Appendix 5.20: Zone substations – 11kV switchboard assembly ASP

Regulatory proposal for the ACT electricity distribution network 2019-24
January 2018

Disclaimer: On 1 January 2018, the part of ActewAGL that looks after the electricity network changed its name to Evoenergy. This change has been brought about from a decision by the Australian Energy Regulator. Unless otherwise stated, ActewAGL Distribution branded documents provided with this regulatory proposal are Evoenergy documents.

evoenergy

ASSET SPECIFIC PLAN

Zone Substations

Zone 11kV Switchboard Assembly

Document Number: SM1101

ActewAGL for you

Version Control

Date	Version	Description	Author	Reviewed
11/12/2014	1.0	2014-19 regulatory submission		
20/09/2017	2.0	New template with options analysis and risk modelling, initial issue for 2019-24 regulatory submission		
13/12/2017	3.0	Updates for 2019-24 regulatory submission		

Approval

Author	**Ross Goggin**	13/12/2017 Name	Date
Endorsed	**Primary Assets Manager**	13/12/2017 Name	Date
Approved	**Branch Manager Asset & Network Performance**	13/12/2017 Name	Date

Reference Documents

Document
National Electricity Rules
National Electricity Law
Utilities Act (ACT)
Electricity Distribution Asset Management Policy v7.0
Asset Management Strategy v2.16
Asset Management Objectives v1.3
Asset Management System Manual
Zone 1kV Switchboard Assembly FMEA and Risk Assessment Worksheet
PR5017 Recovery and disposal of reclaimed network assets
SM4606 Environmental PCB Management Plan

Table of Contents

Glossary

Term	Definition
AAD	ActewAGL Distribution
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ASP	Asset Specific Plan
CAPEX	Capital Expenditure
CB	Circuit Breaker
CT	Current Transformer
FMEA	Failure Mode and Effects Analysis
HV	High Voltage
IED	Intelligent Electronic Device
kA	Kiloampere
kV	Kilovolt
LV	Low Voltage
MVA	Mega Volt Ampere
NER	National Electricity Rules
OPEX	Operational Expenditure
PoF	Probability of Failure
PoW	Program of Work
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
STPIS	Service Target Performance Incentive Scheme
VT	Voltage Transformer
PCB	Polychlorinated Bipheny

All analysis has been undertaken using 2017/18 real dollars unless otherwise stated. Budgeted expenditure for CAPEX & OPEX excludes indirect costs.

Document Purpose

This document is an Asset Specific Plan (ASP). This ASP provides the business case for asset management strategy selection and specifies the activities and resources, responsibilities and timescales for implementation for this specific asset class. In conjunction with the other ASPs, it forms ActewAGL's Asset Management Plan, which describes the management of operational assets of the electricity distribution system.

Asset management options are assessed in the context of the asset class' current state, condition, performance, risks, life cycle costs, trends and external environment. A recommended asset strategy is presented with associated capital expenditure and operational expenditure forecasts, including a 10 year budget forecast, for consideration by ActewAGL management.

Detailed in this document are the systematic and coordinated activities and practices whereby ActewAGL manages the asset class in an optimal and sustainable manner for the purpose of achieving the organisational strategic plan.

Audience

This document is intended for internal use by ActewAGL management and staff. As part of legislative, regulatory and statutory compliance requirements, the audience of this document is extended to relevant staff of the ACT Technical Regulator and the Australian Energy Regulator.

Document Hierarchy

ActewAGLs asset management system aligns with ISO 55001. This document complies with ISO 6.2.2 planning to achieve asset management objectives. Figure 1 shows the alignment of ASPs in the asset management system.

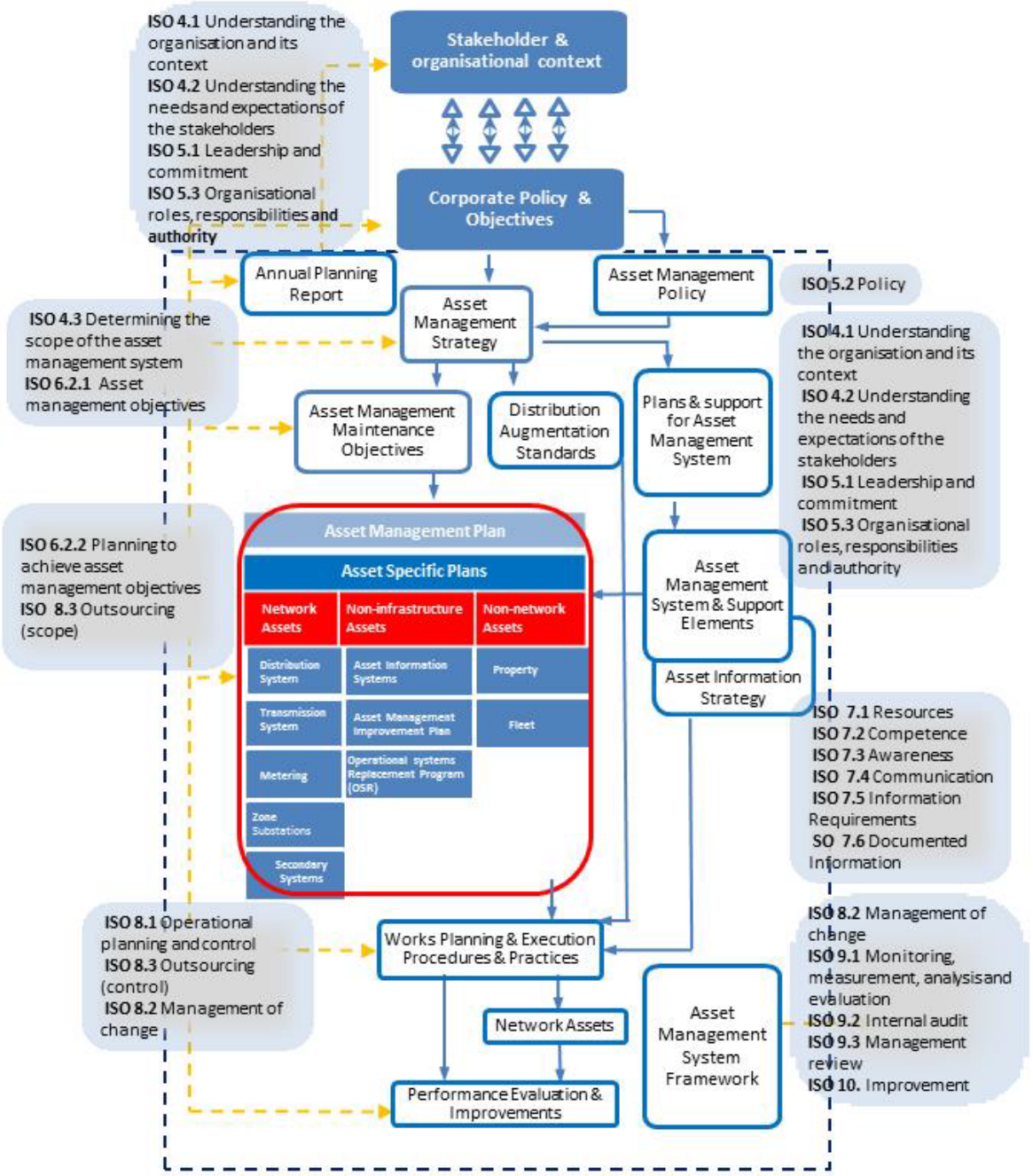

Figure 1: Asset management system structure

1 Executive Summary

The Zone 11kV switchboard assembly asset class is comprised of 11kV switchgear in zone substations which are bulk supply points supplying on average 6,113 customers per switchboard. This equipment is required to switch, protect, isolate and earth electrical plant and networks. Their reliable operation is fundamental to the safe and reliable operation of the network.

Zone 11kV switchboard assembly assets have a very high cost of failure and must be replaced before catastrophic failure to manage the environmental, safety and network reliability risks. There are currently 4 zone 11kV switchboard and 44 zone 11kV circuit breakers which will exceed their design life by the end of 2019-24 and thus need to be effectively managed. These assets are monitored by a condition monitoring program to maximise the in service life and determine the ideal time to replace. In 2017 the condition of these assets is fair with 1 zone 11kV switchboard with 11 zone 11kV circuit breakers forecast to reach end of life and replacement during 2019-24.

With improvements in condition monitoring equipment and a strategic approach for risk based asset management, this provides opportunity to utilise condition monitoring to reduce risk while also extending asset life of aging assets.

Replacement of assets at end of life with modern day equipment also provides additional benefits including reduced OPEX costs and increased safety to operational and maintenance staff.

This ASP evaluates options for the management of this asset class. A summary of the options considered are:

- Option 0: Reactive Strategy – this option considers opportunity for no proactive maintenance or replacement and assesses the impact on risk
- Option 1: Existing Strategy – proactive replace before failure asset replacement strategy, maintenance and condition monitoring to maintain performance and maximise the reliable working life.
- Option 2: Reduce Cost Strategy – this option considers opportunities to reduce cost from the existing strategy and assesses the impact on risk. This is considered by deferral of asset replacements
- Option 3: Reduce Risk Strategy – this option considers opportunities to reduce risk from the existing strategy and assesses the impact on the asset class budget.

The options were evaluated with a risk-condition based approach in accordance with ActewAGL strategic direction to determine the optimal strategy. That is, the preferred strategy meets the asset class objectives, is technically feasible, controls risk at an acceptable level and has the least NPC for customers and the community over the long term.

The evaluation also considers alignment of maintenance and renewal activities with associated asset classes for delivery efficiency.

The preferred option from this evaluation is Option 1 – Existing Strategy.

The estimated 2018-24 budget for CAPEX and OPEX is presented in Table 1.

Total Budget	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
CAPEX	**0**	**0**	**0**	**0**	**0**	**3,071,400**
OPEX	**400,929**	**360,694**	**247,443**	**563,531**	**309,700**	**254,520**
Planned Maintenance	198,405	240,074	85,871	197,199	66,224	133,900
Unplanned Maintenance	120,620	120,620	120,620	120,620	120,620	120,620
Condition Monitoring	81,904	0	40,952	245,712	122,856	0

Table 1: OPEX and CAPEX Optimised Program of Work Budget

This ASP presents a condition and risk based approach to CAPEX replacements for zone 11kV switchboard assembly assets, and an optimised maintenance program. Significant CAPEX replacement projects are justified based on various option considerations in separate Project Justification Report(s).

2 Asset Class Overview

This section provides an overview of the strategy and objectives specific to the asset class covered by this ASP, provides details of the assets included and their function, and explores the needs and opportunities specific to this asset class.

This ASP covers the Zone 11kV Switchboard Assembly asset class, which is part of the zone substations asset portfolio. The switchgear is indoor 11kV metalclad with single and double busbar configurations and rackable circuit breakers including minimum oil and vacuum types. Assets managed by this strategy include:

- Zone 11kV Switchboards
- Zone 11kV Busbars
- Zone 11kV Instrument Transformers (CTs & VTs)
- Zone 11kV Oil Circuit Breakers
- Zone 11kV Vacuum Circuit Breakers
- Zone 11kV Earth/Test Trucks.

A typical zone substation has between 2-3 switchboards which comprise of 2 power transformer connections, 1 bus coupler and 10 feeder circuit breakers per switchboard.

For details of the asset groups contained within this asset class, refer to section 2.2.

Protection and control equipment is also housed in Zone Substation 11kV Switchboards however these assets are not managed under this strategy. For protection and control equipment refer to the Protection ASP.

2.1 Asset Class Objectives

This ASP strategy follows the overall ActewAGL asset management strategy and asset management objectives. The asset class strategy is an integral part of the asset management strategy, with the overall objective to provide safe, reliable and cost effective supply of electricity to customers and compliance with regulatory requirements.

This Zone 11kV Switchboard Assembly ASP has been developed in alignment with the asset management strategy and seeks to meet objectives in the following categories shown in Table 2.

