Asset Management Plan
Overhead Conductor

ERGON ENERGY NETWORK | energex

Part of the Energy Queensland Group

Executive Summary

This Asset Management Plan (AMP) focuses on the management of overhead conductor and conductor accessories.

Energy Queensland Limited (EQL) owns and maintains approximately 179,000km of overhead conductor throughout Queensland at distribution, sub-transmission, and transmission voltages. Approximately 144,000km (80%) of these assets are contained within the Ergon Energy region.

Overhead conductors are an asset of strategic importance to EQL as they provide the physical connection and electrical continuity to allow for the safe and reliable transmission and distribution of electrical power. Failure of overhead conductor assets to perform their function results in negative impacts to the EQL business objectives related to safety, customer, and compliance.

EQL maintains a diverse population of bare and insulated overhead conductor types and sizes due to legacy organisations, the length of the asset's operational life, changes in period supply contracts, and advancements in conductor technology. Galvanised steel is the predominant conductor type due to its prevalence on the rural network.

Approximately 46% of the EQL overhead conductor population is installed at distribution voltages less than or equal to 11kV. An additional 34% of the overhead conductor population is installed as part of the single wire earth return (SWER) distribution network. Using current asset quantities and replacement costs, overhead conductors have an undepreciated replacement value in the order of $9.19 billion, approximately 19% of the EQL total asset replacement value.

Factors influencing the effective management of overhead conductor assets include the large, geographically dispersed asset population, the age, range and variability of conductor materials, and the diverse environmental and operational conditions.

To meet the regulatory obligations of operating an electrically safe network, EQL has commenced proactive conductor replacement programs to remove high risk, aged conductor from the network with particular focus on small diameter hard drawn bare copper (HDBC) due to poor performance. The operational regions of EQL are at different stages in these programs, with significant quantities of HDBC remaining in the Ergon Energy region. The volume of aged, small diameter HDBC replaced per annum has been increased to manage this risk. The addition of aging galvanised steel (SC/GZ) and steel reinforced aluminium conductor (ACSR) into these targeted programs has also occurred, although volumes still represent a very minor component of the renewal mix. This AMP also recommends adding low voltage aerial bundle cable (LV ABC) renewal to the targeted replacement works.

Data quality, ongoing conformance with statutory conductor clearance requirements, and difficulty in obtaining in-situ conductor condition information are key challenges for overhead conductor assets. EQL is working to improve its data quality, and investigating and pursuing advancements in overhead condition assessment using emerging technologies that will further assist in the management of this asset class.

Revision History

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Stakeholders / Endorsements

Title	Role
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1 Introduction

Energy Queensland Limited (EQL) was formed 1 July 2016. It owns and manages several electrical energy related companies that operate to support energy distribution across Queensland including the following distribution network service providers (DNSPs):

1. Ergon Energy, covering the area defined by the Distribution Authority for Ergon Energy Corporation Limited.
2. Energex, covering the area defined by the Distribution Authority for Energex Corporation Limited.

EQL is committed to maximising value from its assets for the benefits of its customers, stakeholders, and the communities in which it operates. In line with our corporate vision and purpose, EQL will look to safely deliver secure, affordable, and sustainable energy solutions to its communities and customers by optimally managing its assets throughout life cycle.

There are variations between EQL's operating regions in terms of asset base and management practice, due to geographic influences, market operation influences, and legacy organisation management practices. This Asset Management Plan (AMP) reflects the current practices and strategies for all assets managed by EQL, recognising the differences that have arisen due to legacy organisation management. These variations are expected to diminish over time with the integration of asset management practices.

1.1 Purpose

EQL has shaped the strategic planning approach to consider what we need to do to deliver financial sustainability whilst balancing our ability to transform in an environment of significant market disruption and increased competition as we evolve towards an 'electric life' and renewable targets as described in Queensland Energy and Jobs Plan (QEJP).

The purpose of this document is to guide the responsible management of overhead conductor and accessories on the EQL network. The objectives of this plan are to:

1. Deliver customer outcomes to the required level of safety and service.
2. Demonstrate alignment of asset management practices with EQL's Strategic Asset Management Plan and business objectives.
3. Demonstrate compliance with regulatory requirements.
4. Manage the risks associated with operating the assets over their lifespan.
5. Optimise the value EQL derives from this asset class.

This AMP will be updated periodically to ensure it remains current and relevant to the organisation and its strategic objectives. Full revision of the plan will be completed every five years as a minimum. All data analytics presented within this AMP refer to FY18-FY23 unless otherwise stated.

This AMP is guided by the following legislation, regulations, rules, and codes:

- *National Electricity Rules (NER)*
- *Electricity Act 1994 (Qld)*
- *Electrical Safety Act 2002 (Qld)*
- *Electricity Regulation 2006 (Qld)*
- *Electrical Safety Regulation 2013 (Qld)*
- *Queensland Electrical Safety Code of Practice 2020 – Works (ESCOP)*
- *Environmental Protection Act 1994 (EP Act)*
- *Work Health & Safety Act 2014 (Qld)*
- *Work Health & Safety Regulation 2011 (Qld)*
- Ergon Energy Corporation Limited Distribution Authority No D01/99
- Energex Limited Distribution Authority No. D07/98

This AMP is a component of EQL's Asset Management System (Figure 1). It is part of a suite of asset management documents, which collectively describe EQL's approach to the lifecycle management of the various assets which make up the network used to deliver electricity to its customers. Appendix 1 contains references to other documents relevant to the management of the asset class covered in this plan.

Figure 1: EQL Asset Management System

1.2 Scope

This plan covers the following assets:

- Bare conductor, including all aluminium conductor (AAC), all aluminium alloy conductor (AAAC), aluminium conductor steel reinforced (ACSR), steel conductor galvanised (SC/GZ), steel conductor aluminium clad (SC/AC), and hard drawn bare copper (HDBC) conductors, and includes overhead earth wires (OHEW) and optical-fibre ground wire (OPGW).
- Covered conductor, including low and high voltage aerial bundled cable (LV ABC and HV ABC), Hendrix type conductors, and other covered conductor types.
- Conductor accessories including but not limited to splices, connectors, and clamps.

EQL aims to provide a co-ordinated and optimised approach to the lifecycle management of all assets within the asset base. The scope of this AMP has a strong linkage to other management plans including those for poles, lattice towers, and pole top structures. These plans should be considered together.

In Queensland, many customers, typically those with high voltage connections, own and manage their own network assets including poles and ancillary equipment. EQL does not provide condition and maintenance services for third party assets, except as an unregulated and independent service.

In New South Wales, where EQL has a relatively small volume of assets, EQL is also required to inspect privately owned assets that are directly connected to EQL assets and advise the owner about material safety risks. This AMP relates to EQL owned assets only and excludes any consideration of such services.

1.3 Total Current Replacement Cost

Overhead conductors are a relatively low unit cost, high volume asset, and are second only behind poles in total replacement cost by asset type (Figure 2). Replacement of this asset can impact the design and construction of the supporting structures such as Poles and Lattice Towers and Pole Top Structures. This relationship is excluded for the purposes of this section.

Using current asset quantities and replacement costs, EQL conductors have a replacement value to the order of $9.19 billion, this valuation is based on gross replacement costs of the assets using the cost of modern equivalents for superseded types on an average per metre basis, excluding savings that may be achieved through quantity replacement optimisation.

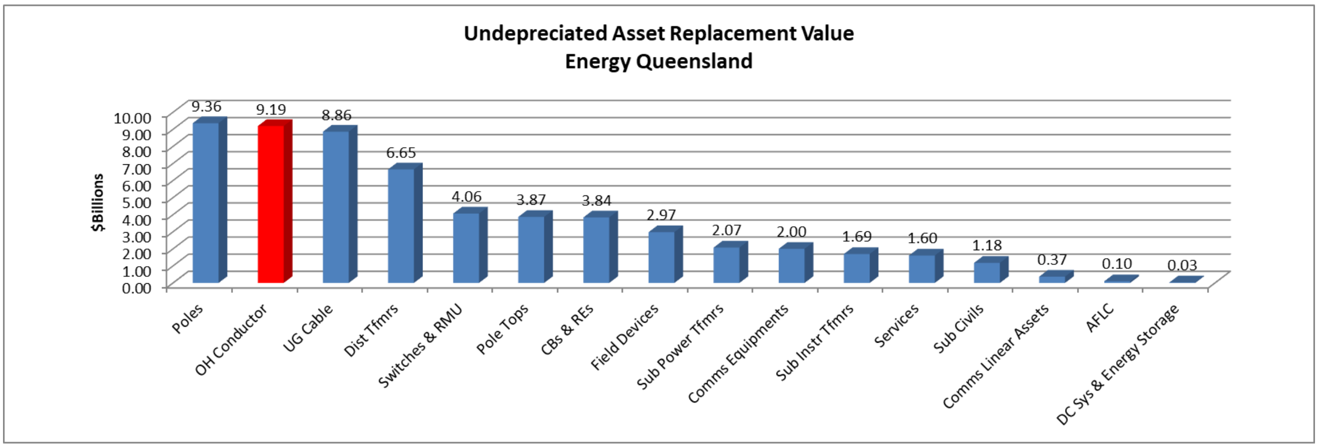

Figure 2: EQL Undepreciated Asset Replacement Value

1.4 Asset Function and Strategic Alignment

Overhead conductor systems are designed and constructed to provide the physical connection and electrical continuity to allow for the safe and reliable transmission and distribution of electrical power between termination sites for the duration of the assets operational life.

The failure of energised overhead conductor assets can pose a safety risk to EQL employees, contractors, and the public through electrical contact and/or secondary damage due to subsequent fire events.

Table 1 details how overhead conductors contribute to EQL's corporate strategic asset management objectives.

Asset Management Objectives	Relationship of Asset-to-Asset Management Objectives
Ensure network safety for staff, contractors, and the community	Integrity and condition of overhead conductors is a key factor in managing safety and environmental hazards, and compliance to legislative and regulatory obligations.
Meet customer and stakeholder expectations	The performance of overhead conductor assets supports the safe, cost effective, secure, and reliable supply of electricity to consumers.
Manage risk, performance standards, and asset investment to deliver balanced commercial outcomes	Performance of overhead conductor assets is integral to managing the hazard of exposure of workers and the public to electrical safety risks, and contributes directly to Network Performance MSS and STPIS reliability targets. Prudent management of overhead conductor assets assists in minimising capital and operational expenditure.
Develop Asset Management capability and align practices to the global ISO55000 standard	This AMP is consistent with ISO55000 objectives and drives asset management capability by promoting a continuous improvement environment.
Modernise the network and facilitate access to innovative energy technologies	This AMP promotes modernisation through increased asset utilisation, industry leading condition and health assessment, and replacement of assets at end of economic life as necessary to meet up to date standards and future requirements.

Table 1: Asset Function and Strategic Alignment

1.5 Owners and Stakeholders

The ubiquitous nature of the electrical distribution network means that there are many stakeholders that influence, or are affected by, operation and performance of EQL's electrical networks. Table 2 lists most of the influential stakeholders that have impacted the strategies defined by this AMP.

Responsible Party	Role
Queensland Government	Development of legislative framework and environment for operation of EQL and its subsidiaries in Queensland. Development of EQL Distribution Authorities.
Queensland Government as sole shareholder of EQL	Owner of company shares, holding equity in EQL and gaining benefits from EQL financial success.
EQL Board of Directors	Corporate direction, operation, and performance of EQL and its subsidiaries, in compliance with corporate and Queensland law.
Chief Financial officer	Company "Asset Owner" – ensuring all EQL investments are consistent with EQL corporate objectives with balanced commercial outcomes
Chief Operating Officer	Overall operational control of EQL networks including maintenance and operation, and execution of project works
Chief Engineer	Overall strategic control of EQL assets, including asset population performance, network risk and financial management
All employees and contractors of Energy Queensland Limited	Performing all duties as required to achieve EQL corporate objectives
All unions that are party to the EQL Union Collective Agreement	Promotion of safe and fair working conditions for all EQL and subsidiary company employees
Queensland Electrical Safety Office	Regulatory overview and control of electrical safety in Queensland
Australian Energy Regulator	Regulatory overview and control of economic performance of Ergon Energy and Energex to promote the long-term interests of all electrical network customers connected to the National Electricity Market
Powerlink	Queensland Transmission Network Service Provider. Owner and operator transmission grid assets and bulk supply substations that connect and deliver energy to EQL networks
All consumers, prosumers and generators connecting to the Energy Queensland network	Operating within the electrical technical boundaries defined by legislation, regulation, and connection agreements.
All communities and businesses connected to the Energy Queensland network.	Economic prosperity of Queensland

Table 2: Stakeholders

2 Asset Class Information

The following sections provide a summary of the key functions and attributes of the assets covered in this AMP.

2.1 Asset Description

EQL owns and maintains approximately 179,000km of overhead conductor throughout Queensland at distribution, sub-transmission, and transmission voltages. Approximately 144,000km (80%) of these assets are contained within the Ergon Energy networks, and 35,000kms are contained within the Energex region.

2.1.1 Bare Conductor

Bare conductor overhead systems are designed and constructed to conduct electrical energy, at a rated voltage and current, safely and reliably between terminations. Bare conductors are constructed from several strands of small diameter wire, concentrically laid up to form a single conductor with specific physical, mechanical, and electrical performance properties.

EQL predecessors installed a range of hard drawn bare copper (HDBC) conductors on overhead distribution lines prior to 1960. Since then, most overhead conductor types installed have been all aluminium conductor (AAC), all aluminium alloy conductor (AAAC), and ACSR. SC/GZ and SC/AC are used in large quantities on the rural network, particularly on SWER systems and some overhead earth wire (OHEW) systems.

Smooth body conductor has also been used in limited quantities in Ergon Energy to reduce wind loading conditions.

The conductor types used to construct the overhead network have changed over time due to:

- Increases in electrical capacity requirements resultant from electricity demand growth
- Improvements in overhead transmission and distribution line construction techniques
- Changes in economic viability and cost.

2.1.2 Overhead Earth Wire (OHEW) and Optical-Fibre Ground Wire (OPGW)

Bare conductors may also be installed as overhead earth wire (OHEW), to shield phase conductors below from lightning strikes, and provide a return path for phase to ground fault currents.

OHEW is installed on all new overhead feeders at sub-transmission and transmission voltages, and at sections of distribution voltage feeders to protect key plant. On legacy 33kV and 66kV wood pole feeders, typically only the last 800m to 1000m section into the substation was shielded unless a requirement for increased reliability was justified.

Optical-fibre ground wire (OPGW) performs the same function as OHEW; it also contains optical fibre that can be used for communications purposes.

2.1.3 Covered Conductor

Low voltage aerial bundled cable (LV ABC) is the current standard low voltage conductor installed on the EQL network. This conductor features four cores of all aluminium conductor (AAC) individually insulated in ultraviolet (UV) stabilised cross linked polyethylene (XLPE). The individual cores are laid up in a bundled cable. LV ABC fittings and clamps are designed to be intrinsically safe with insulation properties designed to remain intact during most failure modes.

At 11kV, covered conductor is sometimes used in areas with trees or heavy vegetation to minimise reliability problems associated with windblown branches, debris, or wildlife. High voltage covered conductors are single core, self-supporting, unscreened, insulated overhead conductors, installed in a similar manner to bare conductors. Covered conductor thick (CCT) has an XLPE layer proportional with the rated voltage. Prior to 2008 the conductor used in CCT was 1120 AAAC. Current CCT is composed of 1350 AAC.

