31 January 2023

Attachment 5.4.a: Asset Replacement Programs

Ausgrid's 2024-29 Regulatory Proposal

Empowering communities for a resilient, affordable and net-zero future.

Contents

1. Introduction

1.1 This document's purpose

This document provides a summary of the proposed **Replacement Programs** forecast expenditure (repex), one of a number of expenditure categories having a driver of replacement. The Replacement Programs form part of Ausgrid's overall forecast of standard control capital expenditure (capex) for the 2024-29 regulatory period. This document paper should be read in conjunction with Ausgrid's **Attachment 5.1 Proposed Capex**.

1.2 This document in context

This document includes the scope of replacement programs only. This does not include replacements covered under:

- Major Projects (refer to Attachments 5.4.b, 5.4.c and 5.4.d),
- Operational Technology & Innovation (refer to Attachments 5.8.c, 5.8.d and 5.8.e),
- Climate Resilience (refer to Attachment 5.5), and

1.3 Related documents

Att #	Document
5.1	Proposed Capex
5.2.c	Customer Value Framework
5.4.b	Major Projects - 11kV Switchgear Replacement
5.4.c	Major Projects - Sub-transmission Cable Replacement
5.4.d	Major Projects – Other Replacement
5.4.e	CBA Approach for Replacement Programs
5.5	Climate Resilience Program
5.8.c	Control System Core Refresh Program
5.8.d	Operational Technology Security Program
5.8.e	Network Digitisation Program
6.2	Network Maintenance Program

1.4 Document overview

To provide a safe and reliable service to customers, existing infrastructure is required to be carefully managed. This includes the replacement of assets at or approaching end of life. Replacement programs include the replacement of individual assets with assets that perform the same function in-line with current standards. It may also include life extension activities such as asset refurbishment.

This document describes the assessment undertaken to form the 2024-29 proposed replacement program expenditure forecast for key standard control asset classes. It includes an explanation of the high-level economic evaluation methods used to form this forecast as well as the risks, option analysis and asset management strategies associated with key asset classes.

2. Executive summary

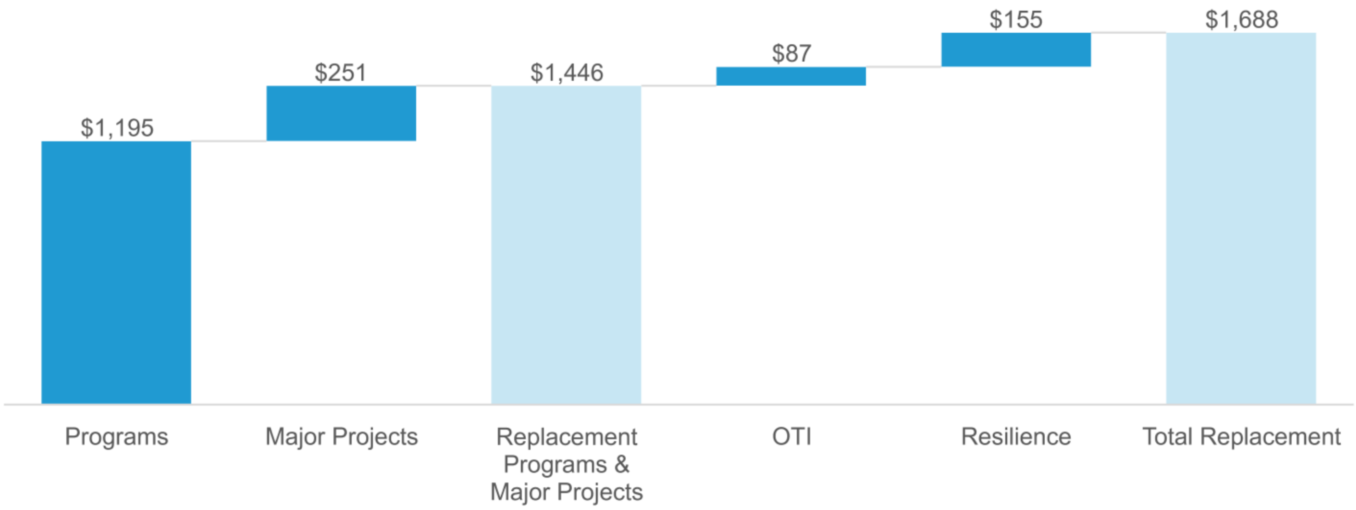
2.1 Replacement Program Forecast Expenditure

We are proposing replacement program expenditure of $1,195 million (real $, FY24) during the 2024-29 regulatory period. Replacement programs represent over 70% of the total replacement expenditure. Total replacement expenditure (repex) consists of:

- $1,195 million under Replacement Programs (this document),
- $251 million under Major Projects,
- $87 million under Operational Technology & Innovation (**OTI**), and
- $155 million of Resilience.

This breakdown is shown in Figure 1, noting that this document covers the scope of replacement programs (**Programs**) only.

Figure 1. Replacement expenditure by Category (real $m, FY24)



Proposed replacement programs and major projects expenditure is $1,446 million during the 2024-29 regulatory period. This represents a $77 million reduction compared to the current 2019-24 regulatory period allowance of $1,523 million.

The OTI program includes $87 million of replacement related expenditure to replace assets with modern technologies, where this can achieve long-term efficiency or short-term services to customers, providing a more reliable and resilient supply than traditional methods have previously allowed.

The resilience program includes $155 million of replacement related expenditure to address the impact of climate change on the network. Its scope includes improvements to design standards and strategic investment in locations most likely impacted by the growth in climate risk. To avoid overlap, the replacement programs covered within this document:

1. exclude climate related failures and customer impacts in its analysis,
2. exclude changes in risk due to the changing climate impacting assets, and
3. only includes costs for replacement to current design standards.

2.2 Replacement Programs Forecast Build-up

The forecast repex has been broken down into the following eight asset classes:

Overhead Support Structures	Used to maintain electrical clearances between live electrical equipment and ground

Includes poles, towers, and their associated cross-arms and insulators (pole-tops)

Overhead Mains	Provides electrical connection/capacity for the distribution of electricity above ground

Includes overhead conductors and connections

Underground Cables	Provides electrical connection/capacity for the distribution of electricity below ground

Includes cables, joints, terminations, pillars, pits, ducts and tunnels

Transformers & Reactive Plant	Transforms electricity between voltages and currents

Includes power transformers, reactors, instrument transformers and neutral earthing resistors

Switchgear	Used to control, protect, switch and isolate segments of the network

Includes circuit breakers, links, switches and fuses

Communications, Control & Protection	Provides monitoring, protection, control and automation to the electrical network

Includes relays, batteries/chargers, remote terminal units, servers and associated communications mediums

Buildings, Grounds & Land	House and physically protect electrical assets

Includes buildings, fencing, civil structures and housings and network support systems such as fire detection/mitigation, substation yard structures, oil containment, air conditioning, security and water treatment

Distribution Substations	An amalgamation of assets within a single substation

Includes transformers, switchgear and either a housing, building, fence or pole depending on the type of substation. These are considered together where it is cost-effective or practical to replace the entire substation rather than the individual assets

Figure 2. Replacement Programs proposed repex by Asset Class (real $m, FY24)

	FY25	FY26	FY27	FY28	FY29	TOTAL
Overhead Support Structures	$38	$39	$39	$39	$39	$194
Overhead Mains	$61	$61	$63	$63	$63	$312
Underground Cables	$58	$58	$58	$57	$56	$286
Transformers & Reactive Plant	$21	$21	$19	$19	$19	$99
Switchgear	$29	$25	$25	$25	$24	$128
Communications, Control & Protection	$15	$13	$14	$14	$13	$69
Buildings, Grounds & Land	$21	$21	$21	$21	$21	$106
TOTAL	**$243**	**$238**	**$240**	**$238**	**$236**	**$1,195**

2.3 Forecast Methodology

In developing our repex forecast, the following forecasting tools have been applied:

1. Age-based assessment,
2. Replace on failure,
3. Cost Benefit Analysis (**CBA**),
4. Maintaining risk,
5. Historical trend, and

6. Repex model

The forecasting methodologies applied to each asset class have been shown in Figure 3.

Figure 3. Forecast method applied and considered to each asset class

	CBA	Maintain Risk	Historical Trend	Repex Model	Age-based Assessment
Overhead Support Structures	●	○	○	○	○
Overhead Mains	◐	○	◐	○	○
Underground Cables	○	○	●	○	○
Transformers & Reactive Plant	◐	○	◐	○	○
Switchgear	◐	○	◐	○	○
Communications, Control & Protection	◐	○	◐	○	○
Buildings, Grounds & Land	↻	↻	●	○	↻

●	selected forecast method
◐	combined forecast method selected
○	considered forecast method
↻	under development

Replace on failure forms part of the CBA assessment and therefore has not been separated in Figure 3. CBA and historical trend were the preferred methods used to forecast replacement program expenditure. The other options were utilised as a top-down evaluation of the forecast. A comparison of the 2024-29 replacement program forecast relative to the likely forecast under each alternative method is shown in Figure 4.

Figure 4. Forecast method expenditure comparison (real $m, FY24)

	Forecast	CBA	Maintain Risk	Historical Trend	Repex Model	Age-based Assessment
Overhead Support Structures	$194	$215	$488	$235	$224	$509
Overhead Mains	$312	$329	$148	$241	$218	$482
Underground Cables	$286	$303	$492	$290	$341	$1,583
Transformers & Reactive Plant	$99	$102	$138	$93	$108	$248
Switchgear	$128	$154	$185	$115	$90	$553
Communications, Control & Protection	$69	$61	$212	$79	$113	$422
Buildings, Grounds & Land	$106	$113*	$113*	$113	$124	$113*
TOTAL	**$1,195**	**$1,277**	**$1,777**	**$1,165**	**$1,218**	**$3,910**

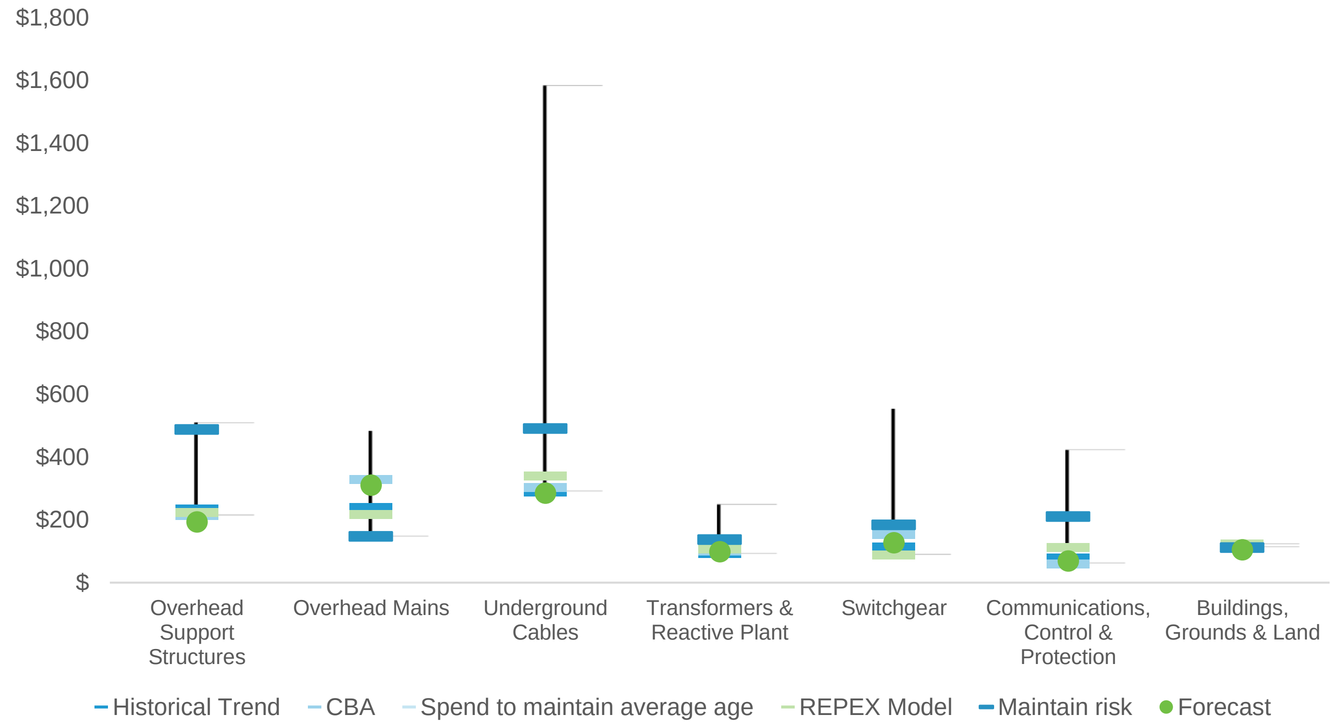
* the value for buildings, grounds and land are historical trend as the respective types of analysis are in development

Given the repex model applies to a larger proportion of the replacement expenditure forecast than is covered within this document, details on the application of this evaluation tool can be found in **Attachment 5.1 Proposed Capex.**

The forecast in Figure 4 is higher than historical trend, however when combined with other replacement investment such as Major Projects, refer to **Attachment 5.1 Proposed Capex**, the overall replacement forecast remains lower than our historical expenditure.

Figure 5 shows the same results as a graph and highlights the range of potential outcomes based on the forecasting method adopted.

Figure 5. Forecast method expenditure comparison ranges (real $, FY24)



The use of multiple forecasting methods supports a robust forecasting approach. The results across all methods support our replacement program expenditure forecast.

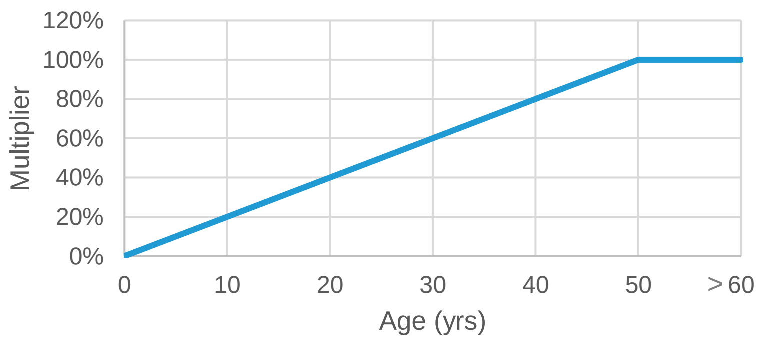
2.3.1 Age-based assessment

Asset age provides a reasonable lead indicator for condition issues and replacement needs. For each asset class we have considered:

- the percentage of the replacement volumes required to maintain the average replacement life, and
- the split of assets replaced at end of life (under the replacement program) versus the percentage of assets replaced under other investment programs (effective retirements by other drivers)

Assets can be replaced at any age under other investment programs (e.g. customer driven works) and do not necessarily reflect assets at end of life. To calculate the effective volume of assets retired by other drivers a multiplier has been applied. The scaling of the multiplier ranges from 0 to the mean repex replacement age and any assets over the mean are given a 100% multiplier. Figure 6 shows how the multiplier has been applied to a 50-year repex replacement age example.

Figure 6. Example non-repex multiplier for 50-year repex replacement age



The overall average age is expected to increase across all asset classes through the 2024-29 regulatory period. Sections 3 to 10 provide further detail of the impact and evaluation of this for each asset class.

Given age provides a reasonable lead indicator for condition, the relationship between age and asset performance will continue to be monitored through the 2024-29 regulatory period to assess whether a future step change in replacement expenditure is required.

Age-based assessment was not adopted as it represented a significant increase in short term replacement expenditure yet to be observed by actual asset performance.

2.3.2 Replace on failure

Utilising historical failure data and statistical analysis techniques, asset failures can be predicted under a 'do nothing' scenario. This prediction forecasts the probability of failure of individual assets in each future year, which when multiplied by the population, produces a volume of predicted failures. These failures may be either repaired or replaced. The ratio of historical repairs to replacements has been applied to forecast the volume of reactive replacements (replace on failure).

The probability of failure is used within the CBA and supports the calculation of risk and to forecast the volume of reactive replacements. When the number of forecasted failures is higher than the CBA positive volume, reactive replacement or repair is considered.

Additionally, we have matured our approach with advanced statistics being used to predict asset failures. This approach uses a multi-variable method to improve the failure prediction accuracy. Further details on this method are described in the **Attachment 5.4.e CBA Approach for Replacement Programs**.

The historical failures used to predict failures does not include failures due to weather events such as storms, floods or bushfires impacting the network. Therefore, these have also been excluded from predicted failures captured in this document. Weather related failures are captured under the resilience program.

The option to replace on failure is embedded in our CBA and is only adopted where the CBA ratio is not positive.

2.3.3 Cost Benefit Analysis

CBA has been applied to most assets and sub-asset classes, however, in some cases it is not practical due to the availability and quality of data, the size of the investment or the suitability of the style of analysis. A detailed explanation of the methodology for CBA and NPV is described in the **Attachment 5.4.e CBA Approach for Replacement Programs**.

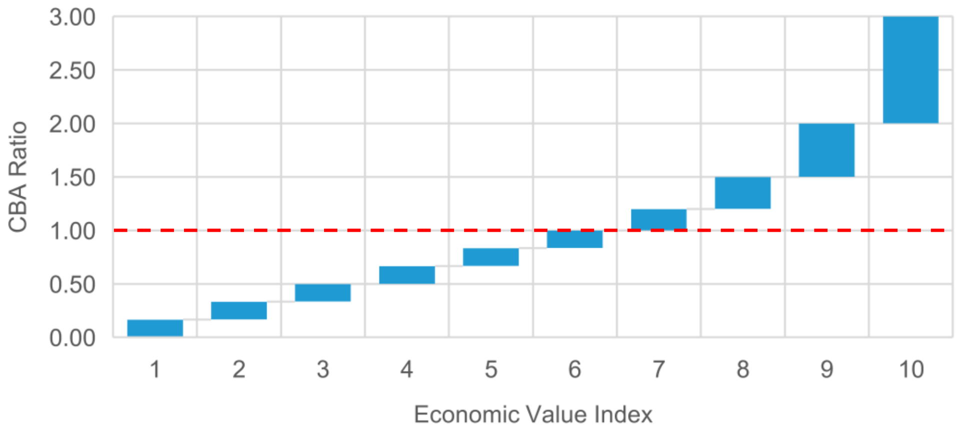
When performing CBA, customer benefits are reflected as costs and risks avoided from undertaking asset replacement. The customer benefits associated with our assets are calculated based on factors including:

- Direct Cost,
- Loss of Supply,
- Fire,
- Public Safety,
- Worker Safety, and
- Environment.

These areas of focus align with the **Attachment 5.2.c Customer Value Framework**. As an assets condition deteriorates over time, its probability of failure increases and so does its risk. This change in risk increases the customer benefit realised from replacement, resulting in a higher CBA ratio.

Due to the high number of assets covered by replacement programs, we have developed an index to show the CBA results across the entire population of assets within each asset class. This index is only used to visualise the outputs for a population of assets. Figure 7 shows the relationship between the economic value index and the CBA ratio that has been used to group populations of assets.

Figure 7. CBA Ratio associated with economic value index



As the CBA ratio increases over time, it moves from economic value index 1 (low CBA ratio) up to economic value index 10 (high CBA ratio). As can be seen from Figure 7, any asset that has a CBA ratio greater than 1, where the customer benefits exceed the cost, has an economic value index of 7 or above and is supported for replacement. This approach can be used to support optimal replacement timing as well as prioritise individual asset replacements based on their CBA ratio. Assets in economic value index 10 are the highest priority for replacement.

As noted above, our CBA approach forecasts the volume associated with reactive replacements in addition to the CBA positive assets. Planned and condition-based replacement (i.e. CBA positive) are assumed to be 100% effective at preventing a reactive failure. Where the number of forecasted failures is higher than the CBA positive volume, reactive replacement or repair is considered. The ratio of historical repairs to replacements has been used to support the forecast.

CBA has been applied to a larger population of assets than for the 2019-24 regulatory proposal. This is the preferred approach to forecast replacement expenditure as it evaluates customer benefits to replacement cost using risk management principles.

2.3.4 Maintaining risk

Where CBA has been undertaken, risks before investment (inherent risk) and after investment (residual risk) can be combined into a single view of risk across all assets. Figure 8 shows the inherent and residual risk across all assets evaluated within this document where CBA outcomes have been validated (i.e. at this stage, CBA outcomes for the Buildings, Grounds and Land asset class is still under development). We have calculated the risk profile based on an FY22 baseline considering a smoothed investment profile prior to and during the 2024-29 regulatory period.

Figure 8. Inherent and residual risk for Ausgrid's network assets (real $, FY24)

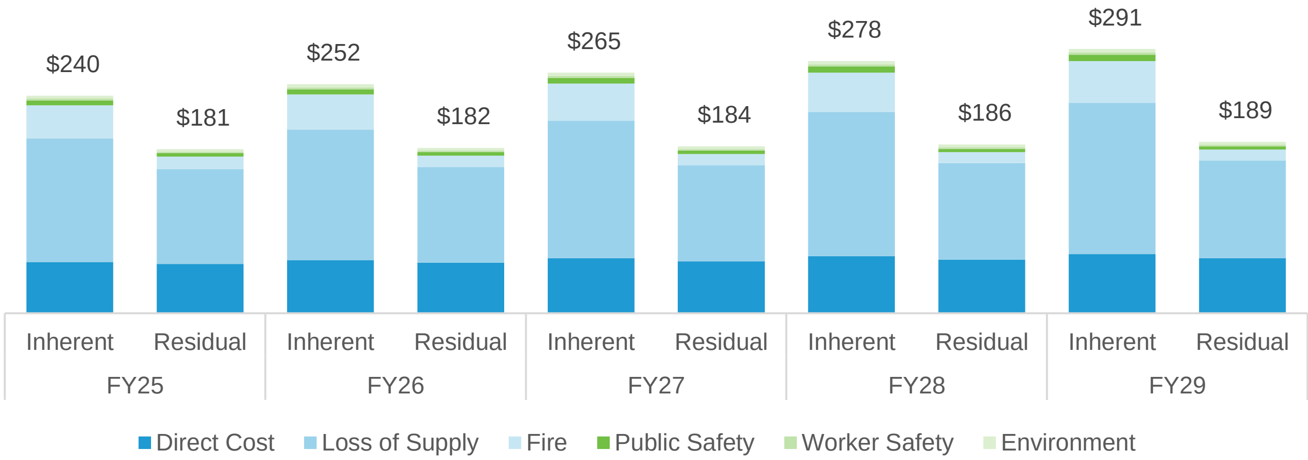


Figure 8 shows that residual risk will increase slightly during the 2024-29 regulatory period despite the investment in assets that are cost benefit positive. This is generally due to the increasing age of the asset base, for the size of the proposed investment. However, other network initiatives beyond replacement programs, including innovation investment, are expected to further mitigate risk and manage risk growth.

Maintaining risk involves keeping overall residual risk (post investment) at baseline levels until the end of the regulatory period (i.e. FY29). Two methods were investigated when determining the level of investment required to maintain risk. These were:

1. maintaining risk for the replacement program portfolio, and
2. maintaining risk at an asset class level.

Maintaining risk at the replacement program level is achieved by adjusting investment to maintain the customer benefit at baseline levels by the end of the period, while at the asset class level they could still be growing or reducing over time.

Figure 9 shows the annual change in residual risk against the change in replacement program expenditure as a percentage of the CBA output. This method is known as the compound annual growth rate (CAGR). This scenario involves investing in assets with the greatest customer benefit and therefore may result in higher expenditure in one asset class over another. From the CAGR analysis, the following observations can be made:

- since our forecast is lower than the CBA outputs, risk is forecast to grow by 0.4% per year,
- if the CBA outputs were adopted, risk would grow by 0.1% per year, and
- to maintain risk to current levels, expenditure would need to increase by 3.5% ($8m per year), relative to the CBA outputs, or 14.5% ($33m per year) relative to the forecast.