Asset Management Objectives	Asset Class Objectives
Responsible	
• Achieve zero deaths or injuries to employees or the public • Maintain a good reputation within the community • Minimise environmental impacts, for example bushfire mitigation • Meet all requirements of regulatory authorities, such as the AER as outlined in the NER, and the ACT Utilities (Technical Regulations) Act 2014.	• No death or injury to employees or the public • Achieve 0 catastrophic asset failures • Ensure design and acceptance for new assets complies with standards
Reliable	
• Tailor maintenance and renewal programs for each asset class based on real time modelling of asset health and risk • Meet network SAIDI and SAIFI KPIs • Record failure modes of the most common asset failures in the network	• Achieve detailed understanding of asset health and incorporation into asset modelling • Measure SAIDI and SAIFI contribution from this asset class • Review ASP at least every 5 years • Record and complete asset failure investigations within 20 business days
Sustainable	
• Enhance asset condition and risk modelling to optimise and implement maintenance and renewal programs tailored to the assets' needs • Make prudent commercial investment decisions to manage assets at the lowest lifecycle cost • Integrate primary assets with protection and automation systems in accordance with current and future best practice industry standards • Deliver the asset class PoW within budget.	• Achieve 90% data completeness for minimum asset data requirements • Deliver PoW outlined in this plan
People	
• Proactively seek continual improvement in asset management capability and competencies of maintenance personnel.	• Implement training for 11kV Switchboard condition assessments • Promote continual improvement

Table 2: Asset class objectives

2.2 Asset Groups

Zone 11kV switchboard assembly assets are classified in terms of asset function and lifecycle characteristics. Table 2 provides a broad-based classification of asset groups within this asset class.

Asset Class	Zone 11kV Switchboard Assembly
Asset Groups	Zone 11kV Switchboards Zone 11kV Oil Circuit Breakers Zone 11kV Vacuum Circuit Breakers Zone 11kV Earth/Test Trucks

Table 3: Asset Classification – Zone 11kV Switchboard Assembly Assets

2.3 Asset Functions

Zone substation 11kV Switchboards and their components enable the connection, isolation, earthing and protection of 11kV distribution feeders. They provide the interface and connection between zone substation power transformers and the distribution feeder network. The main components and their function are;

Zone 11kV Switchboards

Zone 11kV Switchboards are metal-clad switchgear comprising of a series of 11kV switchboard panels. Each panel contains busbars, one circuit breaker and instrument transformers to provide one circuit. The switchboard is the enclosure for busbars, instrument transformers and circuit breakers.

Zone 11kV Busbars

Busbars are housed and supported by the switchboard electrically connecting the switchboard panels. The busbars are air insulated and are supported by insulators. Circuit breakers and VTs connect to the busbars via spouts and CTs mount around the busbars.

Zone 11kV Instrument Transformers (CTs & VTs)

Instrument transformers include Current Transformers (CT) and Voltage Transformers (VT) measure current and voltage on the electrical network which is used by protection, control and metering devices to operate the network.

Zone 11kV Oil Circuit Breakers

Circuit breaker performance is vital for the safe and reliable operation of the distribution network by clearing network faults, providing safe access to the network, load management and restoring supply to customers.

Zone 11kV oil circuit breakers utilise oil as the insulating and arc suppression medium in the breaking chamber.

New 11kV oil circuit breakers have not been installed since 1985 and instead have been replaced by newer generation vacuum circuit breakers. Asset replacement programs will continue to phase out oil circuit breakers.

Zone 11kV Vacuum Circuit Breakers

Circuit breaker performance is vital for the safe and reliable operation of the distribution network by clearing network faults, providing safe access to the network, load management and restoring supply to customers.

Zone 11kV vacuum circuit breakers utilise a vacuum as the insulating and arc suppression medium in the breaking chamber.

Zone 11kV Earth/Test Trucks

Earth/Test trucks provide safe access and test connection points to the electrical network through 11kV switchboards. This is essential for maintenance of the network.

2.4 Needs and Opportunities

Assets in the zone 11kV switchboard assembly asset class are manufactured from 1970 with older generation equipment using oil circuit breaker technology and limited safety features when compared to modern equipment installed today. Opportunities arising from the replacement of older generation equipment with modern switchgear include:

- Safety – improved safety from arc flash, improved operational interlocks and earthing, no oil explosion and fire
- Environmental – no oil reducing risk to the environment through fire or oil spillage
- Lifecycle cost – maintenance of vacuum circuit breakers is less expensive compared to oil
- Reliability – modern design with less moving parts and less energy required in operations.

The need to replace the asset is based on a risk-based condition monitoring philosophy that would provide the organisation with an optimal compromise of asset replacement based on condition deterioration, to maximise returns on the avoided cost of maintenance over the lifetime of the asset.

2.4.1 Needs

2.4.1.1 Wanniassa Switchboard AG and BG Condition Assessments

EMAIL J18X-A24 switchboards and circuit breakers at Wanniassa zone are approaching their design life and the circuit breakers have a history of slow operation causing outages to a large number of customers. A condition assessment on these assets is required to assess condition and estimated remaining life. This will provide the necessary information to inform the ideal time to replace and any additional maintenance requirements to maintain performance.

2.4.2 Opportunities

2.4.2.1 Switchboard Refurbishment

There is an opportunity to economically extend the life of 11kV switchboards through refurbishment. This is the replacement of 11kV circuit breaker trucks at end of life while preserving the existing 11kV switchboard panels including panels, busbars and instrument transformers. Given some oil circuit breakers are approaching end of life, the replacement of 11kV circuit breaker trucks includes the installation of vacuum circuit breaker technology thereby reducing maintenance costs and risk by removal of oil circuit breakers.

2.4.2.2 *Preventative Maintenance Program Optimisation*

The circuit breaker preventative maintenance program can be optimised by delivering the following:

- Schedule maintenance on circuit breaker duty or usage – for CB bays with supported IED protection relays
- Tailor maintenance intervals from circuit breaker condition assessment.

2.4.2.3 *Co-ordinated Asset Replacement with Secondary System Assets*

There is an opportunity to replace primary and secondary equipment together to realise delivery efficiencies, minimise network outages and realise the full potential of modern primary and secondary system integration.

Zone 11kV switchboard assembly assets identified for replacement will also consider the need to replace related secondary equipment and vice versa. If primary or secondary assets are planned for replacement, a cost benefit analysis will determine feasibility to replace both primary and secondary at the same time.

2.5 Associated Asset Classes

Zone 11kV switchboard assembly assets have functional relationships with the following asset classes:

- Zone Substation Protection
- Distribution Substation Protection
- Zone Power Transformers
- Distribution HV UG Cables

2.5.1 Similar Functions

Zone 11kV switchboard assembly assets, specifically circuit breakers, have similar functions to the following asset classes:

- Distribution HV Switchboard Assembly
- Distribution LV Switchboard Assembly.

3 Asset Base

This section provides details of ActewAGL's current asset base for assets that are a part of this asset class, including the current age and condition profiles of the assets and the projected asset count.

3.1 Asset Base Summary

Table 3 gives details of ActewAGL's in-service (including system spares) zone 11kV switchboard assembly assets as at April 2017.

Asset Type	Quantity	Design Life (yrs)	Average Age (yrs)	Oldest Age (yrs)
Zone 11kV Vacuum Circuit Breaker	237	50	22	32
Zone 11kV Switchboard	29	50	28	47
Zone 11kV Oil Circuit Breaker	129	50	40	47
Zone 11kV Earth/Test Truck	57	50	31	41
Total	**452**	**50**	**29**	**47**

Table 4: Zone 11kV Switchboard Assembly Assets

3.2 Asset Service Life Expectancy

The design life of zone substation 11kV switchboard assembly assets is 50 years. The useful life may be less than or greater than the design life which can depend on quality of manufacturing, installation, maintenance and operational conditions.

Over the past decade, two (2) zone substation 11kV switchboards were replaced at Civic zone substation to manage risks to supply security, safety of staff and collateral damage to adjacent assets in the event of catastrophic failure. These assets were assessed at the end of their useful life from electrical and mechanical condition assessments and increasing operational malfunctions. These assets were aged 47 years at retirement.

3.3 Asset Age Profile

Figure 1 shows the age profile of the zone 11kV switchboard assembly assets in 2017.

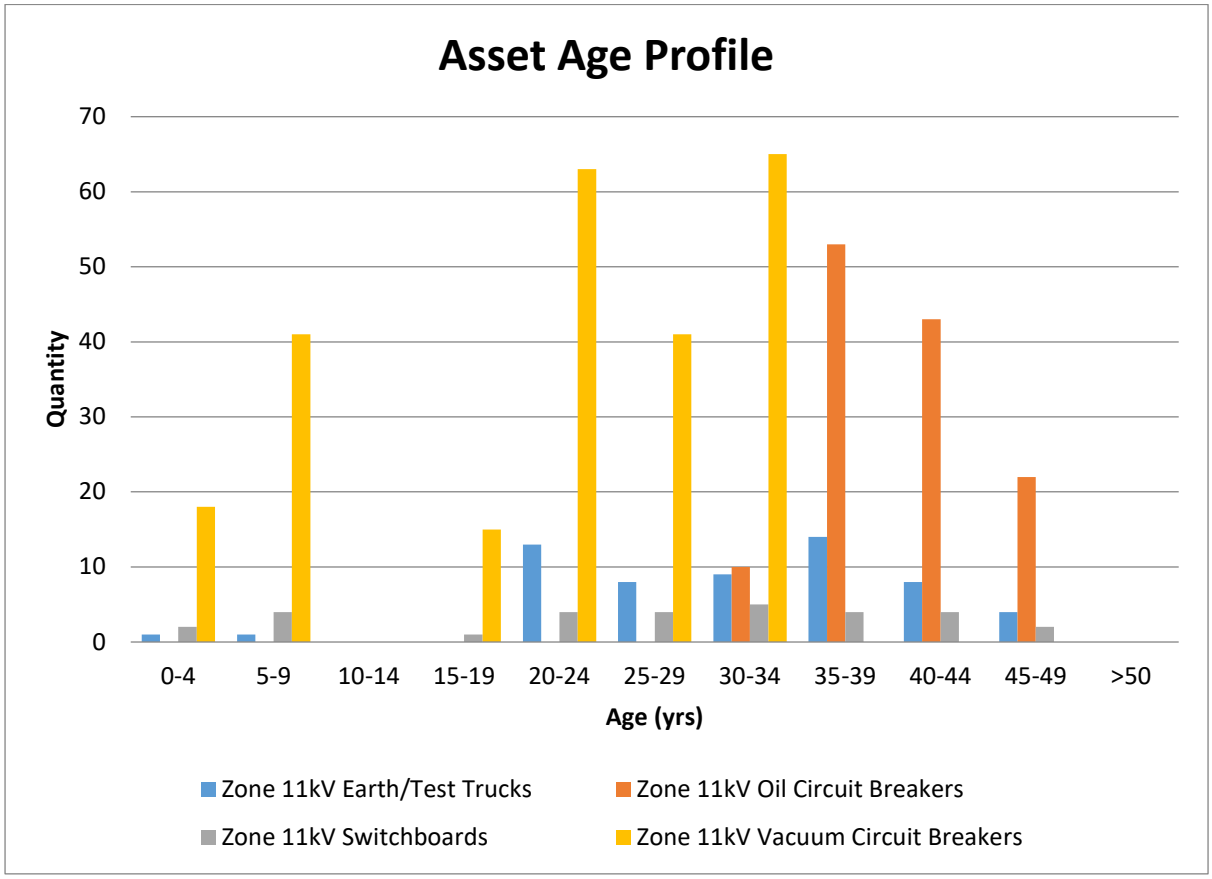

Figure 2: Age Profile of Zone 11kV Switchboard Assembly Assets

In 2017 there are no assets beyond the design life of 50 years however in the 2019-24 regulatory period, 4 zone 11kV switchboard and 44 zone 11kV circuit breakers will exceed their design life.