Aerial bundled cable at 11kV (HV ABC) is used as an alternative where design constraints call for an increased level of insulation and functionality. This cable features three individually copper wire screened, XLPE insulated 1320 AAC, laid up on a galvanised steel catenary (GZ) for mechanical support. The fully insulated screened HV ABC is considered "touch safe". An alternative semi–conductive insulated and screened HV ABC is also available. This conductor has a smaller diameter and is supported by a 7/4.75 aluminium catenary wire. Semi-conductive screened HV ABC cannot be considered "touch safe", as the catenary wire may "float" above earth potential.

On the 33kV network, covered conductor solutions (Hendrix, Amokabel) have been investigated, however, these have not widely been adopted due to the high initial costs and lower current carrying capability compared to bare conductor constructions. This type of construction is limited to areas of heavy vegetation where vegetation management is impractical.

2.1.4 Conductor Accessories

Conductor fittings include the hardware installed ancillary to the conductor, required to attach the conductor to the supporting structure and/or carry the mechanical load, such as ties, clamps, connectors, and terminations. Typical overhead conductor accessories include:

- **Sleeves and splices:** used to extend or repair conductor lengths and can be of helical wrap or compression type.
- **Armour rods:** installed to improve conductor endurance at connection to insulator posts and strings.
- **Top ties and suspension clamps:** installed to attach the conductor to the insulator post or string.
- **Vibration dampeners:** installed to minimise fatigue related failures and include spiral and Stockbridge type dampers.
- **Low voltage spreader rods:** installed to improve reliability by preventing mid span conductor clashing during weather or through fault events.
- **Transmission voltage spacers:** installed on grouped conductors to prevent damage caused by clashing or twisting of conductors.
- **Corona rings:** installed at higher voltages to manage corona or radio interference voltage (RIV).
- **Overhead markers:** improve visual sighting of conductor and include live line indicators, aerial markers, and wildlife protection.
- **Fault indicators:** self-powered current monitoring devices that indicate whenever a current level has been exceeded.
- **Dead-end:** termination of conductors.

Figure 3 shows an example of some of the conductor accessories as used in distribution networks.

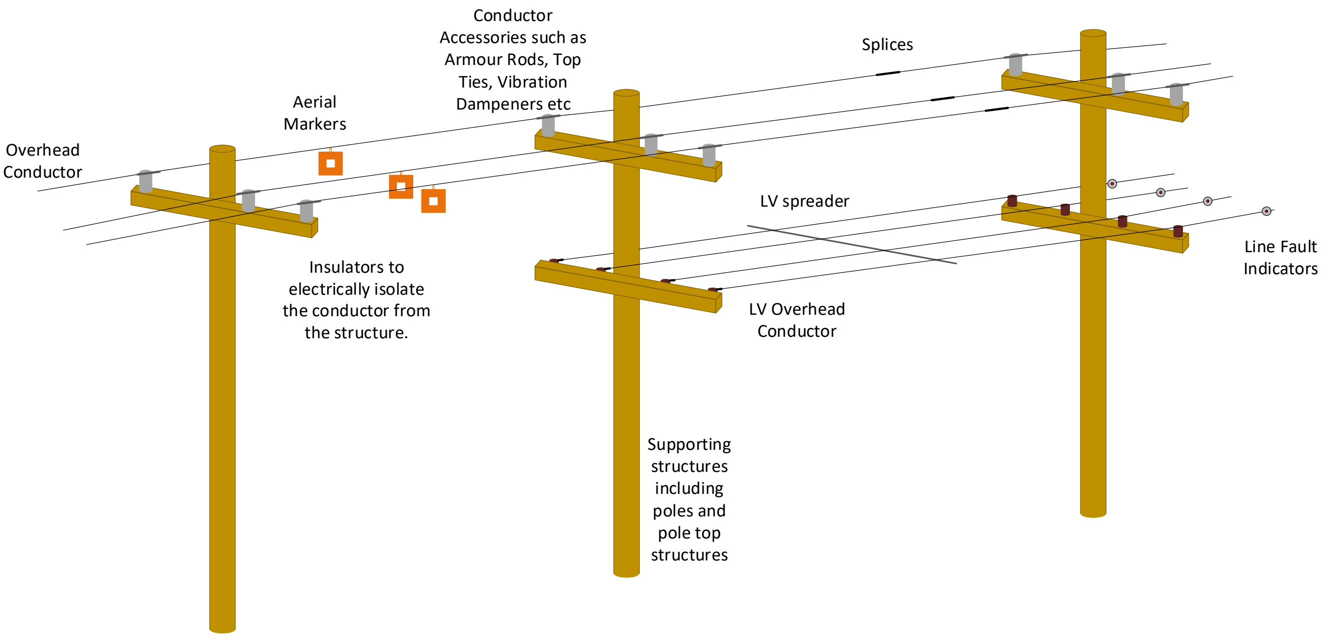

Figure 3: Example - Overhead Distribution Asset and Components

2.2 Asset Quantity and Physical Distribution

EQL operates at a wide variety of voltages including 132kV, 110kV, 66kV, 33kV, 22kV, 11kV and LV (<1kV). A breakdown of the EQL overhead conductor asset base by voltage designation is shown below in Table 3. Note that 66kV and 22kV voltage designations are present in the Ergon Energy Region only.

Overhead Conductor	Ergon Energy	Energex	Total
< = 1 kV	17,502	14,156	31,658
> 1 kV & < = 11 kV	35,101	17,611	52,712
> 11 kV & < = 22 kV ; SWER	62,151	41	62,192
> 11 kV & < = 22 kV ; Single-Ph	3,143	0	3,143
> 11 kV & < = 22 kV ; Multi-Ph	11,825	0	11,825
> 22 kV & < = 66 kV	12,060	2,120	14,180
> 66 kV & < = 132 kV	3,033	1,170	4,203
> 132 kV	0	0	0
Total Route Length (km)	144,815	35,098	179,913

Table 3: EQL Overhead Conductor Asset Population

Approximately 47% of overhead conductor assets are installed at distribution voltages less than or equal to 11kV. Around 34% of the overhead conductor population is installed as part of the single wire earth return (SWER) distribution network.

2.3 Asset Age Distribution

EQL derives its conductor age based on the pole installation date, as the installation date of conductors has not historically been recorded. This has proven to be an accurate representation where the original poles remain in-situ. Where pole replacement has occurred, the conductor age is derived from the oldest pole supporting that section of conductor. Age profiles for the overhead conductor asset base are shown below (Figures 4, Figure 5).

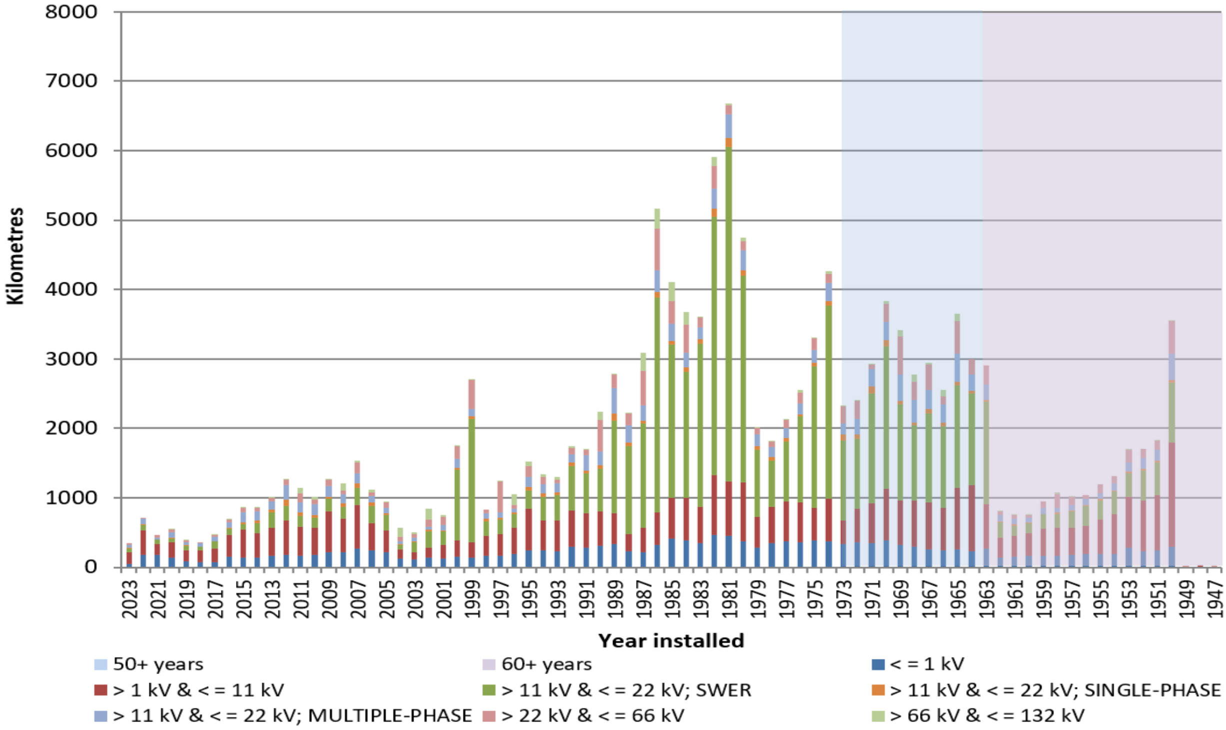

Figure 4: Ergon Energy Conductor Age Profile

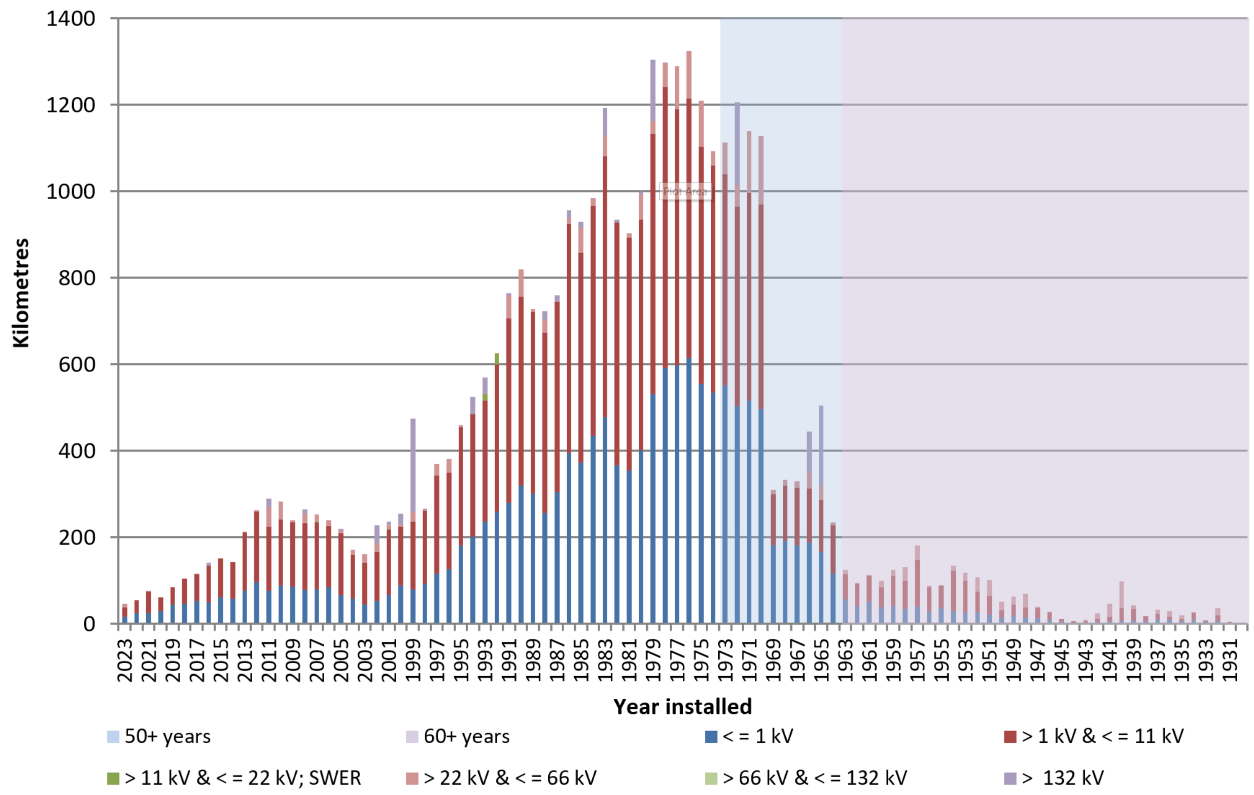

Figure 5: Energex Conductor Age Profile

2.4 Population Trends

EQL maintains a diverse asset population of overhead conductor types and sizes due to legacy organisations, the length of asset operational life, changes in period supply contracts, and advancement in conductor technology. Feeders built prior to the 1960's employed hard drawn copper conductors; however aluminium has become the preferred material due to its economic and weight advantages. Steel reinforced aluminium conductor is used for long spans due to its superior mechanical strength over aluminium or aluminium alloys.

Galvanised steel has historically been used for single wire rural electrification, as its low cost and high tensile strength allows for longer spans and use of fewer poles and pole-top hardware. Due to the geographically dispersed nature of rural communities, galvanised steel is the predominant conductor type currently installed on the network.

Figure 6 includes an approximate breakdown (route kms) of overhead conductor types installed on the EQL networks.

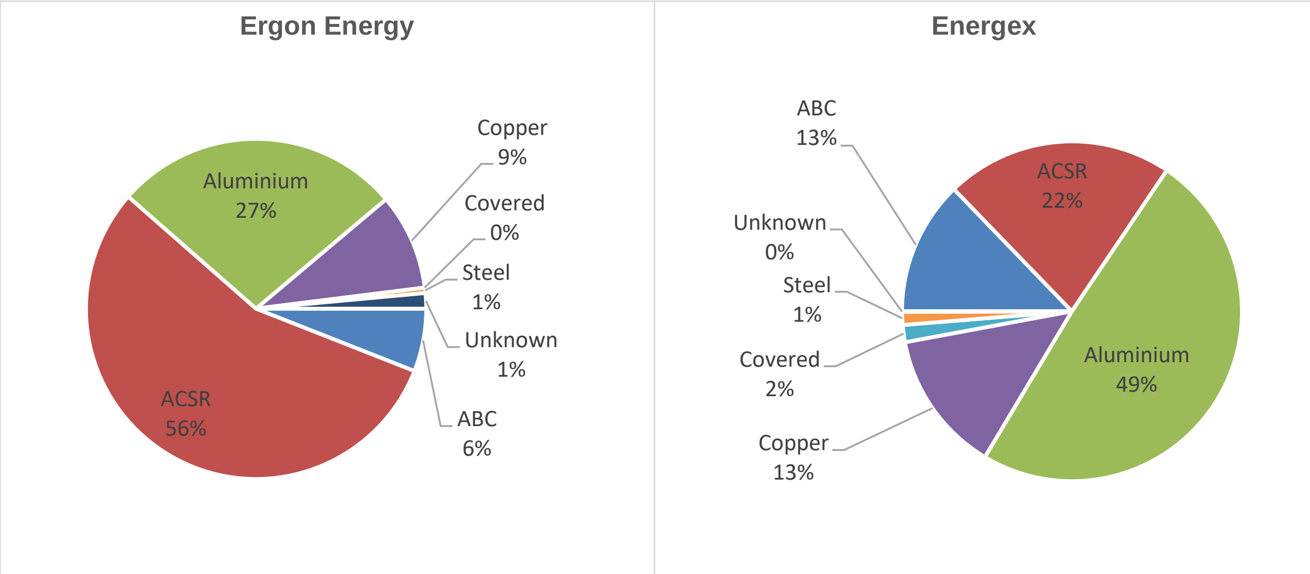

Figure 6: EQL Installed Overhead Conductor Population by Type

2.5 Asset Life Limiting Factors

The following table describes key factors influencing the condition of overhead conductor assets, the impacts of which have a significant bearing on the programs of work implemented to manage the asset lifecycle (Table 4).