Figure 9. Annual replacement program expenditure CAGR

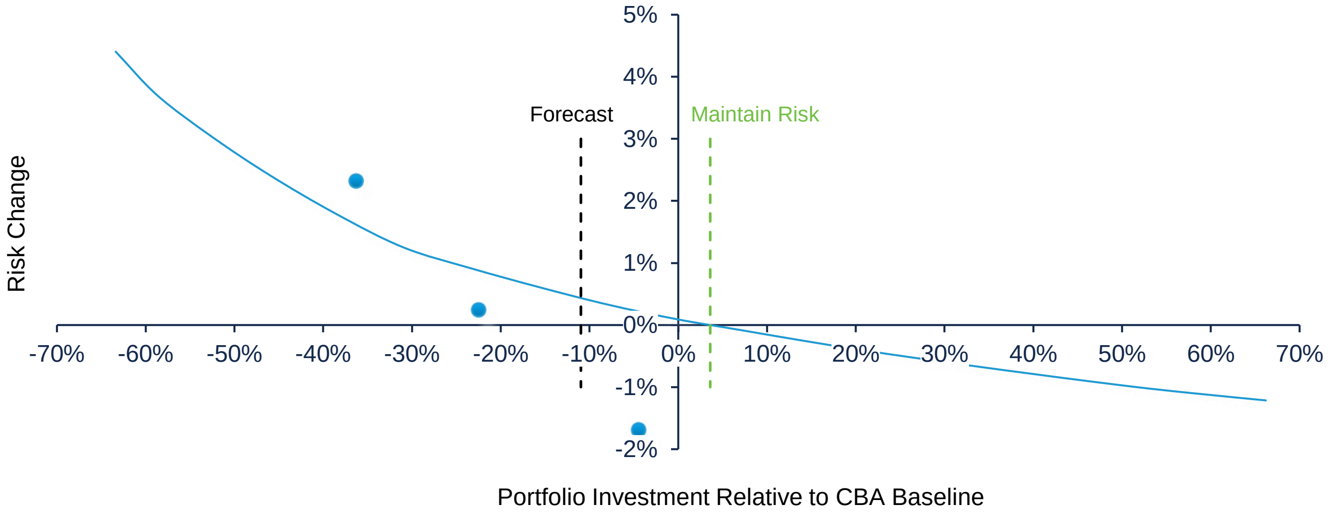
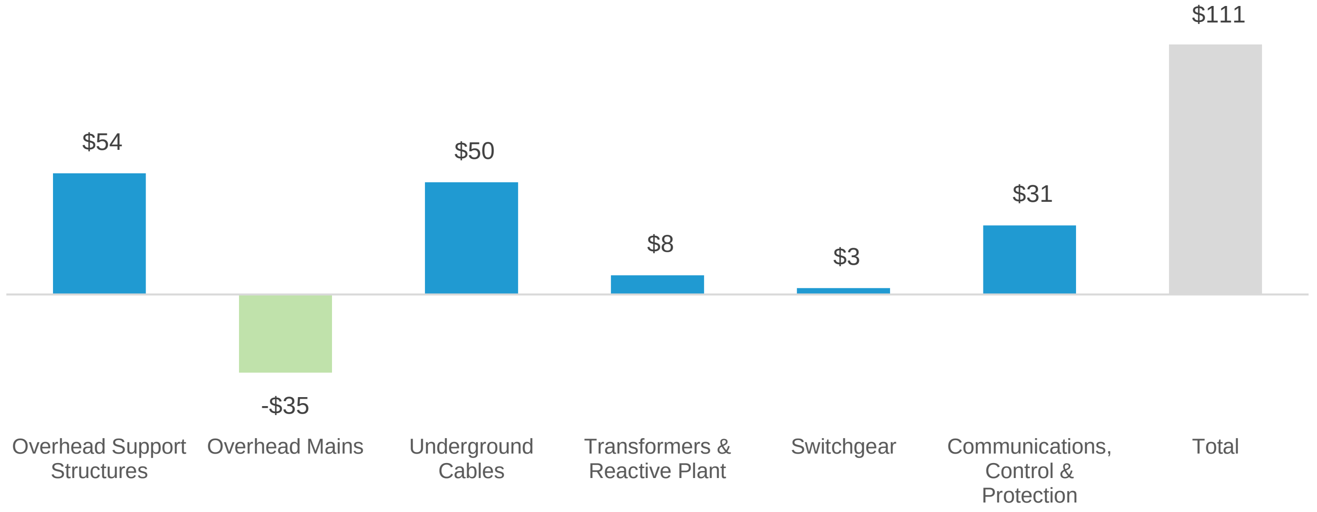


Figure 10 shows the change in expenditure required to maintain baseline risk levels for each asset class.

Figure 10. Annual expenditure relative to CBA baseline to maintain risk at baseline levels (real $m, FY24)



This analysis highlights that in all asset classes except for overhead mains, the risk is forecast to increase. The output for overhead mains is expected given the heightened outage, safety and fire risk inherent to this asset class relative to the others. While this approach provides insight and validation to the forecast, adopting this approach assumes that customer benefit realised from investment within each asset class is equal. As the customer benefit for expenditure is not equal across asset classes, maintaining risk at the asset class level will not result in maximum customer benefit for the expenditure.

We have not adopted a higher forecast to mitigate the growth in risk, recognising that other investments and asset management strategies will support the overall management of risk growth.

2.3.5 Historical Trend

As noted above and shown in Figure 4 and Figure 5, we have compared the forecast replacement expenditure against that of previous regulatory periods including the expected total expenditure during the current 2019-24 regulatory period. This analysis has been performed:

- for each asset class,
- for replacement programs (scope of this document), and
- for total replacement as found in **Attachment 5.1 Proposed Capex**.

The analysis was performed at all levels, recognising that priorities are likely to move between asset classes and replacement drivers across regulatory periods.

We have not solely relied on our CBA and have considered the potential customer impacts of step changes before adopted our CBA results. Where we believe we can still manage asset performance and associated risks at historical investment levels, then we have adopted a forecast in-line with historical trend.

2.3.6 Repex Model

The repex model is one tool used by the AER to undertake a top-down evaluation of replacement expenditure by considering our historical costs and replacement lives and benchmarking these against peer DNSPs. To assist in the evaluation of our replacement investment portfolio, we have used the repex model as part of our top-down evaluation.

As noted above, the repex model applies to a larger proportion of the replacement expenditure forecast than is covered within this document. In evaluating the replacement program, the forecast has been pro-rated to only include the repex components within the scope of replacement programs. Details on the overall repex model results when considering other replacement drivers can be found in **Attachment 5.1 Proposed Capex**.

The repex model applies benchmarking across peers in the NEM and is the preferred method used by the AER to assess the prudency and efficiency of our proposal. We have applied the repex model across all replacement expenditure in support of our proposal.

2.4 Asset management approach

The analysis previously discussed is used to inform the repex forecast. We consider two types of failures:

- **Functional failures:** the inability of an asset to fulfill one or more intended functions leading to reactive replacement or repair, and
- **Conditional failures:** the inability of an asset to meet desired performance criteria which indicates pending functional failure (also known as a defect) leading to condition-based replacement or repair.

Actual replacement decisions are grouped into the three types shown in Figure 11.

Figure 11. Replacement Types

Need Identification	Assessment	Forecast Method
Reactive Replacement		
Generally following asset functional failure Individual replacements are not known until	Reactive treatment is suitable when: • asset criticality is low and asset failure is acceptable, or • the cost of implementing additional controls outweighs the benefit (not CBA positive), or • asset issues are not cost effective to detect, or	Forecast based on failure prediction models where CBA is not positive.

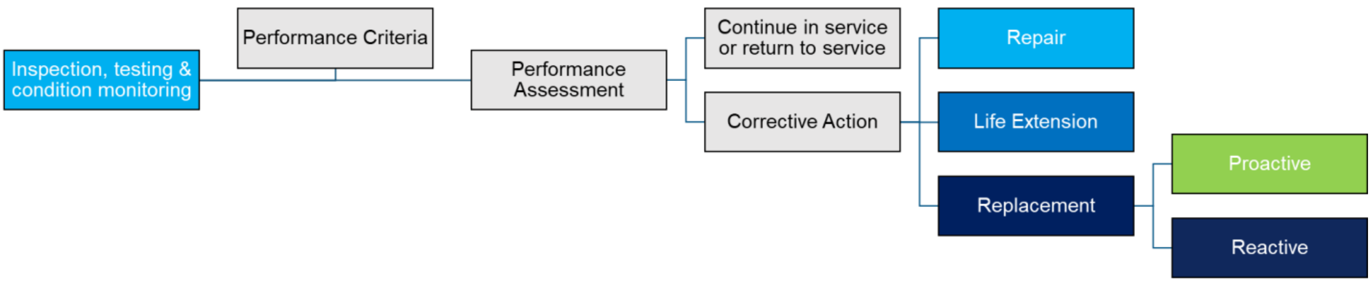
Need Identification	Assessment	Forecast Method
failures occur or risks are realised	• unforeseen risks arise during the period which are not forecast in other programs.	
Condition-based Replacement		
Assessment of asset condition against acceptable risk criteria Individual replacements are not known until an asset is tested and evaluated against performance criteria	Condition-based treatment is suitable when: • the risk mitigation gained (benefits) outweighs the cost (CBA positive), and • risks can be linked to time or asset condition, and • condition-based maintenance is technically effective (condition is detectable) and cost effective.	Forecast based on failure prediction models where CBA is positive. Individual asset replacements are informed by condition assessment.
Planned Replacement		
Assets with known and already unacceptable risk. Individual replacements are known and prioritised before the start of the regulatory period	Planned treatment is suitable when: • The risk mitigation gained (benefits) outweighs the cost (CBA positive), and • Condition-based maintenance is not technically effective or cost effective, or • Further monitoring of condition does not add value.	Forecast based on failure prediction models where CBA is positive. Individual asset replacements are informed by CBA ratio.

Assets are replaced to mitigate risk and provide benefit to customers. Assets that have functionally failed are either repaired or replaced. To avoid the risk of functional failure, assets are repaired or replaced before functional failures occur i.e. at the point of conditional failure. These risks form part of the benefits supporting asset replacement and are grouped into the following categories:

- **Degrading:** risks that increase with time as asset condition deteriorates, and
- **Non-degrading:** risks that already exist or are unpredictable in nature.

Non-degrading risks are either known or unpredictable and therefore suitable for planned or reactive replacement. For degrading risks, condition-based asset replacement decisions utilise a condition-based maintenance (**CBM**) approach. CBM includes inspection, testing and online condition monitoring to assess asset condition and inform corrective actions including repairs or asset replacement. The CBM process is shown in Figure 12.

Figure 12. Condition based maintenance (CBM) approach

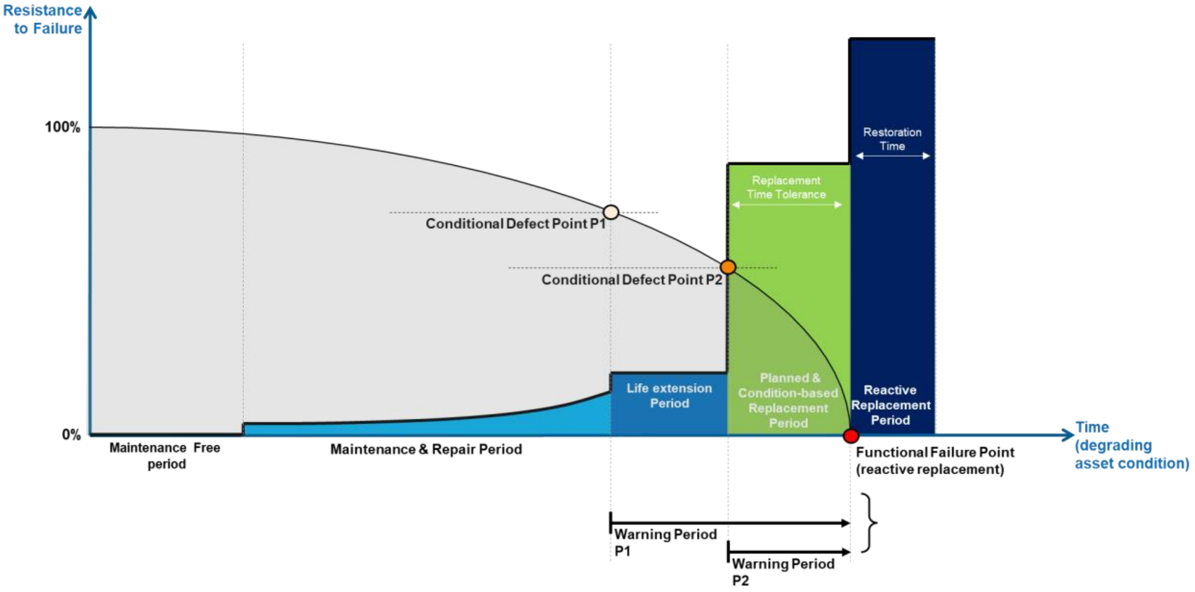


Through an assets life, defects may require maintenance repairs to be undertaken so that the asset remains serviceable. As an assets resistance to failure decreases it approaches the end of its serviceable life and is likely suitable for replacement. While ongoing repairs may be undertaken, the overall condition of the asset continues to deteriorate until a life extension or replacement activity is undertaken. To this extent, when modelling asset risk, we can assume that:

- A repair restores an asset to 'as good as old', and
- A replacement restores an asset to 'as good as new'.

New assets require less maintenance than older assets. Therefore, as the network continues to age, the reasonably stable level of repex proposed for the 2024-29 regulatory period will place upward pressure on maintenance. This is expected to be managed through improved predictive modelling, targeted maintenance and replacement activities and productivity improvement opportunities. Figure 13 shows the linkage between the process for undertaking CBM and the associated corrective actions over an asset's lifecycle.

Figure 13. Asset degradation curve



The following sections provide key information on each asset class to inform our replacement forecast, including:

- Asset class scope including the relationship to the AER's RIN categories,
- Asset age and technology,
- Key degrading and non-degrading risks,
- An evaluation of asset replacement options,
- The proposed management strategy for the asset class, and
- The replacement volume and expenditure forecast.

3. Overhead Support Structures

3.1 Scope

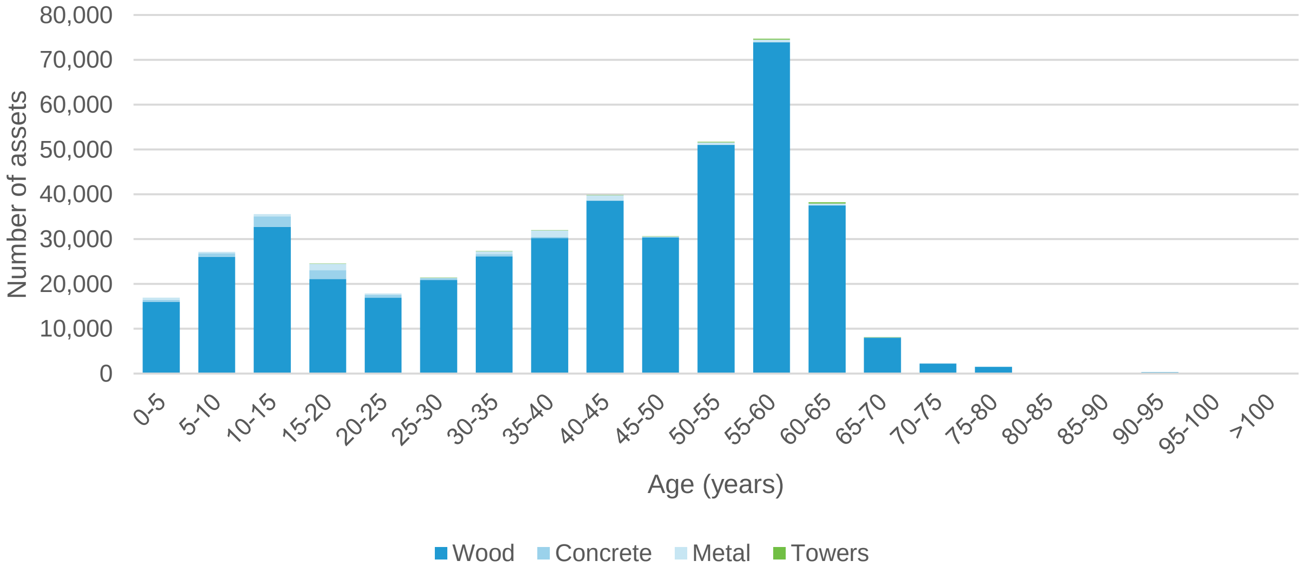
Overhead support structures are used to maintain electrical clearances between live electrical equipment and the ground. This asset class includes poles, towers, and their associated cross-arms and insulators (pole-tops). For the RIN, this asset class is split into:

- Poles (including towers),
- Pole-top Structures (pole-tops), and
- Unmodelled – Other (tower refurbishments).

3.2 Age and Technology

Figure 14 shows the age profile and technology composition of assets in this asset class.

Figure 14. Age Profile for Overhead Support Structures – Poles & Towers



The average age of assets within the modelled portion of this asset class is 39 years. The average age has increased from 35 years over the last five years. Poles represent the largest portion of this asset class, both in population and expenditure, and most of the replacements fall into this asset sub-class. With a population of nearly 450,000 poles (excluding poles specifically used for streetlighting) and an average age at replacement of 52 years, we would need to replace 2% of our assets per year (9,000 poles) to maintain the current average age.

Despite the increasing age profile, our condition-based management approach for these assets supports a level of investment that is lower than the sustainable age-based volume forecast would suggest. While this may lead to a future increase in replacements, pole performance has remained steady through the current regulatory period. This may be attributed to the quality of the poles that were previously installed on the network. Performance metrics will be monitored to determine future needs.

We generally replace poles on a 'like-for-like' basis, with the following exceptions:

- Based on the assessed condition, defect location and cost effectiveness, a reinforcement option (wood poles only) may be utilised. Reinforcement for wood poles involves staking at the base of the pole.
- Composite poles have been installed in difficult to access locations due to their reduced weight and reduced maintenance requirements. They have also been used to support pole-top substations to extend their life.
- Wood poles on transmission lines may be replaced with concrete or steel poles to comply with modern design standards / requirements.

We also maintain a fleet of over 700 steel transmission towers, 83% of which support multiple feeders (circuits) on a single structure. A failure of a single tower can result in outages on multiple feeders and are difficult to recover - this is particularly pronounced where both feeders form the sole supply to a common network area. We replace steel towers with two steel or concrete poles due to reduced maintenance requirements over their operating life.

Steel tower integrity may also be maintained through component replacement and painting (refurbished). Depending on their location, some towers are more prone to accelerated corrosive degradation and therefore are not cost effective to refurbish.

3.3 Key Risks

Overhead support structure failures pose a significant safety risk, particularly to the public. It is likely that pole failures would break the overhead mains they are supporting, resulting in a loss of supply to customers and reactive replacement of the pole to 'make safe' and restore supply.

3.3.1 Degrading risks

Overhead support structures degrade over time. This degradation reduces the mechanical strength of the assets and their ability to support the mechanical load (overhead conductors), eventually leading to asset failure. Key causes of this degradation include:

Causes of asset degradation	Rot; UV or weather exposure; concrete spalling and corrosion

External factors can place additional stress on these assets which can accelerate their degradation. These escalation causes include:

Escalation causes	Ground movement; wind; vegetation impacts; ground contamination; termites and mechanical load

These causes are used to determine the probability of asset failure. If an asset does fail, it may result in a hazardous event. The hazardous events associated with overhead support structures include:

Hazardous events	Loss of electrical continuity; fire starts; contact with live fallen wires; contact with electrical equipment inadvertently energised; struck by fallen objects; exposure to arc flash and fall from heights

3.3.2 Non-degrading risks

We have been working with road authorities to review the risks associated with poles in vehicle accident 'blackspot' areas. Where the location of poles creates a heightened risk of vehicle contact, we may relocate the poles to a safer location. Alternatively, the road authorities may implement road controls to mitigate the risk. The hazardous events associated with non-degrading risks include:

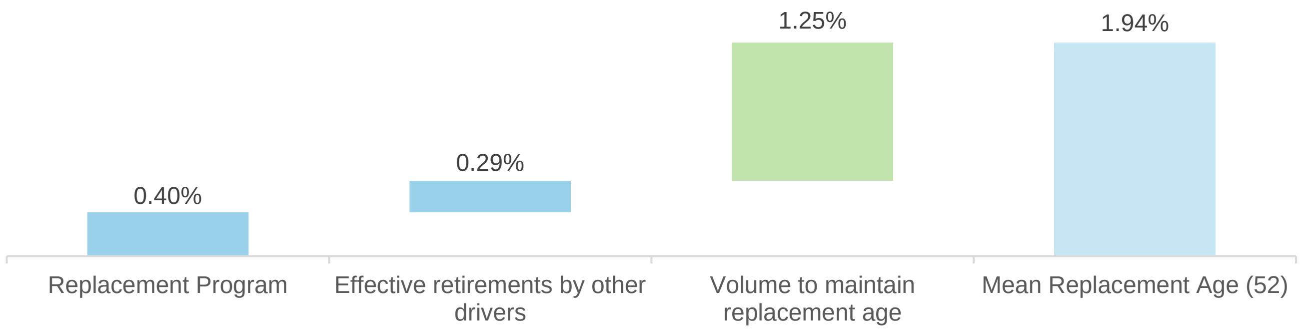
Hazardous events	Vehicle/plant/public impact with asset (ground level); loss of electrical continuity; contact with live fallen wires; struck by fallen objects

3.4 Forecasting replacement

3.4.1 Age-based assessment

We have recently been replacing an average of 1,784 poles per year under our replacement program. However effectively another 1,290 poles are being retired or replaced in conjunction with other works such as customer driven projects (outside the scope of the replacement program). This value is calculated using a scaling multiplier based on the age at replacement as described in Section 2.3.1.

Figure 15. Annual Population replaced by driver for Overhead Support Structures – Poles



This results in a total effective annual volume of 0.68% of the pole population (3,075) replaced each year. With this replacement rate it would take 146 years to replace the entire pole population. Given our recent historical replacement rates are lower than the volume required to maintain the average age of the asset class, this top-down metric suggests that the level of investment is not sustainable in the long term. However, recent performance resulting from our management of these assets does not support the step change required to maintain the average age for this asset class.

3.4.2 Replace on failure

Under a base case scenario, with no replacement investment, the asset failure rate is expected to grow with time. The forecast average annual failures predicted between 2024 – 29 is shown in Figure 16.

Figure 16. Base case failures for Overhead Support Structures (2024 – 29)

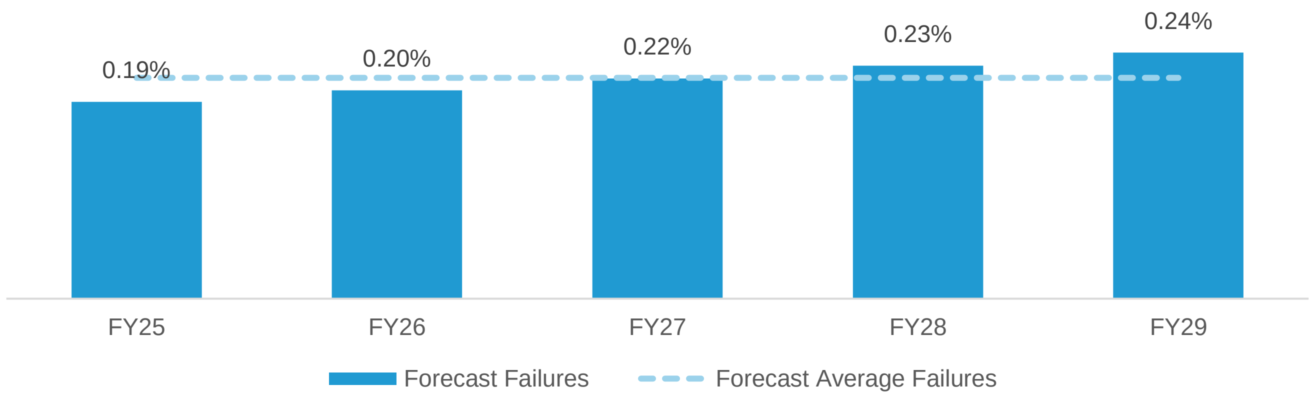
Sub-class	Forecast Average Annual Failures	Annual % of population
Poles	1,518	<1%
Towers	18	2.5%
Pole-tops	1,678	<1%

The high failure rate associated with the towers sub-class is due to a high number of historical defects resulting in repairs. The repair rate of 99% is forecast to continue in the 2024-29 regulatory period. Therefore, under this scenario, <1 tower would be replaced annually following failure.

Although the age profile for this asset class shows approximately 39% of assets already above the 52-year mean replacement age (as demonstrated in Figure 14), the forecast average annual failures remain less than 1% of the population per year. At this failure rate, the average age will continue to increase.

We have a strong history of managing this risk with routine inspections that allow for timely treatment of defects before asset failure. Figure 17 shows the projected failures and average proportion of the asset population expected to fail over the 2024-29 regulatory period. This performance supports the strong recent historical management of this asset class. The volume of predicted failures over the period has also been applied to determine the probability of failure used in our CBA.

Figure 17. Forecast inherent failures as proportion of population for Overhead Support Structures



3.4.3 Economic value through CBA

An economic evaluation has been undertaken on all assets in this asset class utilising CBA. Where the economic value of the risk carried exceeds the cost to replace, the asset is considered suitable for replacement. Figure 18 shows the volume of pole and tower assets and Figure 19 shows the volume of pole-top assets within each economic value index at FY29.

