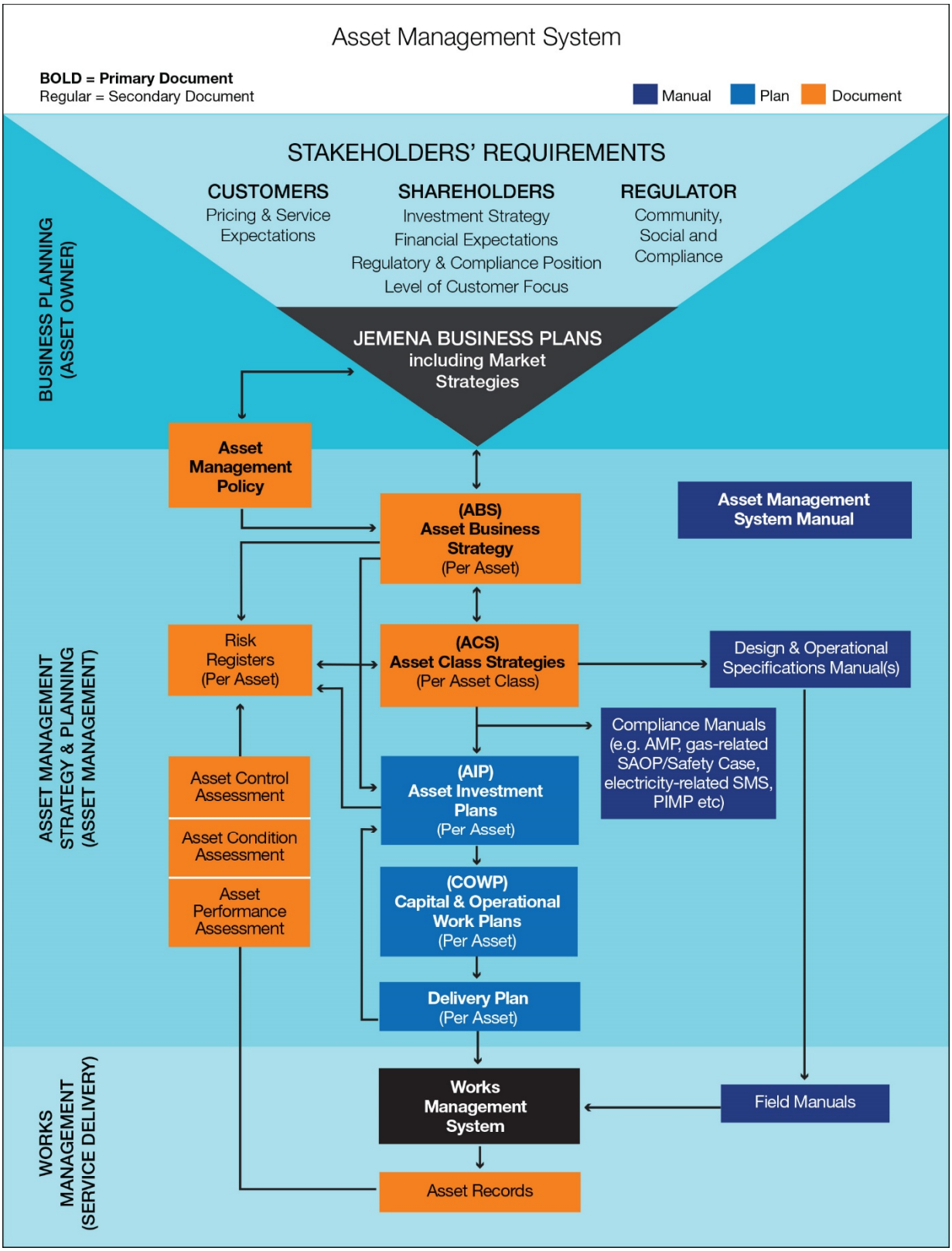
JEN seeks to ensure that lifecycle costs are both efficient and effective. This business case is consistent with this requirement and aligns with the long term vision of the network, as set out in the Asset Management Plan (AMP) and annual planning reports.

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 to its staff or members of the public.

Figure 2 6 outlines the Jemena Asset Management System and shows where the Asset Management Plan (AMP) is positioned within it. The AMP covers the creation, maintenance and disposal of assets, including investment planning to augment network capacity and replace degraded assets to maintain reliability of supply.

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

Figure 2–1: The Jemena Asset Management System



3. Credible Options

3.1 Identifying credible options

The following options were identified to address the business needs, problems or opportunities.