Factor	Influence	Impact
Corrosion	Conductors are subject to deterioration in the presence of oxygen, dissimilar metals, and electrolytes. This is a significant issue at coastal locations.	Corrosion may result in a loss of material and increased resistance, which affects the mechanical and electrical characteristics of the conductor. The reduction in conductivity and strength influences the life of the conductor and leads to increased risk of fallen conductors leading to shock or electrocution of public or personnel, fire or damage to third party plant and equipment, or loss of livestock.
Fatigue	Cyclic stress at a localised point on the conductor weakens the material. Wind induced oscillations (gallop, Aeolian vibration, wake-induced) can introduce fatigue at conductor attachment points.	Uncontrolled vibrations can lead to broken conductor strands leading to a reduction in strength and effective diameter of the conductor. On ACSR, broken strands can lead to overheating and failure of the steel core. Fatigue leads to increased safety risk and third-party damage as above.
Annealing	Conductors operated at high temperatures (due to overloading or fault currents) and the accumulation of these effects over time leads to a permanent loss of tensile strength of the conductor.	Annealing leads to a reduction in tensile strength and ultimate failure of the conductor. Annealing leads to increased safety risk and third-party damage as above.
Creep	Creep is the non-elastic strain placed upon the conductor under tension, causing an increase in conductor length with time.	Conductor sag may increase and encroach on statutory clearance standards

Factor	Influence	Impact
Insulation damage	UV degradation, fire, vermin attack, or other mechanical damage of the insulation.	Exposed live conductor leading to increased risk of shock to public and personnel. Increased risk of corrosion and arcing, leading fallen conductors in bundled cable installations.
Lightning and clashing	Direct and indirect lightning strikes can fuse or damage conductor strands and introduce over voltages that may stress line components.	Mechanical damage to bare conductor, accessories, or the insulation of covered conductor.
Vegetation	Falling branches or trees may cause clashing and bring down live conductors. Vegetation may impact lines causing outages or damage.	Mechanical damage to bare conductor or the insulation of covered conductor.
Animals	Animals such as birds, bats, or possums may initiate arcing faults which may damage and bring down conductors.	Mechanical damage to bare conductor or the insulation of covered conductor

Table 4: EQL Overhead Conductor Life Limiting Factors

2.6 Asset Management Maturity

Based on the Asset Management Council's maturity models, EQL's level of asset management maturity in managing conductors is assessed at level 2 – reactive. EQL's level of asset maintenance maturity is assessed at level 2 – preventative based. These maturity stages are reflected in the lifecycle strategies detailed in Section 9.

3 Levels of Service

The following sections define the level of performance required from the asset class, measures used to determine the effectiveness of delivering corporate objectives, and any known or likely future changes in requirements.

3.1 Desired Levels of Service

This asset class is managed consistent with the corporate asset management policy to achieve all legislated obligations in the most cost-effective manner and is aligned with specifically defined corporate key performance measures.

Safety risks associated with this asset class will be eliminated so far as is reasonably practicable (SFAIRP), and if not able to be eliminated, will be mitigated SFAIRP. All other associated risks will be managed to as low as reasonably practicable (ALARP).

This asset class consists of a functionally alike population, differing in age, brand, technology, material, construction design, technical performance, purchase price, and maintenance requirements. The asset population will be managed consistently based upon common performance outcomes, with an implicit aim to achieve the intended and optimised life cycle costs contemplated for the asset class and application.

All inspection and maintenance activities will be performed consistent with manufacturers' advice, good engineering operating practice and historical performance, with the intent to achieve the longest practical asset life overall.

Life extension techniques will be applied where practical, consistent with overall legislative, risk, financial, and reliability expectations. Problematic assets such as very high maintenance or high safety risk assets in the population may be considered for early retirement.

Assets of this class are managed by population trends, inspected regularly, and allowed to operate as close as safely practical to end of life before replacement. End of asset life will be determined by reference to the benchmark standards defined in the Defect Classification Manuals and or Maintenance Acceptability Criteria. Replacement work practices will be optimised to achieve bulk replacement to maximise efficiency and minimise overall replacement cost and customer impact.

3.2 Legislative Requirements

EQL, and its subsidiary companies Ergon Energy and Energex, are deemed electricity entities. As such, these companies have a duty to comply with all current legislation, regulations, rules, and codes outlined in Section 1.1 of this AMP. For example, electricity entities must comply with the following:

- ***Electrical Safety Act 2002 (Qld)*** **s29**
  An electricity entity must ensure that its works are electrically safe and operated in an electrically safe manner. This includes the requirement that the electricity entity inspects, tests, and maintains the works.
- ***Electricity Regulation 2006 (Qld)***
  An electricity entity must, in accordance with recognised practice in the electricity industry, periodically inspect and maintain its works to ensure the works remain in good working order and condition.
- ***Electricity Safety Regulations 2013 (Qld)***
  General obligations related to safety of works of an electrical entity for this asset class outline specific obligations regarding clearances to ground and nearby structures, including vegetation clearing and management. Schedules 2 and 4 of the Regulations specify the distances required for exclusion zones and clearances. EQL is also required to notify the Electrical Safety Office in the event of any Serious Electrical Incident (SEI) or Dangerous Electrical Event (DEE).

Additionally, good industry design practice, including degradation mechanisms, is described in AS/NZS7000 Overhead Line Design Standard and previous versions of C (b) 1 – Guidelines for the Design and Maintenance of Distribution and Transmission Lines.

Vegetation growth within clearance spaces may impact the safe and effective operational performance of the overhead network with failure modes including:

- Vegetation occurring within arcing distance of an energised conductor, transferring electrical current to the ground and/or to persons near vegetation.
- Vegetation facilitating access, through climbing, to a bare electrical conductor.
- Vegetation in contact with the network, causing abrasion or other damage to the network, resulting in mechanical failure of the conductor.
- Vegetation impacting on the network through whole tree or branch failure, resulting in network damage or unsafe conditions.

However, in adherence with *Electricity Safety Regulations 2013 (Qld)*, EQL and its subsidiaries ensure general safety obligations are met and asset and power supply reliability maintained via an effective vegetation management program under *Vegetation Management Strategy (G001)*.

3.3 Performance Requirements

EQL has a strategic objective to ensure a safe, cost effective and reliable network for the community. Performance targets associated with this asset class, therefore, aim to reduce in-service failures to levels which deliver a safety risk outcome which is considered SFAIRP and as a minimum, maintains current reliability performance standards.

EQL has developed a suite of maintenance programs to identify, prioritise and remediate overhead conductor asset defects. Defects identified via inspection programs are classified and prioritised according to the EQL Lines Defect Classification Manual (LDCM). P1 and P2 defect categories relate to priority of repair, which effectively dictate whether normal planning processes are employed (P2), or more urgent repair works are initiated (P1). Additionally, classification of C3 aims to gather information to inform or create a “watching brief” on possible problematic asset conditions.

Unassisted failures occur where the programs in place to manage the assets do not identify and rectify an issue prior to the asset failing to perform its designed function. Failures that are the result of circumstances beyond the reasonable control of any practical management system are deemed Assisted Failures. Failures typically result in or expose the organisation and the community to risk and represent the point at which asset related risk changes from being proactively managed, to retrospectively mitigated. While there are no specific SEI or DEE targets, EQL is committed to reduce their occurrence in compliance with electrical safety obligations under relevant regulations.

The frequency and duration of outages are tracked and analysed to ensure ongoing compliance with minimum service standards defined by the Electricity Industry Code. Under the Service Target Performance Incentive Scheme (STPIS), EQL is provided with financial incentive to maintain and improve reliability performance.

3.4 Current Levels of Service

3.4.1 Safety Impact

Almost every conductor failure results in the energised conductor falling to some degree, and (with a small number of exceptions) can be considered a potential organisational and/or public safety risk. Many (but not all) high voltage conductor failures are automatically detected, leading to proactive de-energisation. Most low voltage conductor failures are not automatically detected and typically involve a community member advising of the situation in the first instance. In contrast, only some conductor accessory failures e.g., splices, result in falling conductors. Nearly all conductor failures and some accessory failures result in a loss of supply or voltage quality issue.

EQL records significant material safety events that occur when unassisted conductor failures have resulted in an SEI involving significant electrical shock leading to hospitalisation or fatality. Most of these events involve root cause conditions that are beyond the ability of any maintenance management system to prevent (e.g., vehicle accident or crane lifting into conductor). Analytics on these events demonstrate the occurrence of SEI's continue to improve (Figure 7, Figure 8).

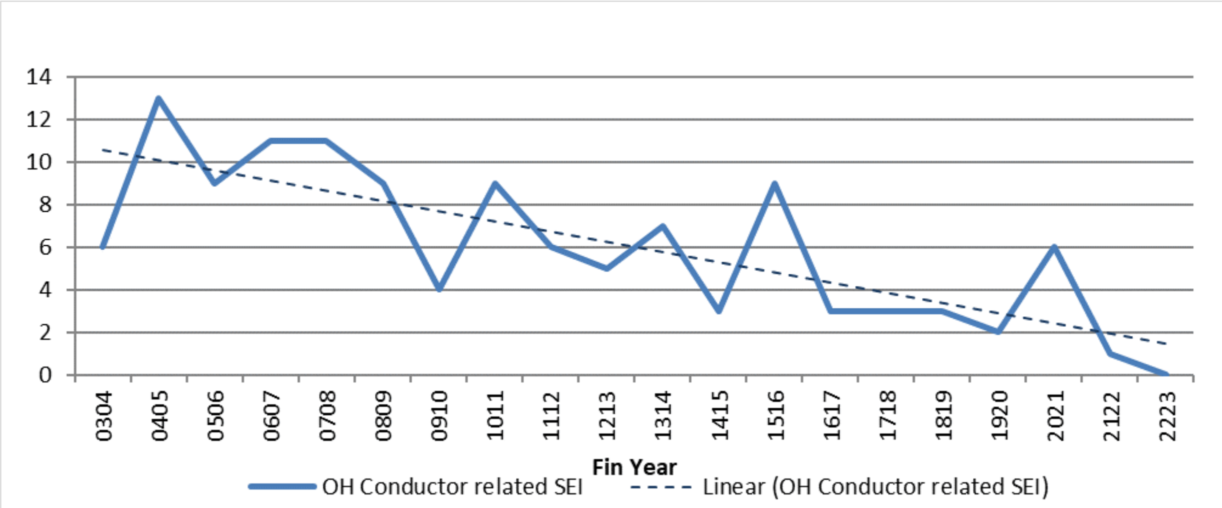

Figure 7: Ergon Conductor Related SEIs

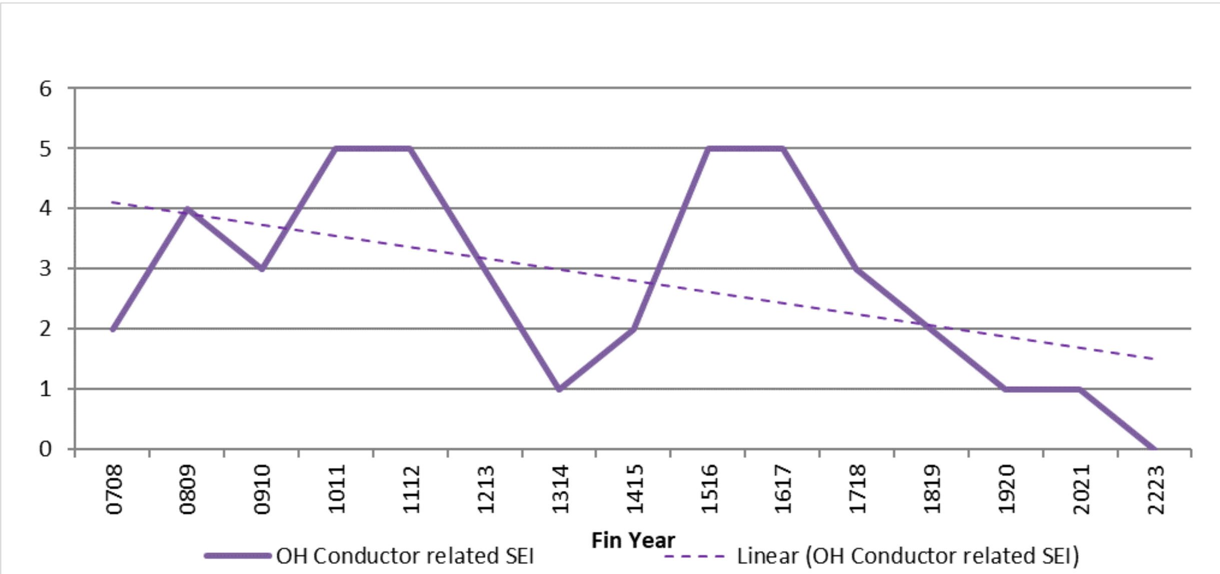

Figure 8: Energex Conductor Related SEIs

3.4.2 Asset Reliability

EQL conductor performance is affected by seasonal weather variations; unassisted failures increase during warmer months and decrease during cooler periods.

Unassisted Conductor Failures

FY18-FY23 analytics for annual unassisted failures show a decreasing overall trend for Ergon Energy, while an initial steady decline in Energex unassisted failures to FY21 culminated in an increase to 306 for FY23 (Figure 9). With 5-year predicted failure rates of 752 for Ergon Energy and 196 for Energex, FY23 figures report 628 and 306 failure occurrences respectively indicating a below average result for Ergon Energy whilst Energex exceeded the average. Ergon Energy normalised failure rates for FY23 detail 4.4 failures per 1,000km, while Energex report 8.7 failures per 1,000km. These figures reflect effective maintenance and/or replacement programs within Ergon Energy over the last twelve months. However, the 6-year high shown for Energex warrants further detailed investigation. Analysis is necessary to ascertain why a 61% increase in unassisted failures on the previous year has occurred, and how to mitigate and reduce the number moving forward.