Figure 18. Economic value index for Overhead Support Structures – Poles & Towers

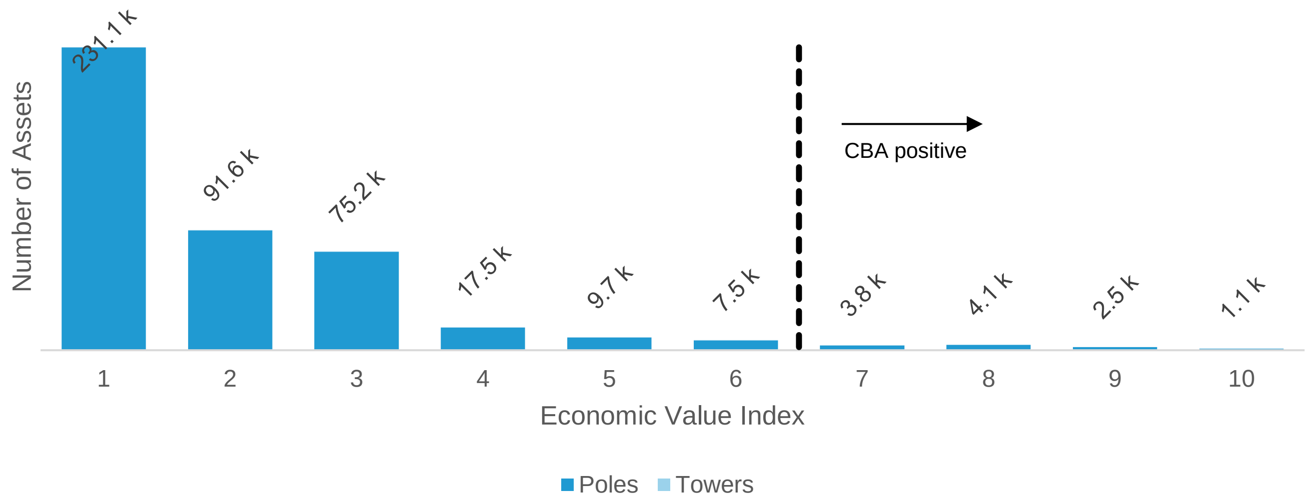
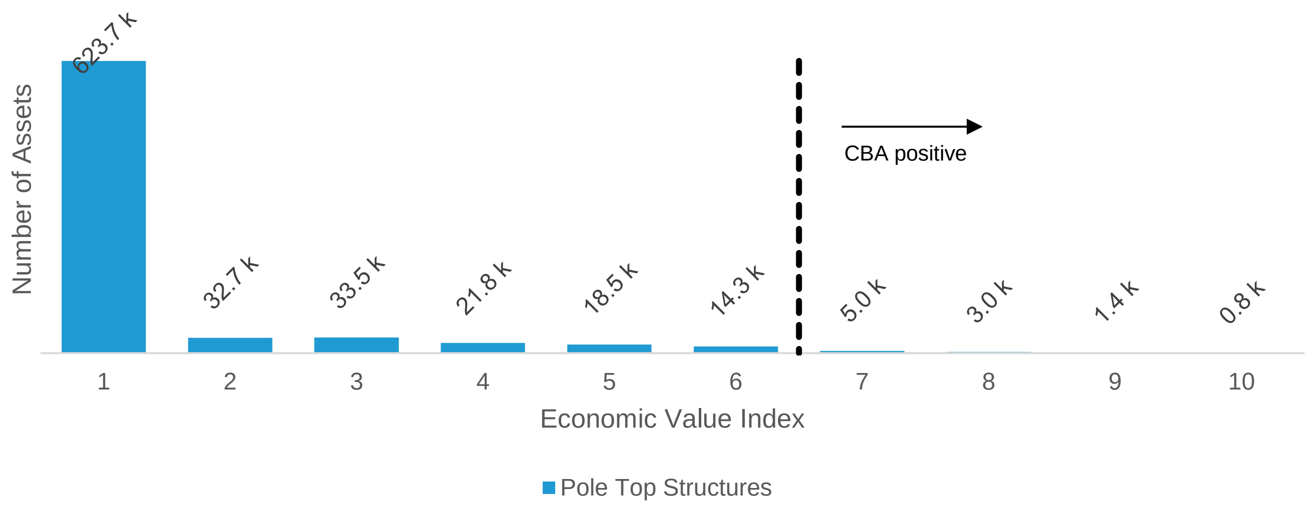


Figure 19. Economic value index for Overhead Support Structures – Pole-top Structures



The assets at or above an economic value index of 7 are expected to be cost benefit positive before the end of FY29. Given the number of cost benefit positive assets exceeds the modelled predicted failures, the supported replacement investment for the 2024-29 regulatory period reflects the figures above, which translates to an investment of $215 million (real $, FY24) over the five years. A breakdown of the replacement volume is detailed in Figure 20 below.

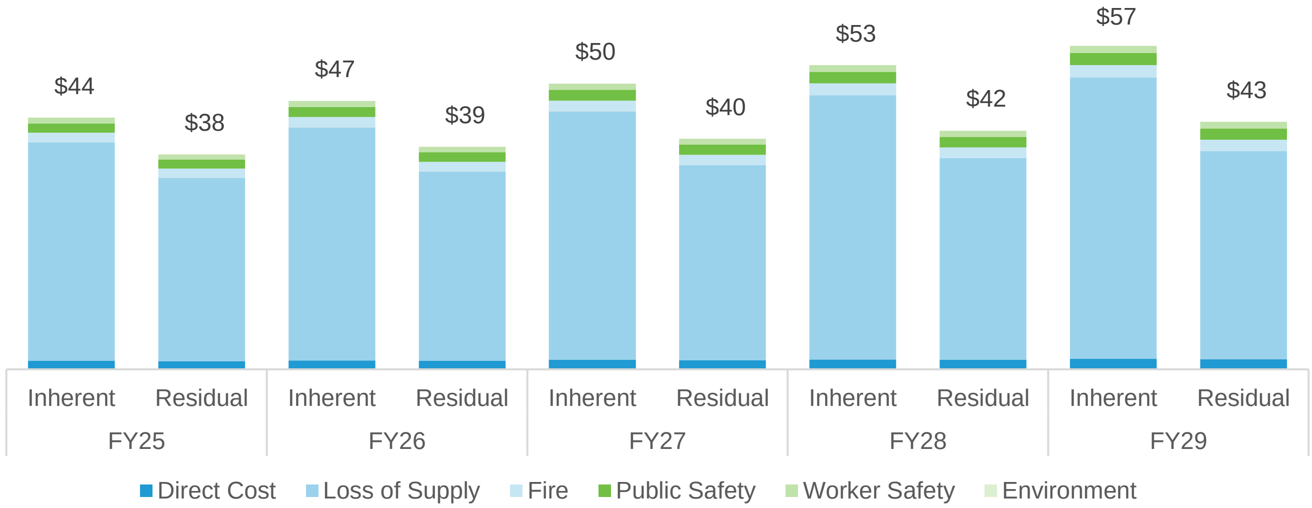
Figure 20. CBA supported replacement volume by subclass for 2024 – 29 Overhead Support Structures

Asset Subclass	Supported total replacement volume	Annual % of Population
Poles	11,489	0.5%
Towers	24	0.7%
Pole-tops	10,259	0.3%

3.4.4 Maintain risk

Figure 21 shows the annual risk carried for this asset class before investment (inherent) and after CBA forecast investment (residual), based on replacing assets that are cost benefit positive. This analysis is based on a population and failure rate using FY22 as the base year and assumes a smooth investment for FY23-FY24. Given the average age of this asset class will continue to increase through the regulatory period, the residual risk is also expected to increase. Figure 10 highlights an additional $54m in replacement expenditure per year required to maintain risk for this asset class. This risk growth will likely be partially mitigated by other investment programs across our capital portfolio.

Figure 21. Inherent and residual risk by financial year for Overhead Support Structures (real $m, FY24)



3.5 Options

3.5.1 Reactive replacement

Under this option there is no consideration for planned or condition-based replacement or refurbishment. Following failure assets are either repaired or replaced in-line with the predicted volume under the base case scenario. This option is only selected where the benefits of replacement do not outweigh the costs.

3.5.2 Reinforce/Refurbish on condition

Based on their assessed condition, defect location and cost effectiveness, a reinforcement option (wood poles only) or refurbishment option (towers only) may be utilised. Reinforcement for wood poles involves staking at the base of the pole to improve the pole strength below ground.

For some poles, a counterweight known as a ‘pole stay’ is used to balance uneven loads. These stays can deteriorate faster than the poles themselves and therefore may require replacement before the pole has reached end of life.

Refurbishment of towers involves replacing corroded steel members and fastenings, removing existing paint coverage, and then fully repainting the tower with modern corrosion protection coatings. Many of these towers were originally painted using lead paint. The cost to treat and remove lead paint is significantly higher than non-lead based paint, limiting the ongoing economic feasibility of tower refurbishment.

Reinforcement or refurbishment of poles or towers cannot mitigate all failure modes or inherent design limitations and do not return the asset to an ‘as new’ condition, however, they do provide a life extension to the asset and are often lower cost than full asset replacement. These options are adopted where they are cost effective.

3.5.3 Replace on condition / planned

Figure 22 outlines the replacement strategies for each sub-class. These strategies are considered condition-based as they are informed through periodic maintenance. This maintenance includes mechanical and structural integrity testing as well as engineering assessments based on degradation assumptions.

Figure 22. Asset sub-class replacement strategies for Overhead Support Structures

Sub-class	Strategy
Poles	Replacement / refurbishment decisions for poles are based on maintenance serviceability criteria (condition-based). Poles that do not meet the criteria or are unsuitable for reinforcement are replaced. Other poles can be identified for replacement in conjunction with the road authorities following analysis of vehicle accident data.
Pole-tops	The preferred approach to manage pole-top structures is through condition monitoring (condition-based). This addresses the risks associated with the known failure modes for these assets rather than planned replacement based on age or design issues.

Sub-class	Strategy
	As the pole-top is an integral component of the pole, replacement of the pole itself may be required where it is economical on a 'whole of life' cost or where conductor safety clearances required by modern standards cannot be maintained. Replacing the whole asset (pole-top structure and pole) aligns the age of all components following replacement and leaves them in an 'as new' condition.
Towers	Typically, the most cost-effective solution for steel tower replacement is to replace them with steel or concrete poles. This solution reduces long term maintenance costs and improves recovery time in the event of a failure.

3.5.4 Options not considered feasible

Figure 23 shows the options that were considered and assessed as not feasible.

Figure 23. Options not considered feasible for Overhead Support Structures

Option	Rationale
Increased maintenance & inspections	The condition issues have already been identified and cannot be rectified through increased maintenance or inspections, and therefore it is not a technically feasible solution to address the need.
Undergrounding of the network	This would greatly reduce many of the risks however, this solution is typically not cost effective. Undergrounding locations where the value can be demonstrated through cost benefit analysis is considered as part of our climate resilience strategy.
Non-network solutions	Non-network solutions provide suitable risk mitigation in limited scenarios, however, are rarely practical or justifiable on the condition of overhead support structures alone.

3.6 Proposed Management Strategy

We have maintained a strong performance in managing risks from this asset class through our condition-based approach. There is an overall small reduction in investment, compared to historical trend and our CBA results, within this asset class where assets with known issues have predominately been addressed.

Given the population of assets between 50 and 60 years of age, we will continue to monitor trends in condition (leading indicator) and failures (lagging indicator) and review proposed replacement volumes for future regulatory periods.

Life extension options such as pole reinforcement, pole stays, and tower refurbishment will be applied depending on individual asset suitability (informed through condition assessment) and whole of life cost assessment. These practical differences may mean that actual replacement expenditure does not always reflect the forecast. To address the condition issues with towers, while managing lead paint, the proposal is for a small increase in tower replacements relative to the current regulatory period.

3.7 Investment Forecast

Utilising this proposed management strategy, Figure 24 shows the forecast replacement volumes for the sub-classes within overhead support structures for the 2024-29 regulatory period.

Figure 24. Overhead Support Structures 2024-29 forecast volume

	Poles	Towers	Pole-Tops	Pole Reinforcement	Pole Relocation	Pole Stays	Tower Refurbishment
Volume	9,461	25	10,831	4,055	52	101	4
Population annual %	0.3%	0.7%	n/a	0.2%	n/a	n/a	n/a

The replacement expenditure forecast shown in Figure 25 is proposed for the 2024-29 regulatory period.

Figure 25. Overhead Support Structures forecast repex (real $m, FY24)

	FY25	FY26	FY27	FY28	FY29	TOTAL
Poles	$24	$24	$25	$25	$25	**$122**
Towers	$2	$2	$2	$2	$2	**$8**
Pole-Tops	$11	$11	$11	$11	$11	**$55**
Pole Reinforcement	$0.8	$0.8	$0.8	$0.9	$0.9	**$4**
Pole Relocation	$0.5	$0.5	$0.5	$0.5	$0.5	**$3**
Pole Stays	$0.2	$0.2	$0.2	$0.2	$0.2	**$1**
Tower Refurbishment	$0.1	$0.1	$0.1	$0.1	$0.1	**$0.5**
TOTAL	**$38**	**$39**	**$39**	**$39**	**$39**	**$194**

4. Overhead Mains

4.1 Scope

Overhead mains carry electricity across our network area from transmission supply points to customer premises, wherever that part of the network is above ground. This asset class includes service lines as well as all other overhead network conductors and connections. Underground to Overhead Connections (**UGOHs**) are excluded from this asset class and are considered under Underground Cables. For the RIN, this asset class is split into:

- Overhead conductors,
- Service lines, and
- Unmodelled – Other (access tracks & earthing).

4.2 Age and Technology

Figure 26 shows the age profile and length of overhead mains in this asset class (excluding service lines) by operating voltage. Figure 27 shows the age profile and population of overhead service lines in this asset class.

Figure 26. Age Profile for Overhead Mains (excluding Service Lines)

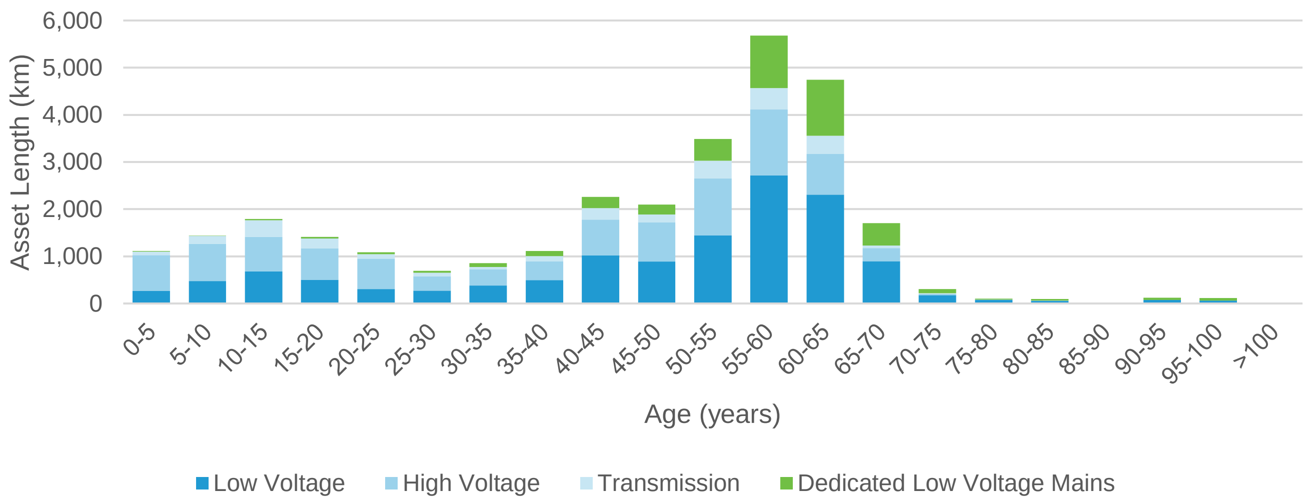
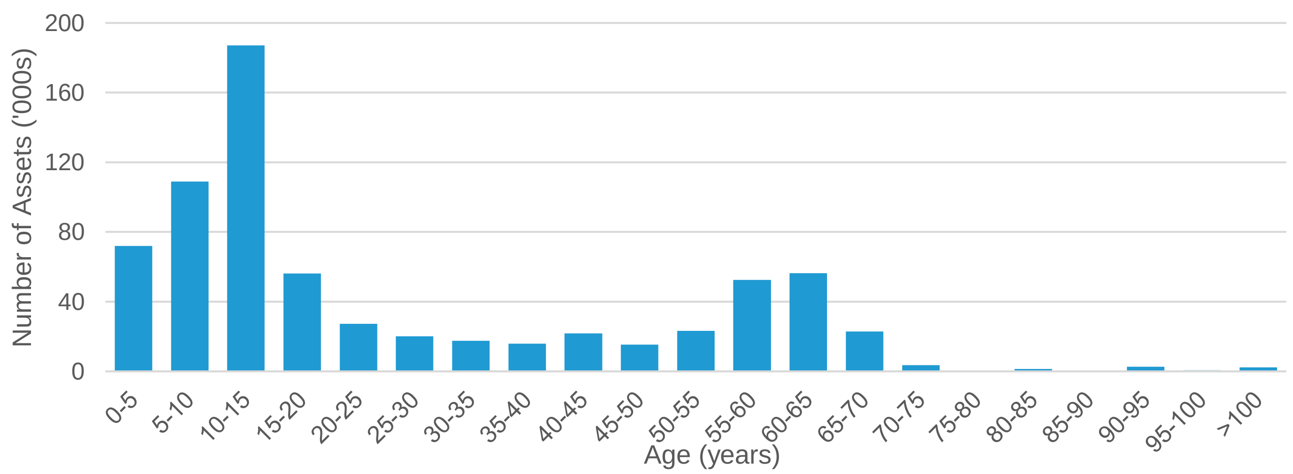


Figure 27. Age Profile for Overhead Mains – Service Lines



Older types of overhead conductors are uninsulated 'bare mains', typically made from copper. Some older overhead conductors (including overhead earth wires) were constructed from steel. Steel conductors were typically used in rural or remote areas as they could be strung over longer distances with a minimal number of poles however, have a lower breaking strength than modern technology. Advancements in technology for overhead mains have resulted in the following being used on the network:

- Aluminium conductors – with or without steel reinforcing strands,
- Insulated coverings on conductors, and
- Bundled insulated conductors.

In addition to the technology changes described above, we have progressively been transitioning legacy dedicated low voltage streetlight mains onto the standard LV network (incorporating individual PE cells to control street light operation).

The average age of overhead conductors, excluding legacy dedicated streetlight mains, is 42 years. The average age has increased from 39 years over the last five years. Uninsulated 'bare mains' represent the largest portion of this asset sub-class, both in population and expenditure, and the majority of the replacements fall into this sub-category. With a population of over 30,000 km, and an average age at replacement of 61 years, we would need to replace 1.65% of our assets per year (428 km) to maintain the current average age.

The average age for overhead service lines has been forecast separately. Their average age is 26 years, representing a decrease from their average age five years ago (28 years). Historically, the largest portion of this asset sub-class was uninsulated service lines or service lines with PVC insulation (later determined to degrade prematurely with exposure to UV light) and the majority of the replacements fall into this sub-category. With a population of over 700,000, and an average age at replacement of 56 years, our existing replacement program has effectively managed the average age of these assets.

Overhead mains can be replaced like for like (for example bare mains with bare mains) or may be upgraded with insulated or bundled conductors where modern standards require them or are otherwise supported by CBA. We generally utilise existing support structures when replacing overhead mains with exceptions where the structure needs to be mechanically stronger to support the new mains, or if safety clearances cannot be maintained.

4.3 Key Risks

Overhead mains failures pose a significant safety risk, to the public, and result in a loss of supply to customers and reactive replacement to 'make safe' and restore supply.

4.3.1 Degrading risks

Overhead mains degrade over time. This degradation reduces the insulation quality and mechanical strength of the assets, eventually leading to asset failure. Key causes of this degradation include:

Causes of asset degradation	Corrosion; UV exposure; and conductor annealing or stranding.

External factors can place additional stress on these assets which can accelerate their degradation. These escalation causes include:

Escalation causes	Wind; vegetation impacts; and coastal or polluted environments

These causes are used to determine the probability of asset failure. If an asset does fail, it may result in a hazardous event. The hazardous events associated with overhead mains include:

Hazardous events	Loss of electrical continuity; fire starts; domestic shocks; contact with live fallen wires; and contact with electrical equipment inadvertently energised

4.3.2 Non-degrading risks

Overhead mains breaching safety clearances due to external factors (for example new buildings or landscapes) or service lines without insulation are considered non-degrading risks. The hazardous events associated with non-degrading risks include:

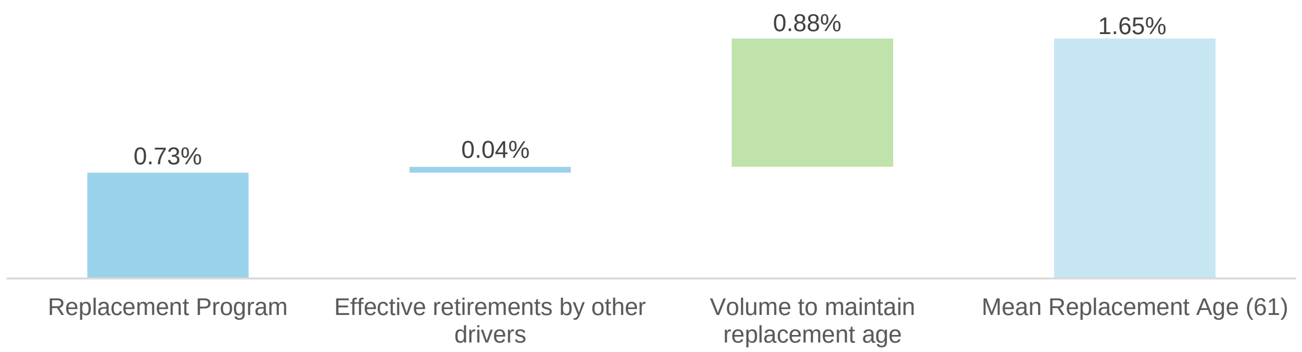
Hazardous events	Loss of electrical continuity; fire starts; contact with live fallen wires; contact with electrical equipment inadvertently energised; and make contact with overhead assets

4.4 Forecasting replacement

4.4.1 Age-based assessment

Figure 28 shows that we have recently been replacing an average of 189 km per year of overhead mains under our replacement programs. However effectively another 10 km are being retired or replaced as part of other works, such as augmentation or customer driven work (outside the scope of the replacement program). This value is calculated using a scaling multiplier based on age at replacement as described in Section 2.3.1.

Figure 28. Annual Population replaced by driver for Overhead Mains (excluding Services Lines and dedicated Low Voltage Mains)



This results in a total effective annual volume of 0.77% of the overhead mains population (199 km) replaced each year. With this replacement rate it would take 130 years to replace the entire overhead mains population. Given our recent historical replacement rates are lower than the volume required to maintain the average age of the asset class, this top-down metric suggests that the level of investment is not sustainable in the long term. While a significant number of failures of these assets have exposed the public to the safety risks from live fallen wires, initiated fires and caused customer outages, the step change to maintain the average age would result in a significant increase in cost during the 2024-29 regulatory period.

4.4.2 Replace on failure

Under a base case scenario, with no replacement investment, the asset failure rate is expected to grow with time. The total number of failures predicted between 2024 – 29 is shown in Figure 29.

Figure 29. Base case failures for Overhead Mains (2024 – 29)

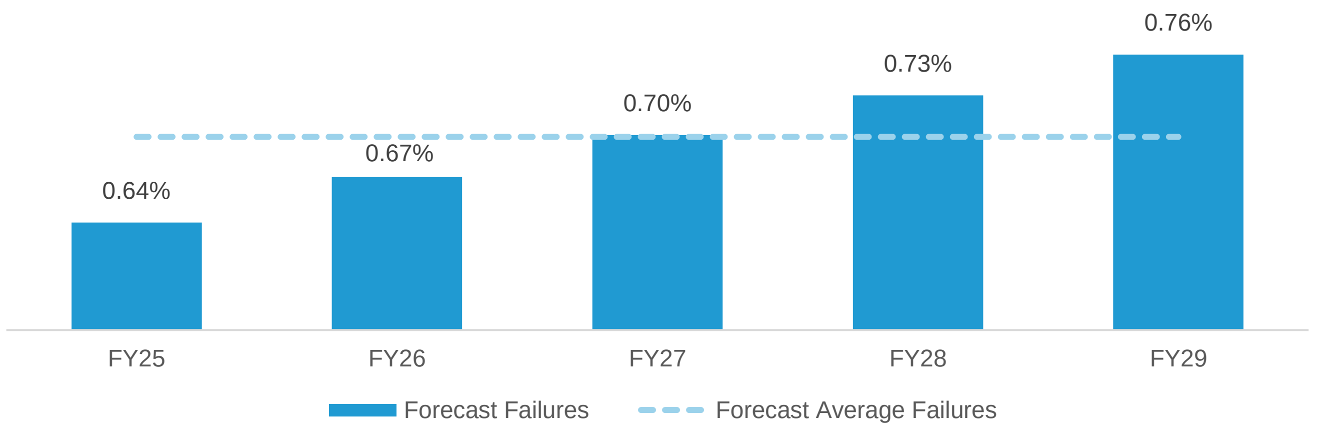
Sub-class	Forecast Average Annual Failures	Annual % of population
Dedicated Mains	1,422	1 per 3.5km
Service Lines	7,650	1%
Low Voltage	1,043	1 per 12km
High Voltage	124	1 per 80km
Transmission	40	1 per 101km

The historical repair rate of 79% is forecast to continue in the 2024-29 regulatory period. Therefore, under this scenario, only 21% (1,860) of overhead mains failures would be replaced annually following failure.

The forecast annual failures reflect the age profile for each asset sub-class, with approximately 24% of line length and 13% of services above the 61-year mean replacement age. At these failure rates, the average age will continue to increase.

Under this approach, repairs may be undertaken to mitigate failures however, given the growth in risk, this would lead to increased opex and would only provide short term risk mitigation as the mains condition continues to deteriorate. Figure 30 shows the projected failures and average over the 2024-29 regulatory period. The volume of predicted failures over the period has also been applied to determine the probability of failure used in our CBA.

Figure 30. Forecast inherent failures as proportion of population for Overhead Mains



4.4.3 Economic value through CBA

An economic evaluation of all assets in this asset class has been undertaken utilising CBA. Where the economic value of the risk carried exceeds the cost to replace, the asset is considered suitable for replacement. Figure 31 shows the volume of overhead mains assets (excluding service lines) and Figure 32 shows the volume of overhead service line assets within each economic value index at FY29.