- Option 1 - Do nothing
- Option 2 - Test and assess at-risk bushing and replace as required
- Option 3 - Replace all potentially defective bushings
- Option 4 - Non-network solution

Preliminary assessments were conducted on all options to determine its credibility to be analysed further. The preliminary assessment determined options 3 and 4 would not be considered further due to the following reasons:

Option 3

- All potentially defective bushings will be replaced without confirming its condition leading to inefficient expenditure

Option 4

- All issues highlighted remain unresolved
- The condition of the asset that remains in service will lead to an unacceptable risk profile with heightened consequences
- Increased costs with no ability to realise delivery and operational efficiencies inherent in implementing standardised equipment and JEN asset strategies
- The scope of the non-network solution will likely be impractical with the condition of at-risk assets not confirmed leading to a non-network solution implemented for up to 50% of the electricity distribution network.

3.2 Developing credible options

Table 3-1 shows the extent to which each option addresses the identified issues.

Table 3-1: Options Analysis

Issue	Option 1 Do nothing (base case)	Option 2 Test and assess at-risk bushing and replace as required
Issue 1 - Safety Compromising people safety when in the vicinity of the affected assets	○	●
Issue 2 – Asset Shortened lifecycle of transformer with benefits not fully realised	○	●
Issue 3 - Supply Unacceptable Financial, Operational and Reputational risks (reduction in capacity, loss of supply, network reliability, regulatory and compliance risk) should a catastrophic failure occur	○	●

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

3.3 Options analysis

3.3.1 Option 1: Do Nothing

The ‘do nothing’ option assumes business as usual, continuing current maintenance activities such as inspections, condition monitoring, preventive maintenance and defect repairs. However, this option does not address any of the identified condition issues. For instance, industry evidence from a transformer manufacturer has indicated that certain types of bushings installed on JEN transformers are potentially defective. Defective bushings can only be confirmed by testing and should ‘bad’ condition bushings with a high probability of failure remain in service, transformer failure risks are heightened. 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.

3.3.2 Option 2: Upgrade as a standalone project

This option would involve progressively replacing aged, deteriorated or defective equipment based on an inherent design issue. Replacement would comply with the required standard, be targeted, effective and efficient. The Project methodology would involve replacement of critical, high-risk assets at risk of failure, prioritised by the Primary Team Lead – Network Assets. The equipment condition and status would be monitored throughout the program with increased intervals of routine inspections conducted by operational personnel.

Option 2 is the preferred option. This option resolves all identified issues while aligning with the JEN asset class and business strategies. Outcomes from this option ensure an acceptable level of risk to JEN is maintained. Compliance to industry regulations & standards to provide a safe environment for the public, as well as JEN staff and contractors working at these sites is also achieved. The total cost of this option is outlined in Table 1–2 and has a positive Net Present Value (NPV) as outlined in Table 1-3. This preferred solution is proposed to commence in 2027 with completion in 2031.

4. Option Evaluation

4.1 Economic evaluation

In line with the objective of the National Electricity Rules, JEN's augmentation investment decisions aim to maximise the present value of the net economic benefit to all those who produce, consume and transport electricity in the 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 failure of power transformers in zone substations on the electricity distribution network. This includes the safety risks associated with Option 1 (do nothing) as described in section 3.3.1. The following table summarises the economic analysis undertaken.

Table 4-1: Economic Analysis Results Summary, $2024

($M)	Option 1	Option 2
Total Expected costs	0	7.5
Total Expected market benefits	0	16.96
Net market benefits	0	10.8
Option ranking	2	1

4.1.1 Disposals

An assessment had been made on the equipment which will be replaced as part of this project. The equipment has no written-down value due to its age and design life.

5. Recommendation

This business case proposes a total capital investment as outlined in Table 1–2.

It is recommended that Option 2 be adopted. The scope of works includes test and assessment of at-risk assets. Only at-risk assets that have been validated by test results will be replaced ensuring technical requirements are met via an efficient cost and delivery program.

This option maximises the net present value to JEN customers' and addresses all identified risk and issues, therefore mitigating negative impacts on safety, reliability and security of customer supply.

The option is based on commencement in 2027 and completion in 2031.

6. Exclusions

There are no exclusions within this business case.

Appendix A
Financial Evaluation Spreadsheets

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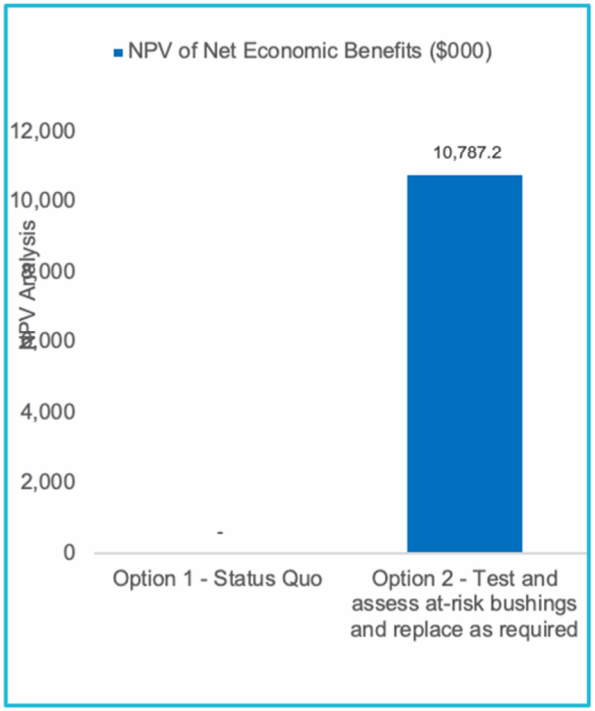
A1. Financial Evaluation Spreadsheets