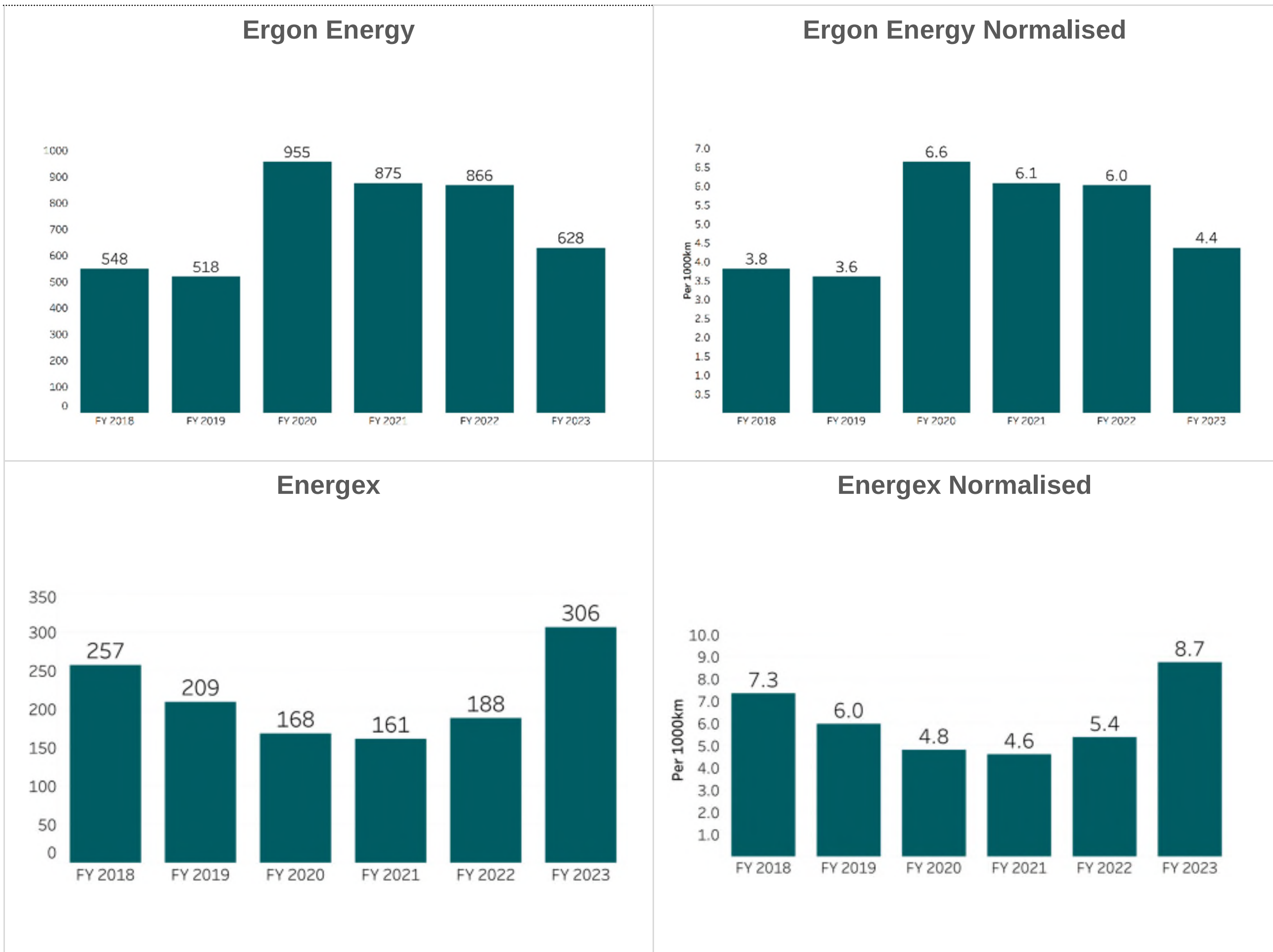

Figure 9: EQL Overhead Conductor Unassisted Failures + Normalised (per 1,000km)

Consistent leading failure modes for Ergon Energy assets include corrosion, vibration, and age, whilst leading failure modes for Energex include fatigue, unknown, and other (Table 5, Table 6).

Msss Cause Description	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Age	279	246	215	233	225	136
Corrosion	179	197	197	223	225	209
Vibration	189	152	141	140	129	151
Fatigue	121	121	126	123	116	86
Incorrect Installation	72	65	88	93	89	

Table 5: Ergon Energy Top 5 Unassisted Failure Breakdowns

Cause	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Unknown	36	39	60	36	40	88
Fatigue	59	51	38	43	45	53
Other	54	42		23	31	89
Corrosion	47	35	38	24	39	25
Clashing	19	22	8	12	7	19

Table 6: Energex Top 5 Unassisted Failure Breakdowns

Conductor Type Failure Rates

The worst performing Ergon Energy conductor types for FY23 normalised values were HV ABC, LV ABC, and bare copper conductor; Energex reports bare HV covered conductor, LV ABC, and bare steel conductor for the same (Table 7, Table 8).

Ergon Energy – Normalised		
Conductor Type	Total Length km	FY2023 Failures per 1000 km
Bare Al. Conductor	15012.26	2.26
Bare Cu Conductor	7661.98	6.66
Bare Steel Conductor	61073.28	1.33
HV ABC	0.84	3585.74
LV ABC	4979.80	13.45
HV Covered Conductor	3.69	0
LV Covered Conductor	435.73	2.29
Bare ACSR Conductor	46499.08	0.39
Bare Al. Alloy Conductor	7916.11	1.01
Bare Conductor, Unknown	1232.92	-

Table 7: Ergon Energy Overhead Conductor Type Failure Rates Normalised

Energex – Normalised		
Conductor Type	Total Length km	FY2023 Failures per 1000 km
Bare Al. Conductor	17134.82	3.33
Bare Cu Conductor	4771.85	0.63
Bare Steel Conductor	434.85	13.80
HV ABC	44.00	-
LV ABC	4465.48	4.03
HV Covered Conductor	571.17	5.25
LV Covered Conductor	2.11	0
Bare ACSR Conductor	7653.91	1.44
Bare Al. Alloy Conductor	221.49	-
Bare Conductor, Unknown	20.74	-

Table 8: Energex Overhead Conductor Type Failure Rates Normalised

It should be noted that Ergon Energy HV ABC conductor total asset length is 0.84km. Additionally, a significant portion (43%) of the Ergon Energy rural network is comprised of SWER systems and not subject to many of the failure modes that affect the performance of conductors in an urban environment e.g., coastal corrosion, high loading, high fault currents, or conductor clashing.

Conductor Replacements

To address the significant volume of conductors considered 'end of life' remaining in the EQL networks, 2023 conductor replacements were 675kms (0.38% of total conductors), consistent with forecast recommendations suggested by REPEX models (Figure 10, Figure 11). Most of this replacement has targeted small copper and problematic conductors. The replacement rate is expected to increase due to the volume of aged conductors, and substantially change the medium-term failure rates.

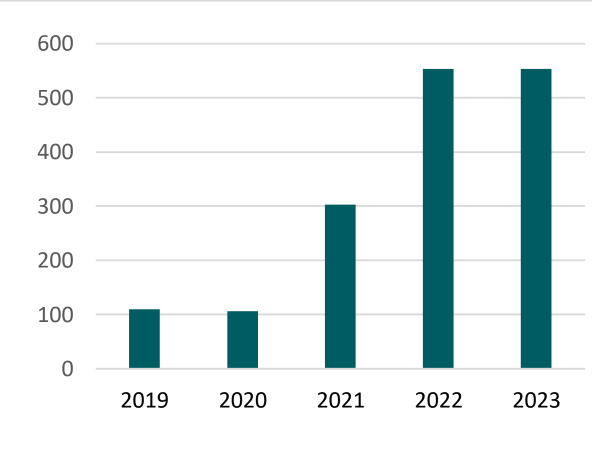

Figure 10: Ergon Energy Overhead Conductor Replacement History (kms)[1]

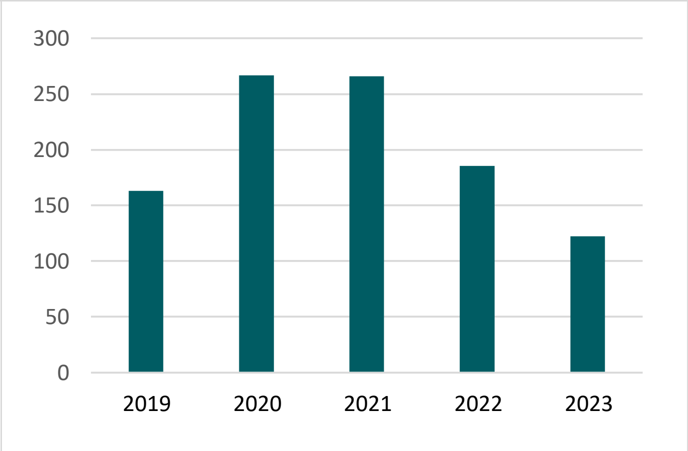

Figure 11: Energex Overhead Conductor Replacement History (kms)[2]

Ground and Structure Clearance

Conductor clearance to ground and clearance to structure tolerances are strictly regulated. A significant number of clearance issues have been documented and are actively being eliminated. Section 6.2 expands on this issue in more detail.

Defect Volumes

EQL defects are allocated an expected rectification completion period utilising the following defect categories to assign priority:

- P0 – Within 1 day/7days
- P1 – Within 30 days
- P2 – Within 9 months

[1] This data is derived from published RIN data.
[2] This data is derived from published RIN data.

Ergon Energy

Ergon Energy – Defect Priorities

FY18-FY23 Ergon Energy defect volume rates show a decreasing trend in both P1 and P2 defects, with total defects for FY23 returning a below-average result against the previous 5-year average (Figure 12). FY23 reported an increase of P0 defects resulting from CTS and CTG defects. The FY23 P1-P2 defect ratio presents a 5 year low, demonstrating the effectiveness of proactive maintenance and the conductor replacement programs.

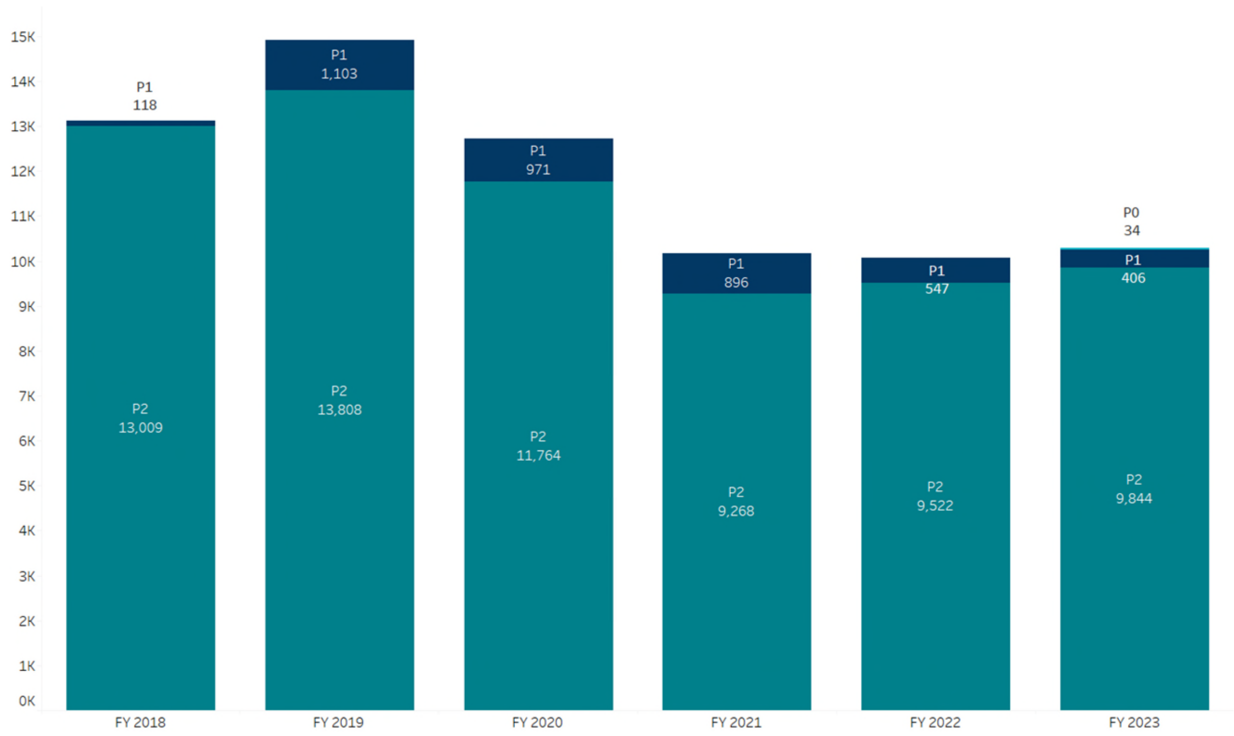

Figure 12: Ergon Energy Defect Volumes

Normalised FY18-FY23 EQL defect volumes show a decreasing trend with minimal P1 defects, and a consistent reduction in P2 defects per 1,000km (Figure 13).

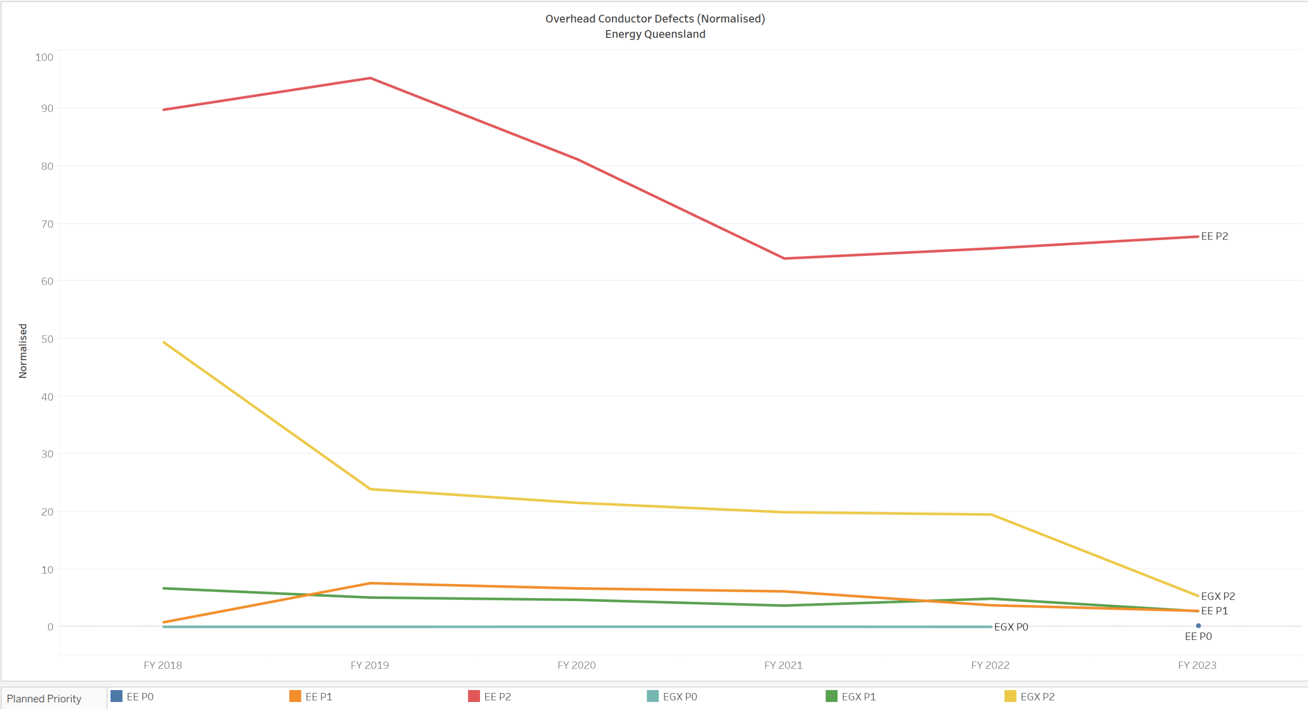

Figure 13: EQL Overhead Conductor Defects Normalised by Asset Population

Ergon Energy defects data indicates contributing components of conductors (leading component), clamp/connectors, dampers, splice and dead end, and others, informing the overall FY18-FY23 reporting period, of which conductors and overhead accessories defect figures fluctuate accordingly (Figure 14). Key factors impacting Ergon Energy defects can be contributed to insulation deterioration (leading factor), corrosion, and incorrect use (Figure 15). Most corrosion defects were categorised P2, and mainly associated with dead-ends, steel conductors, and clamps.