Figure 31. Economic value index for Overhead Mains (excluding Service Lines)

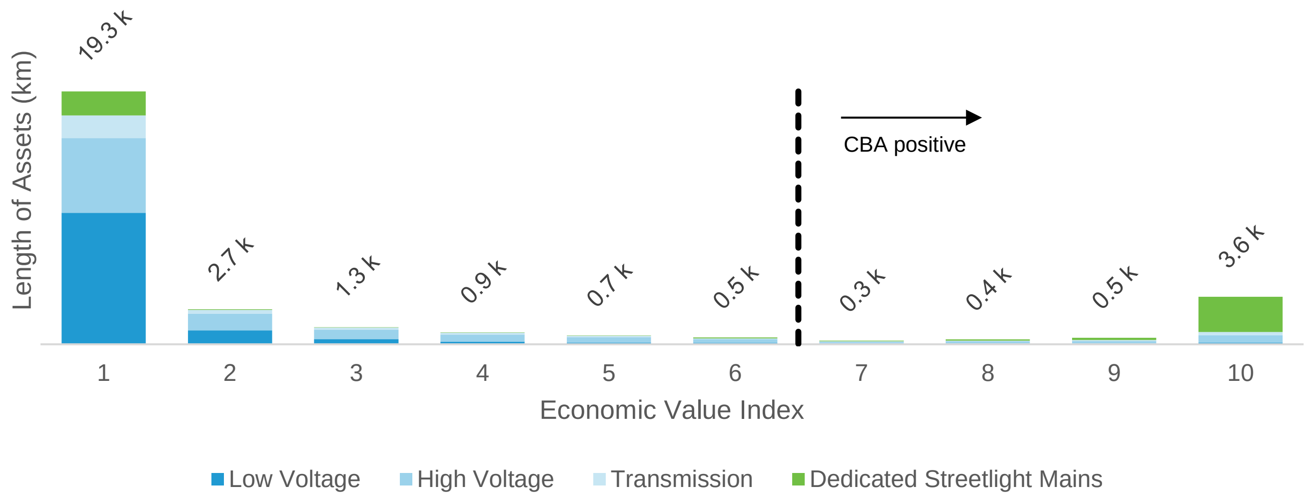
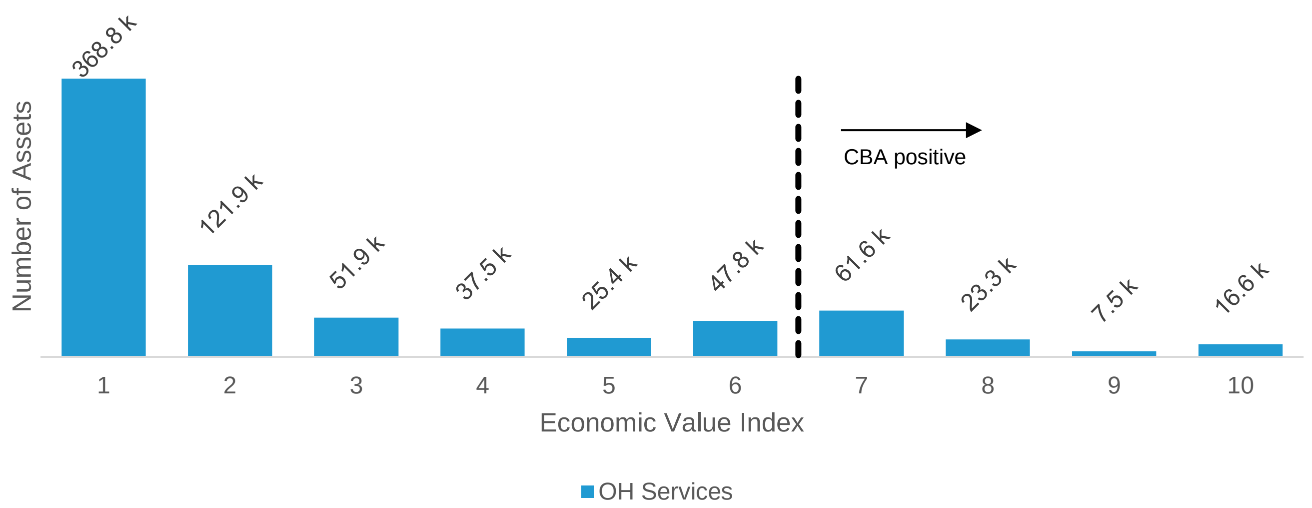


Figure 32. Economic value index for Overhead Mains – Service Lines



The assets at or above an economic value index of 7 are expected to be cost benefit positive before the end of FY29. Given the number of cost benefit positive assets exceeds the modelled predicted failures, the supported replacement investment for the 2024-29 regulatory period reflect the figures above, which translates to an investment of $329 million (real $, FY24) over the five years.

For service wires, the CBA supports a significant step change due to a combination of end of life and early life safety issues (predominately domestic shocks). As such, alternative controls are being investigated to limit this risk without adopting a significant step change in investment. A breakdown of the replacement volume is detailed in Figure 33.

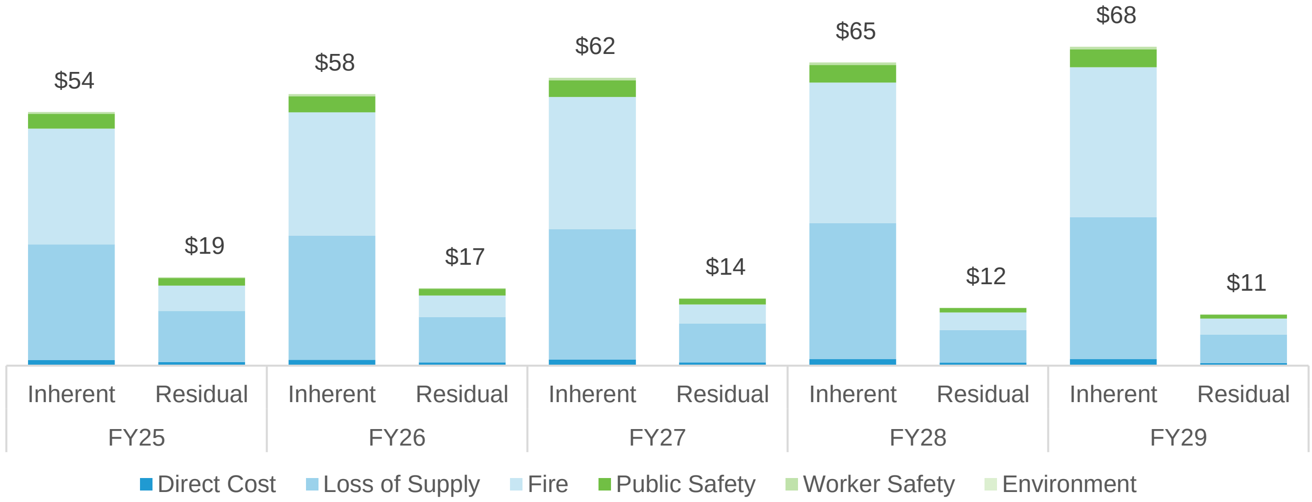
Figure 33. CBA supported replacement volume by subclass for 2024 – 29 Overhead Mains

Asset Subclass	Supported total replacement volume	Annual % of Population
Dedicated Mains (km)	2,997	12%
Service Lines	108,933	2.7%
Low Voltage (km)	299	0.5%
High Voltage (km)	1,055	2.1%
Transmission (km)	419	2.1%

4.4.1 Maintain risk

Figure 34 shows the annual risk carried for this asset class before investment (inherent) and after CBA forecast investment (residual), based on replacing assets that are cost benefit positive. This analysis is based on a population and failure rate using FY22 as the base year and assumes a smooth investment for FY23-FY24. Given the significant volume of supported dedicated low voltage mains removal and services, the residual risk under this scenario would decrease. Figure 10 highlights a reduction of $35m in replacement expenditure per year would maintain risk for this asset class.

Figure 34. Inherent and Residual Risk by Financial Year for Overhead Mains (real $m, FY24)



The significant reduction in forecast residual risk is due to the large volume of replacement expenditure in service lines and dedicated mains supported by our CBA.

4.5 Options

4.5.1 Reactive replacement

Under this option there is no consideration for planned or condition-based replacement or refurbishment. Following failure assets are either repaired or replaced in-line with the predicted volume under the base case scenario. This option is only selected where the benefits of replacement do not outweigh the costs.

4.5.2 Replace on condition

We undertake inspections and condition assessments of overhead mains to determine the appropriate option when condition issues are identified. Different overhead conductors have different failure modes and these inform assessment criteria for replacement. Condition monitoring is not always effective as degradation / corrosion cannot easily be assessed from ground inspection. Options to improve maintenance effectiveness are considered, however, typically result in higher whole of life costs. Therefore, some conductors with known failures modes and historical poor performance are also targeted for replacement. Figure 35 outlines some key replacement strategies. These strategies are informed through regular visual inspections and monitoring of asset performance.

Figure 35. Replacement strategies for Overhead Mains

Sub-class	Strategy
Low Voltage mains – Bare	Upgrade the low voltage network to insulated conductors. The majority of this investment is condition-based, however, some strategic priority may be given to areas where vegetation poses an increased risk of causing an interruption or bushfire, otherwise requiring significant removal of major limbs and trees.
High Voltage mains – low tensile strength	Corrosion or annealing of conductor strands for steel mains and small ACSR or copper conductor types pose risks to the public, customers and workers as well as a bushfire risk. As these are known failure modes these conductor types have been targeted as part of a planned replacement program.
Overhead mains	Continue to manage overhead mains through condition monitoring (condition-based). This addresses the risks associated with the known failure modes for these assets rather than a planned aged-based replacement.
Low overhead mains	Rectify low overhead mains against current clearance standards including horizontal clearances (close to buildings). The overhead mains are generally replaced with insulated conductors such as ABC or CCT and reduce the risk of the public (including vehicles) contacting live overhead conductors.
Dedicated low voltage mains	The primary function of these dedicated mains is to supply electricity to streetlights. These circuits were generally constructed with bare, small diameter conductors. There is a low likelihood of failure detection hence these circuits are being reconfigured to mitigate the associated public safety risks.

As described above a combination of planned and condition-based replacement has been adopted for overhead mains.

4.5.3 Options not considered feasible

Figure 36 shows the options that were considered and assessed as not feasible.

Figure 36. Options not considered feasible for Overhead Mains

Option	Rationale
Increased maintenance & inspections	The condition issues have already been identified and cannot be rectified through increased maintenance or inspections, and therefore this option is not a technically feasible solution to address the need.
Repair or refurbish	Where appropriate, repair or refurbishments are completed and are considered an operational expense. Low mains can be re-tensioned however if condition issues are identified the overhead mains repair is often not appropriate as the integrity and strength of the asset could be compromised.
Undergrounding of the network	This would greatly reduce many of the risks however, this solution is typically not cost effective. Undergrounding locations where the value can be demonstrated through cost benefit analysis is considered as part of our climate resilience strategy.
Non-network solutions	Non-network solutions provide suitable risk mitigation in limited scenarios (for example, stand-alone power systems), however, are rarely practical or justifiable on the condition of overhead mains alone.

4.6 Proposed Management Strategy

The age-based assessment and CBA are supporting a step change in investment in overhead mains relative to historical expenditure. The forecast risk reduction for the asset class is supported by the mitigation of bushfire, loss of supply and public safety issues. However, the significant reduction in residual risk under a maintain risk option does not reflect historical performance and is not likely to result in risk reduction shown by Figure 34.

As a result, we are proposing a forecast between the historical expenditure and the CBA results, predominantly driven by the risk associated with our dedicated low voltage mains. Given the population of assets above 50 years of age, we will continue to monitor trends in condition (leading indicator) and failures (lagging indicator) and review proposed replacement volumes again for future regulatory periods.

The forecast is for a reduction of service wire replacements to an expected longer term sustainable volume. This is due to all service wires expected to have insulated conductors and the use of smart meter data to monitor upstream network issues, reducing the likelihood of safety risks previously observed.

4.7 Investment Forecast

Utilising the proposed management strategy above, Figure 37 shows the forecast replacement volumes for the different asset sub classes within overhead mains for the 2024-29 regulatory period.

Figure 37. Overhead Mains 2024-29 forecast volume

	Dedicated Mains	Low Voltage	High Voltage	Trans.	Service Lines	Trans. Earthing	Access Tracks
Volume	2,690	284km	1,003km	118km	76,307	127	81km
Population annual %	13%	0.4%	2.0%	0.8%	2.1%	n/a	n/a

The replacement expenditure forecast shown in Figure 38 is proposed for the 2024-29 regulatory period.

Figure 38. Overhead Mains forecast repex (real $m, FY24)

	FY25	FY26	FY27	FY28	FY29	TOTAL
Dedicated Mains	$28	$29	$29	$29	$29	**$143**
Service Lines	$9	$9	$9	$9	$9	**$45**
Low Voltage	$7	$6	$7	$7	$7	**$35**
High Voltage	$9	$9	$9	$9	$9	**$47**
Transmission	$2	$2	$2	$2	$2	**$12**
Transmission Earthing	$5	$5	$5	$5	$5	**$26**
Access Tracks	$0.5	$0.5	$0.5	$0.5	$0.5	**$3**
TOTAL	**$61**	**$61**	**$63**	**$63**	**$63**	**$312**

5. Underground Cables

5.1 Scope

Underground cables carry electricity across our network area from transmission supply points to customer premises, wherever that part of the network is below ground. This asset class also includes underground service lines and Underground to Overhead connections (UGOHs). For the RIN, this asset class is split into:

- Underground cables,
- Service lines, and
- Unmodelled – Other (pillars, pits, link boxes, UGOH's).

Similar to previous regulatory periods, transmission underground cables with voltages greater than 66 kV are considered separately due to insufficient comparison to other DNSPs making benchmarking using the repex model impractical. Given the significance and size of investment to replace these cables, as well as 33 kV and 66 kV cables, replacement is considered under the scope of a major project, rather than a replacement program and are only shown in this document for context. As such replacement of transmission cables is included in **Attachment 5.4.c Major Projects - Sub-transmission Cable Replacement**.

5.2 Age and Technology

Figure 39 shows the age profile and length of underground cables in this asset class (excluding service lines) by operating voltage. Figure 40 shows the age profile and count of underground service lines and underground equipment (e.g. pillars, pits, link boxes) in this asset class.

Figure 39. Age Profile for Underground Cables (excluding Service Lines and Equipment)

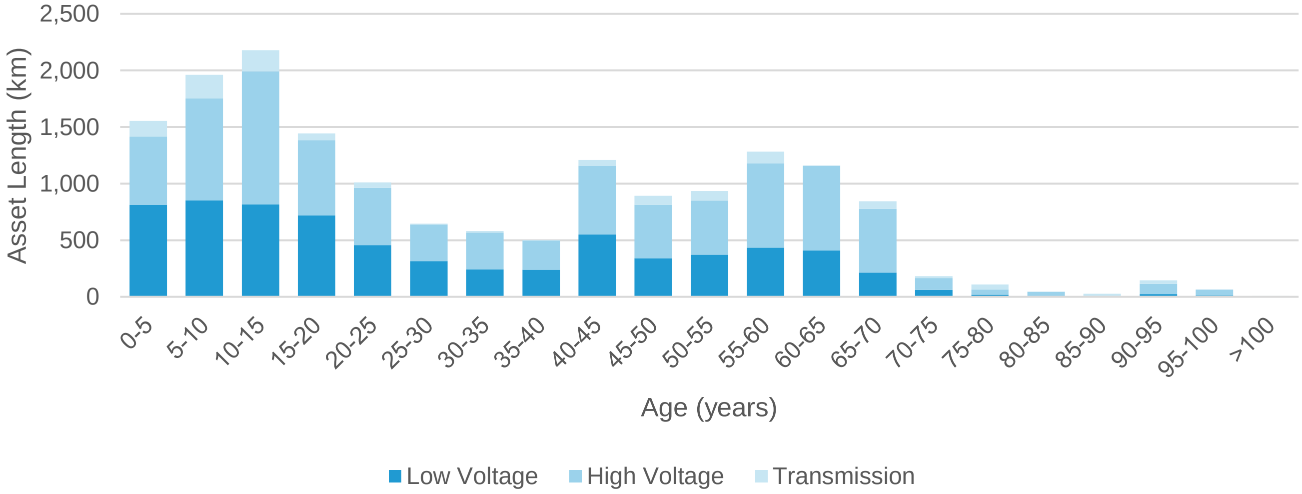
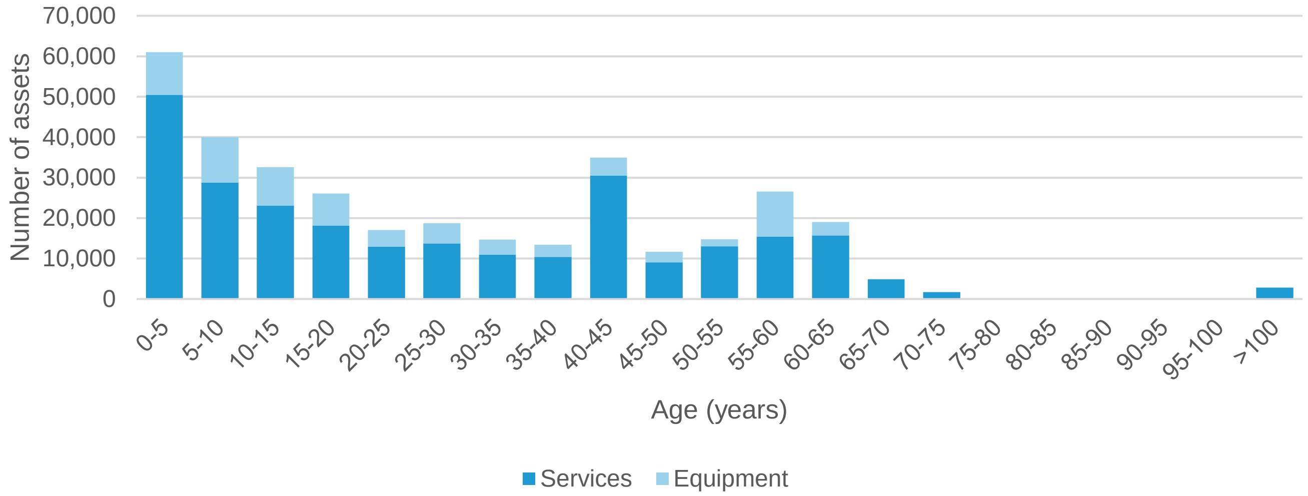


Figure 40. Age Profile for Underground Cables – Service Lines and Equipment



Underground cable technologies include paper-lead cables, oil or gas insulated cables and cables with modern insulation types (XLPE / EPR). The conductive cores within the cables are typically copper or aluminium. There is a large variety of accessories and equipment related to these cable configurations as well as a variety of cable laying methods.

Underground equipment includes pillars, pits and link boxes. Pillars and link boxes have been used for many decades to provide access to low voltage cable terminations and to house network switches or fuses. Older versions of pillars often had housings made from steel (as opposed to insulated plastic housings on modern pillars) and these pose safety risks to workers and the public due to degraded internal components. Link boxes and pits may pose safety risks to the public or workers due to overheating of connections or degradation of the pit or pit lids.

The average age of our underground cables (excluding service lines) is 32 years. The average age has increased from 31 years over the last five years. With a population of approximately 16,500km, and an average age at replacement of 95 years, we would need to replace 1.05% of our assets per year (176 km) to maintain the current average age.

The average age for underground service lines is 28 years, which is a small decrease from their average age five years ago (29 years). This decrease is partly due to service replacement undertaken in conjunction with low voltage cable replacement as well as resolving data quality issues.

The condition of underground cables and underground equipment cannot be cost effectively monitored. In weighing up the risks of asset failure, we have plans to gradually replace all assets with known design issues (low voltage CONSAC, HDPE and metallic sheath cables) that have resulted in higher failure rate and safety risk for these cable types compared to other cable types. Performance metrics for these and other cable types will continue to be monitored to determine future needs.

Underground cables and equipment can be replaced like for like (for example in an existing conduit) or may be upgraded with installation in new conduits where modern standards or physical locations require them.

5.3 Key Risks

Failures of underground cables and equipment pose loss of supply risks as well as safety risks to workers and the public.

5.3.1 Degrading risks

Underground cables degrade over time. This degradation reduces the insulation and mechanical protection of the assets, eventually leading to asset failure. Key causes of this degradation include:

Causes of asset degradation	Sheath corrosion; moisture ingress; and insulation breakdown

External factors can place additional stress on these assets which can accelerate their degradation. These escalation causes include:

Escalation causes	Electrical loading; thermal cycling; and coastal or wet environments;

These causes are used to determine the probability of asset failure. If an asset does fail, it may result in a hazardous event. The hazardous events associated with underground cables and underground equipment include:

Hazardous events	Loss of electrical continuity; fire starts; domestic shocks; contact with electrical equipment inadvertently energised; struck by expelled object; struck by falling objects; and leak, spill or discharge of a contaminating substance into the environment

5.3.2 Non-degrading risks

Underground cables and equipment with an obsolete design such as pits and cable trenches are considered non-degrading risks. The hazardous events associated with non-degrading risks include:

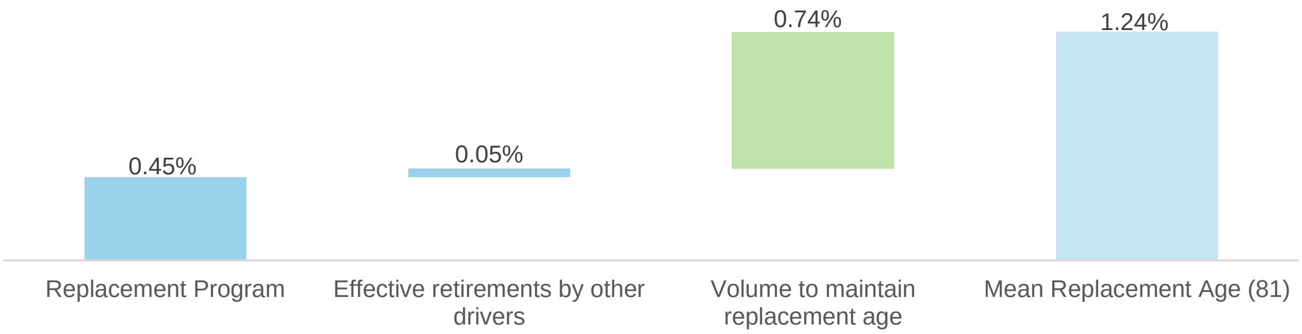
Hazardous events	Loss of electrical continuity; exposure to enclosed space / depletion of oxygen; entrapment or entanglement; exposure to hazardous chemicals and materials; unauthorised access to the network (physical); slip, trip or fall; and contact with underground assets (3rd party damage).

5.4 Forecasting replacement

5.4.1 Age-based assessment

Figure 41 shows that we have recently been replacing an average of 76 km per year of underground cables under our replacement programs. However effectively another 8 km are being retired or replaced as part of other works, such as customer or augmentation driven work (outside the scope of the replacement program). This value is calculated using a scaling multiplier based on age at replacement as described in Section 2.3.1.

Figure 41. Annual Population replaced by driver for Underground Cables (excluding Services Lines & Equipment)



5.4.2 Replace on failure

Under this option there is no consideration for planned replacement or refurbishment and the assets are either repaired (opex) or replaced on failure (reactive). Under a base case scenario, with no replacement investment, the asset failure rate is expected to grow with time. The total number of failures predicted between 2024-29 is shown in Figure 42.

Figure 42. Base case failures for Underground Cables (2024 – 29)

Sub-class	Forecast Average Annual Failures	Annual % of population
Low Voltage (km)	855	1 per 9km
High Voltage (km)	238	1 per 36km
Transmission (km)	Captured under Major Projects	
Equipment	308	0.4%
UGOHs	371	0.5%
Service Lines	105	0.1%

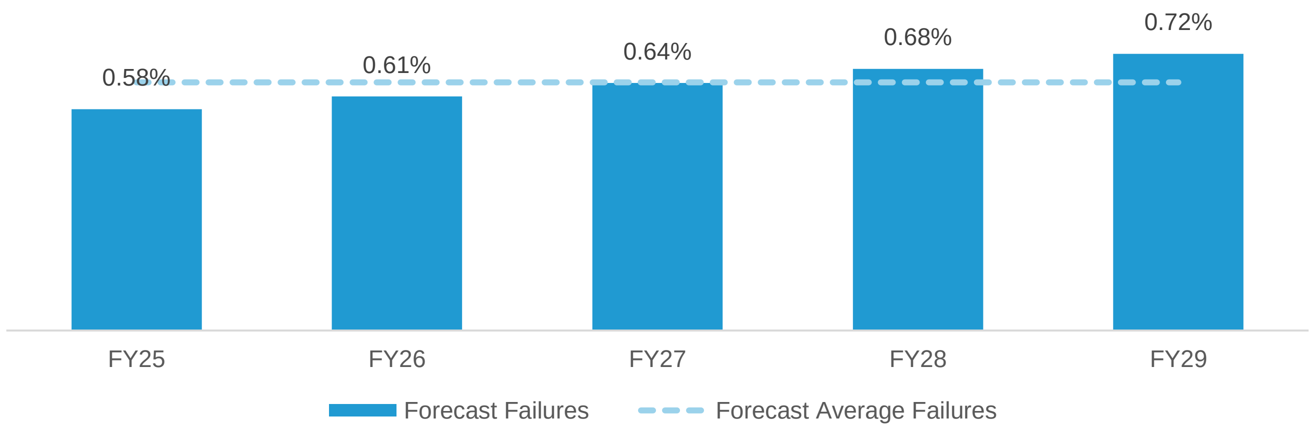
A reactive replacement approach is only accommodated in the forecast when historical reactive replacements are greater than cost benefit positive forecast planned or condition-based replacements. For the UGOH sub-class, the failures above those supported by planned or condition-based replacement will be managed through repairs. This high repair rate of 80% is forecast to continue in the 2024-29 regulatory period. Therefore, under this scenario, only 20% (74) of UGOHs would be replaced annually following failure.