Within this asset class, zone 11kV Oil Circuit Breakers are the oldest assets in service and have not been installed since 1987. All new and replacement circuit breakers are vacuum circuit breaker type which have a lower consequence of failure (environmental and safety impact) and have lower OPEX costs.

3.4 Asset Health Profile

Asset health represents the condition of assets and is assessment of an assets capacity to perform its function(s) at the required level of service. Asset condition is calculated using and age-based degradation model and modified by known asset condition, environmental or usage information. Table 5 shows asset health in 2017.

Asset Type	Manufacturer	Model	Asset Quantity	Asset Quantity - Critical Health 2018-24	Average Health 2017
Zone 11kV Switchboard			**30**	**1**	**Good**
	ABB		**6**	0	**Excellent**
		ZS1	6	0	**Excellent**
	BRUSHSWITCHGEAR		**5**	0	**Fair**
		N/A	5	0	**Fair**
	EMAIL		**5**	**1**	**Poor**
		N/A	5	**1**	**Poor**
	GEC		**8**	0	**Good**
		SBV3/DB	5	0	**Good**
		SBV1	3	0	**Good**
	GECHED		**4**	0	**Good**
		SBV1	4	0	**Good**
	HAWKERSIDDELEY		**2**	0	**Good**
		N/A	1	0	**Fair**
		VHM	1	0	**Good**
Zone 11kV Oil Circuit Breaker			**129**	**11**	**Good**
	BRUSHSWITCHGEAR		**85**	0	**Good**
		Q20/2MK2	20	0	**Good**
		Q20/2MK3	1	0	**Good**
		R8/2MK4	64	0	**Good**
	EMAIL		**44**	**11**	**Fair**
		J18X-A24	32	**8**	**Fair**
		J22X-A30	12	**3**	**Fair**
Zone 11kV Vacuum Circuit Breaker			**243**	**0**	**Good**
	ABB		**59**	0	**Excellent**
		VD4	59	0	**Excellent**
	GEC-ALSTOM		**79**	0	**Good**
		SBV3/DB	79	0	**Good**
	GECHED		**90**	0	**Good**
		SBV1	90	0	**Good**
	HAWKERSIDDELEY		**15**	0	**Good**
		VMH	15	0	**Good**

Table 5: Zone 11kV Switchboard Assembly Asset Condition

Asset Type	Manufacturer	Model	Asset Quantity	Asset Quantity - Critical Health 2018-24	Average Health 2017
Zone 11kV Earth/Test Truck			**58**	4	**Fair**
	ABB		**2**	0	**Excellent**
		ZS1	2	0	**Excellent**
	BRUSHSWITCHGEAR		**18**	0	**Fair**
		N/A	18	0	**Fair**
	EMAIL		**8**	4	**Poor**
		N/A	8	4	**Poor**
	GEC-ALSTOM		**16**	0	**Good**
		SBV3/DB	16	0	**Good**
	GECHED		**14**	0	**Good**
		SBV1	14	0	**Good**
Grand Total			**460**	16	**Good**

Table 6: Zone 11kV Switchboard Assembly Asset Condition

The following assets are identified in poor condition approaching end of life with increasing risk. The asset class objective is zero catastrophic failures and therefore the strategy must implement condition monitoring and planned replacement of these assets when they reach end of life.

- Zone 11kV Switchboard - Email
- Zone 11kV Oil Circuit Breaker - Email J18X-A24
- Zone 11kV Oil Circuit Breaker - Email J22X-A30
- Zone 11kV Earth/Test Truck – EMAIL.

The asset class health profile in 2017 is summarised in Figure 3.

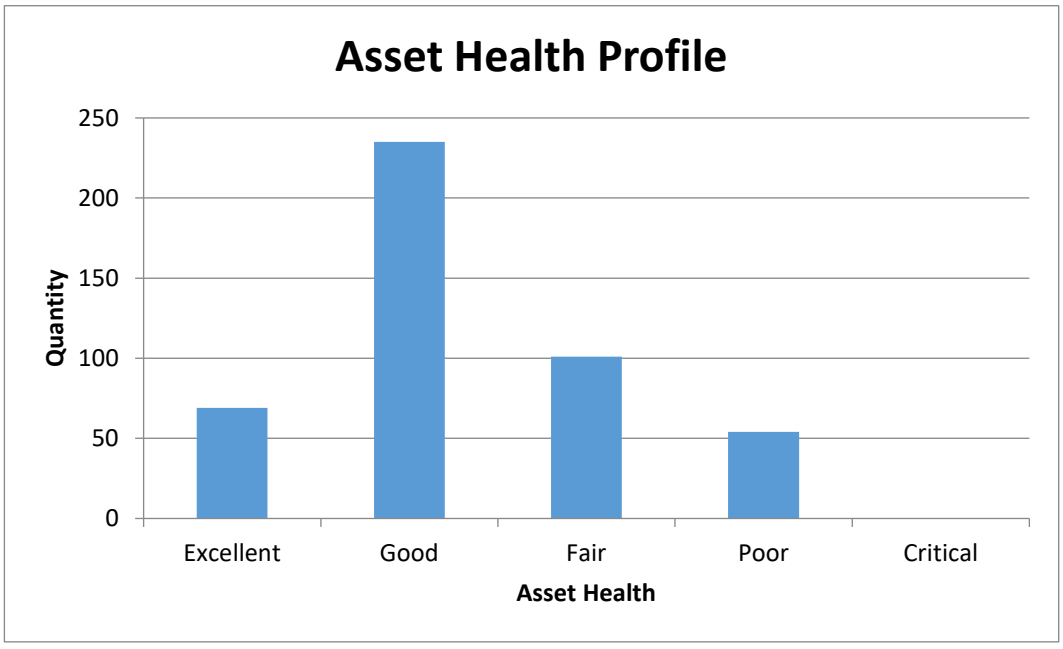

Figure 3: Zone 11kV Switchboard Assembly Asset health profile – 2017

3.5 Projected Asset Count

The projected asset count is an estimate of the number of zone 11kV switchboard assembly assets by year. The estimate includes asset additions and retirements through estimated network augmentation and asset retirements over the period. Refer to Figure 2 for details.

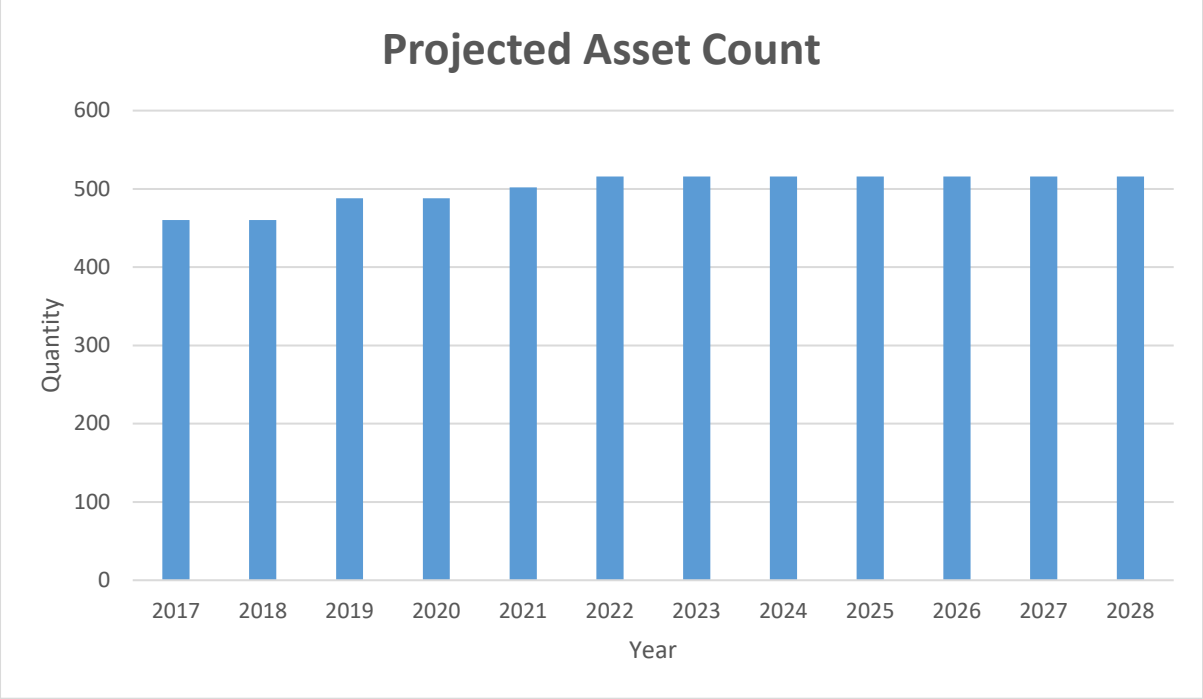

Figure 4: Zone 11kV Switchboard Assembly Projected Asset Count

3.5.1 Network Augmentation and Infrastructure Development

Network augmentation projects affecting the asset class population are detailed in the following sub-sections.

3.5.1.1 Molonglo Zone Substation Construction

East Lake zone substation augmentation project includes the addition of 1 x zone 11kV Switchboard, 13 x zone 11kV Vacuum Circuit Breakers and 4 x zone 11kV Earth/Test Trucks. The planned commissioning date for these assets is 2021/22.

3.5.1.2 Gold Creek Zone Augmentation

Gold Creek zone substation augmentation project includes the addition of 1 x zone 11kV Switchboard, 13 x zone 11kV Vacuum Circuit Breakers and 4 x zone 11kV Earth/Test Trucks. The planned commissioning date for these assets is 2019/20.

3.5.1.3 Belconnen Zone Augmentation

Belconnen zone substation augmentation project includes the addition of 1 x zone 11kV Switchboard, 13 x zone 11kV Vacuum Circuit Breakers and 4 x zone 11kV Earth/Test Trucks. The planned commissioning date for these assets is 2019/20.

3.5.1.4 Strathnairn Zone Substation Construction

Strathnairn zone substation augmentation project includes the addition of 1 x zone 11kV Switchboard, 13 x zone 11kV Vacuum Circuit Breakers and 4 x zone 11kV Earth/Test Trucks. The planned commissioning date for these assets is 2022/23.

3.6 Data Sources

Effective asset management relies on accurate asset information. The Asset Management System uses the following data sources for asset management:

- Geospatial Information System (GIS) Including Asset Inventory – esri GIS
- Works Management System - Cityworks
- Advanced Distribution Management System (ADMS) – Schneider Electric
- Finance Management System - Oracle
- Asset Management & Modelling System - Riva Modelling

3.6.1 Data Quality

3.6.1.1 Data Completeness

- Asset inventory is complete and accurate
- Condition and performance data is not complete and being collected during maintenance
- All assets proposed to be installed or removed during the regulatory period are considered
- Historic financial history specific to this asset class is available from June 2014 only.

3.6.1.2 Data Accuracy

The following outlines data quality issues affecting the quality of this ASP:

- Maintenance and condition assessment data quality for analytical asset modelling

Data Improvements

- Improve maintenance and condition assessment data quality
- Capture asset fault history and root cause analysis of faults
- Improve process and systems for data capture into asset modelling systems

4 Asset Performance Requirements

This section details the reliability and performance requirements of the zone 11kV switchboard assembly asset class.

4.1 Failure Modes

4.1.1 Failure Mode Effects Analysis (FMEA)

This ASP uses a risk based methodology, based on the ActewAGL Failure Mode and Effects Analysis (FMEA) approach to improving reliability and reducing maintenance costs. A series of factors contributing to probability and consequence of failure for respective asset classes are identified, analysed and rated by a team of cross-functional subject matter experts. These are then utilised as inputs to the overall risk cost calculations.