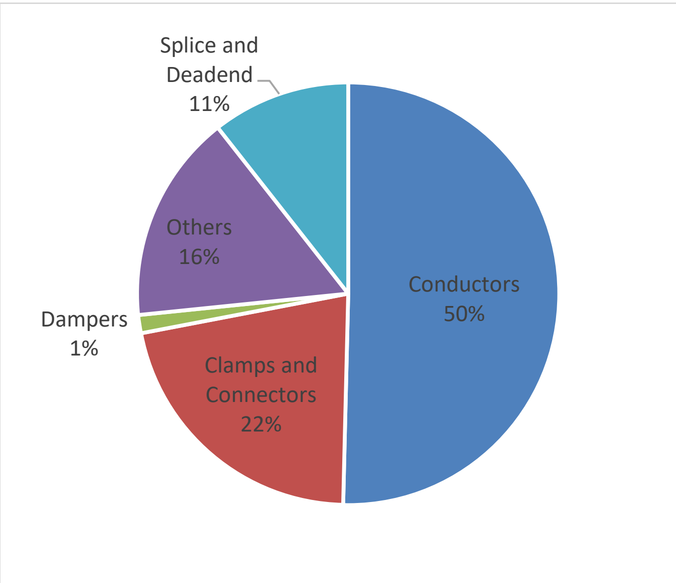

Figure 14: Ergon Energy Defect Component Breakdown

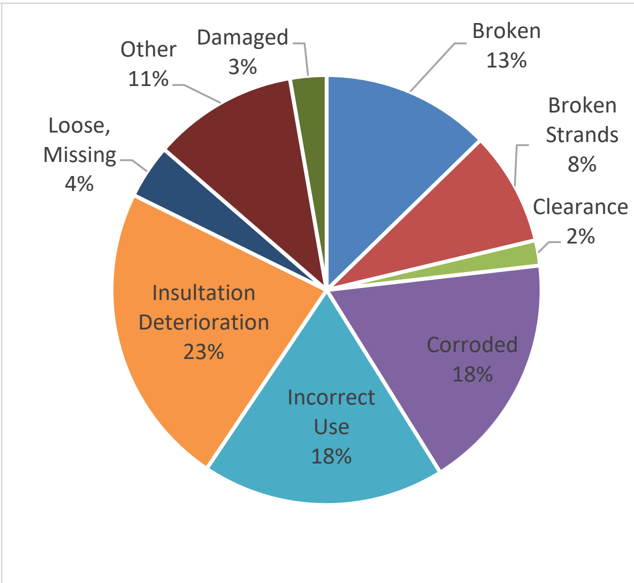

Figure 15: Ergon Energy Defect Factors

Most conductor defects were categorised P2, and mainly associated with aluminium alloys, steel, and copper types (Figure 16). As the primary failure factor, insulation deterioration has been instrumental in aluminium alloys conductors reporting the highest defect count. Incorrect use of dual clamp stirrups was the leading defect for Ergon Energy overhead accessories. Similarly, normalised over 1000km, HV CCT conductors maintain the highest defect count due to the small population size followed by LV CCT, and HV ABC (Figure 17) (Refer 9.2).

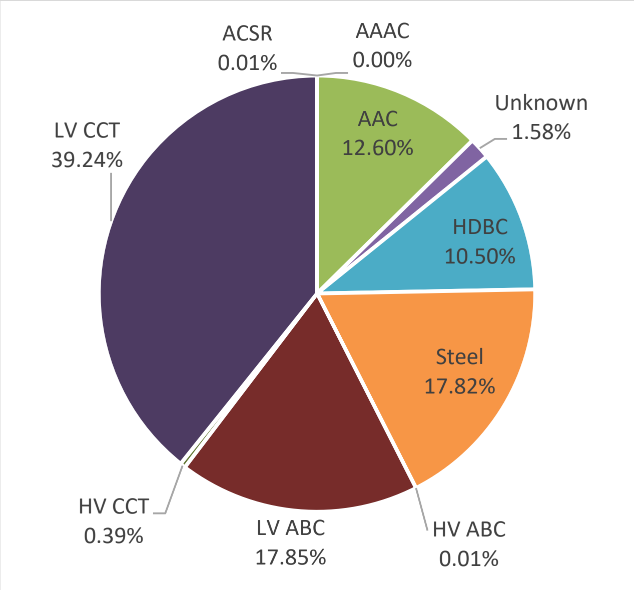

Figure 16: Ergon Energy Conductor Defect Breakdown

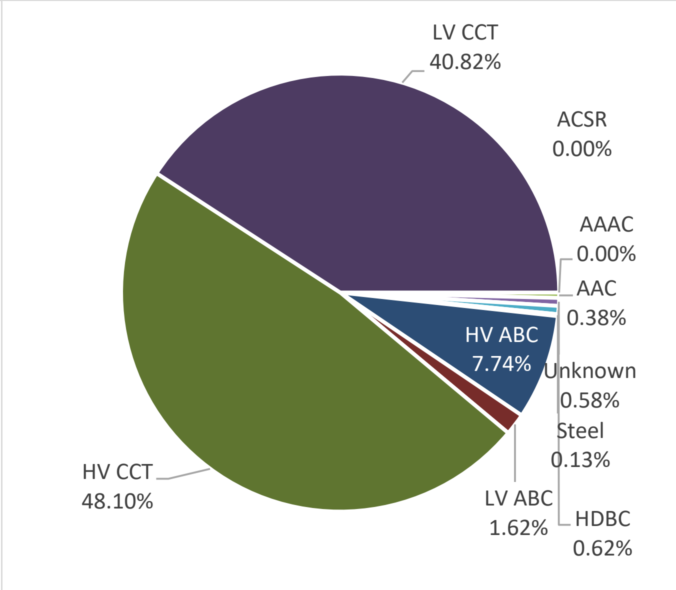

Figure 17: Ergon Energy Conductor Defect Breakdown Normalised

Energex

Energex – Defect Priorities

There is a difference between Ergon Energy and the Maintenance Strategy Support System (MSSS), therefore a defect analysis cannot be achieved due to insufficient Energex data.

An analysis on corrective maintenance was completed to identify problematic conductors and overhead accessories. From FY19 to FY23, defect numbers trended downwards, the majority of which were related to conductors, with FY18 displaying the highest number of conductor and accessory related defects (Figure 18, Figure 19).

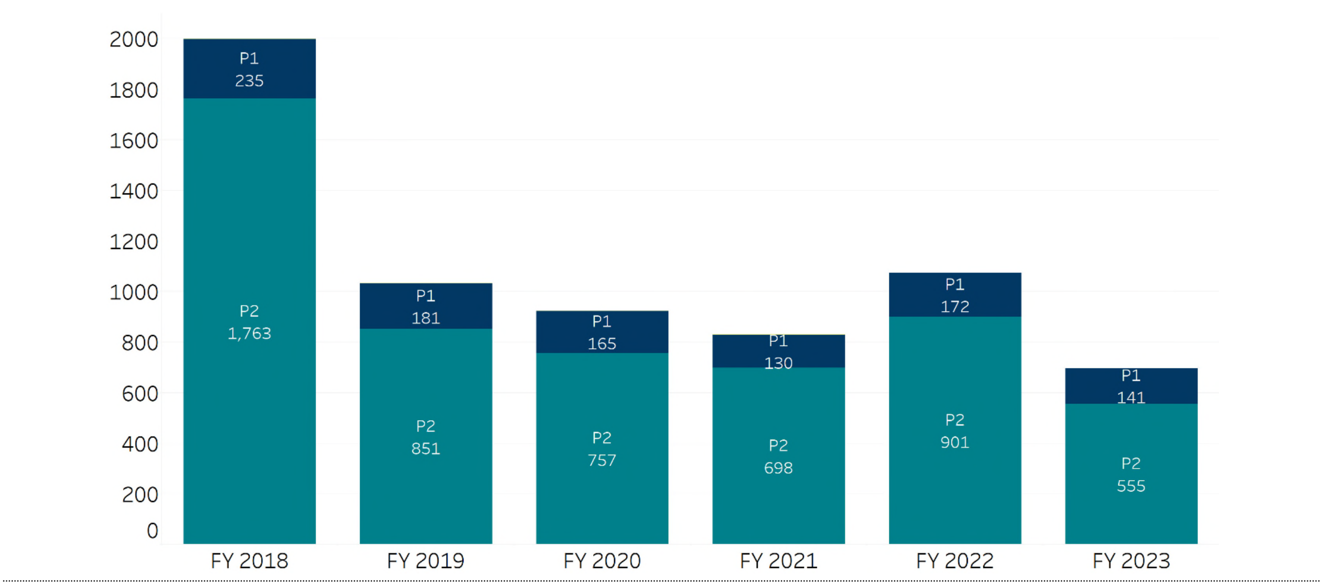

Figure 18: Energex Overhead Conductor Defect Volume

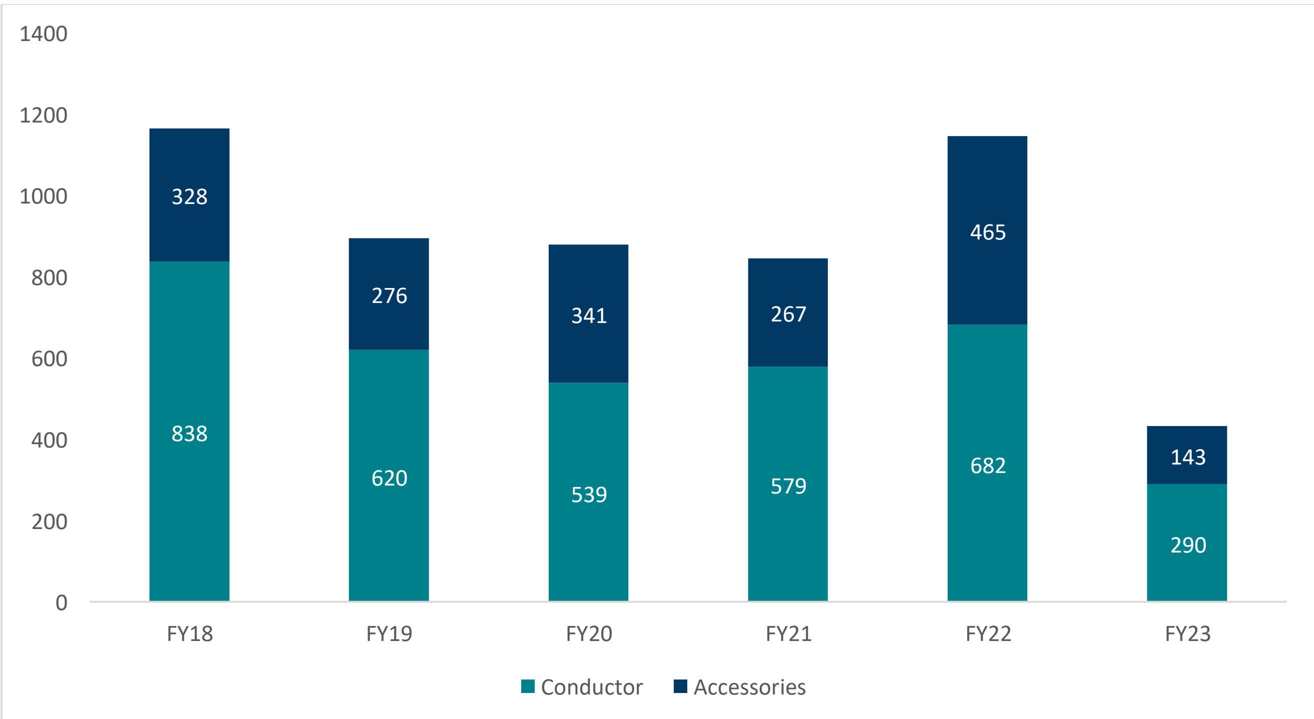

Figure 19: Energex Overhead Conductor vs Accessory Defect Volume

Energex – Unassisted Failures

FY18-FY23 Energex unassisted failures data shows major contributing components of conductor cable (50%), hardware (31%), and bridge (15%) (Figure 20). LV and HV bridge conductors, and LV hardware splice reported the highest breakdowns of voltage, bridge, and accessory data (Figure 21). Key factors impacting Energex voltage bridge failures can be contributed to fatigue, corrosion, and clashing (Figure 22).

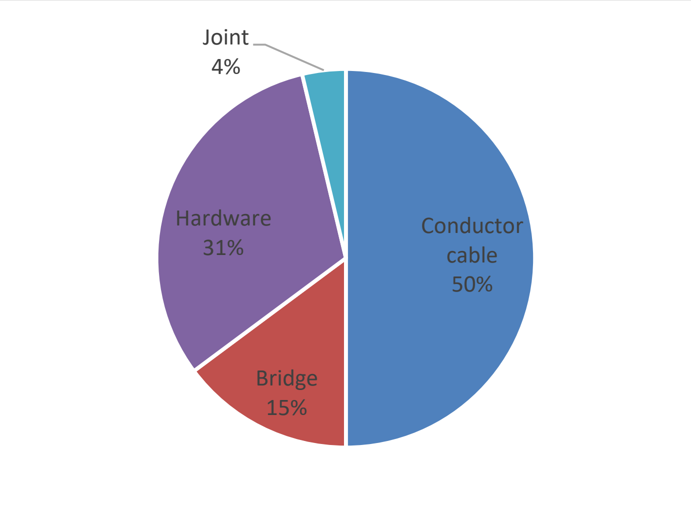

Figure 20: Energex Unassisted Failure Overhead Major Component Breakdown

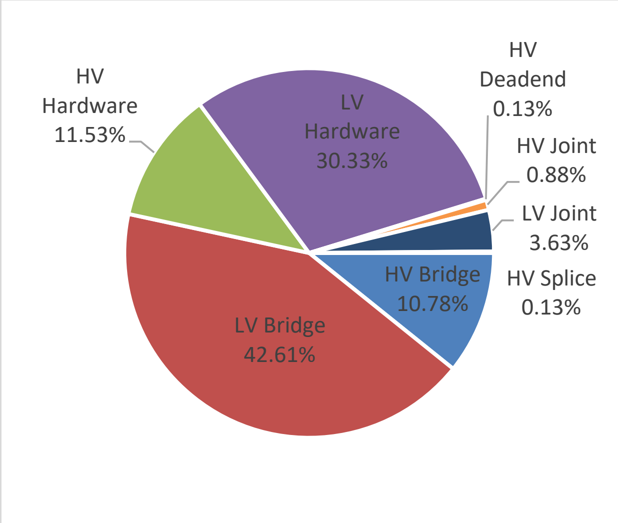

Figure 21: Energex Unassisted Failure Voltage, Bridge and Accessory Component Breakdown

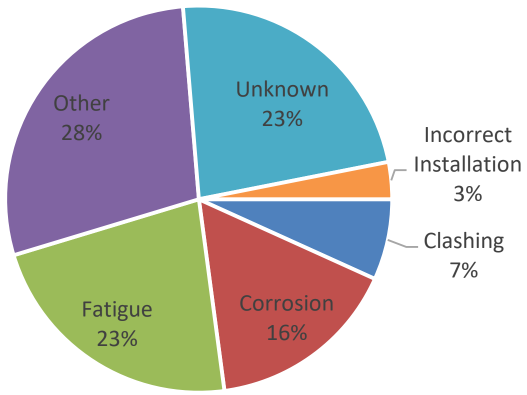

Figure 22: Energex Unassisted Failure Factors

3.5 Risk Valuation

Ergon Energy is committed to adopting an economic, customer value-based approach when it comes to ensuring the safety and reliability of the network. To substantiate the advantages of this approach for the community and businesses over the modelling period, we have employed Net Present Value (NPV) modelling. This commitment is in line with their efforts to minimise the impact on customer prices.