Although the age profile shows approximately 2% of assets above the 81-year mean replacement age, at the expected rate of reactive replacement, as determined by the forecast failures above, the average age of underground cable will continue to increase. The volume of predicted failures over the period has also been applied to determine the probability of failure used in our CBA.

Underground cable and equipment failures are often initially repaired to enable them to be returned to service. Where new cable is required to be pieced in as part of a repair, this generally means two additional joints are required in the existing cable. Joints often form weak points on the cable and therefore it is expected that cable deterioration and the probability of failure will accelerate with more cable joint. Further analysis of this linkage will be undertaken in the future.

Transmission cables and some underground equipment (pits and pillars) are managed through routine inspections that allow for timely treatment of defects. Other cables and service lines are managed when defects are identified or when failures occur. Figure 43 shows the projected failures and average over the 2024-29 regulatory period. The volume of predicted failures over the period has also been applied to determine the probability of failure used in our CBA.

Figure 43. Forecast inherent failures as proportion of population for Underground Cables



This results in a total effective annual volume of 0.5% of the underground cables population (84 km) replaced each year. With this replacement rate it would take 200 years to replace the entire underground cable population. Given our recent historical replacement rates are lower than the volume required to maintain the average age of the asset class, this top-down metric suggests that the level of investment is not sustainable in the long term.

5.4.3 Economic value through CBA

An economic evaluation has been undertaken on this asset class utilising CBA. Where the economic value of the forecast carried risk exceeds the cost to replace, planned replacement is supported. Figure 44 shows the volume of underground cable assets and Figure 45 shows the volume of underground service lines and underground equipment assets within each economic value index at FY29.

Figure 44. Economic value index for Underground Cables (excluding Service Lines & Equipment)

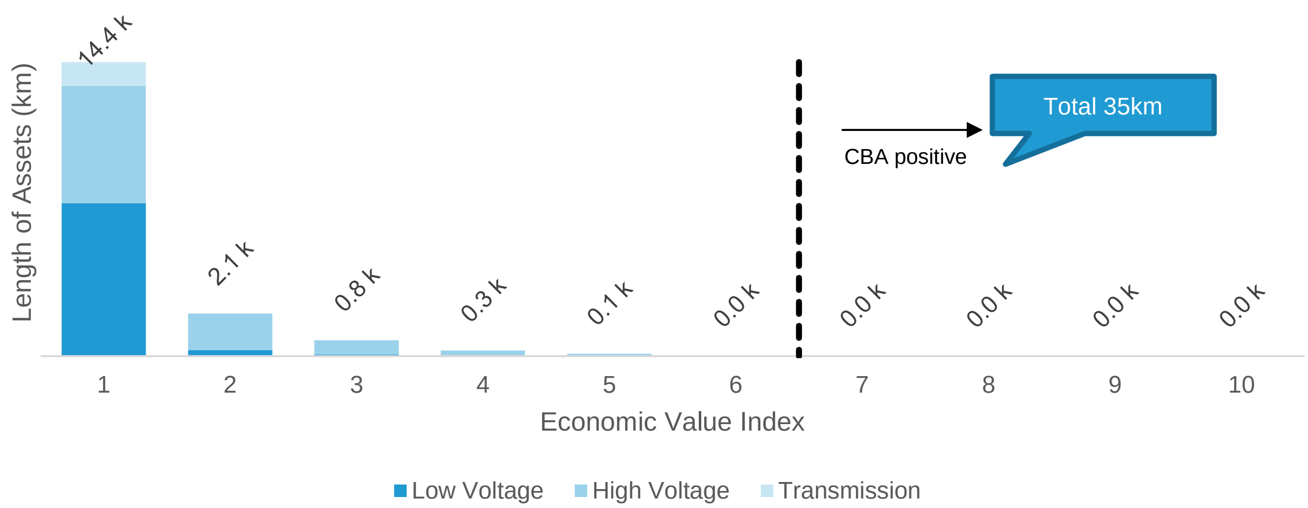
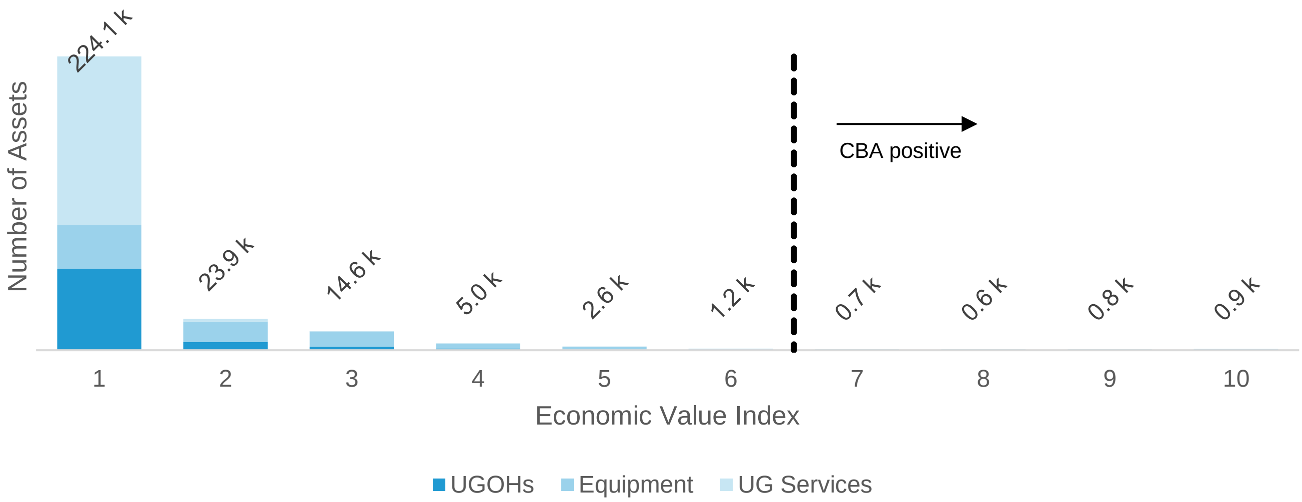


Figure 45. Economic value index for Underground Cables – Service Lines & Underground Equipment



The assets at or above an economic value index of 7 are expected to be cost benefit positive before the end of FY29. Given the number of cost benefit positive assets does not exceed modelled predicted failures, the supported replacement investment for the 2024-29 regulatory period reflects the figures above plus an additional volume for reactive replacement. Overall, approximately $303 million (real $, FY24) of replacement investment is supported during the 2024 – 29 Regulatory Period. This includes $207 million of reactive replacement. A breakdown of the planned replacement volume is detailed in Figure 46. Given most investment supported is reactive (replace on failure), these values are significantly smaller than the overall replacement volume.

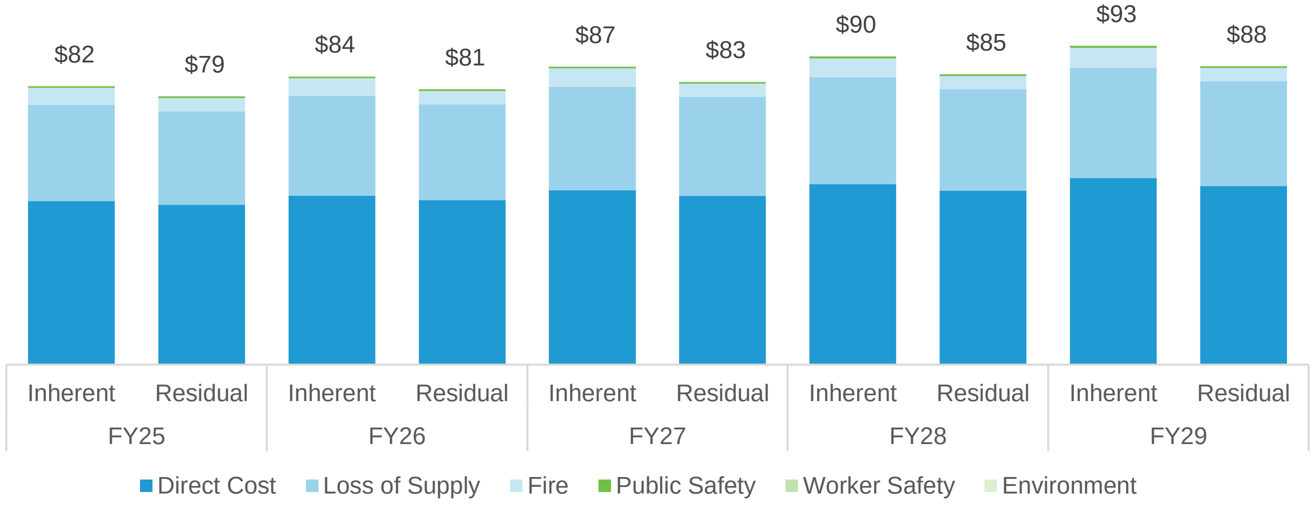
Figure 46. CBA supported replacement volume by subclass for 2024 – 29 Underground Cables

Asset Subclass	Supported total replacement volume	Annual % of Population
Low Voltage (km)	19	< 0.1%
High Voltage (km)	16	< 0.1%
Transmission (km)	Captured under Major Projects	
Equipment	2,389	0.7%
UGOHs	577	0.2%
Service Lines	-	n/a

5.4.4 Maintain risk

Figure 47 shows the annual risk carried for this asset class before investment (inherent) and after CBA forecast investment (residual), based on replacing assets that are cost benefit positive. This analysis is based on a population and failure rate using FY22 as the base year and assumes a smooth investment for FY23-FY24. Given the average age of this asset class will continue to increase and the majority of investment is reactive, the residual risk is expected to increase. Figure 10 highlights an increase of $50m in replacement expenditure per year to maintain risk for this asset class.

Figure 47.   Inherent and Residual Risk by Financial Year for Underground Cables (real $m, FY24)



5.5 Options

5.5.1 Reactive Replacement

Under this option there is no consideration for planned or condition-based replacement or refurbishment. Following failure assets are either repaired or replaced in-line with the predicted volume under the base case scenario. This option is only selected where the benefits of replacement do not outweigh the costs.

It is difficult to predict failures of underground cables without a significant increase in opex to undertake testing. Therefore, unless there are known condition issues with a sub-set of cable types, these assets are replaced following a failure.

5.5.2 Replace on condition

We undertake condition assessments of oil and gas underground transmission cables to determine the appropriate option when condition issues are identified. Pillars also are assessed with visual and thermal inspections to determine their condition. Condition monitoring on other underground cables and equipment is not cost effective. Therefore, only cables and equipment with known failures modes or safety risks are targeted for planned replacement. All other cables are replaced on failure.

Figure 48 outlines some key replacement strategies. These strategies are considered based on failure history and construction type.

Figure 48.   Replacement strategies for Underground Cables

Sub-class	Strategy
Low Voltage Cables	There are three types of LV cables that have been targeted for planned replacement due to their construction type, failure rates and inherent risks. These are HDPE, CONSAC and LV metallic sheathed cables. All other underground low voltage cables are managed reactively following failures.
High Voltage Cables	High voltage underground cables are only managed through reactive replacement following a failure.
Transmission Cables	Transmission underground cables are replaced as part of area plan works or reactively following a failure (refer to **Attachment 5.4.c**).

Sub-class	Strategy
Equipment	Pillars, pits and link boxes are used to provide access to, and house, low voltage cables, terminations, network switches and service cable connections for customers or fuses. They are in public areas. Older versions of pillars often had steel housings and pose public safety risks due to degraded internal components energising the steel cover. Some sub-populations of steel housing pillars have been identified as requiring planned replacement due to these safety risks. The replacement decisions for underground equipment are primarily based on condition from inspections (poor thermal testing, degraded pit lids) or in-service failures.
UGOHs (Underground-to-Overhead transitions)	UGOHs are used for the transition from an underground cable to overhead conductors. They are mounted on poles in public areas. Older terminations were made of metal or aluminium and have porcelain insulators and porcelain surge arrestors which pose public safety risks due to degraded components causing explosive failure. These older style UGOHs are targeted for planned replacement due to these public safety risks.
Service lines	Service lines are managed through reactive replacement following a failure. Underground service lines are also tested when low voltage distributors are replaced. If these service lines do not pass the requisite tests, they are replaced.

5.5.3 Options not considered feasible

Figure 49 shows the options that were considered and assessed as not feasible.

Figure 49. Options not considered feasible for Underground Cables

Option	Rationale
Increased maintenance & inspections	The condition issues have already been identified and cannot be rectified through increased maintenance or inspections, and therefore this option is not a technically feasible solution to address the need.
Repair or refurbish	Where cost effective, repair or refurbishments are completed however, they are considered an operational expense.
Non-network solutions	Non-network solutions provide suitable risk mitigation in limited scenarios (e.g. micro-grids or stand-alone power systems) however, are rarely practical or justifiable on the condition of underground cables alone.

5.6 Proposed Management Strategy

The forecasting methods above support an increase in replacement expenditure in underground cables for the 2024-29 regulatory period relative to historical expenditure. However, without improved condition monitoring, targeted planned replacement options are limited.

Due to the known condition issues associated with some types of low voltage underground cables, we are proposing to continue planned replacement for these population subsets. The remainder of underground cables on the low and high voltage network are replaced reactively following a failure. As a result, we are proposing a forecast with a small reduction relative to all forecasting methods.

Given the population of assets above 55 years of age, we will continue to monitor trends failures (lagging indicator) and review proposed replacement volumes for future regulatory periods. We will also investigate online condition monitoring options within our innovation program to improve the effectiveness of condition assessment.

5.7 Investment Forecast

Utilising the proposed management strategy above, Figure 50 shows the forecast replacement volumes for the different asset sub classes of underground cables which is proposed for the 2024-29 regulatory period.

Figure 50. Underground Cables 2024-29 forecast volume

	Low Voltage	High Voltage	Transmission	Equipment	UGOHs	Service Lines
Volume	118km	41km	0km	6,450	125	215
Population annual %	0.3 %	<0.1%	n/a	1.7%	<0.1%	<0.1%

The replacement expenditure forecast shown in Figure 51 is proposed for the 2024-29 regulatory period.

Figure 51. Underground Mains forecast repex (real $m, FY24)

	FY25	FY26	FY27	FY28	FY29	TOTAL
Low Voltage (km)	$38	$38	$38	$38	$36	**$188**
High Voltage (km)	$14	$14	$14	$14	$14	**$70**
Transmission (km)	$3	$3	$3	$3	$3	**$14**
Equipment	$2	$2	$2	$2	$2	**$11**
UGOHs	$0.6	$0.6	$0.6	$0.6	$0.6	**$3**
Service Lines	$0.2	$0.2	$0.2	$0.2	$0.2	**$1**
TOTAL	**$58**	**$58**	**$58**	**$57**	**$56**	**$286**

6. Transformers & Reactive Plant

6.1 Scope

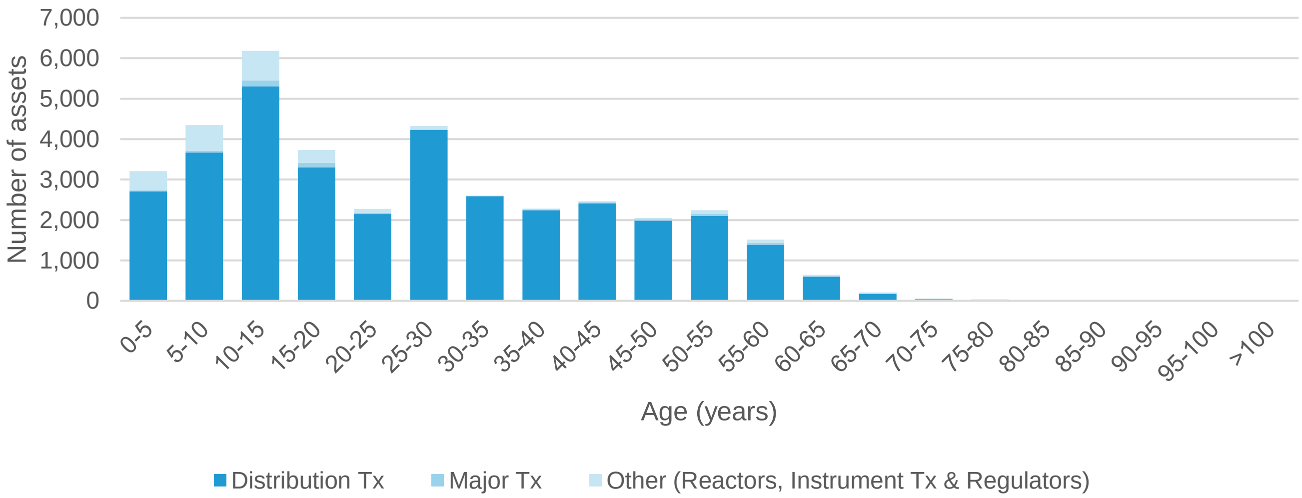
Transformers and reactive plant form an integral part of the equipment in sub-transmission, zone and distribution substations. They transform electricity from higher to lower voltages allowing the voltage supplied to customers to be within an allowable range whilst enabling efficient transmission of electricity across our network. This asset class includes major (transmission) power transformers, distribution power transformers, reactors, instrument transformers, regulators, and neutral earthing resistors. For the RIN, this asset class is split into:

- Transformers, and
- Unmodelled – Other (Instrument Transformers, Regulators, Neutral Earthing Resistors & 132/66kV Bushings).

6.2 Age and Technology

Figure 52 shows the age profile and technology composition of assets in this asset class.

Figure 52. Age Profile for Transformers



The average age of assets within the modelled portion of this asset class is 26 years. The average age has increased from 25 years over the last five years. Power transformers represent the largest portion of this asset class, both in population and expenditure, and the majority of the replacements fall into this sub-category. With a population of over 35,000 power transformers and a mean age at replacement of 46 years, we would need to replace 2.17% of our assets per year (770 transformers) to maintain the current average age.

The core technology associated with transformers remains the same. There have been some improvements in design such as the installation of resin bushings which provide improved safety outcomes over existing oil filled porcelain bushings and externally mounted tap-changers on major transformers, making them easier to maintain.

The analysis we have undertaken for the 'major transformer' asset sub-class includes power transformers, reactors and their associated bushings.

6.3 Key Risks

Transformer failures pose loss of supply risks as well as environmental and fire start risks.

6.3.1 Degrading risks

Transformers and reactive plant, including their associated equipment (such as tap changers), degrade over time and with use. This degradation reduces the electrical and mechanical integrity of the assets, eventually leading to asset failure. Key causes of this degradation include:

Causes of asset degradation	Environmental exposure; design decisions; material selection and asset operations (usage)

External factors can place additional stress on these assets which can accelerate their degradation. These escalation causes include:

Escalation causes	Severe weather / lightning; animal or vegetation contact; contamination; and high pollution areas

These causes are used to determine the probability of asset failure. If an asset does fail, it may result in a hazardous event. The hazardous events associated with transformers or reactive plant include:

Hazardous events	Loss of electrical continuity; fire starts; exposure to arc flash; contact with electrical equipment inadvertently energised; leak, spill or discharge of a contaminating substance into the environment; struck by falling object; exposure to excessive asset noise; and damage to property

6.3.2 Non-degrading risks

The presence of hazardous chemicals such as asbestos and mercury are also issues faced with obsolete designs of transformers & reactive plant. The hazardous events associated with non-degrading risks include:

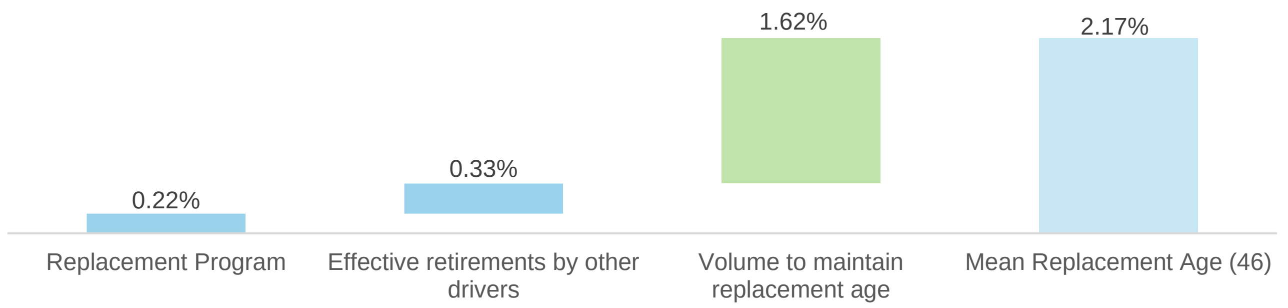
Hazardous events	Exposure to hazardous atmosphere; exposure to hazardous chemicals and materials

6.4 Forecasting replacement

6.4.1 Age-based assessment

Figure 53 shows that we have recently been replacing an average of 78 power transformer assets per year under the replacement program. However, an average of 119 power transformer assets per year are being retired or replaced in conjunction with other works such as augmentation or customer driven work (outside the scope of the replacement program). This value is calculated using a scaling multiplier based on age at replacement as described in Section 2.3.1.

Figure 53. Annual Population replaced by driver for Transformers (Power Transformers only)



This results in a total effective volume of 0.55% of the transformer population (197) replaced each year. With this replacement rate it would take 180 years to replace the entire transformer population. Given our recent historical replacement rates are lower than the volume required to maintain the average age of the asset class, this top-down metric suggests that the level of investment is not sustainable in the long term. Adopting this approach would result in a significant step change in transformer replacements and therefore a significant cost increase. Replacing assets within this asset class based on age would lead to a significant step change in expenditure, not justified by recent asset performance.

6.4.2 Replace on failure

Under a base case scenario, with no replacement investment, the asset failure rate is expected to grow with time. The total number of failures predicted between 2024-29 is shown in Figure 54.

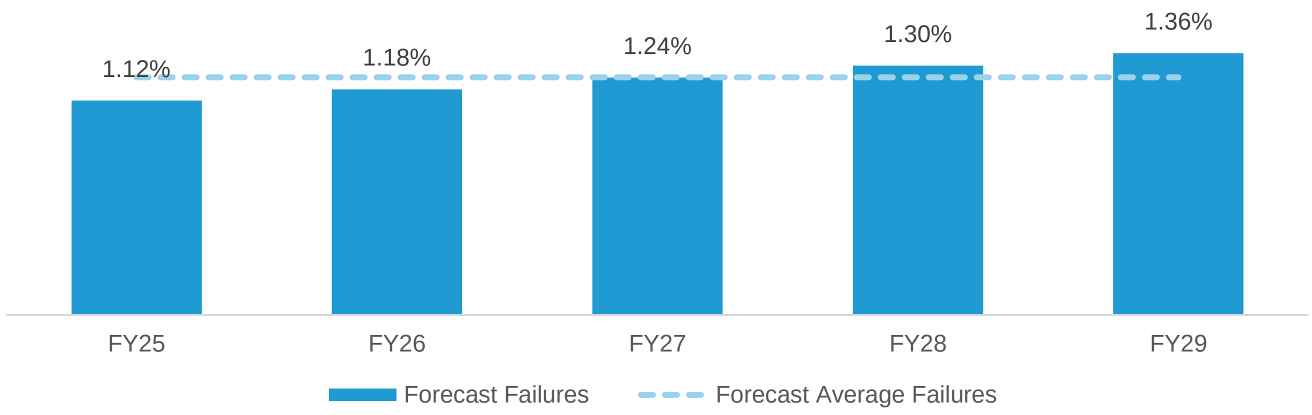
Figure 54. Base case failures for Transformers & Reactive Plant (2024 – 29)

Sub-class	Forecast Average Annual Failures	Annual % of population
Major Power Transformers, Resistors & Reactors	47	7.7%
Distribution Power Transformers	323	0.9%
Instrument Transformers	20	1.4%

The high failure rate is due to a high number of historical defects resulting in repairs. A reactive replacement approach is only adopted when historical reactive replacements are greater than forecast planned or condition-based replacements. For this asset class the failures above those supported by planned or condition-based replacement will be managed through repairs as reflected by history and due to the higher cost to replace. This repair rate of 32% for instrument transformers and 99% major power transformers, resistors and reactors is forecast to continue in the 2024 -29 regulatory period.

The age profile shows approximately 18% of assets above the 46-year mean replacement age. At this failure rate, the average age will continue to increase. Figure 55 shows the projected failures and average over the 2024-29 regulatory period. The volume of predicted failures over the period has also been applied to determine the probability of failure used in our CBA.