4.1.2 Deterioration Drivers and Common Modes of Failure

Tables in the following section for each asset type summarise their common modes of failure. They have been configured to show the assessed effects of each failure mode in terms of severity, occurrence and detection which are the inputs to Riva. Column 6 shows the resultant generated Risk Priority Number (RPN)

The following summarises the deterioration drivers and common failure modes for zone 11kV switchboard assembly assets by asset type;

4.1.2.1 Zone 11kV Switchboards

Deterioration Drivers

- Deterioration of insulation from moisture ingress, heat (loading) and overvoltages
- Wear and tear of mechanical components (shutters and doors) from normal use
- Ingress of dust from polluted switchroom environment.

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Complete – Insulation failure	Cause: Breakdown of insulation Effect: explosion, fire, complete switchboard outage	10	2	5	100
Partial (major) – mechanical failure	Cause: Switchgear doors, shutters, racking mechanisms malfunction. Effect: extended duration for switching or maintenance	7	5	4	140
Partial (minor) – Instrument Transformer (CT/VT) failure	Cause: CT or VT failure, insulation or open circuit Effect: 11kV feeder or switchboard incomer trip	7	1	5	35

Table 7: Zone 11kV Switchboard failure modes

4.1.2.2 Zone 11kV Oil Circuit Breakers

Deterioration Drivers

- Reduced insulating oil condition from network switching and ingress of moisture
- Deterioration of insulation from moisture ingress, heat (loading) and overvoltages
- Drying of lubrication over time
- Wearing and tear of mechanical mechanism from normal use
- Ingress of dust from dirty switchroom environment
- Contact wear on main and arcing contacts.

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Complete – Insulation failure	Cause: Insulation breakdown resulting from degraded insulation, main circuit and oil insulated interrupting chamber Effect: explosion, fire, complete switchboard outage	10	2	5	100
Partial (major) – mechanical failure	Cause: Does not close or open on command, or closes or opens without command. Effect: feeder or switchboard outage	10	8	9	720
Partial (minor) – Secondary circuit failure	Cause: Auxiliary or control circuit failure, prevents circuit breaker operating or operates without command. Effect: feeder or switchboard outage	10	4	9	360

Table 8: Zone 11kV Oil Circuit Breaker failure modes

4.1.2.3 Zone 11kV Vacuum Circuit Breakers

Deterioration Drivers

- Deterioration of insulation from moisture ingress, heat (loading) and overvoltages
- Drying of lubrication over time
- Wearing and tear of mechanical components from normal use
- Ingress of dust from a polluted switchroom environment
- Contact wear on main and arcing contacts.

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Complete – Insulation failure	Cause: Insulation breakdown resulting from degraded insulation, main circuit and vacuum interrupting chamber Effect: explosion, complete switchboard outage	10	1	10	100
Partial (major) – mechanical failure	Cause: Does not close or open on command, or closes or opens without command. Effect: feeder or switchboard outage	10	2	4	80
Partial (minor) – Secondary circuit failure	Cause: Auxiliary or control circuit failure, prevents circuit breaker operating or operates without command. Effect: feeder or switchboard outage	10	5	9	450

Table 9: Zone 11kV Vacuum Circuit Breaker failure modes

4.1.2.4 Zone 11kV Earth/Test Trucks

Deterioration Drivers

- Deterioration of insulation from moisture ingress
- Drying of lubrication over time
- Wearing and tear of mechanical components from normal use
- Ingress of dust from a polluted switchroom environment.

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Complete – Insulation failure	Cause: Insulation breakdown resulting from degraded insulation Effect: circuit not earth during maintenance or testing, safety risk	9	2	2	36
Partial (minor) – mechanical failure	Cause: Does not rack into switchgear cubicle to earthed or test. Effect: extended duration for switching or maintenance	8	2	2	32

Table 10: Zone 11kV Earth/Test Truck failure modes

4.2 Asset Utilisation

This section details the utilisation level of the assets. Depending on the asset type, utilisation will have a direct impact on asset condition and performance deterioration rates.

4.2.1 Capacity

The capacity of zone 11kV switchboard assembly assets is determined by the equipment rating. Equipment ratings are supplied by manufacturers specifying the design rating and are generally given by its continuous capacity in MVA or Amps and its fault level rating in kA.

ActewAGL's current operating and network planning philosophy for these assets is to not exceed the equipment design ratings. This is justified by the current utilisation level which is discussed in section 4.2.2.

4.2.2 Utilisation

Zone 11kV switchboard assets operate continuously and the utilisation is driven by network demand and network configuration. Assets may be exposed to short term higher loading during contingent network configurations.

Utilisation for this asset class is a measure of;

- Network demand on the equipment capacity rating in MVA or Amps;
- Number of 11kV feeder circuit breaker feeders in service.

4.3 Risk and Criticality

This section details the criticality of the zone protection assets in the distribution system and the exposure to risk.

4.3.1 Asset Criticality

Zone substations are bulk supply points in the network where asset failures present significant risk to network performance. Zone Substation 11kV switchboard assembly assets supply a large number of downstream customers with an average of 6,113 customers supplied per switchboard and 692 customers per 11kV circuit breaker and therefore can have large impacts on SAIFI and SAIDI performance.

The combined financial, operations, reputation, safety and environmental risk cost of a catastrophic failure of an 11kV switchboard is over $10.5M. This is a significant cost and is more than tripple the planned replacement cost.

The successful operation of zone 11kV switchboard assembly assets is crucial in ensuring network reliability, community safety, the safety of ActewAGL personnel and equipment.

4.3.2 Geographical Criticality

Zone 11kV switchboard assembly assets are installed indoors and not in direct contact with outdoor weather conditions. Geographical location does not affect the performance and reliability of these assets in AAD's network.

Geographical location of these assets effects the consequence of failure for environmental risk. Environmental risk of these assets is dependent on the bushfire risk and assets are categorised into three environmental risk zones, urban, Bushfire Abatement Zone (BAZ) and rural.

4.3.3 Asset Reliability

Reliability is essential from zone 11kV switchboard assembly assets given the high criticality rating and significant cost of failure.

In the past 10 years ActewAGL's asset class strategy has achieved zero complete failures and a total of 7 partial failures for this asset class. A summary of failures for this asset class is shown in Table 10.

Failure Type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Complete	0	0	0	0	0	0	0	0	0	0
Partial	0	2	3	1	0	0	1	0	0	1

Table 11: Zone 11kV Switchboard Assembly Asset Failures

Failure data in Table 9 is extracted from the outage database.

The most common failures are:

Complete

- Insulation failure
- Circuit breaker interrupter failure

Partial

- Circuit breaker slow operation
- Circuit breaker no operation
- Circuit breaker or earth truck racking mechanical malfunction (includes busbar shutters)

5 Asset Management Strategy Options

This section outlines the options considered for the management of zone 11kV switchboard assembly assets throughout their lifecycle and their assessed relative merits. It recommends an asset specific strategy that best supports the business asset management policy, strategy and objectives.

5.1 Option Evaluation Methodology

5.1.1.1 Financial Cost/Benefit Assessment

The options are assessed in terms of their resultant OPEX, CAPEX and quantitative risk exposure costs. The option specific financial assessments are generated as outputs from the Riva system which are then factored into the options assessment process.

5.1.1.2 Qualitative Risk Assessment

Qualitative assessments of the risks and consequences inherent to each option have been undertaken utilising the standard methodology from the ActewAGL "Energy Networks Risk Assessment Tables".

5.2 Options - Discussion

Options considered for the management of zone 11kV switchboard assembly assets are as follows:

- Option 0 – Reactive Strategy
- Option 1 – Existing Strategy
- Option 2 – Reduce Cost Strategy
- Option 3 – Reduce Risk Strategy.

5.2.1 Option 0 – Reactive Strategy

For this option all actions are reactive and no controls, proactive maintenance, condition assessment or planned replacement are applied. Any maintenance or asset replacement is purely reactive and is undertaken when the asset is no longer suitable for service which may be due to any of the following reasons:

- Functional failure.

Thus this option incorporates:

- Reactive (unplanned) maintenance;
- Reactive replacement of (failed) assets.

5.2.1.1 Risk Outcomes

The risk outcomes of this option increase over time as the condition of the assets deteriorate through the combined aging effects and as a consequence their reliability also deteriorates as they approach the end of their expected life.

The summary of risks are:

- 11 High rating asset class risks
- Catastrophic failure risk exposure cost – Exceeds $10.5m
- NPC risk (30 years) is $41.00m

A qualitative risk assessment of this option highlights the inherent risks (no controls) of this asset class and the risk exposure. This is shown in Table 11.

		Option 0 – Do Nothing Strategy				
Likelihood	Almost Certain					
	Likely	Low 17	Medium 2	High 4		
	Possible	Low 1	Medium 1	Medium 6	High 3	
	Unlikely	Low 4	Low 1	Medium 1	Medium 1	High 4
	Rare					
		Negligible	Minor	Moderate	Major	Severe
		Consequence				

Table 12: Risk Assessment – Option 0

A quantitative risk assessment for this option has been modelled to estimate the risk exposure and is shown in Figure 5.

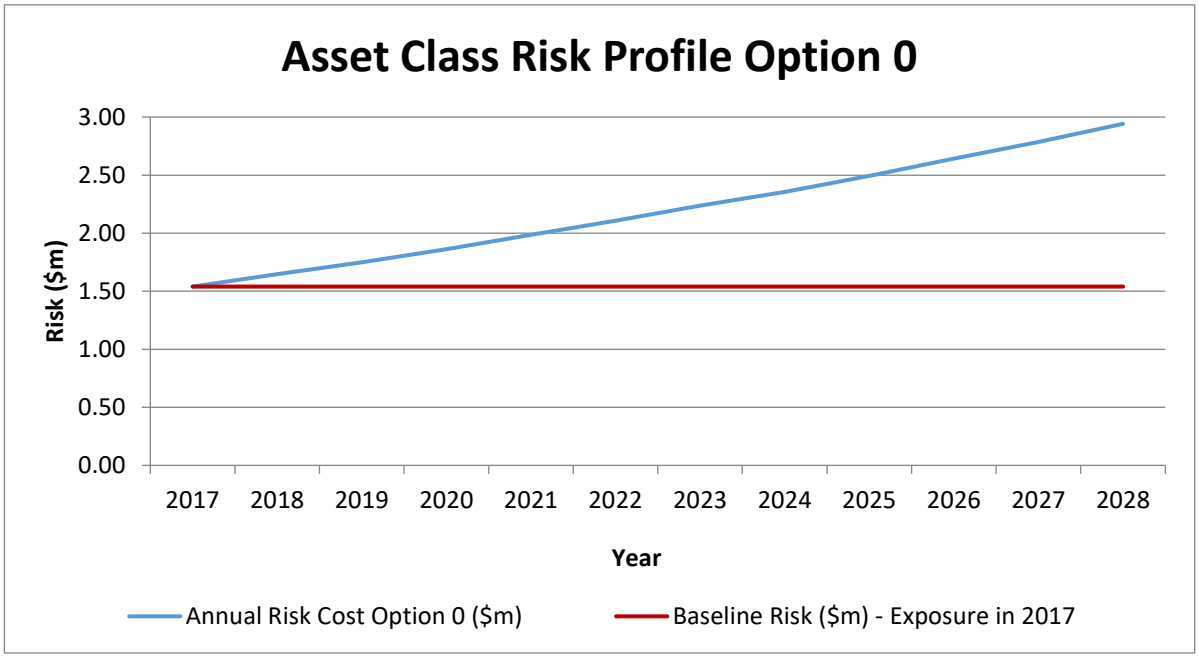

Figure 5: Risk-Cost Analysis – Option 0

5.2.1.2 *Summary of Benefits*

- This option delivers the least OPEX and CAPEX at least in the early part of the asset life. CAPEX will continue to be deferred as OPEX and risk costs escalate as the assets deteriorate through their life.

5.2.1.3 *Summary of Dis-benefits*

This option delivers the following dis-benefits (negative outcomes):

- Non-compliant with regulatory obligations;
- Non-compliant with contemporary industry practice or prudent asset management;
- Very high risk exposure including safety, environmental, network reliability and replacement costs including collateral damage and clean up expenses, and
- Critical assets fail in service with high costs of failure (significantly higher than planned replacement costs).