A cost benefit analysis has been conducted to confirm that the conductor replacements are prudent capital investments.

4 Asset Related Corporate Risk

As outlined in Section 3.2, EQL and its subsidiaries have a duty to ensure its assets are electrically safe. This safety duty requires EQL to eliminate safety related risks SFAIRP, and if not able to be eliminated, they are to be mitigated SFAIRP. Risks in all other categories are managed to levels ALARP.

EQL undertakes several actions to eliminate or mitigate the risks SFAIRP, such as inspections and maintenance, as shown in the Threat Barrier Diagram (Figure 23). This safety duty results in most inspection, maintenance and replacement works and expenditure related to overhead conductors being entirely focused upon preventing and mitigating failures.

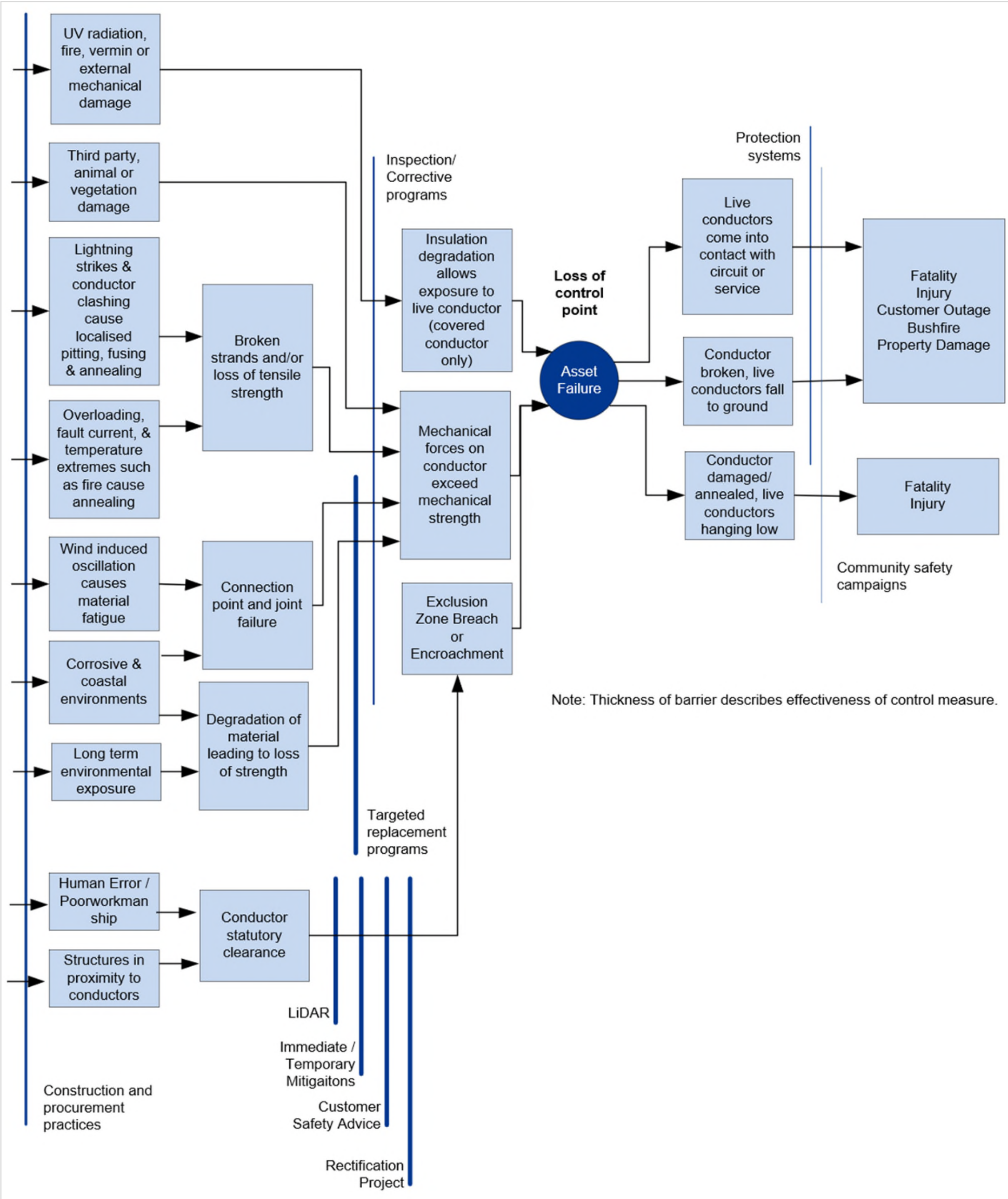

Figure 23: Overhead Conductor Threat Barrier Diagram

5 Health, Safety & Environment

While there is no scientific evidence supporting a hypothesis that electromagnetic fields (EMF) are harmful to human health, EQL adopts a policy of prudent avoidance for the design, construction, and operation of its facilities with regards to EMF. Based on current industry guidelines and best practice, overhead conductors are configured and constructed with specific clearances to minimise occupational and public exposure to EMF.

6 Current Issues

The following sections outline current issues that have been identified as having the potential to impact EQL's ability to meet corporate objectives.

6.1 Accessory Defects – Ergon Energy

FY18-FY23 Ergon Energy failures and defect data for overhead conductors and accessories has been evaluated to ascertain potential accessory related issues. Analytics utilised P1 and P2 defects revealing overhead accessories account for approximately 50-70% of defects across the FY18 and FY19 period, predominantly P2 (Figure 24). However, both overhead conductors and accessories display a consistent decreasing volume trend. Similarly, a decreasing trend can be seen for both overhead conductor and accessory unassisted failures, with accessories accounting for 40-58% of all unassisted failures during this period (Figure 25).

Continuous focus should be applied to identifying and resolving defects through business-as-usual (BAU) refinement of defect categories assigned to conductors as critical assets. There is no substantial cause for concern around Ergon Energy accessory related defects and unassisted failures.

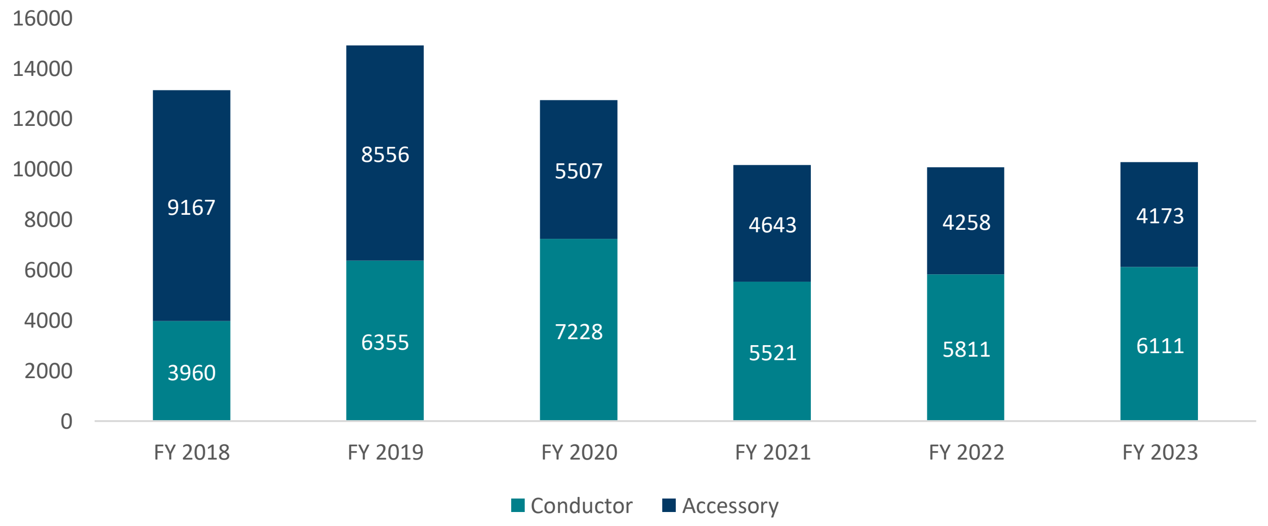

Figure 24: Ergon Energy Defect Volume Overhead Conductor vs Accessory

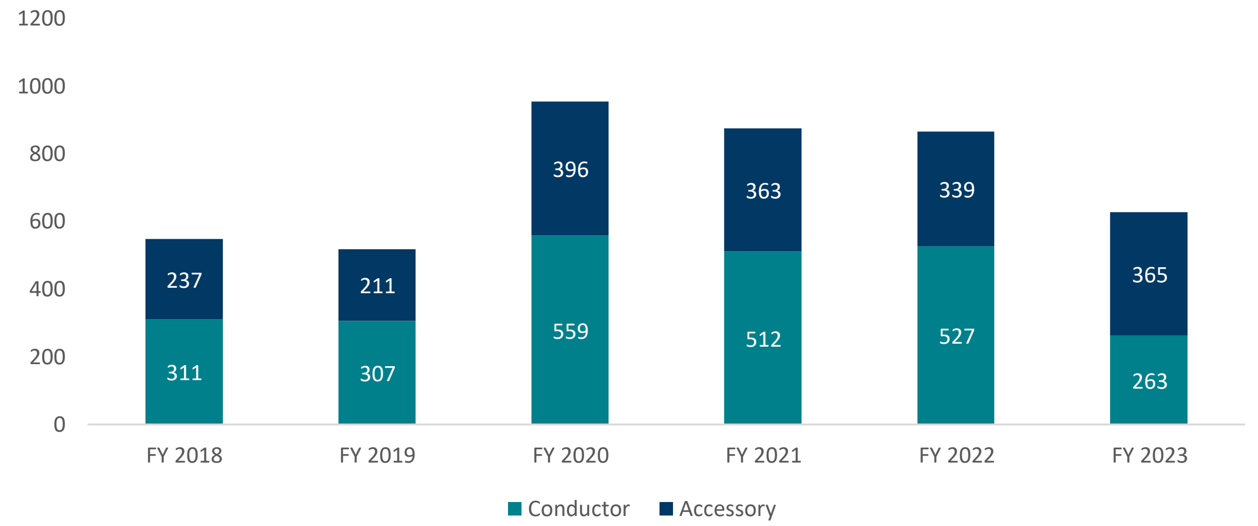

Figure 25: Ergon Energy Unassisted Failures Overhead Conductor vs Accessory

6.2 Conductor Clearance to Ground (CTG) and Clearance to Structure (CTS) Programs

Non-conformance with statutory conductor clearance requirements has traditionally been identified manually through ground-based inspection and rectified using the P1/P2 defect process under routine EQL maintenance programs. More recently, EQL has embraced the introduction of light detection and ranging (LiDAR) technology and three-dimensional network/environment modelling, initially for vegetation management. This has provided the business with the ability to efficiently identify statutory clearance impingement across the network with greater accuracy and in shorter timeframes than traditional inspection methods. It has resulted in a significant increase in the number of potential clearance non-conformances triggering rectification requirements. EQL undertakes risk assessments to evaluate, prioritise and address each instance, ensuring ongoing compliance with regulatory obligations.

Clearance defects are influenced by third party land use in the vicinity of assets. EQL may opt to move/augment these assets or place responsibility on the customer to rectify the situation, whichever is appropriate. EQL continues to engage with concerned parties (land and property owners, business operators, government agencies and building approval bodies) to increase awareness of obligations.

Remediation of clearance to ground, and clearance to structure defects initially identified via LiDAR based technology was targeted for completion in late 2019, however, this intent has proven to be unachievable. While the need to remediate CTG/CTS was recognised during development of this AMP (V1) in 2018, no specific asset management action was recorded.

At the time of development of this AMP, remediation is expected to be ongoing through, and likely past, the 2025-30 AER regulatory period. The business reports quarterly updates to the Electrical Safety Office regarding total completed and outstanding remediation works. Dedicated Network Asset Maintenance plans manage CTS and CTG programs (MS10, CA62 and CA64).

6.3 Copper Replacement Programs

Legacy line assets installed prior to the 1960s were constructed using HDBC conductor. HDBC conductor with diameters of 7/0.104 and smaller have been identified as susceptible to mechanical failure due to fault current exposure (annealing) or loss of material (corrosion/scaling). EQL has commenced proactive conductor replacement programs to remove high risk, small diameter HDBC conductor from the networks. EQL regions are at different stages in these programs with significant populations of HDBC conductor remaining in the Ergon Energy networks.

The replacement of 7/0.064 has been completed in the Energex Network and focus placed on 7/0.080 in the Energex reconductoring program. However, Ergon Energy retains approximately 6,000km of small diameter HDBC in service. The program to remove low voltage small diameter HDBC, which is mostly sized 7/0.064 and smaller, from Ergon Energy networks is anticipated to progress through to FY27. Targeted replacement of high voltage 7/0.064 in the Ergon Energy networks will follow, and be ongoing through and likely past, the 2025-30 AER regulatory period.

The required annual volume of copper conductor replacement required has been significantly increased in future regulatory periods to manage the risk of aged HDBC sized 7/0.104 and smaller in the Ergon Energy networks.

6.4 Bushfire Mitigation Strategies

EQL has implemented bushfire risk management plans for the overall bushfire mitigation strategy. To mitigate bushfire risk, maintenance strategies such as ground and aerial asset inspections have been maintained in addition to the following:

- Implementation of technology such as LiDAR to identify clearance issues to ground and structures.
- Thermal surveying to identify potential overheating of the overhead.
- Privately owned energy line inspections to ensure customer poles and services are in a serviceable condition.
- Defect remediation within the specified timeline in accordance with Defect Classification Manual.
- Vegetation management to maintain adequate clearance to overhead line equipment, reducing the potential to cause a short circuit fault.
- Installation of cover conductor thick in high-risk vegetation areas to reduce the potential faults.

EQL is actively removing problematic conductor types such as aging small copper conductors. The reconductoring program is expected to reduce conductor failure quantities and reduce bushfire risk. Investigation of new technology such as the early fault detection trials on SWER powerlines will allow the business to identify defects in rural areas promptly.

7 Emerging Issues

The following sections outline emerging issues which have been identified as having the potential to impact on EQL's ability to meet corporate objectives in the future.