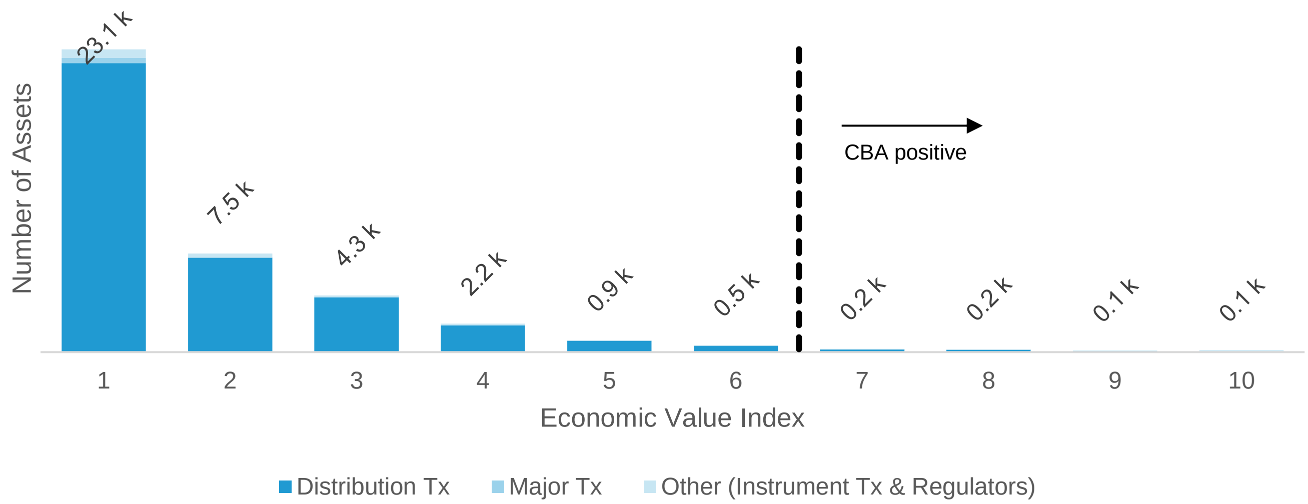
Figure 55. Forecast inherent failures as proportion of population for Transformers & Reactive Plant



6.4.3 Economic value through CBA

An economic evaluation has been undertaken on this asset class utilising CBA. Where the economic value of the risk carried exceeds the cost to replace, the asset is considered suitable for replacement. Figure 56 shows the volume of transformer and reactive plant assets within each economic value index at FY29.

Figure 56. Economic value index for Transformers and Reactive Plant



The assets at or above an economic value index of 7 are expected to be cost benefit positive before the end of FY29. Given the number of cost benefit positive assets exceeds the modelled predicted failures, the supported replacement investment for the 2024-29 regulatory period reflects the figures above, which translates to an investment of $84m (real $, FY24) over the five years. A breakdown of the forecast replacement volume is detailed in Figure 57.

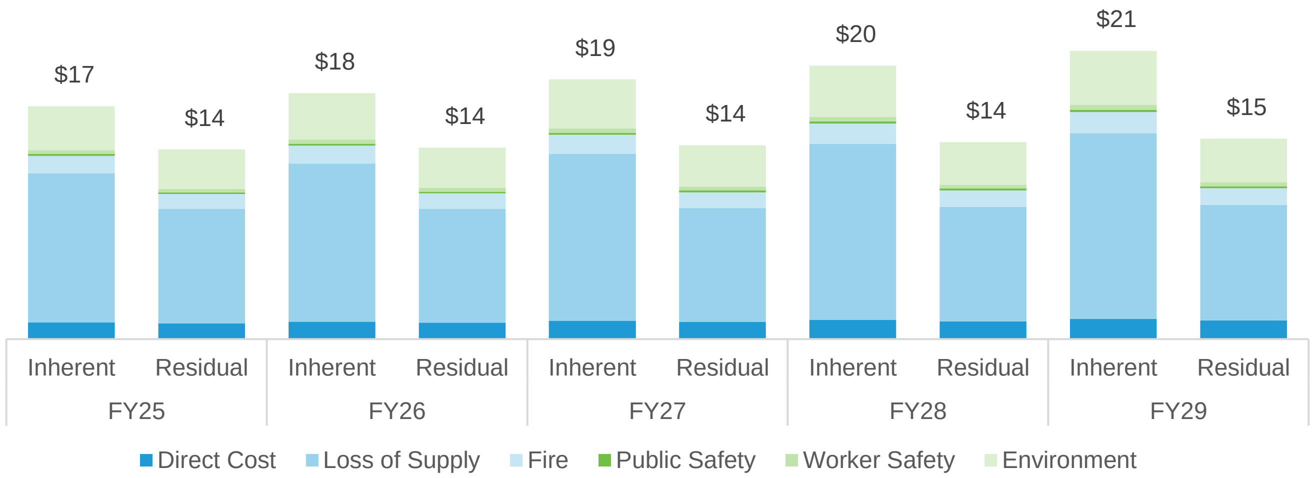
Figure 57. CBA supported replacement volume by subclass for 2024 – 29 Transformers and Reactive Plant

Asset Subclass	Supported total replacement volume	Annual % of Population
Transmission Power Transformers, Resistors & Reactors	40	1.3%
Distribution Power Transformers	496	0.3%
Instrument Transformers	170	2.4%

6.4.4 Maintain risk

Figure 58 shows the annual risk carried for this asset class before investment (inherent) and after CBA forecast investment (residual), based on replacing assets that are cost benefit positive. This analysis is based on a population and failure rate using FY22 as the base year and assumes a smooth investment for FY23-FY24. Given the average age of this asset class will continue to increase through the regulatory period, the residual risk is also expected to increase. Figure 10 highlights an increase of $8m in replacement expenditure per year to maintain risk for this asset class. This will likely be partially mitigated by other investments across our capital portfolio including major projects.

Figure 58. Inherent and Residual Risk by Financial Year for Transformers & Reactive Plant (real $m, FY24)



6.5 Options

6.5.1 Reactive replacement

Under this option there is no consideration for planned or condition-based replacement or refurbishment. Following failure assets are either repaired or replaced in-line with the predicted volume under the base case scenario. This option is only selected where the benefits of replacement do not outweigh the costs.

6.5.2 Replace/Refurbish on condition

Figure 59 outlines the replacement strategies for each asset sub-class. These strategies are considered condition-based which is informed through regular maintenance. This maintenance includes visual inspections, mechanical servicing and insulation integrity testing. These measurements are used to perform engineering assessments based on degradation assumptions. Given the historical performance within the asset class and the high effectiveness of existing maintenance activities, it is proposed that the existing condition-based approach to managing these assets be adopted.

Figure 59. Asset sub-class replacement strategies for Transformers and Reactive Plant

Sub-class	Strategy
Major Power Transformers, Resistors and Reactors	Refurbishment is considered for major transformers due to their high economic value. There is a planned program of bushing replacement for major transformers which is used to manage the risks associated with oil-impregnated bushings. Transformers are assessed for refurbishment when condition issues are identified. Refurbishment works include replacing gaskets to address significant leaks or re-painting a transformer to address significant rust and are only undertaken where it is cost effective to do. The replacement decisions for major power transformers and reactors are based on condition (such as excessive leaking and poor insulation testing) or from in-service failures. At the point of major transformer replacement, the ongoing need for these assets is assessed before replacement is progressed and retirement is considered. The planned replacement of the small number of Neutral Earthing Resistors is due to their poor condition and network limitations on maintenance.
Distribution Power Transformers	Replacement decisions for distribution power transformers are predominantly based on in-service failures however replacement decisions may also be based on the transformer failing maintenance serviceability criteria. Certain specialised distribution transformers in the Sydney CBD form part of a planned replacement program due to inherent issues with their design, known condition issues and access restrictions. Replacing these generally requires road closures within the CBD as they are located under the roadway.
Instrument Transformers	The replacement decisions for instrument transformers is based on condition (poor insulation testing results) or in-service failures.

6.5.3 Options not considered feasible

Figure 60 shows the options that were considered and assessed as not feasible.

Figure 60. Options not considered feasible for Transformers and Reactive Plant

Option	Rationale
Increased maintenance & inspections	Transformer condition issues cannot be rectified through increased maintenance or inspections, and therefore it is not a technically feasible solution to address the need.
Non-network solutions	Non-network solutions for transformers or reactive plant would include distributed energy resources, community batteries and small-scale generation. These solutions are currently not cost effective and practicable, however, may be in the future

6.6 Proposed Management Strategy

The forecasting methods above support a stable investment in transformers and reactive plant for the 2024-29 regulatory period. As a result, we are proposing a forecast between the historical expenditure and the CBA results.

6.7 Investment Forecast

Utilising the proposed management strategy above, Figure 61 shows the forecast replacement volumes for the different asset sub classes of transformers and reactive plant which is proposed for the 2024-29 regulatory period.

Figure 61. Transformers & Reactive Plant 2024-29 forecast volume

	Transmission Power Transformers, Resistors & Reactors	Distribution Power Transformers	Instrument Transformers
Volume	46	80	45
Population annual %	1.6%	<0.1%	0.7%

The replacement expenditure forecast shown in Figure 62 is proposed for the 2024-29 regulatory period.

Figure 62. Transformers and reactive plant forecast repex (real $m, FY24)

	FY25	FY26	FY27	FY28	FY29	TOTAL
Transmission Power Transformers, Resistors & Reactors	$12	$12	$10	$10	$10	**$54**
Distribution Power Transformers	$8	$8	$8	$8	$8	**$40**
Instrument Transformers	$1	$1	$1	$1	$1	**$5**
TOTAL	**$21**	**$21**	**$19**	**$19**	**$19**	**$99**

7. Switchgear

7.1 Scope

When used in conjunction with protection systems, switchgear allows for the automatic protection of the power system and provides fast and efficient fault clearing. Switchgear also provides switching capability for power flow management and isolation points for maintenance, repairs, network augmentation or during supply restoration. Switchgear helps to maintain the reliability and security of the network. This asset class includes circuit breakers (**CB**), switches and fuses. For the RIN, this asset class is split into:

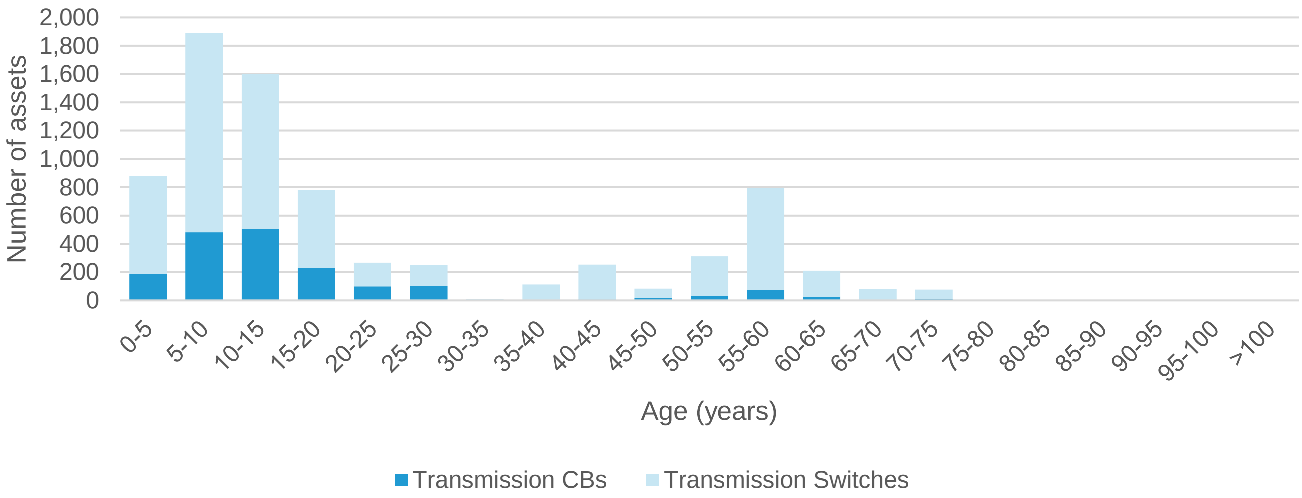
- Switchgear; and
- Unmodelled – Other (circuit breaker refurbishments).

Replacement of entire switchboards is considered in **Attachment 5.4.b Major Projects - 11kV Switchgear Replacement** and **Attachment 5.4.d Major Projects – Other Replacement**.

7.2 Age and Technology

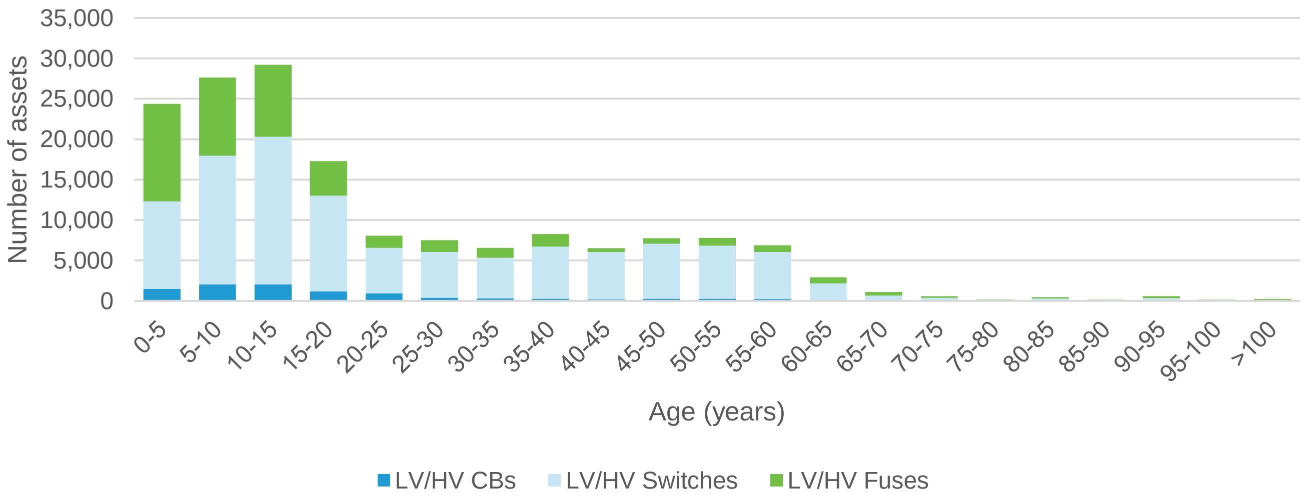
The age profile and technology composition of transmission assets in this asset class is shown in Figure 63.

Figure 63. Age profile for transmission switchgear



The age profile and technology composition of HV/LV assets in this asset class is show in Figure 64.

Figure 64. Age profile for HV/LV switchgear



The average age of assets within the modelled portion of this asset class is 25 years. The average age has increased from 24 years over the last five years. With a population of over 125,000 assets and a mean replacement age of 46 years, we would need to replace 2.17% of our assets per year (2,743 assets) to maintain the current average age. Fuses have been removed from this calculation as the recent history associated with these assets includes a significant program of replacement of younger technology with known design issues.

The switchgear that we are currently installing is technically advanced compared to the assets they are replacing. The technical advances for the different switchgear types include:

- the use of sulphur hexafluoride (SF6) gas, vacuum or air for arc control when the switchgear operates (compared to oil as previously used),
- the use of SF6, air or polymeric materials for electrical insulation (compared to oil or bitumen compounds as previously used),
- 'arc rated' cladding, 'load break heads' and enclosed switches to protect workers and the public against uncontrolled arcing during switching and fire starts, and
- capability for remote operation (when combined with appropriate Communications, Control & Protection assets).

7.3 Key Risks

Failures of switchgear pose loss of supply risks as well as safety risks to workers and the public.

7.3.1 Degrading risks

Switchgear degrades over time and with use. This degradation reduces the mechanical strength of the assets and its insulation integrity, eventually leading to asset failure. Key causes of this degradation include:

Causes of asset degradation	Environmental exposure; design decisions; material selection and asset operations (usage)

External factors can place additional stress on these assets which can accelerate their degradation. These escalation causes include:

Escalation causes	Severe weather / lightning; animal or vegetation contact; contamination; and high pollution areas

These causes are used to determine the probability of asset failure. If an asset does fail, it may result in a hazardous event. The hazardous events associated with switchgear include:

Hazardous events	Loss of electrical continuity; fire starts; exposure to arc flash; contact with electrical equipment inadvertently energised; struck by falling object and make contact with third party assets

7.3.2 Non-degrading risks

Globally there is increased pressure to remove assets containing SF6 due to the environmental impact of this form of insulation. The presence of hazardous chemicals such as asbestos and lead are also issues faced with obsolete designs of switchgear. The hazardous events associated with non-degrading risks include:

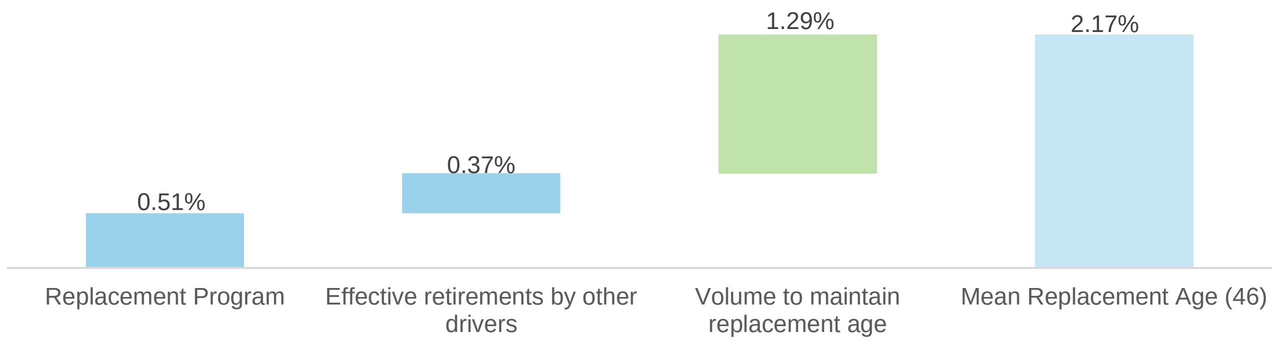
Hazardous events	Exposure to hazardous atmosphere; exposure to hazardous chemicals and materials

7.4 Forecasting replacement

7.4.1 Age-based assessment

Figure 65 shows that we have recently been replacing an average of 642 switchgear assets per year under our replacement programs. However, an average of 471 other switchgear assets per year are being retired or replaced as part of other works, such as augmentation or customer driven work (outside the scope of the replacement program). This value is calculated using a scaling multiplier based on age at replacement as described in Section 2.3.1.

Figure 65. Annual Population replaced by driver for Switchgear (excluding Fuses)



This results in a total effective annual replacement volume of 0.88% of the switchgear population (1,113 switches) replaced each year. With this replacement rate it would take 113 years to replace the entire switchgear population. Given our recent historical replacement rates are lower than the volume required to maintain the average age of the asset class, this top-down metric suggests that the level of investment is not considered to be sustainable in the long term. Adopting an age-based approach would result in a significant step change in cost not currently justified through asset performance.

7.4.2 Replace on failure

Under this option there is no consideration for planned replacement or refurbishment and the assets are either repaired (opex) or replaced on failure (reactive). With no replacement investment, the asset failure rate is expected to grow with time. The total number of failures predicted between 2024 – 29 is shown in Figure 66 below.

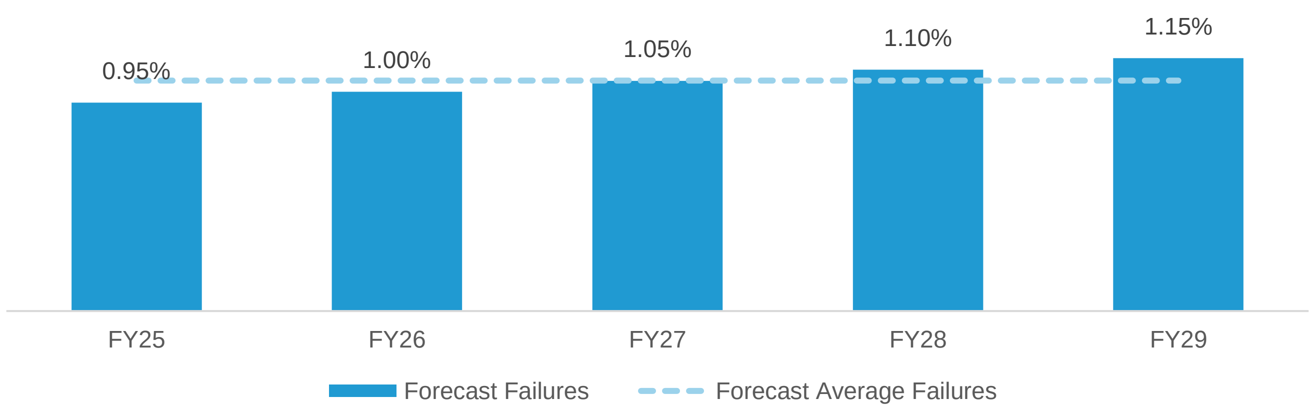
Figure 66. Base case failures for Switchgear (2024 – 29)

Sub-class	Forecast Average Annual Failures	Annual % of population
LV/HV Switches/Fuses	2,300	0.7%
LV/HV CBs	571	5.7%
Transmission CBs	31	1.7%
Transmission Switches	134	2.3%

The high failure rate for LV/HV CBs is due to a high number of historical defects resulting in repairs. This high repair rate of 93% is forecast to continue in the 2024-29 regulatory period. Therefore, under this scenario, only 7% (40) LV/HV CBs would be replaced annually following failure.

Although the age profile shows approximately 17% of assets already above the 46-year mean replacement age, from statistical modelling, the forecast average annual failures remain low. Figure 67 shows the projected failures and average over the 2024-29 regulatory period. At this failure rate, the average age will continue to increase. The volume of predicted failures over the period has also been applied to determine the probability of failure used in our CBA.

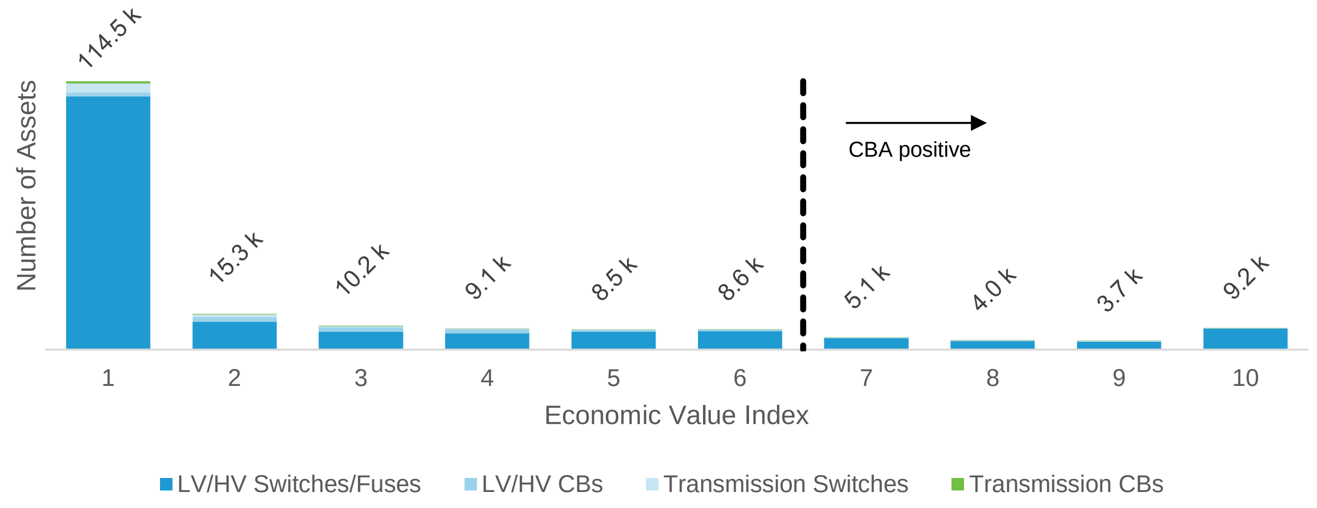
Figure 67. Forecast inherent failures as proportion of population for Switchgear



7.4.3 Economic value through CBA

An economic evaluation has been undertaken on this asset class utilising CBA. Where the economic value of the risk carried exceeds the cost to replace, the asset is considered suitable for replacement. Figure 68 shows the volume of switchgear assets within each economic value index at FY29.

Figure 68. Economic value index for Switchgear



The assets at or above an economic value index of 7 are expected to be cost benefit positive before the end of FY29. Given the number of cost benefit positive assets does not exceed modelled predicted failures, the supported replacement investment for the 2024-29 regulatory period reflects the figures above plus an additional volume for predicted reactive replacement.

Overall, approximately $154m (real $, FY24) of replacement investment is supported during the 2024-29 regulatory period. This includes $11m of reactive replacement. A breakdown of the replacement volume is detailed in Figure 69.

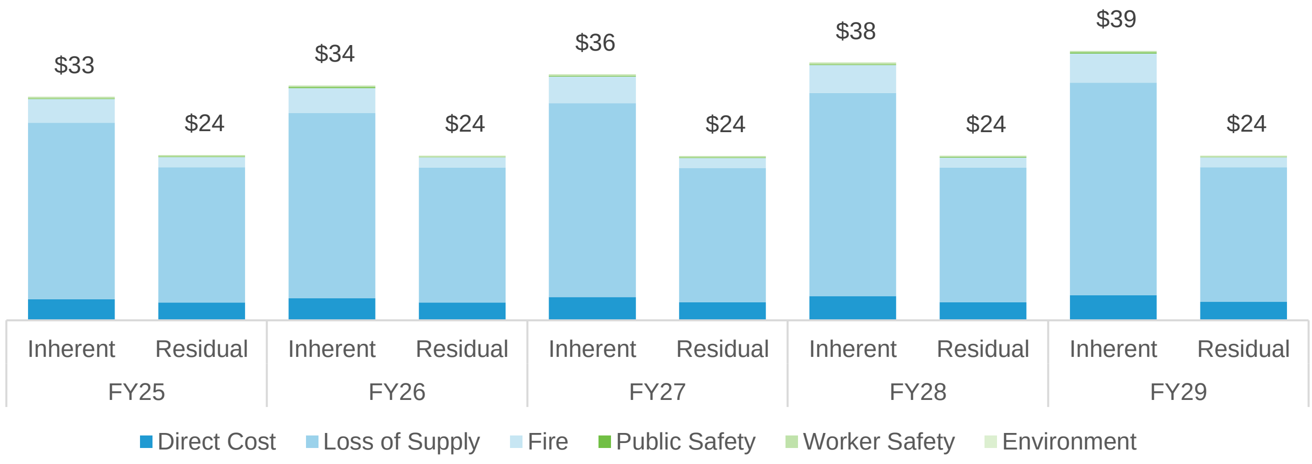
Figure 69. CBA supported replacement volume by subclass for 2024 - 29 Switchgear

Asset Subclass	Supported total replacement volume	Annual % of Population
LV/HV Switches/Fuses	20,795	2.4%
LV/HV CBs	1,093	2.2%
Transmission Switches	73	0.2%
Transmission CBs	58	0.7%

7.4.4 Maintain risk

Figure 70 shows the annual risk carried for this asset class before investment (inherent) and after CBA forecast investment (residual), based on replacing assets that are cost benefit positive. This analysis is based on a population and failure rate using FY22 as the base year and assumes a smooth investment for FY23-FY24. Using this CBA scenario results in a steady residual risk (marginally increasing) over the 2024-29 regulatory period. Figure 10 highlights an increase of $3m in replacement expenditure per year to maintain risk for this asset class. This will likely be partially mitigated by other investments across our capital portfolio including major projects.