5.2.2 Option 1 – Existing Strategy

This option covers the existing strategy as applied to the management of the zone 11kV switchboard assembly assets. This strategy includes proactive planned maintenance, condition monitoring and replacement to manage assets at their lowest lifecycle cost. This strategy looks to optimise CAPEX and OPEX costs and manage the risk presented through considered CAPEX and OPEX trade-offs which incorporate:

- Planned maintenance, unplanned maintenance and condition monitoring
- Replace assets before complete failure– with assets identified from asset condition and risk or opportunities to lower the asset lifecycle cost.

The strategy uses a granular, bottom up approach to quantify individual asset condition, probability of failure and risk. The risk estimate for all assets provides a relative ranking between high and low risk assets and opportunity to implement tailored replacement or refurbishment programs to target the assets' needs.

Risk mitigation is by replacement or refurbishment to achieve life extension (where economically and technically viable). In both instances assets are replaced when they reach critical condition.

Opportunity based replacements are justified through a cost benefit analysis test.

5.2.2.1 Risk Outcomes

This option manages the risks presented by critical assets in poor or critical condition.

The summary of risks are:

- 0 High rating asset class risks
- NPC risk (30 years) is $17.25m

The exposed asset class risk ratings for this option are shown in Table 12.

		Option 1 Risk				
Likelihood	Almost Certain					
	Likely					
	Possible	Low 17	Medium 2	Medium 4		
	Unlikely	Low 5	Low 1	Medium 7	Medium 3	
	Rare		Low 1		Medium 1	Medium 4
		Negligible	Minor	Moderate	Major	Severe
		Consequence				

Table 13: Risk Assessment – Option 1

The risk profile for this option has been modelled to estimate the risk exposure and is shown in Figure 6.

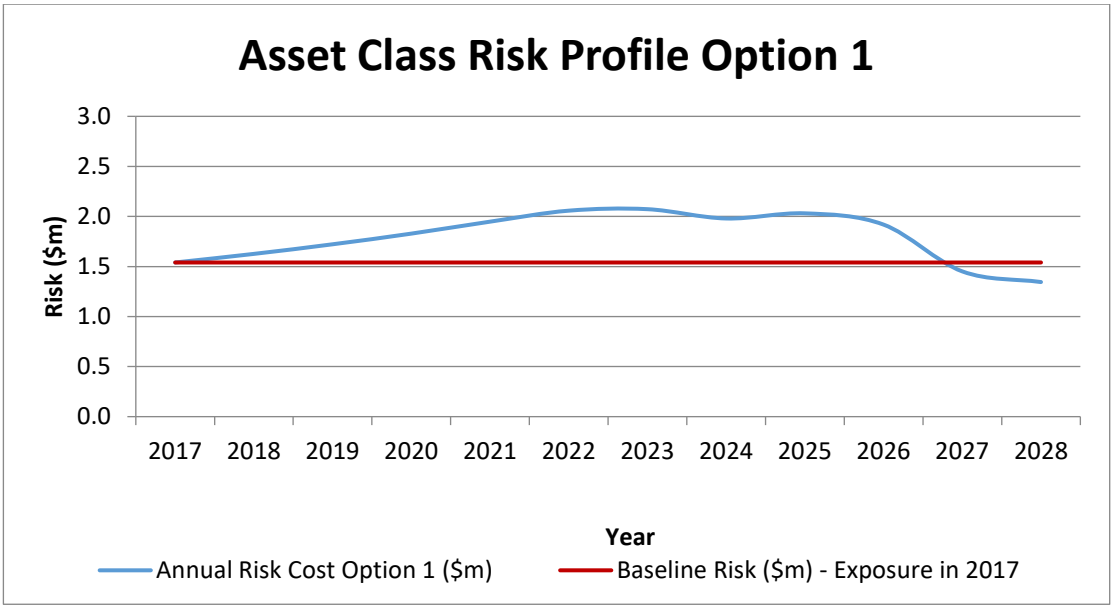

Figure 6: Risk Profile – Option 1

5.2.2.2 Summary of Benefits

This option delivers the following benefits:

- Control risk by treating high risk assets prior to the onset of failure
- Allow low risk assets to continue in service
- Replace high risk assets assessed as being in critical condition
- Improved safety – replacement equipment has operator safety improvements
- Lower maintenance costs – replacement equipment has lower maintenance costs.

5.2.2.3 Summary of Dis-benefits

Inherent to this option is the ongoing operational and capital expenditure associated with planned maintenance, condition monitoring and planned replacement activities. This necessitates careful review to optimise the stage of life at which this expenditure is implemented. If implemented too early then the expenditure could be unnecessary and premature. If implemented late it will result in undetected incipient or catastrophic failure conditions and an increased exposure to the risks they present.

5.2.3 Option 2 – Reduce Cost

This option evaluates a scenario of reduced cost for this asset class. It considers opportunities to reduce costs when compared to the existing strategy (option 1). For this option the following changes are made to the existing strategy to reduce cost:

11kV Vacuum Circuit Breakers

- Extend the planned maintenance time based interval from 8 to 10 years

The planned maintenance interval is increased for vacuum circuit breakers only. This is due to their lower risk compared to oil circuit breakers. In ActewAGL's network, 11kV vacuum circuit breakers have a higher average condition, reduced maintenance needs and lower cost of failure than oil circuit breakers.

11kV Zone Switchboards

- Defer asset replacement and refurbishment in 2019-24 to next regulatory period.

Capital expenditure is reduced by deferring all asset replacements and refurbishments. Deferral of these activities is by 5 years or 1 complete regulatory cycle.

5.2.3.1 Risk Outcomes

The risk outcomes of this option increase from the reduced maintenance of vacuum circuit breakers and deferring asset replacement and refurbishment to the next regulatory period.

The summary of risks are:

- Qualitative summary – 0 High rating asset class risks;
- NPC risk (30 years) is $21.78m

The exposed asset class risk ratings for this option are shown in Table 13.

		Option 2 Risk				
Likelihood	Almost Certain					
	Likely					
	Possible	Low 17	Medium 2	Medium 4		
	Unlikely	Low 5	Low 1	Medium 7	Medium 3	
	Rare		Low 1		Medium 1	Medium 4
		Negligible	Minor	Moderate	Major	Severe
		Consequence				

Table 14: Risk Assessment – Option 2

The risk profile for this option has been modelled to estimate the risk exposure and is shown in Figure 7.

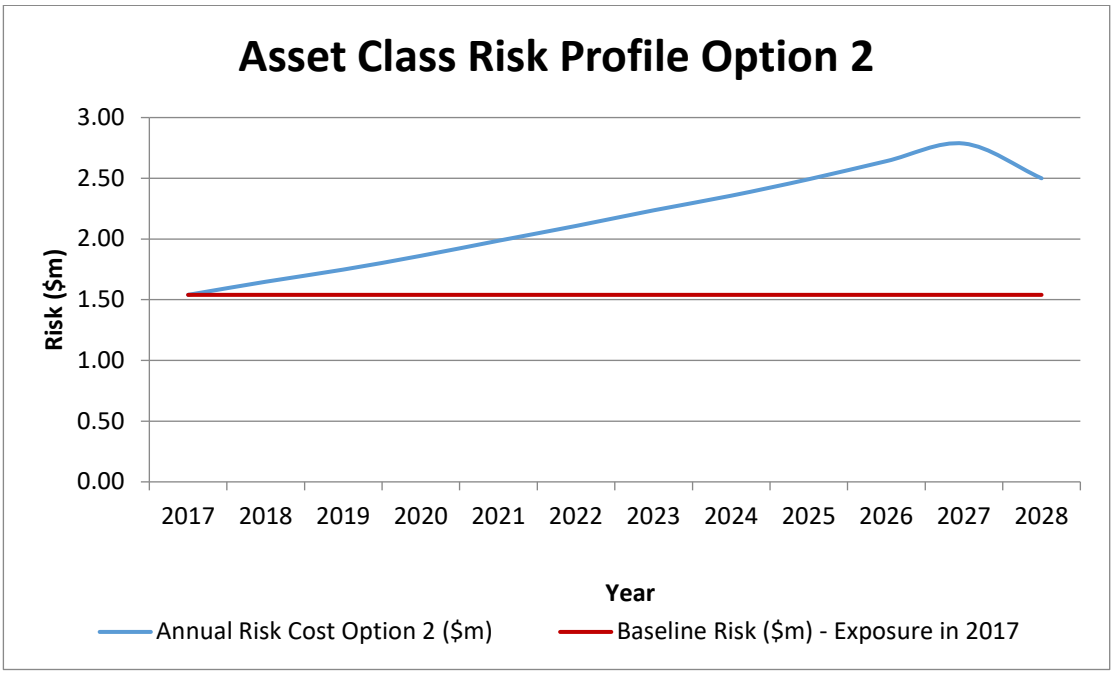

Figure 7: Risk Profile – Option 2

5.2.3.2 Summary of Benefits

This option delivers the following benefits:

- Reduced operational expenditure on vacuum circuit breakers
- Reduced capital expenditure for the 2019-24 regulatory period.

5.2.3.3 Summary of Dis-benefits

This option delivers the following dis-benefits (negative outcomes):

- Higher risk exposure than current strategy – assets operated in critical condition with increased probability of failure
- Higher risk exposure than current strategy – less frequent maintenance of vacuum circuit breakers may result in poor performance.

5.2.4 Option 3 – Reduce Risk

This option evaluates a scenario of reduced risk for this asset class. It considers opportunities to reduce risk when compared to the existing strategy (option 1). For this option the following changes are made to the existing strategy to reduce risk:

11kV Oil Circuit Breakers

- Replace oil circuit breaker trucks in poor condition with retrofit vacuum circuit breakers in existing 11kV switchboards

11kV Zone Switchboards

- Increase condition monitoring. Reduce interval from 4 to 2 years on assets over 40 years old.

5.2.4.1 Risk Outcomes

The risk exposure of this option is reduced by increased condition monitoring to reduce the likelihood of catastrophic switchboard failure and replacement of oil circuit breakers in poor condition.

Condition monitoring is increased by performing insulation testing every 2 years on switchboards. Increased testing reduces the likelihood of catastrophic failure by early detection of defects before failure.

Oil circuit breakers are an old design using oil as insulation and arc extinguishing medium. This type of circuit breaker was last installed in ActewAGLs network in 1987 and has two main disadvantages compared to modern vacuum and SF6 11kV circuit breakers available today. These are increased risk and higher maintenance costs.

When oil circuit breakers catastrophically fail, the consequence is significantly higher due to the oil being highly flammable and the switchgear design does not contain or control explosions compared to modern switchgear. Oil circuit breaker failures have high consequences for:

- Environmental - oil pollution and fire
- Safety - uncontrolled explosion and fire near operation and maintenance staff
- Economic- collateral damage to adjacent assets and buildings.

In this option, oil circuit breakers are progressively replaced with lower risk vacuum circuit breakers lowering the asset class risk.

The summary of risks are:

- Qualitative summary – 0 High rating asset class risks
- NPC risk (30 years) is $18.27m

The exposed asset class risk ratings for this option are shown in Table 14.

		Option 3 Risk				
Likelihood	Almost Certain					
	Likely					
	Possible	Low 17	Medium 2	Medium 4		
	Unlikely	Low 5	Low 1	Medium 7	Medium 3	
	Rare		Low 1		Medium 1	Medium 4
		Negligible	Minor	Moderate	Major	Severe
		Consequence				

Table 15: Risk Assessment – Option 3

The risk profile for this option has been modelled to estimate the risk exposure and is shown in Figure 8.