7.1 3/12 (3/2.75mm) Galvanised Steel

SC/GZ is the predominant conductor material installed on the EQL network with an asset population of approximately 62,000 km (34% of the total asset base). The relatively high tensile strength of steel allows for long spans and has therefore proven an economic material for use in lightly loaded single and multi-wire rural electrification. It has also been used historically as a low-cost material for overhead earth wire.

SC/GZ conductor exhibits poor performance in coastal and polluted environments. To address this failure mode, EQL has modified its design standards to install SC/AC conductor on new steel lines installed in proximity to coastal areas. Steel conductor has been targeted for removal in Energex urban locations due to thermal limitations under high fault currents.

In Ergon Energy, most of these conductors installed in non-coastal locations are part of the SWER network. SWER conductors are typically installed in non-corrosive environments, are lightly loaded, and not subject to high fault currents, conductor clashing, or other factors that may significantly affect the performance of conductors in an urban environment.

In the Energex network, corrosion of SC/GZ conductors and subsequent elevated risk of failure has been observed at approximately 55 years into the asset lifecycle, though it is anticipated that most rural galvanised steel conductors will perform well beyond this age. Figure 9 and Table 7 highlight the actual failure rates of various broad-based conductor types in Ergon Energy networks in FY23. With an overall failure rate of 2.74 defects per 1000kms (excluding HV ABC), SC/GZ performance is better than other conductor types, notably copper conductor, and LV ABC. However, considering the volume, defects (Figure 26) and age of SC/GZ, replacement volumes will need to be addressed. A watching brief on performance remains essential.

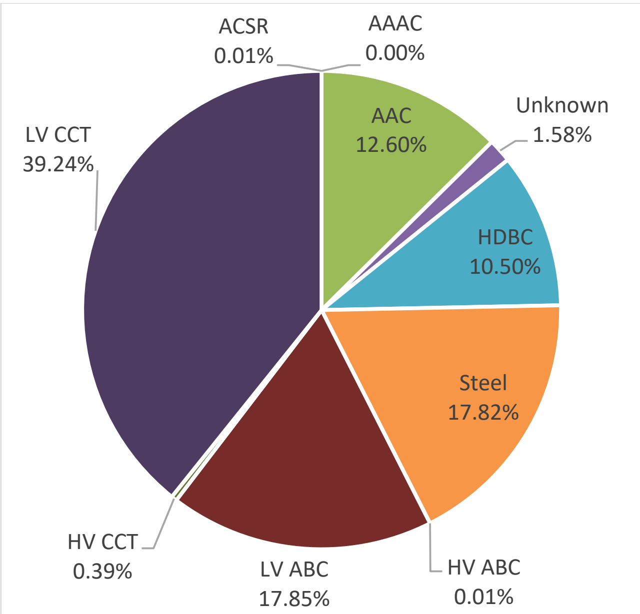

Figure 26: Ergon Energy Overhead Conductor Defect Breakdown

7.2 Aluminium Conductor, Steel Reinforced (ACSR) Conductor

EQL has a significant population of ACSR conductor installed on the network; Ergon Energy employs around 46,499 kms. This conductor typically has a galvanised steel core and is used most frequently at sub-transmission, transmission, and on long spans in rural networks.

The steel core of ACSR conductor is susceptible to mechanical failure due to both environmental and galvanic corrosion once the galvanising layer is lost. Grease is now commonly applied during manufacture to retard galvanic corrosion. This is due to the dissimilar metal construction of steel core and aluminium strands; however, it may not be present in all ACSR conductors in the population. Inconsistent application of grease by the manufacturer or break down over time can lead to localised corrosion, directly affecting the mechanical strength.

Table 7 highlights the actual failure rates of various broad-based conductor types in Ergon Energy networks in FY23. ACSR conductors make up approximately 32% of all Ergon Energy conductors (by distance) and have a failure rate of approximately 0.39 failures per 1000 km, which is significantly lower than most other conductor types. Renewal of Ergon Energy ACSR conductors should be a lower priority compared to renewal of other conductor types, e.g., LV ABC and Copper. Performance will continue to be monitored as BAU.

7.3 Smooth Body ACSR Conductor

There is a small volume smooth body ACSR conductor installed in Ergon Energy networks. This type of conductor, constructed to a Canadian standard, is not common globally, and has a specific application (to reduce wind loading). It is costly to maintain, and appropriate accessories are difficult to obtain limiting its widespread use.

The availability of replacement conductor and accessories has been identified as a risk to the network although with only limited quantities installed, further investigation is required to determine if a replacement strategy is warranted.

Consultation with field staff has revealed adoption and employment of standard ACSR fittings and accessories, and overall reliable performance outcomes in general. Table 7 highlights that the failure rate for all ACSR types is relatively low, providing support for this approach.

7.4 Low Voltage Aerial Bundled Cable (LV ABC)

FY18-FY23 analytics indicate LV ABC places within the top 3 worst performing conductor types for unassisted and normalised failures in Ergon Energy networks for this period (Figure 27). The volume of LV ABC unassisted failures occurring annually is constant, with most attributed to deterioration of insulation (Table 9); year-on-year data is consistent with the overall averages represented. A similar result is demonstrated for FY23 failure rates per 1,000km (Table 7).

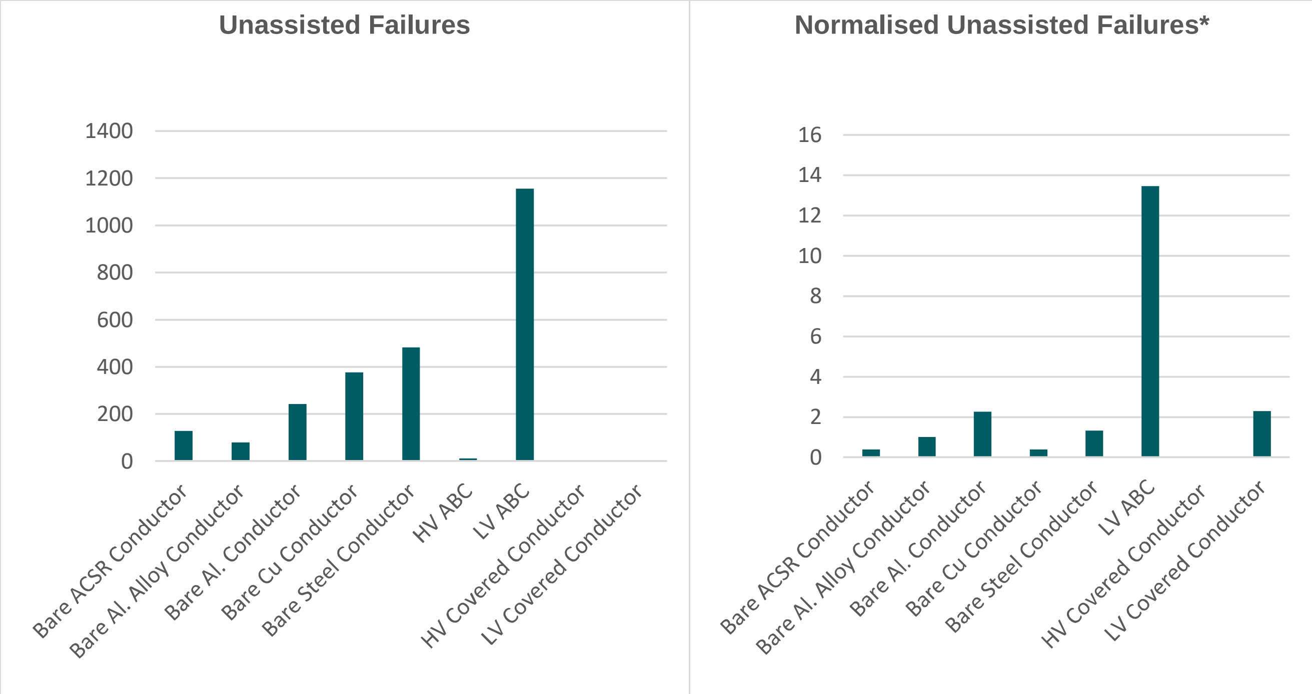

Figure 27: Ergon Energy Overhead Conductor Unassisted Failure + Normalised without HV ABC

** HV ABC (0.83km population size) has been removed from normalised analytics to mitigate inflated representation.*

Issue	Prevalence
Deteriorated fittings	16.93%
Deteriorated insulation	78.85%
Clearance issues	2.23%
No damage	1.95%
Out of Sag	0.02%
Short Circuit	0.02%
Total	**100.0%**

Table 9: Ergon Energy LV ABC Defect Type Prevalence

Queensland legislation differentiates LV ABC from other conductor types with respect to clearance obligations because of its insulation. LV ABC clearances (to ground, to cultivation, to structure) are effectively defined by EQL. Use of LV ABC allows reduced clearances (compared to other conductor types) without compromising community safety. This allows cost-effective construction in special situations and community priorities (e.g., traversing through sensitive vegetation, past cultural heritage sites, past existing structures etc.). Deteriorated insulation defects merit attention and remediation considering the normalisation rate.

8 Improvements and Innovation

The following sections outline any improvements or innovations to asset management strategies relevant to this asset class being investigated by EQL.

8.1 ENA Overhead Conductor Condition Monitoring

Energy Networks Australia (ENA) is the peak national body representing gas distribution and electricity transmission and distribution businesses throughout Australia. ENA has acknowledged that conductor populations are ageing globally, and despite technology advancements, there has been little change in cost effective methods for monitoring the condition of conductor assets. During FY20 and FY21, ENA investigated reliable and cost-effective methods to assess the likelihood of a conductor failure. Their conclusions were to develop a bespoke Health Index Model and a recommendation to use drones for inspection. To date, drone inspection methods have proven uneconomical for the large distances involved. CASA regulations effectively require direct human flight supervision. EQL is an active member of ENA and will continue to participate in and support similar ENA projects whenever they arise.

8.2 Dynamic Ratings

Dynamic conductor ratings are being explored on specific feeders to enable better utilisation of conductor assets. In addition to the operational advantages, the introduction of dynamic ratings would also allow for real time awareness of statutory clearance requirements, and improved modelling of condition-based failure modes on critical feeders.

8.3 ACSR Corrosion Detection

Due to the concentric construction of ACSR, corrosion of the steel core is difficult to assess by visual inspection. Commercial, non-destructive devices are available that can estimate the remaining thickness of the zinc or aluminium coating on the steel core wire of ACSR conductors, and therefore provide an indication of remaining life. As this technology is still in its infancy, there are concerns over the accuracy of the results.

8.4 Future Technologies to Deliver Inspection Capability

Emerging technologies such as image recognition and defect classification may provide an efficient, effective, and economical solution for condition monitoring of overhead conductor assets. Technologies in this field are continuing to evolve to deliver greater quality with reduced implementation cost. EQL continually monitors advancements in this field through the market to evaluate the potential to provide efficiencies in program delivery and risk reduction.

It is recommended that EQL continue to investigate technology-based techniques to monitor condition of overhead conductors and deliver greater risk reductions at lower cost.

8.5 Future Technologies as an Alternative to Replacement

Technology advancement in areas which present an alternative to the traditional network is currently increasing at an unprecedented rate. Technologies such as distributed generation, batteries and isolated grids may present a viable alternative to like-for-like replacement to mitigate risk, particularly in rural areas.

It is recommended that EQL continue to investigate technology-based techniques to provide an alternative to like-for-like replacement to deliver greater risk reductions at lower cost.

8.6 Health Index and Risk Monetisation

To support / justify the increased replacement volumes and resolve the economic limitation of Ergon Energy, EQL has:

- Developed a condition-based risk quantification modelling tool to establish optimum replacement volumes.
- Committed to adopt an economic, customer value-based approach when it comes to ensuring the safety and reliability of the network. To substantiate the advantages of this approach for the community and businesses over the modelling period, we have employed Net Present Value (NPV) modelling. This commitment is in line with efforts to minimise the impact on customer prices.
- Conducted a cost benefit analysis to confirm that the overhead conductor asset replacements are prudent capital investments.

8.7 Early Fault Detection Trial

An Early Fault Detection technology (EFD) trial has been implemented within Ergon Energy and Energex. The EFD technology monitors live radio-frequency signals on the powerlines. The technology utilises GPS time-synchronisation and time-of-flight algorithm to predict early defects before a conductor failure can occur.

The early fault detection technology has been installed in the Cairns network at Gordonvale, Manoora, and Redlynch. The technology managed to identify damaged insulations, bird caging on conductor, and vegetation in proximity of the overhead conductors. The technology has been installed on the Cleveland network in the Energex region.

The EFD technology data is being monitored, and field staff are carrying out inspections to verify the validity of the outputs. The trial period is expected to be completed in 2024.

9 Lifecycle Strategies

The following sections outline the approach of EQL to the lifecycle asset management of this asset class.

9.1 Philosophy of Approach

Historically and around the world, distribution level conductor condition assessment has mostly been via visual assessment (in-service) or laboratory analysis (off-line). Very few conductors have been actively monitored to support dynamic ratings and provide condition data. Ergon Energy and Energex networks do not have any on-line conductor condition monitoring facilities installed, and to date, such systems have yet to be proven cost-effective (Refer Sections 8.1 and 8.2).

The main asset maintenance strategy employed for conductors involves periodic ground-based visual inspection and replacement upon identification of defects that herald imminent failure. The inspection timing is effectively periodic only, and without adjustment based upon reliability performance. Therefore, EQL's asset maintenance approach to the conductor asset class is preventative only.[3] Progression to a condition-based regime will require implementation of sensor data and a rules-based logic and alert system.

EQL have implemented the Condition Based Risk Management (CBRM) tool to predict the health of each conductor segment. Ideally the key input for the development of the model is observed and measured condition data. Due to the limitation explained above, supplementary asset information such as asset performance trend and identified problematic conductor types based on failure history and age, has been applied in the process of developing health score and probability of failure (PoF). Hence EQL's asset management approach to the conductor asset class is essentially considered to be changed from reactive to proactive in recent years.

9.2 Supporting Data Requirements

There is a disparity between asset records being kept in the Ergon Energy and Energex regions. Historical data capture practices restrict the ability to analyse the large volumes of data associated with this asset class without substantial manual effort, and offers significant potential for improved asset management.

Legacy organisation Ergon Energy developed and implemented a recording system for all failures, incorporating a requirement to record the asset component (object) that failed, the damage found, and the cause of the failure using MSSS in Ellipse (the current Enterprise Asset Management System [EAMS]). Energex maintained detailed records of failures in a separate outage related database external to the corporate asset management system. EQL has adopted the MSSS approach and is building this record system over time, providing the information necessary to support improvements in inspection and maintenance practices. There is an expectation that this will also support and influence standard design and procurement decisions. Alignment of failure and defect data capture across regions is required to take full advantage of the larger data set available across the state.

To support the forecasting of replacement quantities for business planning purposes, specific information such as the conductor type, age, location, and environment in which assets fail, is being developed. This is the source of much of the information detailed in this AMP. Over time, this will support the application of probabilistic reliability engineering techniques such as Weibull analysis.

9.3 Acquisition and Procurement

EQL's procurement policy and practices are detailed in policy P011 Sustainable Procurement Policy. Overhead conductors and ancillary equipment are specified in line with relevant Australian Standards, industry best practice, and in consultation with stakeholders and subject matter experts (SMEs). These assets are procured on period contracts awarded through technical and commercial evaluation in line with Queensland Government's QTenders process.