Figure 70. Inherent and Residual Risk by Financial Year for Switchgear (real $m, FY24)



7.5 Options

7.5.1 Reactive replacement

Under this option there is no consideration for planned or condition-based replacement or refurbishment. Following failure assets are either repaired or replaced in-line with the predicted volume under the base case scenario. This option is only selected where the benefits of replacement do not outweigh the costs

7.5.2 Replace on condition

Figure 71 outlines the replacement strategies for each asset sub-class. These strategies are considered condition-based which is informed through regular maintenance. This maintenance includes visual inspections, mechanical servicing and insulation integrity testing. These measurements are used to perform engineering assessments based on degradation assumptions. Assets that fail test or asset types with known condition issues are replaced.

Figure 71. Asset sub-class replacement strategies for Switchgear

Sub-class	Strategy
LV/HV Switches	The planned program to replace low voltage and high voltage switches is based on known condition issues with oil filled switch types. Other switches including air and gas insulated are replaced based on maintenance test results (condition-based). HV air break switches are replaced under a planned program targeting known design and condition issues. LV overhead switches are replaced reactively following a failure.
LV/HV Fuses	The planned replacement of a small portion of remaining poor condition fuses is continuing into the 2024-29 regulatory period which will complete this program of works. Small volumes of replacement will continue reactively or as part of larger assets (e.g. kiosk replacement – refer to Section 10).
LV/HV CBs	For the majority of low voltage and high voltage circuit breaker replacement decisions are based on condition (operation or insulation testing) or in-service failures. High voltage bulk oil circuit breakers in distribution substations form part of a planned replacement program to remove bulk oil circuit breakers due to their design and known condition issues. Other circuit breakers are replaced based on maintenance test results (condition-based). Switchboards and associated high voltage circuit breakers in zone substations are replaced as part of major projects (refer to **Attachment 5.4.b**).

Sub-class	Strategy
Transmission Switches	Due to a number of significant failures, there is a planned replacement program for older construction type 33kV Isolation and Earth switches as they pose safety risks to workers during operation.
Transmission CBs	For the majority of transmission circuit breakers replacement decisions are based on condition (operation or insulation testing) or in-service failures. A small portion of remaining transmission bulk oil circuit breakers form part of a planned replacement program or as part of major projects (refer to **Attachment 5.4.d**).

7.5.3 Options not considered feasible

Figure 72 shows the options that were considered and assessed as not feasible.

Figure 72. Options not considered feasible for Switchgear

Option	Rationale
Increased maintenance & inspections	The condition issues cannot be rectified through increased maintenance or inspections, and therefore this option is not a technically feasible solution to address the need.
Refurbishment	Historically 11kV switchboards have been refurbished with the installation of new vacuum circuit breakers (replacing oil) to extend the life of the switchboard. This option has been completed on all practicable major substations. This option was not considered feasible for distribution substations due to the small size of the switchboards.
Removing switchable capability	This would reduce many of the risks related to worker safety however, this solution would create other risks such as greatly increasing outage times and number of customers affected. Given the advantages of a switchable network for control and protection this has not been deemed feasible.
Non-network solutions	Non-network solutions for switchgear assets would require the substation to no longer be required. This provides suitable risk mitigation in limited scenarios such as distribution substations however, are rarely practical or justifiable on the condition of switchgear alone.

7.6 Proposed Management Strategy

The forecasting methods above support an increase in replacement expenditure in switchgear for the 2024-29 regulatory period relative to historical expenditure. We are not proposing to adopt the higher forecast from our CBA and have instead adopted a forecast between the historical expenditure and the CBA results, recognising the larger proportion of younger assets in this asset class and the previous investment in transmission circuit breakers and switches.

While newer switchgear technology is safer, it generally has a shorter life than older technology. Therefore, we will continue to monitor trends in condition (leading indicator) and failures (lagging indicator) and review proposed replacement volumes for future regulatory periods.

7.7 Investment Forecast

Utilising the proposed management strategy above, Figure 73 shows the forecast replacement volumes for the different asset sub-classes of switchgear which is proposed for the 2024-29 regulatory period.

Figure 73. Switchgear 2024-29 forecast volume

	LV/HV Switches	LV/HV Fuses	LV/HV CBs	Transmission Switches	Transmission CBs
Volume	1,621	167	272	75	33

Population annual %	0.3%	0.1%	0.5%	0.3%	0.1%

The replacement expenditure forecast shown in Figure 74 is proposed for the 2024-29 regulatory period.

Figure 74. Switchgear forecast repex (real $m, FY24)

	FY25	FY26	FY27	FY28	FY29	TOTAL
LV/HV Switches	$11	$10	$10	$10	$10	**$51**
LV/HV Fuses	$4	$4	$4	$4	$4	**$21**
LV/HV CBs	$9	$9	$9	$9	$9	**$45**
Transmission CBs	$3	$0.5	$0.5	$0.6	$0.6	**$5**
Transmission Switches	$1	$1	$1	$1	$1	**$5**
TOTAL	**$29**	**$25**	**$25**	**$25**	**$24**	**$128**

8. Communications, Control & Protection

8.1 Scope

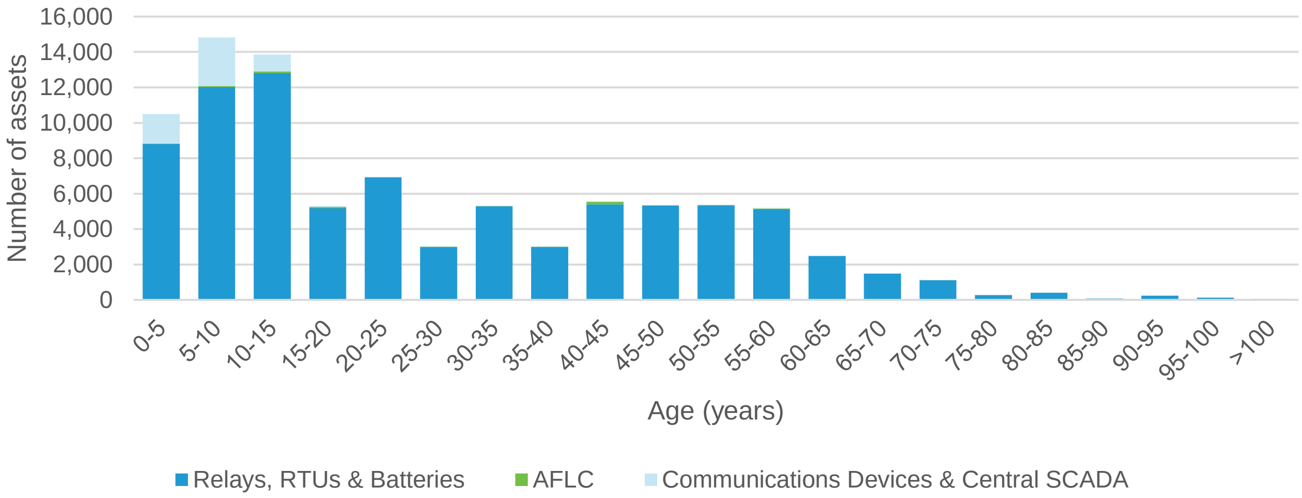
Communication, Control & Protection equipment (generally referred to as Secondary Systems) provide monitoring, protection, control and automation for the primary network. This equipment also provides load control of customer equipment and secure communications of data/information between the field and control rooms. This asset class includes relays, batteries/chargers, Remote Terminal Units (**RTUs**), Audio Frequency Load Control (**AFLC**), communications devices and central Supervisory Control And Data Acquisition (**SCADA**) systems. For the RIN, this asset class is split into:

- Unmodelled – SCADA, Network Control & Protection Systems (majority of assets), and
- Unmodelled – Other (compliance programs).

8.2 Age and Technology

The age profile and technology composition of assets in this asset class is shown in Figure 75 (excluding wiring/communications mediums). The AFLC asset population is a small proportion of this asset class and is overwhelmed by the volume of the other assets.

Figure 75. Age Profile for Communications, Control & Protection



The average age of assets within the asset class is 26 years. The average age has decreased from 31 years[1] in the last five years. With a population of over 90,000 assets and a mean replacement age of 53 years, we would need to replace 1.87% of our assets per year (1,695 assets) to maintain the current average age. Communications mediums and central SCADA have been removed from this calculation as age information is limited. Also note that modern technologies include advanced micro-processors which provide additional functionality, however, will not realise the same mean replacement age as previous electro-mechanical technologies.

The communications, control and protection equipment that we are currently installing is technically advanced compared to the assets they are replacing. The technical advances for the different communications, control and protection types include:

- the installation of digital equipment which incorporates self-monitoring, allows multiple functions to be incorporated into a single unit and enables enhanced integration between devices,
- the installation of newer sealed battery technologies with reduced maintenance requirements, and
- continued migration of communications from copper based linear assets to optical fibre based digital systems which increase communications capacity.

[1] The definition we use to categorise these assets has been updated during this period and some population data cleansing has occurred.

8.3 Key Risks

Communications, control and protection equipment failures pose loss of supply risks as well as safety risks to workers and the public. In most instances a multiple contingency failure would need to occur to realise the risk for communications, control and protection assets, such events are rare

Depending on the type of asset and how it is used, the network related consequences can vary as shown in Figure 76.

Figure 76. Network related consequences for Communications, Control & Protection assets

Sub-class	
Relays	Spurious operation of protection devices such as relays can cause loss of electrical supply however these events are rare. The main consequence of protection devices failing is not detecting a fault/initiating a tripping pulse to the switchgear assets which most commonly results in an upstream protection device operating. This results in a larger loss of electrical supply event than would otherwise be encountered. In some situations, physical damage to the primary network is exacerbated by the delays in removing the fault.
SCADA & Comms	The unavailability of remote monitoring and control for one or more network elements can lead to uncertainty of network status and delays in responding to events which increases the loss of electrical supply risk. Communication mediums (pilot cables) are crucial to the operation of specific unit protection systems. Failure of a pilot cable results in a different form of protection and/or an upstream protection device operating causing a larger loss of electrical supply event than would otherwise be encountered.
Batteries/Chargers	The battery in a substation is crucial to the operation of protection/switchgear systems. The loss of a battery supply results in an upstream protection device operating instead of a local device, causing a larger loss of electrical supply event than would otherwise be encountered. In some situations, physical damage to the primary network is exacerbated by the delays in removing the fault.
AFLC	Audio Frequency Load Control not operating means the controlled load of customers is not triggered on schedule which may result in lack of hot water triggering customer complaints.

8.3.1 Degrading risks

Communications, control and protection equipment degrades over time and with use. Key causes of this degradation include:

Causes of asset degradation	Environmental exposure; design decisions; material selection and asset operations (usage)

External factors can place additional stress on these assets which can accelerate their degradation. These escalation causes include:

Escalation causes	Environmental exposure (high temperature, particulates and humidity); and high pollution areas

These causes are used to determine the probability of asset failure. If an asset does fail, it may result in a hazardous event. The hazardous events associated with communications, control and protection include:

Hazardous events	Loss of electrical continuity; fire starts; exposure to arc flash; contact with electrical equipment inadvertently energised; compliance breach; exposure to hazardous chemicals and materials; exposure to excessive asset noise; and struck by expelled object

8.3.2 Non-degrading risks

Modern digital equipment can face technical obsolescence through manufacturers not providing ongoing support including firmware updates, cyber security patches and spare components availability. The presence of hazardous materials such as asbestos are issues faced with obsolete designs of communications, control and protection equipment. The hazardous events associated with non-degrading risks include:

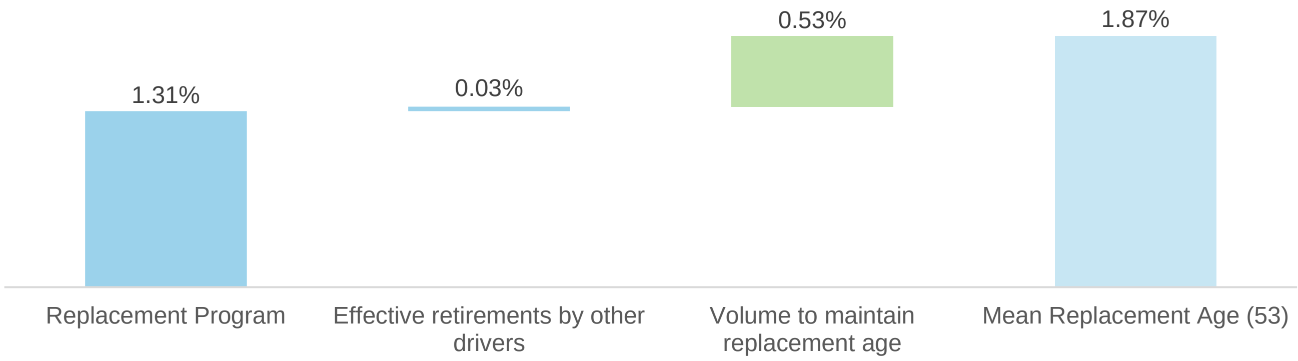
Hazardous events	Unauthorised access to the network (cyber); loss of electrical continuity; compliance breach; exposure to hazardous chemicals and materials

8.4 Forecasting replacement

8.4.1 Age-based assessment

Figure 77 shows that we have recently been replacing an average of 1,188 communications, control and protection assets per year under our replacement programs. However, an average of 43 communications, control and protection assets per year are being retired or replaced as part of other works, such as augmentation or customer driven work (outside the scope of the replacement program). This value is calculated using a scaling multiplier based on age at replacement.

Figure 77. Annual Population replaced by driver for Communications, Control & Protection



This results in a total effective annual replacement volume of 1.3% of the communications, control and protection population (1,217 assets) replaced each year. With this replacement rate it would take 74 years to replace the entire communications, control and protection population. Given our recent historical replacement rates are lower than the volume required to maintain the average age of the asset class, this top-down metric suggests that the level of investment is not considered to be sustainable in the long term.

8.4.2 Replace on failure

Under this option there is no consideration for planned replacement or refurbishment and the assets are either repaired (opex) or replaced on failure (reactive). Under a base case scenario, with no replacement investment, the asset failure rate is expected to grow with time. The total number of failures predicted between 2024-29 is shown in Figure 78. The volume of predicted failures over the period has also been applied to determine the probability of failure used in our CBA.

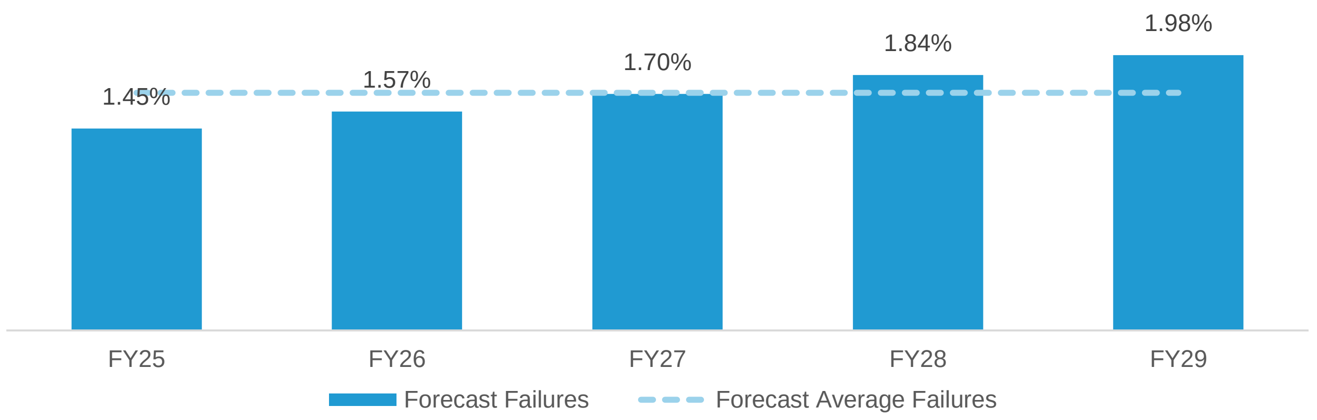
Figure 78. Base case failures for Communications, Control & Protection (2024 – 29)

Sub-class	Forecast Average Annual Failures	Annual % of population
Relays	780	1.1%
SCADA & Comms	504	5.6%
Batteries/Chargers	184	5.8%
AFLC	41	6.6%

The high failure rate is due to a high number of historical defects resulting in repairs. This high repair rate of 87%-97% depending on the asset sub-class is forecast to continue in the 2024-29 regulatory period. Therefore, under this scenario, <1% of communications, control and protection assets would be replaced annually following failure.

Although the age profile shows approximately 14% of these assets are already above the 53-year mean replacement age, given the changing proportion of electromechanical compared to digital relays and the associated change in expected service life is contributing to the forecast average annual failures. Figure 79 shows the projected failures and average over the 2024-29 regulatory period.

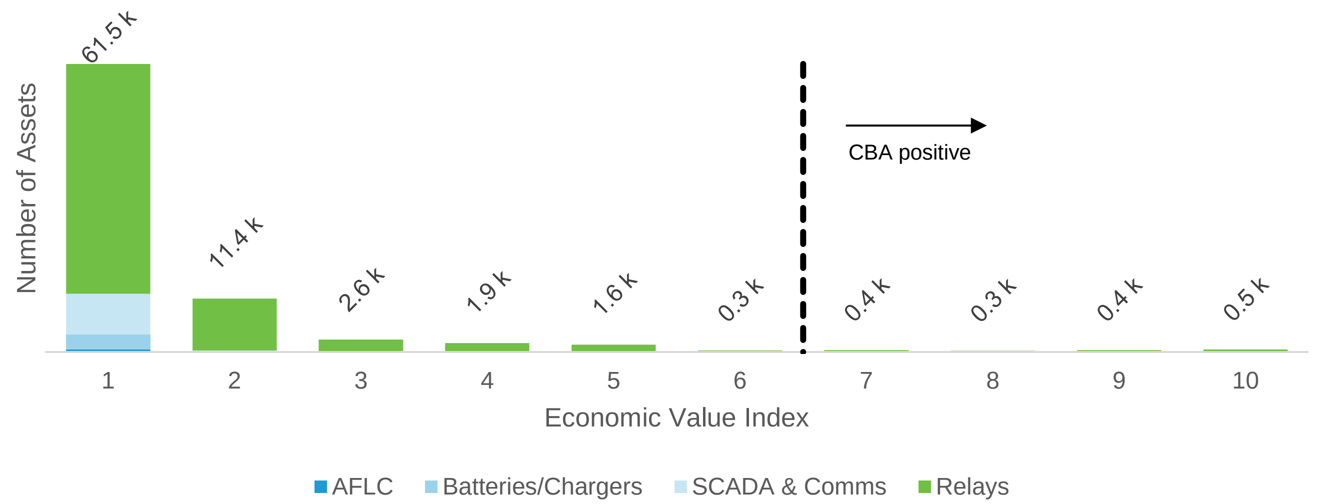
Figure 79. Forecast inherent failures as proportion of population for Communications, Control & Protection



8.4.3 Economic value through CBA

An economic evaluation has been undertaken on this asset class utilising CBA. Where the economic value of the risk carried exceeds the cost to replace, the asset is considered suitable for replacement. Figure 80 shows the volume of communications, control and protection equipment assets within each economic value index at FY29.

Figure 80. Economic value index for Communications, Control & Protection



The assets at or above an economic value index of 7 are expected to be cost benefit positive before the end of FY29. Given the number of cost benefit positive assets does not exceed modelled predicted failures, the supported replacement investment for the 2024-29 regulatory period reflects the figures above plus an additional volume for predicted reactive replacement.

Overall, approximately $61m (real $, FY24) of replacement investment is supported during the 2024-29 regulatory period. This includes $23m of reactive replacement. A breakdown of the replacement volume is detailed in Figure 81.

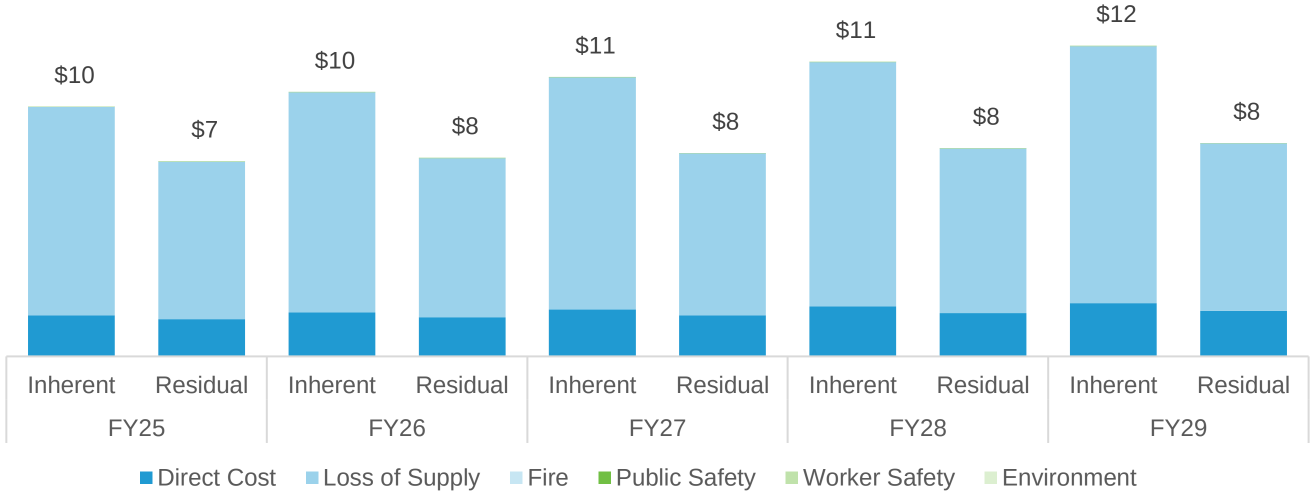
Figure 81. CBA supported replacement volume by subclass for 2024 – 29 Communications, Control & Protection

Asset Subclass	Supported total replacement volume	Annual % of Population
Relays	1,616	0.5%
SCADA & Comms	2	<0.1%
Batteries/Chargers	-	n/a
AFLC	-	n/a

8.4.4 Maintain Risk

Figure 82 shows the annual risk carried for this asset class before investment (inherent) and after CBA forecast investment (residual), based on replacing assets that are cost benefit positive. This analysis is based on a population and failure rate using FY22 as the base year and assumes a smooth investment for FY23-FY24. The residual risk is expected to remain reasonably stable through the 2024-29 regulatory period. Figure 10 highlights an increase of $31m in replacement expenditure per year to maintain risk for this asset class. The increase required for an apparently stable residual risk, reflect the marginal benefit available from increasing investment in this asset class.

Figure 82. Inherent and Residual Risk by Financial Year for Communications, Control & Protection (real $m, FY24)



8.5 Options

8.5.1 Reactive replacement

Under this option there is no consideration for planned or condition-based replacement or refurbishment. Following failure assets are either repaired or replaced in-line with the predicted volume under the base case scenario. This option is only selected where the benefits of replacement do not outweigh the costs.

8.5.2 Replace on condition

Figure 83 outlines the replacement strategies for each asset sub-class. This asset class has experienced a significant transition in technology. Replacement is informed by assets with known condition issues and replacement of older electromechanical technology.

Figure 83. Asset sub-class replacement strategies for Communications, Control & Protection

Sub-class	Strategy
Relays	For most protection schemes/relays, replacement decisions are based on their condition (determined through maintenance) or, with more modern relays, through associated alarms. Relays are also replaced in conjunction with their associated primary asset. A small portion of the population of electromechanical relays form part of a planned replacement program due to their design and known condition issues.
SCADA & Comms	For the majority of SCADA equipment, replacement decisions are based on condition or are replaced in conjunction with an upgrade of the primary assets at the substation to enable greater capacity for other equipment to be monitored/controlled. A small volume of SCADA equipment forms part of a planned replacement program due to known design and condition issues including supportability of software and hardware. The routers that form our communication network are monitored so replacements occur reactively when failure is approaching or occurs (depending on the component). Communications mediums (pilot cables) were historically constructed with copper conductors however new installations use fibre optic cables. Communications mediums carry protection/control signals and are replaced reactively or when relay

Sub-class	Strategy
	replacement requires modern communication mediums such as fibre optic cables instead of cooper. Where practical, pilot cables are converted to fibre optic and the associated relays at each end are replaced.
Batteries/Chargers	For batteries in major substations, replacement decisions are generally based on condition as part of maintenance and on-line condition monitoring. A small volume of old technology batteries exist in major substations and are subject for planned replacement due to known condition issues.
AFLC	Substation and customer meter board Audio Frequency Load Control equipment are replaced reactively following failure. Smart meter roll-out is expected to make these assets obsolete but requires full penetration in an entire area. Investment is AFLC is therefore minimal and is aimed at maintaining serviceability.