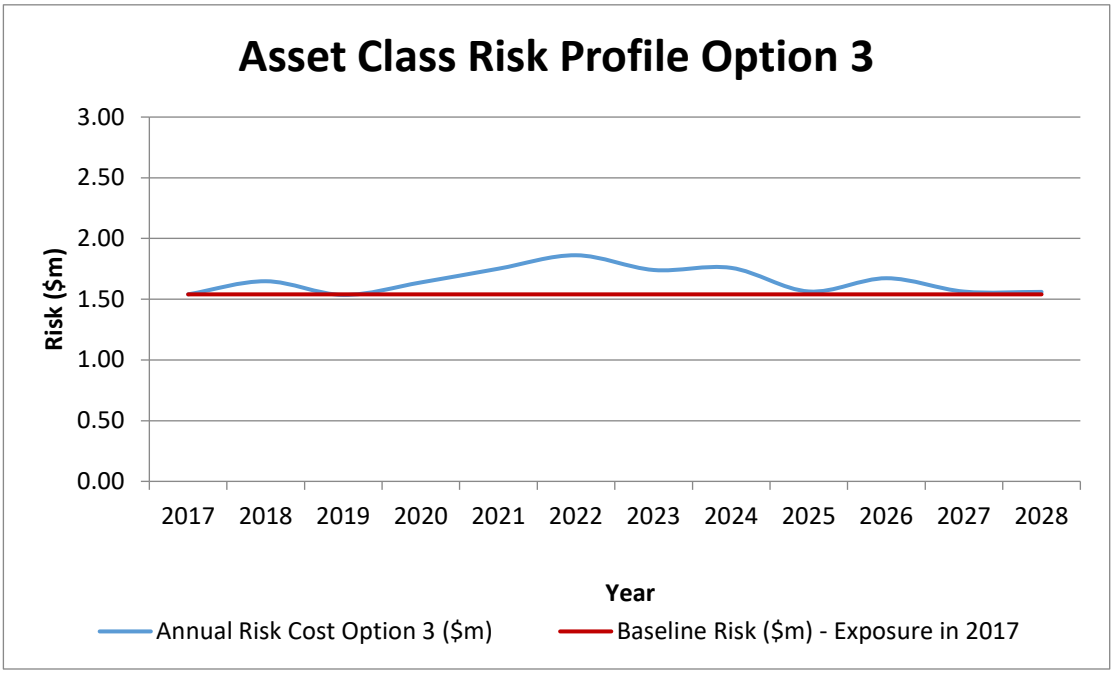

Figure 8: Risk Profile – Option 3

5.2.4.2 Summary of Benefits

This option delivers the following benefits:

- Reduced risk of catastrophic failure from increased condition monitoring
- Phase out of OCBs thereby reducing the associated environmental, safety and economic risk

5.2.4.3 Summary of Dis-benefits

This option delivers the following dis-benefits (negative outcomes):

- Increased on-going maintenance costs
- Possible premature capital replacement expenditure due to replacement of OCBs in poor condition.

5.3 Option Evaluation

This section provides a summary comparison of the evaluations of the options.

5.3.1 Engineering & Risk Evaluation

The key hazardous events for 11kV switchboard assembly assets include:

- Insulation failure
- Interrupter failure (higher for OCBs than VCBs)

These events have very high consequence of failure up to $10.5m for a single switchboard failure. For assets approaching end of life with increasing probability of failure, the risk is unacceptable for assets to continue in service.

Option 0 – Reactive strategy is not preferred due to no controls mitigating high risk assets at end of life with very high consequence of failure.

Option 1, 2 & 3 are proactive strategies with planned maintenance, condition monitoring and proactive asset renewal. These strategies satisfy the asset class objectives, control risk to an acceptable level and are technically feasible.

Of these options, option 1 and 2 and their associated asset replacements have greater safety benefits by installing modern switchgear with arc fault control and additional operational interlocks increasing the safety for operational and maintenance staff.

5.3.2 Financial Evaluation

Financial comparison of technically feasible and acceptable risk options are summarised in Table 15. This summary includes forecast budget CAPEX and OPEX for the period 2018-24 and for comparison the 30 year NPC of TOTEX and risk exposure.

Option	Budget ($m) 2018-24			NPC ($m)		Average Annual Risk 30 years ($m)	Rank
	TOTEX	CAPEX	OPEX	Risk	TOTEX + Risk		
Option 0 – Reactive Strategy	-	-	-	41.00	-	3.71	-
Option 1 – Existing Strategy	5.21	3.07	2.14	17.34	57.36	1.26	1
Option 2 – Reduce Cost Strategy	2.83	0.00	2.83	21.78	59.25	1.56	2
Option 3 – Reduce Risk Strategy	6.54	4.94	1.60	18.27	61.67	1.33	3

Table 16: Cost and Risk Strategy Options Summary

The financial comparison ranks options based on the lowest NPC of TOTEX and Risk.

The graph in Figure 9 provides an overview of long term risk exposure for all options.

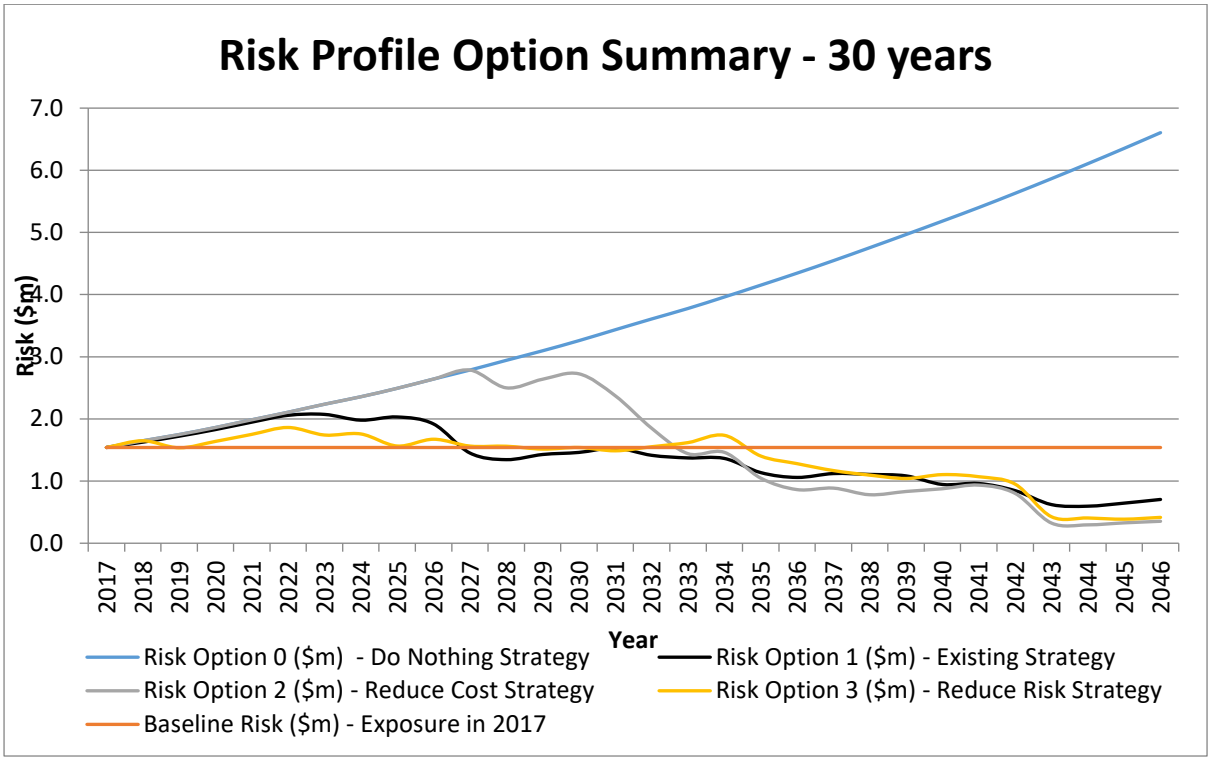

Figure 9: Risk Profile Comparison – Zone 11kV Switchboard Assembly

5.3.3 Corporate Criteria Satisfaction Comparison

The evaluated options are also compared utilising the ActewAGL corporate methodology in which qualitative assessment is made of the extent to which each option satisfies the specified criteria as shown in the following table.

Criteria	Description and Weighting
Cost	This ranks the relative CAPEX and OPEX costs associated with the options. The weighting reflects the relative importance of this criterion.
Risk – Safety, Environmental, Reliability, Other	The extent to which the option provides mitigation/controls to risks identified. The weighting reflects the relative importance of this criterion.
Strategic Objectives	The extent to which the option meets the requirements of the asset management strategic objectives. The weighting reflects the relative importance of this criterion.
Innovation/Benefits	The extent to which the option provides business benefits including but not limited to information or intelligence to support innovative asset management and network operation. The weighting reflects the relative importance of this criterion.

Table 17: Option Evaluation Scoring Criteria

	Criteria				Option Score
	Cost	Risk	Strategic Objectives	Innovation/ Benefits	
Criteria Weighting	**30%**	**30%**	**30%**	**10%**	**100%**
Option 0 *- Do nothing Strategy*	*3*	*0*	*1*	*1*	*43%*
Option 1 *- Existing Strategy*	*2*	*3*	*3*	*3*	*90%*
Option 2 *- Reduce Cost Strategy*	*3*	*2*	*3*	*2*	*87%*
Option 3 *- Reduce Risk Strategy*	*1*	*3*	*2*	*1*	*63%*

Scoring Key			
0	Fatal flaw	1	Unattractive
2	Acceptable	3	Attractive

Table 18: Scoring Matrix

5.4 Recommended Option

This section provides and overview of the recommended option and its outcomes.

5.4.1 Recommendation

From the engineering, financial and risk evaluation it's recommended Option 1 – Existing Strategy is implemented. This option satisfies the asset class objectives, proactively controls risk as far as reasonably practical and has the lowest NPC ensuring assets are managed sustainability and at the lowest cost to customers and the community.

This option also replaces assets at end of life with modern equipment with additional safety benefits.

The preferred option includes the replacement of assets which will be justified in a Project Justification Report (PJR).

5.4.2 Forecast Asset Health

Health profile is determined by asset condition and performance history. Condition is determined by the asset's capacity to meet requirements, asset reliability and its level of obsolescence. Obsolescence will be determined by maintenance requirements and availability of support from manufacturers.

The future health profile is the asset health profile at the end of the Regulatory Period, year 2024, under the recommended option to maintain risk exposure. This forecast is based on:

- Initial health profile
- Deterioration due to aging
- Deterioration where condition monitoring identifies specific risks for certain models of equipment
- Allowance made for replacement and refurbishments.

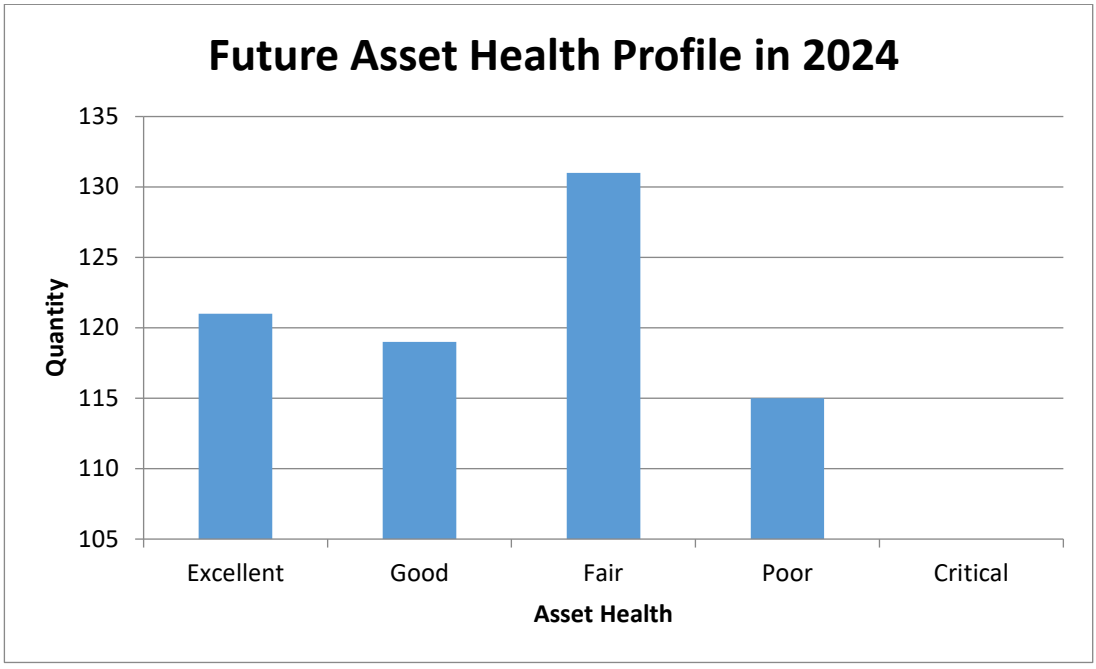

Figure 10: Asset Future Health Profile – Zone 11kV Switchboard Assembly

6 Implementation

This section provides implementation details for the recommended asset management strategy option.