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[3] Asset maintenance maturity model definition reflects a rating scale published by Schneider Electric, 2015

Overhead networks associated with connection assets such as large customer or subdivision connections may also be designed, procured, and constructed by approved service providers to EQL standards, under the contestable works process. The connection assets are “gifted” to EQL following final product audit and acceptance of the installation. EQL takes responsibility to own, operate, maintain, and replace these assets from the date of acceptance.

9.4 Operation and Maintenance

Operation and maintenance includes planned and corrective maintenance. Operation and maintenance procedures are supported by a suite of documentation. The suite describes in detail the levels of maintenance applicable, the activities to be undertaken, the frequency of each activity, and the defect and assessment criteria to which the condition and testing are compared to determine required actions. The relevant documents are included in Appendix 1 for reference.

EQL and its subsidiaries have an obligation under the Electricity Act and Regulations to maintain a safe and reliable electrical supply network. This obligation is in turn reflected by the need to achieve and demonstrate compliance with the applicable EQL maintenance policies and standards.

EQL continues to improve the safety and cost-effective performance of its vegetation management program through use of the latest inspection and analysis techniques (LiDAR, imagery, predictive analytics), optimal delivery models/techniques, and active participation through Energy Networks Australia (ENA) working groups.

9.4.1 Preventive Maintenance

Preventive maintenance is comprised of scheduled inspection and maintenance activities required to ensure network assets remain serviceable and fit for purpose throughout their asset lifecycle.

Ground and aerial inspections are performed to provide an integrated approach to condition assessment of overhead conductor and ancillary assets. Defects including, but not limited to, statutory clearance impingement, corrosion, broken strands, loose connections, and wear/corrosion of mechanical fittings can be identified and rectified prior to ultimate failure or incident. Known augmentation and replacement plans are considered prior to carrying out defect repairs.

In addition to routine ground and aerial inspections, an annual, high-level preventative ‘Summer Preparedness Patrol’ is also undertaken on critical feeders to mitigate the risk of storm/bushfire damage, and to identify obvious line components that have failed or are at imminent risk of failure prior to the storm/bushfire season. Overhead conductor maintenance task and frequency rates are contained in the maintenance standard document MAF.

Vegetation management occurs consistent with Electricity Safety Regulations 2013 (Qld) and is controlled by Vegetation Management Strategy (G001).

Under the inspection process, conductors are assessed according to a set of pass/fail benchmark criteria documented in the LDCM. Individual benchmark failure records are labelled “Defects”. The benchmark criteria are reviewed periodically based upon overall population failure and refurbishment statistics, as well as reported situational circumstances that have been encountered. The conductor inspection process mostly consists of ground-based personnel checking for visual clues of defects on the conductors and accessories.

Defects are scheduled for repair according to a documented risk-based priority scheme (P1/P2/C3/no defect). Actual individual repair periods are recorded and monitored, with performance criteria established for the population repair period statistics.

9.4.2 Corrective Maintenance

Corrective maintenance is initiated from preventive maintenance programs, ad-hoc inspections, public reports, and in-service failures. Urgent maintenance (i.e. immediately life threatening or loss of supply) is addressed immediately. Non-urgent maintenance is scheduled to allow appropriate planning and coordination to occur.

For corrective maintenance, overhead conductor assets are repaired to the current standard or the standard in place at the time of original commissioning; the former occurs where cost effective and technically feasible.

Emergency maintenance may be required at any time of the day or night due to failure or third-party damage. This requires experienced and skilled staff, a range of tools and equipment well maintained, records and instructions, and adequate stocks of conductor and accessories.

9.5 Refurbishment and Replacement

The following sections outline the practices used to either extend the life of the asset through refurbishment or to replace the asset at the end of its serviceable life.

9.5.1 Refurbishment

On identification of defects or improvements through regular inspection and testing, EQL undertakes refurbishment of overhead conductor assets to ensure they remain safe and fit for purpose. The mechanical properties of the conductor itself cannot be restored once lost. Inspection driven refurbishment is therefore typically limited to statutory clearance compliance and items ancillary to the conductor such as connectors, clamps, and fittings.

9.5.2 Replacement

In accordance with maintaining the network within acceptable levels of performance, renewal management of aging assets has become increasingly influential. To determine the asset's condition, several contributing factors have been considered including appropriate probabilistic impact scales aligning with CBRM and Common Network Asset Indices Methodology (CNAIM) principles. Both measured (number of joints in a span) and observed condition data (wear and tear, corrosion etc) from inspections are incorporated into the Health Index (HI) for all conductors to calculate the future PoF to estimate the prudent replacement volume.

The PoF is calculated based on a well-established equation set out in CBRM/CNAIM modelling after analysing global data about the relationships between HI and PoF for different assets. The equation involves the application of two specific constant factors to align the PoF of an asset with historical failure data experienced by the DNSP functioning in different operating conditions. This section needs to be read in conjunction with the CBRM/CNAIM process document.

Replacement work practices are optimised to achieve bulk replacement minimising overall cost and customer impact. Conductors are proactively replaced based on the CBRM process where asset performance trend is the key input, and criteria indicates that assets are either at, or near, end of service life.

The HI is calculated on a scale of 0 to 10 which represents the extent of condition degradation; 0 indicating new conductor in excellent condition (very low PoF), and 10 indicating the worst condition (high PoF) (Figure 28).

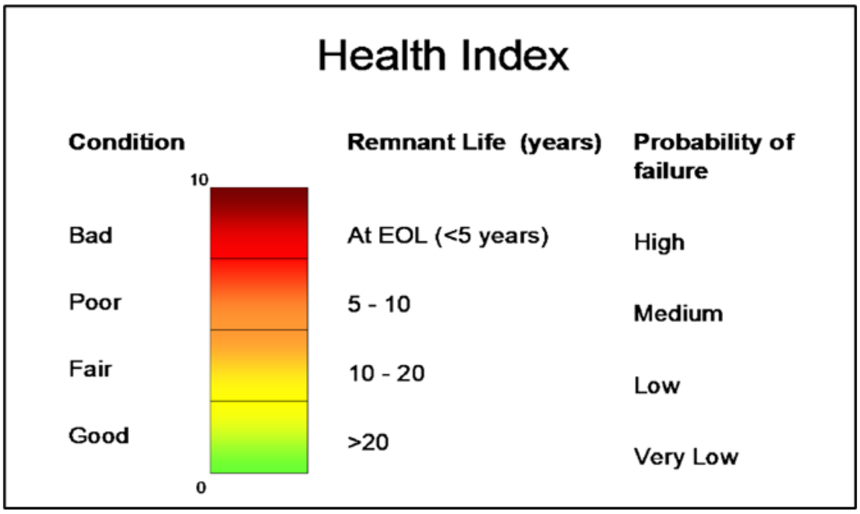

Figure 28: CBRM Model

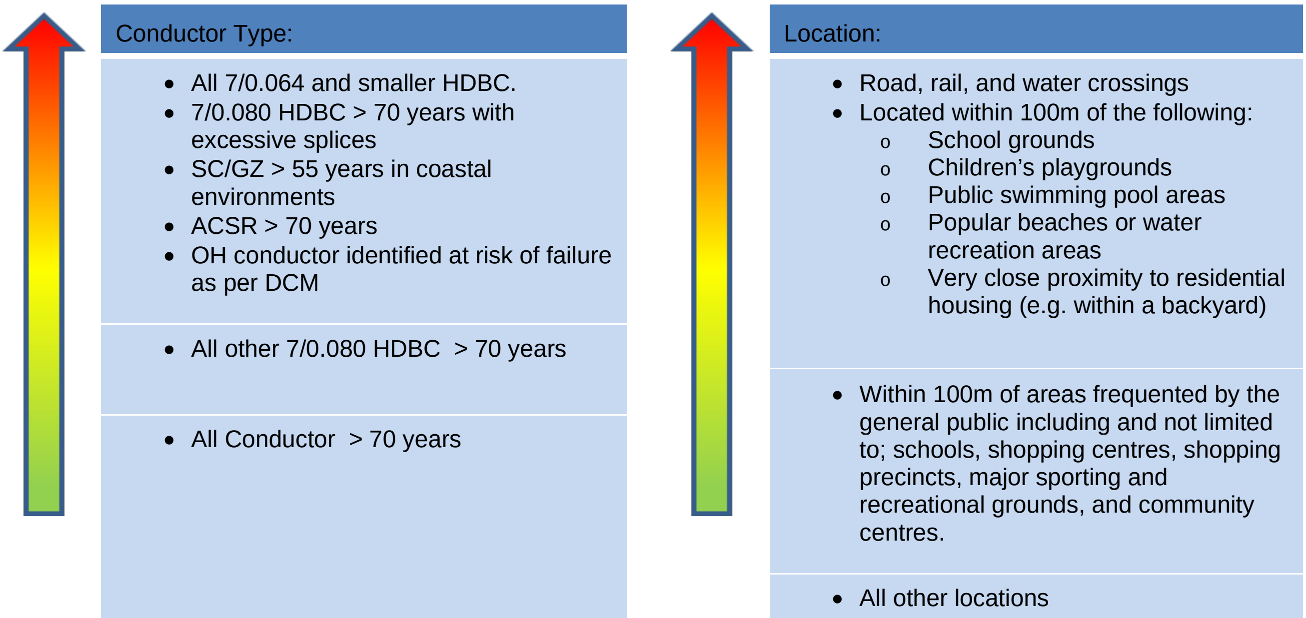

Figure 29: EQL Overhead Conductor Replacement Priorities

Overhead conductor replacement priority is derived from asset performance trend, informed by the CBRM model to calculate health score for each conductor segment (Figure 29). A HI of 7.5 is typically used as the point at which assets are identified as candidates for requiring an intervention. By 2043, intervention will be required for approximately 50,000km Ergon and 8,000 km Energex. EQL is in the process of managing the sustainable replacement volume to manage in-service failures and defects, aligning SFAIRP (So Far as Is Reasonably Practicable).

The current plan is for Ergon Energy to replace 550km per annum in the current regulatory period 2020-25 and step change to 750 per annum in 2025-30. Energex is to uphold 300km per annum to maintain the current levels of service.

9.5.3 Spares

EQL does not currently require a documented spares strategy for conductors but maintains an inventory of strategic spares where deemed appropriate by SMEs. Spares holdings are periodically reviewed to ensure the minimum holding quantity is appropriate for the installed population. It is impractical to carry spares for all conductor types and accessories. Critical or obsolete conductor types require special attention to provide adequate coverage for emergency situations.

9.6 Disposal

Recovered overhead conductor assets, which may include copper or aluminium conductor together with other materials, are disposed of via scrap merchants reflective of prudent and responsible recycling outcomes.

10 Program Requirements and Delivery

The programs of maintenance, refurbishment, and replacement required to outwork the strategies of this AMP are documented in the Network Program Plan and reflected in corporate management systems. Programs are typically coordinated to address the requirements of multiple asset classes at a higher level, such as a substation sites or feeders, to provide delivery efficiency and reduce travel costs and overheads. The Network Program Plan provides a description of works included in the respective programs as well as the forecast units.

Program budgets are approved in accordance with the Corporate Financial Policy. The physical and financial performance of programs is monitored and reported monthly to manage variations in delivery and resulting network risk.

Appendix 1. References

It takes several years to integrate all standards and documents after a merger between two large corporations. This table details all documents authorised/approved for use by EQL, or in either legacy organisation (and therefore authorised/approved for use by EQL) that supports this AMP.

Legacy Organisation	Document Number	Title	Type
EQL	Net Policy - 001	Asset Management Policy	Policy
EQL	P011	Sustainable Procurement Policy	Policy
EQL	P043	Risk Management Policy	Policy
EQL	Q015	Risk Appetite Statement.	Policy
EQL	690403	Vegetation Management Strategy	Strategy
EQL	2948464	Standard for Classifying the Condition of Network Assets	Standard
EQL	2928929	Standard for Maintenance Acceptance Criteria	Standard
EQL	2023-Q4	Lines Defect Classification Manual	Manual
Energex	EX 00302	Overhead Design Manual	Manual
Ergon Energy **Energex**	EX 04920	Overhead Construction Manual	Manual

Appendix 2. Definitions

Term	Definition
Condition based risk management	A formal methodology used to define current condition of assets in terms of health indices and to model future condition of assets, network performance, and risk based on different maintenance, asset refurbishment, or asset replacement strategies.
Corrective maintenance	This type of maintenance involves planned repair, replacement, or restoration work that is carried out to repair an identified asset defect or failure occurrence, to bring the network to at least its minimum acceptable and safe operating condition. An annual estimate is provided for the PoW against the appropriate category and resource type.
Distribution	LV and up to 22kV networks, all SWER networks
Forced maintenance	This type of maintenance involves urgent, unplanned repair, replacement, or restoration work that is carried out as quickly as possible after the occurrence of an unexpected event or failure; to bring the network to at least its minimum acceptable and safe operating condition. Although unplanned, an annual estimate is provided for the PoW against the appropriate category and resource type.
Preventative maintenance	This type of maintenance involves routine planned/scheduled work, including systematic inspections, detection, and correction of incipient failures, testing of the condition and routine parts replacement designed to keep the asset in an ongoing continued serviceable condition, capable of delivering its intended service.
Sub-transmission	33kV and 66kV networks
Transmission	Above 66kV networks

Appendix 3. Acronyms and Abbreviations

The following abbreviations and acronyms may appear in this asset management plan.

Abbreviation or Acronym	Definition
AAAC	All Aluminium Alloy Conductor
AAC	All Aluminium Conductor
ABC	Aerial Bundled Cable
ACSR	Aluminium Conductor Steel Reinforced
AIDM	Asset Inspection & Defect Management system
ALARP	As Low As Reasonably Practicable
AMP	Asset Management Plan
Augex	Augmentation Expenditure
BOP	Basis of Preparation
CBRM	Condition Based Risk Management
CCT	Covered Conductor Thick
DEE	Dangerous Electrical Event
DPORG	Defect Point of Reference Guide
DLA	Dielectric Loss Angle
EMF	Electromagnetic Fields
ENA	Energy Networks Australia
EQL	Energy Queensland Limited
ESCOP	Electricity Safety Code of Practice
ESR	Queensland Electrical Safety Regulation (2013)
GZ	Galvanised Steel
HDBC	Hard Drawn Bare Conductor (copper)
HV	High Voltage
IoT	Internet of Things
ISCA	In-Service Condition Assessment
LiDAR	Light Detection and Ranging
LDCM	Lines Defect Classification Manual
LV	Low Voltage
MSSS	Maintenance Strategy Support System
MVAr	Mega-VAr, unit of reactive power
OH	Overhead
OHEW	Overhead Earth Wire
OPGW	Optical-fibre Ground Wire
POC	Point of Connection (between EQL assets and customer assets)
POEL	Privately owned Electric Line

Abbreviation or Acronym	Definition
PVC	Poly Vinyl Chloride
QLD	Queensland
RED	Repository of Energex Documents
REPEX	Renewal Expenditure
RIN	Regulatory Information Notice
RIV	Radio Interference Voltage
SC/AC	Steel Conductor Aluminium Clad
SC/GZ	Steel Conductor Zinc Galvanised
SEI	Serious Electrical Incident
SFAIRP	So Far As Is Reasonably Practicable
STPIS	Service Target Performance Incentive Scheme
SME	Subject Matter Expert
SWER	Single Wire Earth Return
UV	Ultraviolet
XLPE	Cross–linked Polyethylene