8.5.3 Options not considered feasible

Figure 84 shows the options that were considered and assessed as not feasible.

Figure 84. Options not considered feasible for Communications, Control & Protection

Option	Rationale
Increased maintenance & inspections	The packaging of maintenance considers efficiencies of undertaking tasks at the same time. Increasing maintenance/ inspections on communications, control and protection equipment would not be cost effective considering several items are not preventatively maintained. Modern digital equipment has the ability to self-monitor, as such increasing maintenance/inspections would not be useful.
Repair or refurbishment	Repairs are completed where cost effective, however they are considered an operational expense.
Removing communications, control and protection equipment	Communications, control and protection equipment allows associated primary assets to respond in real-time to events (e.g. faults) as well as providing that operational data back to our network Control Rooms. This solution would create other risks such as greatly increasing outage times and the number of customers affected, as such this is not deemed feasible.
Non-network solutions	Non-network solutions for communications, control and protection assets would generally require the substation to no longer be required. This provides suitable risk mitigation in limited scenarios such as distribution substations, however, would rarely be practical or justifiable on the condition of communications, control and protection equipment alone.

8.6 Proposed Management Strategy

The CBA is suggesting a reduction in replacement expenditure in communications, control & protection relative to the historical expenditure. All other forecasting methods support an increase. The average age of communications, control and protection equipment has decreased in the last five years, however, the expected life of assets (particularly for modern digital equipment) is lower than the current effective replacement age.

Following a review of the existing programs with known condition issues, we are proposing a forecast for the 2024-29 regulatory period between our CBA and historical trend. Asset records and data capture has not been as strong in this asset class, therefore we will focus on establishing leading and lagging performance indicators.

8.7 Investment Forecast

Utilising the proposed management strategy, Figure 85 shows the forecast replacement volumes for the different asset sub classes of communications, control & protection which is proposed for the 2024-29 regulatory period. These values are based on the outcomes of our CBA and top-down evaluation. Forecast annual failure volumes are higher than the investment forecast, with the remainder requiring repairs under maintenance (opex).

Figure 85. Communications, Control & Protection 2024-29 forecast volume

	Relays	SCADA & Comms	Batteries/Chargers	AFLC
Volume	807	250	97	2
Population annual %	0.2%	1.3%	0.6%	<0.1%

The repex forecast shown in Figure 86 is proposed for the 2024-29 regulatory period.

Figure 86. Communications, Control & Protection forecast repex (real $m, FY24)

	FY25	FY26	FY27	FY28	FY29	TOTAL
Relays	$8	$7	$7	$7	$7	**$37**
SCADA & Comms	$3	$3	$3	$3	$3	**$14**
Power Quality	$3	$2	$3	$2	$2	**$12**
Batteries/Chargers	$1	$1	$2	$2	$1	**$6**
AFLC	$0.1	$0.1	$0.1	$0.1	$0.1	**$0.6**
TOTAL	**$15**	**$13**	**$14**	**$14**	**$13**	**$69**

9. Buildings, Grounds & Land

9.1 Scope

The electrical assets on our network are supported by a range of systems, services and infrastructure to maintain the electrical assets in a safe, secure and functional state. This asset class includes buildings, security, oil containment facilities, substation earthing and fire systems. For the RIN, this asset class is split into:

- Unmodelled – Other

Figure 87 outlines which sub-systems apply to each substation type.

Figure 87. Outline of Buildings, Grounds & Land assets for each substation type

Substation Type	Buildings	Grounds & Land	Security	Fire Equipment & Systems	Oil Containment	Substation Earthing
Major	✓	✓	✓	✓	✓	✓
Kiosk	✓	✓	✓	x	✓*	✓
Chamber	✓	✓	✓	✓	✓	✓
Underground	✓	✓	✓	✓	✓	✓
Outdoor Enclosure	✓	✓	✓	x	✓	✓
Pole-top	x	x	x	x	x	✓

* Modern contracts require oil containment however historically this was not the case

9.2 Age and Technology

An indicative representation of the age of the population of this asset class is provided by the age profile for our distribution substations as shown in Figure 88 and major substations shown in Figure 89.

Figure 88. Age profile of distribution substations

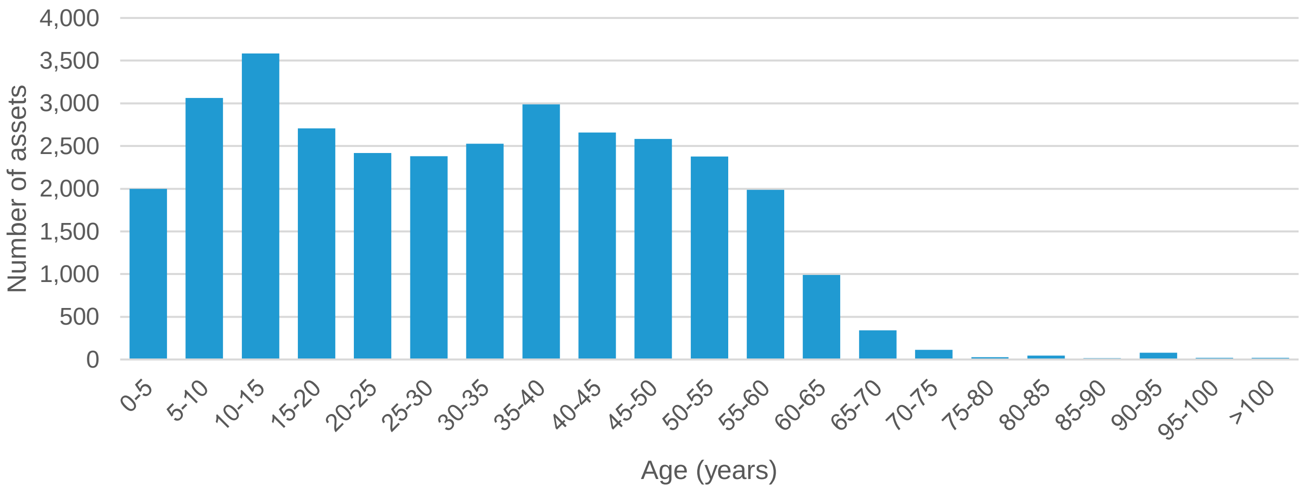
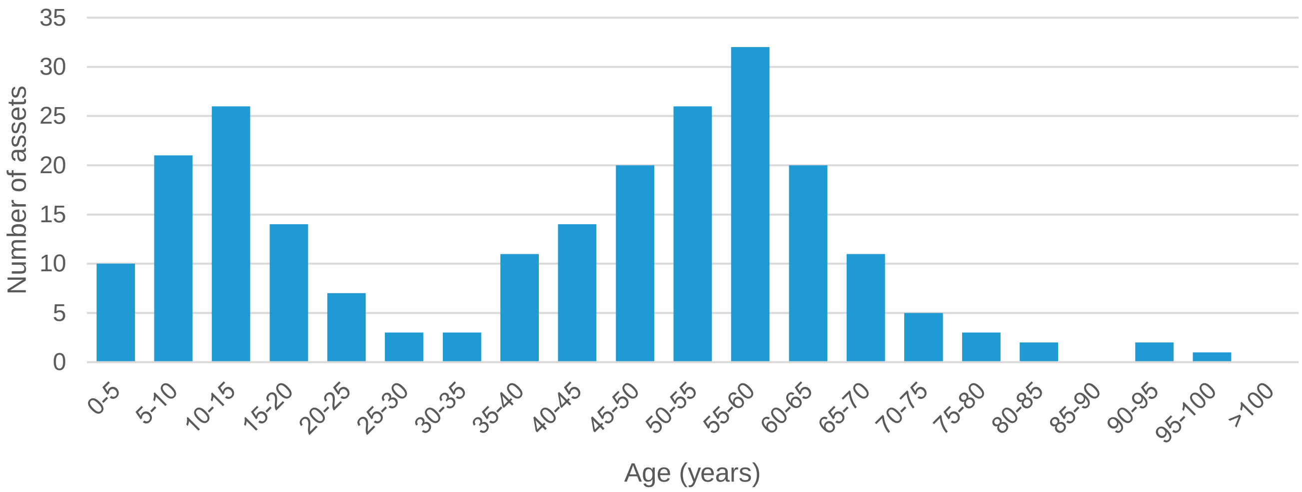


Figure 89. Age profile of major substations



9.3 Key Risks

Failures can lead to exposure in a number of risk areas such as fire, security, environment and safety however, for most asset sub classes (oil containment facilities, substation earthing and fire systems) a failure of a primary asset would also need to occur to realise the risk.

9.3.1 Degrading risks

The assets associated with buildings, grounds & land, security, oil containment facilities, substation earthing and fire systems degrade over time and with use. Key causes of this degradation include:

Causes of asset degradation	Environmental exposure; moisture ingress; corrosion; design decisions; material selection and asset usage

External factors can place additional stress on these assets which can accelerate their degradation. These escalation causes include:

Escalation causes	Severe weather and wind; contamination; mining subsidence; and high pollution areas

The causes above are used to determine the probability of asset failure. If an asset does fail, it may result in a hazardous event. The hazardous events associated with buildings, grounds and land, security, oil containment facilities, substation earthing and fire systems include:

Hazardous events	Fire starts; exposure to hazardous chemicals and materials; struck by falling object; exposure to biological hazard, flora & fauna; exposure to hazardous chemicals and materials; leak, spill or discharge of a contaminating substance into the environment; slip, trip or fall; unauthorised access to the network (physical); entrapment or entanglement; exposure to enclosed space / depletion of oxygen; unauthorised harm to heritage or ecology; and contact with live electrical equipment inadvertently energised.

9.3.2 Non-degrading risks

The presence of hazardous chemicals such as asbestos, perfluorooctanesulfonic acid (PFOS) and lead are non-degrading issues faced with these assets. Issues also relate to compliance with fire safety, security, confined spaces and heritage requirements. The hazardous events associated with non-degrading risks include:

Hazardous events	Exposure to hazardous chemicals and materials; unauthorised access to the network (physical); slips, trip or fall; exposure to contaminated land; exposure to hazardous atmosphere; compliance breach; and unauthorised harm to heritage or ecology.

9.4 Forecasting replacement

Buildings and associated assets have not had the same level of data rigour applied as other assets. Additionally, standard replacement options such as like-for-like replacement are not common when it comes to building assets. Fire systems, oil containment and now security investment are predominately related to compliance and therefore not suitable for the same advanced modelling used for end of life decisions

9.5 Options

9.5.1 Reactive replacement

Under this option there is no consideration for proactive condition-based replacement of buildings, grounds & land, security, oil containment facilities, substation earthing or fire systems and the assets are replaced on failure (reactive). There is an inherent increase in risk over time as assets age and degrade.

Replacements for some assets within this asset class often have long lead times and extensive civil design and planning requirements, hence this is not an appropriate management strategy.

9.5.2 Replace on condition

Figure 90 outlines the replacement strategies for each asset sub-class. These strategies are informed based on the condition of the asset which is determined through regular maintenance. This maintenance includes visual inspections, mechanical tasks and earthing and fires systems integrity testing. These measurements are used to perform engineering assessments based on degradation assumptions.

Figure 90. Asset sub-class replacement strategies for Buildings, Grounds & Lands

Sub-class	Strategy
Major Substations	The majority of buildings, grounds and lands replacement decisions for major substations are based on condition which is determined during routine inspections. There is a small portion of planned replacements due to the inherent issues with design and known condition issues such as fire doors and roofs.
Distribution Substations	The majority of buildings, grounds and lands replacement decisions for distribution substations are based on condition which is determined during routine inspections. There is a small portion of planned replacements due to inherent issues with design and known condition issues such as fire doors and louvres.
Security	There are planned programs for substation security focusing on fencing, physical security and electronic security. These programs are in place to ensure unauthorised access does not occur, mitigating inadvertent or deliberate access to dangerous and critical infrastructure.
Fire Equipment/Systems	Fire equipment and systems receive regular maintenance, replacement decisions are based on condition or in-service failures. There are a small portion of planned programs focusing on fire equipment and systems due to inherent issues with their design (standards) and condition issues such as smoke detection and fire hydrant replacements.
Oil Containment	The planned replacement of older style oil containment systems is continuing into the 2024-29 regulatory period. In most cases these systems are replaced with a modern and more effective equivalent.
Substation Structures	Replacement decisions for steel structures within substations are based on failing maintenance serviceability criteria. In certain situations, these structures are replaced with poles (steel or concrete).
Substation Earthing	Replacement decisions for substation earthing is based on failing maintenance serviceability criteria, following theft or in-service failures.

9.5.3 Options not considered feasible

Figure 91 shows the following options that were considered and assessed as not feasible.

Figure 91. Options not considered feasible for Buildings, Grounds & Land

Option	Rationale
Increased maintenance & inspections	The condition issues cannot be rectified through increased maintenance or inspections, and therefore this option is not a technically feasible solution to address the need.
Removing assets	Buildings, grounds & land, security, oil containment facilities, substation earthing and fire systems assets provide support to primary assets or assist in a failure event. This option would create other risks such as greatly increasing environmental impact or fire spread, as such this is not deemed feasible.
Non-network solutions	Non-network solutions for buildings, grounds & land, security, oil containment facilities, substation earthing and fire systems assets would require the substation to no longer be required. This provides suitable risk mitigation in limited scenarios such as distribution substations, however, would rarely be practical or justifiable on the condition of the supporting asset alone.

9.6 Proposed Management Strategy

An evaluation has been undertaken on this asset class utilising a trend of historical expenditure. The assets associated with buildings, grounds & land, security, oil containment facilities, substation earthing and fire systems are unmodelled due to limited data available for cost benefit analysis. This is in-line with the AER Repex Model approach for this asset class.

Most programs are a continuation of investment in the current and previous periods. There is an overall small reduction in investment within this asset class where a number of programs including fencing and roofs are shifting from planned replacement towards condition-based replacement as known issues have predominately been addressed.

9.7 Investment Forecast

Utilising the proposed management strategy, Figure 92 shows the forecast replacement volumes for the different asset sub classes of buildings, grounds and land which is proposed for the 2024-29 regulatory period.

Figure 92. Buildings, Grounds & Land 2024-29 forecast volume

	Major Subs	Distribution Subs	Security	Fire Equipment / Systems	Oil Containment	Substation Structures	Earthing
Volume	81	1,207	335	390	18	27	43
Population annual %	7%	0.7%	n/a	n/a	n/a	n/a	n/a

The replacement expenditure forecast shown in Figure 93 is proposed for the 2024-29 regulatory period.

Figure 93. Buildings, Grounds & Land forecast repex (real $m, FY24)

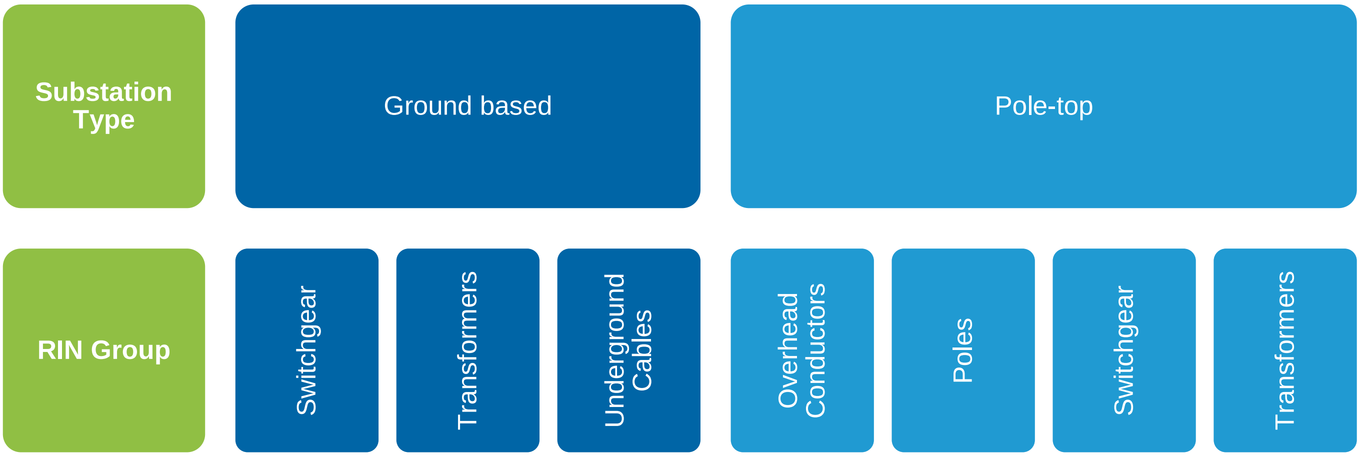
	FY25	FY26	FY27	FY28	FY29	TOTAL
Major Subs	$4	$4	$4	$4	$4	**$19**
Distribution Subs	$5	$4	$4	$4	$4	**$21**
Security	$6	$6	$6	$6	$6	**$32**
Fire Equipment / Systems	$5	$5	$5	$5	$5	**$24**
Oil Containment	$1	$2	$1	$1	$1	**$7**
Substation Structures	$0.4	$0.4	$0.4	$0.4	$0.4	**$2**
Substation Earthing	$0.3	$0.3	$0.3	$0.3	$0.3	**$1**
TOTAL	**$21**	**$21**	**$21**	**$21**	**$21**	**$106**

10. Distribution Substations

10.1 Scope

Distribution substations transform electricity from higher to lower voltages, typically 11kV to 415V, whilst providing the equipment for switching, power quality management and protection of the network. For most ground-based distribution substations[2] the equipment can generally be replaced in a piecemeal manner. Given the equipment within a particular distribution substation is generally of similar age and condition, we also consider the combined risk for the whole substation and conduct CBA for addressing the total risk as a combined replacement. Figure 94 shows the RIN asset groups that are relevant to each substation type.

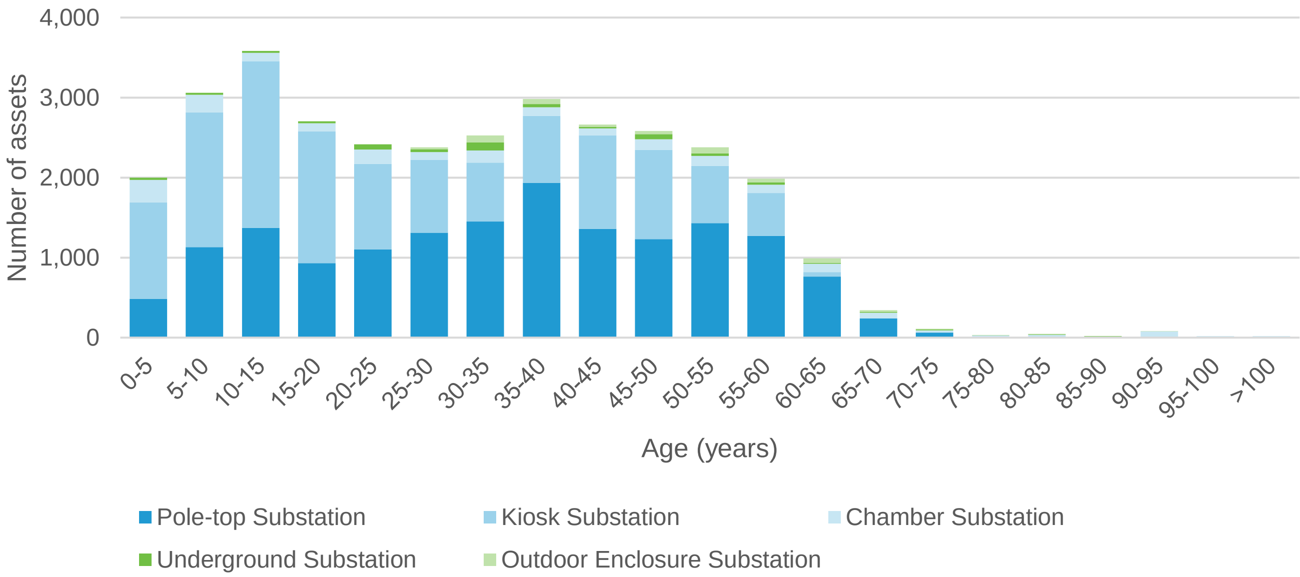
Figure 94. RIN Asset Groups relevant to Distribution Substations



10.2 Age and Technology

Figure 95 shows the age profile of distribution substations by substation type.

Figure 95. Age Profile for Distribution Substations



The average age of distribution substations is 30 years. The average age has increased by 9% (from 27 years) over the last five years. We have a population of nearly 33,000 distribution substations.

[2] Some legacy substations are impractical to retrofit with currently available equipment due to inherent design risks or limitations so are most efficiently replaced in totality.

10.3 Options

Component replacement is considered as described in the previous individual Asset Class sections. An overview of the strategies by asset sub-class is shown in Figure 96.

Figure 96. Asset sub-class strategies for Distribution Substations

Sub-class	Strategy
Pole-top Substations	Pole-top substations are generally replaced following the pole failing maintenance serviceability criteria or due to an inability to supply the required electrical output.
Outdoor Enclosure Substations	Our intention is to retire this asset sub-class, so the preferred option is replacing these with a modern equivalent (generally a kiosk substation).
Kiosk Substations	Newer kiosks are able to have their individual components replaced, however depending on component condition, it may be more cost effective to replace the kiosk entirely. A number of older kiosks have design limitations that make whole kiosk replacement the preferred option.
Underground Substations	Our intention is to remove underground vault style substations as network configuration allows. Other underground configurations are able to have individual components replaced/refurbished (as identified under individual asset classes).
Chamber Substations	The majority of chamber substations have individual components replaced/refurbished (as identified under individual asset classes).

10.4 Proposed Management Strategy

As set out in Figure 96, our strategy is to replace substations based on asset condition monitoring against serviceability criteria defined in our standards or as reactive replacements following a failure.

A historical trend and an uplift using funds previously in the buildings, grounds & land has been applied to forecast substation replacement expenditure for distribution substations, noting that a condition-based approach will be adopted to identify units to be replaced. The age profile for this asset class is relatively stable, supporting a continuation of previous investment levels.

10.5 Investment Forecast

Utilising the proposed management strategy above, we have considered the consolidated risk and investment benefit to determine which assets are better considered as bigger units e.g. distribution substations. The investment forecast has been shown in the respective asset class chapters of this document.

11. Appendix – Summary of Replacement Programs

Asset Sub-class	% assets over 50 years	Primary Replacement Approach	Forecast Method	2024-29 Expenditure Forecast (Real FY24 $M)
Overhead Support Structures				
Poles	39%	Condition-based	CBA	$122
Towers	91%	Planned	CBA/Historical trend	$8
Pole-Tops	n/a	Condition-based	CBA/Historical trend	$55
Pole Reinforcement	n/a	Condition-based	Historical trend	$4
Pole Relocation	n/a	Planned	Historical trend	$3
Pole Stays	n/a	Planned	Historical trend	$1
Tower Refurbishment	n/a	Condition-based	Historical trend	$0.5
Overhead Mains				
Dedicated Low Voltage	81%	Planned	CBA	$143
Service Lines	23%	Planned	Historical trend[3]	$45
Low Voltage	60%	Planned	CBA/Historical trend	$35
High Voltage	38%	Condition-based	CBA/Historical trend	$47
Transmission	46%	Planned	Historical trend	$12
Transmission Earthing	n/a	Planned	Historical trend	$26
Access Tracks	n/a	Condition-based	Historical trend	$3
Underground Cables				
Low Voltage (km)	23%	Planned / Reactive	CBA/Historical trend	$188
High Voltage (km)	33%	Reactive	CBA	$70
Transmission (km)	32%	Reactive	CBA/Historical trend	$14
Equipment	21%	Reactive	Historical trend	$11
UGOHs		Planned	Historical trend	$3
Service Lines	20%	Reactive	Historical trend	$1
Transformers & Reactive Plant				
Transmission Power Transformers, Resistors & Reactors	20%	Condition-based	CBA/Historical trend	$54
Distribution Power Transformers	12%	Condition-based	CBA	$40
Instrument Transformers	9%	Condition-based	CBA	$5
Switchgear				
LV/HV Switches	15%	Planned	CBA/Historical trend	$51
LV/HV CBs	10%	Planned	CBA/Historical trend	$45
LV/HV Fuses	8%	Condition-based	Historical trend	$21
Transmission CBs	8%	Planned	CBA/Historical trend	$5

[3] Service wire trend is based on long-term sustainable replacement assumptions

Asset Sub-class	% assets over 50 years	Primary Replacement Approach	Forecast Method	2024-29 Expenditure Forecast (Real FY24 $M)
Transmission Switches	23%	Planned	CBA/Historical trend	$5
Communications, control & protection				
Relays	20%	Planned	CBA/Historical trend	$37
SCADA & Comms		Planned	CBA/Historical trend	$14
Batteries/Chargers		Planned	Historical trend	$6
Power Quality	n/a	Reactive	Historical trend	$12
AFLC	15%	Reactive	Historical trend	$0.6
Buildings, grounds & land				
Major Subs	44%	Condition-based	Historical trend	$19
Distribution Subs	18%	Condition-based	Historical trend	$21
Security	n/a	Planned	Historical trend	$32
Fire Equipment / Systems	n/a	Condition-based	Historical trend	$24
Oil Containment	n/a	Planned	Historical trend	$7
Substation Structures	n/a	Condition-based	Historical trend	$2
Substation Earthing	n/a	Condition-based	Historical trend	$1