6.1 Asset Creation Plan

Assets are added to the network from asset replacement and network expansion plans. This asset specific plan considers all known network augmentation projects which change the asset class population.

Switchboard configuration may comprise of single or double busbar type arrangement depending on the existing and future zone substation and 11kV distribution network configurations. Vacuum 11kV CBs are the preferred CB type which is in line with good industry practice and assists with achieving asset management objectives.

6.2 Asset Maintenance Plan

The objective of this maintenance plan is to provide the detailed activities required to implement the recommended asset management strategy. This is done through condition monitoring, planned maintenance and unplanned maintenance and has been adapted to ActewAGL's assets, operating environment and conditions.

6.2.1 Development

The maintenance plan is designed to achieve the objectives of the asset specific strategy. The following engineering techniques were used to develop the maintenance plan:

- Failure Modes and Effects Analysis (FMEA)
- Condition monitoring
- Historic performance
- Equipment manuals
- Continuous review of asset performance and fine-tuning of maintenance triggers.

Asset Type	Maintenance Task	Maintenance Trigger
Zone 11kV Switchboard	Condition Assessment	2 years when age > 40 years
	Visual Inspection	3 months
	Thermographic Inspection	6 months
Zone 11kV Earth/Test Truck	Earth/Test Truck Maintenance	8 years
Zone 11kV Oil Circuit Breaker	11kV Oil Circuit Breaker Maintenance	4 years or 6 fault operations
Zone 11kV Vacuum Circuit Breaker	11kV Vacuum Circuit Breaker Maintenance	8 years or 10 fault operations

Table 19: Zone 11kV Switchboard Assembly Maintenance Interval Summary

6.2.2 Condition Monitoring

6.2.2.1 Inspection

Inspections are performed to detect defects through visual inspections and thermographic inspections.

6.2.2.2 Testing

Switchboard condition is determined by comprehensively testing electrical and mechanical performance. The condition assessment includes all switchboard components including switchboard panels, circuit breakers, instrument transformers and earth/test trucks.

Assets are tested to ensure the condition is satisfactory and can remain in service and operate reliably and safely. This test also supports the condition based replacement strategy and is performed when assets are approaching the end of their design life and are at greater risk of failure. To adequately plan for end of life replacement, testing is undertaken on assets over 40 years old and then every 5 years until retirement.

6.2.3 Planned Maintenance

6.2.3.1 Earth/Test Trucks

The Earth/Test truck maintenance strategy is designed to ensure the safe and reliable operation for providing earthing or test connections to cables or switchgear. The condition of these assets deteriorates due to drying of the lubricant in racking mechanisms and the integrity of earthing and test connections must be verified.

Planned maintenance is initiated from elapsed time on an interval which aligns with oil and vacuum circuit breaker maintenance enabling efficient delivery of maintenance programs.

6.2.3.2 Circuit Breakers

The maintenance strategy for circuit breakers is designed to maintain reliability by managing the deterioration of operating mechanisms, main contacts, arcing contacts and interrupting chambers. The condition of these components deteriorates in service due to drying of lubrication, ingress of dust, switching operations and fault interruptions.

Maintenance is tailored to the type of circuit breaker and is initiated from elapsed time or number of fault operations, whichever comes first. The schedule is developed to perform maintenance when condition has deteriorated to a level where maintenance is required. Equipment manuals provide the foundation of the maintenance strategy and FMEA, analysis of condition monitoring results and historical performance optimise the maintenance intervals.

Circuit breaker condition is checked during maintenance, testing the operating mechanism and interrupting system. Circuit breaker timing tests are performed on all circuit breakers and interrupting system tests are specific to the circuit breaker type.

Timing tests are performed to assess the operating mechanism condition which degrades in service due to dust, dirt, dried grease, corrosion and wear and tear. This includes the ‘first trip’ tests analysing ‘real world’ operating conditions before maintenance. ‘First trip’ tests are preferred because operation of the circuit breaker numerous times during maintenance frees up the operating mechanism which may provide a false indication of in-service performance.

Oil circuit breaker interrupting systems are inspected by assessment of insulating oil and contacts. Insulating oil deteriorates with time, switching and fault interruption and must be maintained. This

deterioration of oil makes it necessary to inspect the oil condition and if in poor condition replace with new oil. If oil condition is good it's re-inspected at the next maintenance cycle.

Switching operations cause contact wear and contacts must be inspected and replaced if required. For oil circuit breakers this is a visual inspection performed during maintenance.

Vacuum circuit breaker interrupting systems are maintenance free and their condition should be checked to ensure their condition is serviceable. If condition is found unserviceable the vacuum interrupter must be replaced. Vacuum interrupters are checked by measuring the overtravel of the closing contact and/or electrical testing.

The integrity of the vacuum is tested during maintenance by performing a HV test across the vacuum when the circuit breaker is in the open position.

6.2.4 Un-planned Maintenance

Defects detected during inspection or maintenance activities are recorded by the asset defects process and prioritised for repair by their severity.

Reactive repairs are carried out when faults occur and are prioritised for repair in-line with network operational requirements.

6.3 Asset Renewal Plan

This asset renewal strategy minimises risk through planned replacement or refurbishment of assets at end of life before catastrophic failure. The condition based replacement strategy uses asset condition to trigger asset replacement or refurbishment and considers the following factors:

- Poor condition from condition assessments and consequently high risk
- Economic obsolescence (economical to replace with alternative product)
- Technological obsolescence (availability of spare parts and support)
- Safety risk (inherent fault in a type of equipment)
- Suitability of ratings.

Asset renewal is identified from the needs or opportunities outlined by the strategy. The cost to replace or refurbish 11kV Switchboard Assembly assets is high and as such will be analysed on a case by case basis in a Project Justification Report (PJR).

6.3.1.1 Refurbishment

Refurbishment of 11kV switchboards includes repairs to insulation, bushings and mechanical linkages and replacement of rackable circuit breaker trucks.

6.3.1.2 Replacement

Assets are replaced with modern switchboards with vacuum circuit breaker technology reducing the whole of life cost compared to oil circuit breakers and include operator safety improvements such as arc fault containment.

6.4 Asset Disposal Plan

Assets are assessed for recovery or disposal under the 'Recovery and disposal of reclaimed network assets' procedure PR5017.

Retired assets are assessed for their requirement and suitability for recovery. If required, retired assets will be recovered for spare parts while other assets of the same type remain in service. All other assets are disposed of according to procedure Recovery and Disposal of Reclaimed Network Assets.

Assets containing oil are tested for PCB and oil is disposed of according to the 'Environmental PCB Management Plan' SM4606 manual.

6.5 Associated Asset Management Plans

This section outlines related asset classes which are considered in this ASP. Planning and alignment with associated asset classes is important to provide the best technical and economic option which may integrate with other asset classes.

6.5.1 Secondary Systems Control & Protection

Protection and control equipment for 11kV switchboards and feeder protection is housed in the LV compartments of 11kV switchboards. The decision to replace or refurbish primary assets also considers the lifecycle management of secondary system assets is aligned to optimise cost and asset performance.

The need or opportunity to replace 11kV switchboard assembly assets or associated secondary system assets is analysed in a PJR.

6.6 Asset Strategy Optimisation Plan

The asset strategy optimisation plan lists initiatives and future improvement opportunities to improve the management of this asset class. This includes:

- Online circuit breaker condition analysis from supported protection relays
- Enhance asset condition models and maintenance scheduling from condition measures

7 Program of Work

This section provides the program of work and the resulting operational and capital expenditure forecasts.

7.1 Maintenance Program

This section outlines the operational expenditure for preventative maintenance, corrective maintenance and condition monitoring.

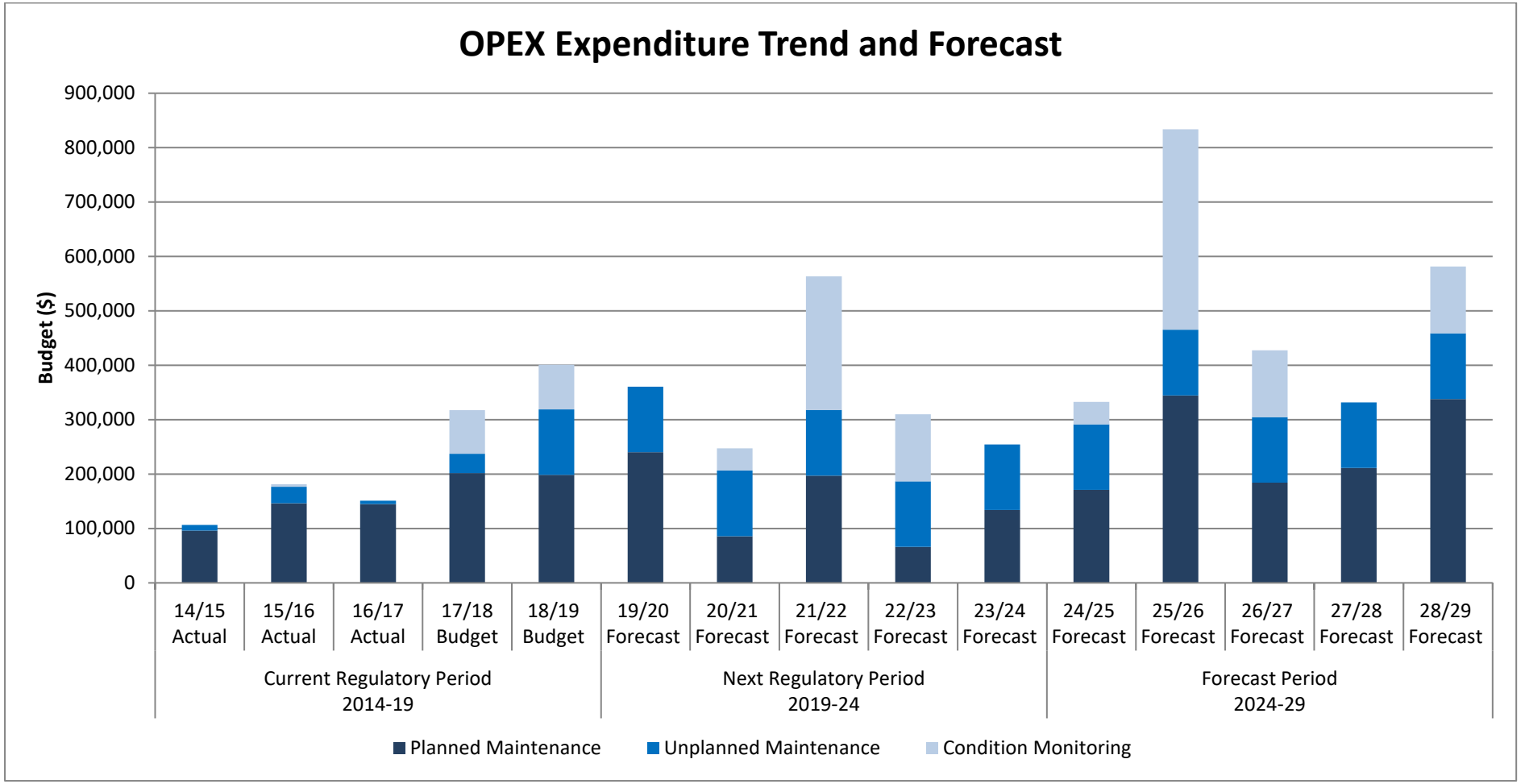

Figure 11: OPEX for Maintenance Program – Zone 11kV Switchboard Assembly

7.2 Capital Program

This section outlines the capital expenditure for asset replacement and refurbishment.