Overview of Options Analysis		
Options	**Option 1 - Status Quo**	**Option 2 - Test and assess at-risk bushings and replace as required**
Recommended Option		✓
NPV of Net Economic Benefits ($000)	-	**10,787.2**
NPV of Total Economic Benefits ($000)	-	16,959.1
Avoided cost at asset failure	-	*452.4*
Improved energy reliability	-	*16,506.7*
Reduced energy losses	-	-
Other Economic Benefits	-	-
NPV of Incremental Total Costs ($000)	-	6,171.8
Total Incremental Net Capex	-	*6,171.8*
Total Incremental Opex - One-off	-	-
Total Incremental Opex - Ongoing	-	-
Sensitivity on Economic Benefit NPV ($000)		
Economic Benefits turn out to be 10% lower	-	9,091.3



Appendix B
Network Risk Assessment Summary

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on Bernardo

Workshop Date: 7/2/2024

...s - ...tio ...outi ...ors)	Risk Consequence Category	Risk Consequence - Description	Risk Owner	Untreated Consequence	Untreated Likelihood	Untreated Risk Rating	Current Controls	Control Assessment Frequency	Control Owner	Control Effectiveness	Overall Control Effectiveness	Current Consequence	Current Likelihood	Current Risk Rating	Risk Assessment Frequency	Risk Treatment Option	Acceptance Comment	Action Plan	Action Owner	Due Date	Status	Target Consequence	Target Likelihood	Target Risk Rating
...ces ...or ...ue ...ent ...on	Employee	- Injury to employees or contractors working in the vicinity of outdoor equipment in the switchyard (near power transformer bushings) - Regulatory investigations	M Ciavarella	Catastrophic	Rare	Significant	Asset Management System (ACS) including Asset Class Strategy.	6-monthly	M Ciavarella	Effective	Effective	Catastrophic	Rare	Significant	6-monthly	Treat		Initiate project to: 1. Test all affected bushings. 2. Assess test results 3. Replace the affected transformer bushings	M Chng	01/07/26	On Track	Minor	Rare	Low
							VESI Switchgear Manual	6-monthly	M Gardiner	Effective															
							The VESI Green Book	6-monthly	M Gardiner	Effective															
							Emergency management plan	6-monthly	F Dunk	Effective															
							Stakeholder/Customer engagement plan and procedures	6-monthly	J Ng	Effective															
							Job Safety Assessments (JSA), pre-start documentation and checks, associated pre-requisite procedures when completing site activities	6-monthly	L Cross	Effective														
...ces ...or ...ue ...ent ...on	Operational	- Unable to operate the transformers intended - Loss of supply to a high profile HV customer and	M Ciavarella	Catastrophic	Rare	Significant	Primary Asset Class Strategy	6-monthly	M Chng	Effective	Effective	Catastrophic	Rare	Significant	6-monthly	Treat		Initiate project to: 1. Test all affected bushings. 2. Assess test results 3. Replace	M Chng	01/07/26	On Track	Minor	Rare	Low

ptio outi ors)	Risk Consequence Category	Risk Consequence - Description	Risk Owner	Untreated Consequence	Untreated Likelihood	Untreated Risk Rating	Current Controls	Control Assessment Frequency	Control Owner	Control Effectiveness	Overall Control Effectiveness	Current Consequence	Current Likelihood	Current Risk Rating	Risk Assessment Frequency	Risk Treatment Option	Acceptance Comment	Action Plan	Action Owner	Due Date	Status	Target Consequence	Target Likelihood	Target Risk Rating
		- Negative reputational impact - STIPIS financial penalties - Regulatory investigations					VESI Switchgear Manual	6-monthly	M Gardiner	Effective														
							The VESI Green Book	6-monthly	M Gardiner	Effective														
							Emergency management plan	6-monthly	F Dunk	Effective														
							Stakeholder/Customer engagement plan and procedures	6-monthly	J Ng	Effective														
							Job Safety Assessments (JSA), pre-start documentation and checks, associated pre-requisite procedures when completing site activities	6-monthly	L Cross	Effective														