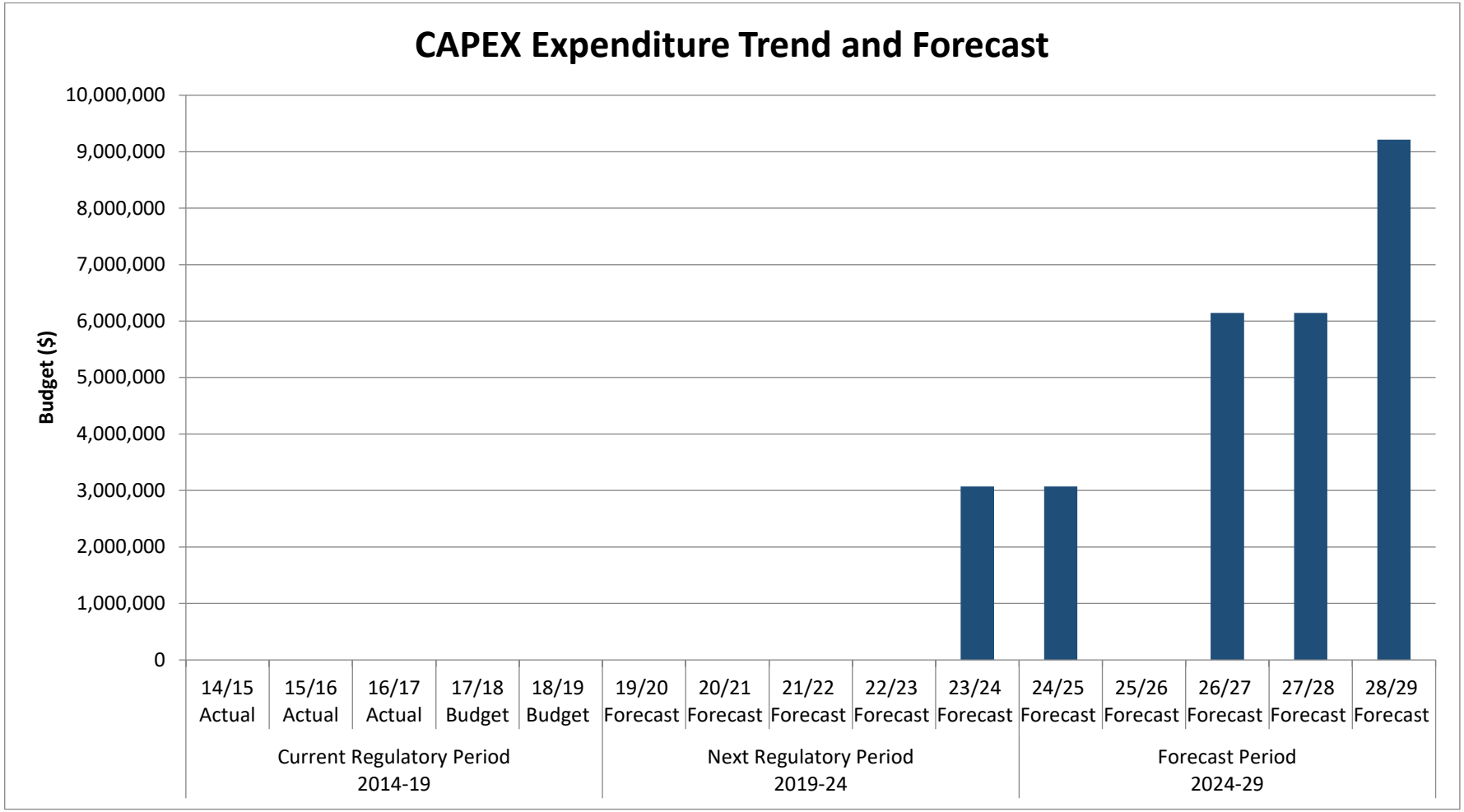

Figure 12: CAPEX Program – Zone 11kV Switchboard Assembly

7.3 Budget Forecast

This section provides a budget forecast for CAPEX & OPEX budgets.

Total Budget	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29
CAPEX	**0**	**0**	**0**	**0**	**0**	**3,071,400**	**3,071,400**	**0**	**6,142,800**	**6,142,800**	**9,214,200**
OPEX	**400,929**	**360,694**	**247,443**	**563,531**	**309,700**	**254,520**	**332,480**	**833,772**	**427,571**	**331,868**	**581,506**
Planned Maintenance	198,405	240,074	85,871	197,199	66,224	133,900	170,908	344,584	184,095	211,248	338,030
Unplanned Maintenance	120,620	120,620	120,620	120,620	120,620	120,620	120,620	120,620	120,620	120,620	120,620
Condition Monitoring	81,904	0	40,952	245,712	122,856	0	40,952	368,568	122,856	0	122,856

Table 20: Zone 11kV Switchboard Assembly CAPEX & OPEX Budget Forecast Summary

The replacement projects are justified through Project Justification Report(s).

7.4 Program of Work Summary

The program of work for summary for 2018-24 is shown in Table 19.

Year	2018/19		2019/20		2020/21		2021/22		2022/23		2023/24	
Tasks	**Units**	**Budget ($)**	**Units**	**Budget ($)**	**Units**	**Budget ($)**	**Units**	**Budget ($)**	**Units**	**Budget ($)**	**Units**	**Budget ($)**
CAPEX	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**3,071,400**
Replacement	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**3,071,400**
Replace Zone 11kV Switchboard	0	0	0	0	0	0	0	0	0	0	1	3,071,400
OPEX	**108**	**400,929**	**151**	**360,694**	**73**	**247,443**	**120**	**563,531**	**71**	**309,700**	**104**	**254,520**
Planned Maintenance	**62**	**198,405**	**107**	**240,074**	**28**	**85,871**	**70**	**197,199**	**24**	**66,224**	**60**	**133,900**
Maintain Zone 11kV Oil Circuit Breaker	17	40,545	62	147,870	11	26,235	35	83,475	16	38,160	44	104,940
Maintain Zone 11kV Vacuum Circuit Breaker	45	157,860	16	56,128	17	59,636	31	108,748	8	28,064	4	14,032
Maintain Zone 11kV Earth/Test Truck	0	0	29	36,076	0	0	4	4,976	0	0	12	14,928
Unplanned Maintenance	**44**	**120,620**	**44**	**120,620**	**44**	**120,620**	**44**	**120,620**	**44**	**120,620**	**44**	**120,620**
Frequency Based Maintenance	44	120,620	44	120,620	44	120,620	44	120,620	44	120,620	44	120,620
Condition Monitoring	**2**	**81,904**	**0**	**0**	**1**	**40,952**	**6**	**245,712**	**3**	**122,856**	**0**	**0**
Test Zone 11kV Switchboard	2	81,904	0	0	1	40,952	6	245,712	3	122,856	0	0
Grand Total	**108**	**400,929**	**151**	**360,694**	**73**	**247,443**	**120**	**563,531**	**71**	**309,700**	**105**	**3,325,920**

Table 21: Zone 11kV Switchboard Assembly Program or Work Summary

Appendix A Maintenance Plan Details

Appendix A provides additional details of the data used in evaluation of the asset management strategy options, including the costing and budget forecasting.

A.1 Asset Management Tasks Unit Costs

Unit costs for this asset class have been estimated and are summarised below.

A.1.1 Planned Maintenance Tasks

Asset Type	Task	Unit Cost ($)
Zone 11kV Oil Circuit Breakers	Maintain Zone 11kV Oil Circuit Breaker	2,385
Zone 11kV Vacuum Circuit Breakers	Maintain Zone 11kV Vacuum Circuit Breaker	3,508
Zone 11kV Earth/Test Trucks	Maintain Zone 11kV Earth/Test Truck	1,244

Table 22: Planned Maintenance Task Unit Costs

A.1.2 Unplanned Maintenance Tasks

Asset Type	Task	Unit Cost ($)
Zone 11kV Oil Circuit Breakers	Frequency Based Maintenance	2,793
Zone 11kV Vacuum Circuit Breakers	Frequency Based Maintenance	2,509

Table 23: Unplanned Maintenance Task Unit Costs

A.1.3 Condition Monitoring Tasks

Asset Type	Task	Unit Cost ($)
Zone 11kV Switchboards	Test Zone 11kV Switchboard	40,952

Table 24: Condition Monitoring Task Unit Costs

A.1.4 Replacement and Refurbishment Tasks

Asset Type	Task	Unit Cost ($)
Zone 11kV Switchboards	Replace Zone 11kV Switchboard	3,071,400

Table 25: Replacement and Refurbishment Task Unit Costs

Appendix B Risk Definitions

Appendix B provides reference information detailing how the severity of an effect, the probability of failure and the likelihood of detection are defined and ranked for the analysis of risk.

B.1 Severity

Effect	SEVERITY of Effect	Ranking
Catastrophic	Hazardous-without warning. Very high severity ranking, potential failure mode affects safety, noncompliance with policy and without warning.	10
Extreme	Hazardous-with warning. Very high severity ranking, potential failure mode affects safety, noncompliance with policy with warning.	9
Very High	Item inoperable, with loss of primary function	8
High	Item operable, but primary function at reduced level of performance	7
Moderate	Equipment operable, but with some functions inhibited	6
Low	Operable at reduced level of performance	5
Very Low	Does not conform. Defect obvious.	4
Minor	Defect noticed by routine inspection	3
Very Minor	Defect noticed by close inspection	2
None	No effect	1

B.2 Occurrence

PROBABILITY of Failure	Failure Probability	Failure rate Lamda "λ"	Ranking
Very High:Failure is almost inevitable	Very High: Failure is almost inevitable. Possible Failure Rate >= 1 every week.	0.1429	10
	Very High: Failure is almost inevitable. Possible Failure Rate >= 1 every month.	0.0333	9
High:Repeated failures	High: Repeated failures. Possible Failure Rate >= 1 every 3 months.	0.0111	8
	High: Repeated failures. Possible Failure Rate >= 1 every 6 months.	0.0056	7
Moderate: Occasional failures	Moderate: Occasional failures. Possible Failure Rate >= 1 every year.	0.0027	6
	Moderate: Occasional failures. Possible Failure Rate >= 1 every 3 years.	0.0009	5

PROBABILITY of Failure	Failure Probability	Failure rate Lamda "λ"	Ranking
	Moderate: Occasional failures. Possible Failure Rate >= 1 every 5 years.	0.0005	4
Low: Relatively few failures	Low: Relatively few failures. Possible Failure Rate >= 1 every 8 years.	0.0003	3
	Low: Relatively few failures. Possible Failure Rate >= 1 every 15 years.	0.0002	2
Remote: Failure is unlikely	Remote: Failure is unlikely. Possible Failure Rate >= 1 every 20 years.	0.0001	1

B.3 Detection

Detection	Likelihood of DETECTION	Ranking
Absolute Uncertainty	Control cannot prevent / detect potential cause/mechanism and subsequent failure mode	10
Very Remote	Very remote chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	9
Remote	Remote chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	8
Very Low	Very low chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	7
Low	Low chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	6
Moderate	Moderate chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	5
Moderately High	Moderately High chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	4
High	High chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	3
Very High	Very high chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	2
Almost Certain	Control will prevent / detect potential cause/mechanism and subsequent failure mode	1