EQL Asset Management Plan
Pole Top Structures

Part of the Energy Queensland Group

Executive Summary

This Asset Management Plan (AMP) focuses on the management of pole top structures. Pole top structures are made up of crossarms, insulators, and other accessories.

Pole top structures support the overhead network which delivers electricity to customers across Queensland. Energy Queensland Limited (EQL) manages over 2,400,000 pole top structures, comprised of around 1,800,000 in Ergon Energy and 610,000 in Energex.

EQL undertakes lifecycle management of pole top structures through performance and condition monitoring processes that include periodic routine inspections, maintenance, refurbishment and replacement to achieve optimum performance, and where possible extend asset service life. These key functions ensure that EQL is consistent with sound asset and risk management principles to operate safely as an efficient and effective organisation, deliver customer expectations, meet regulatory requirements, and manage long term strategic risks in relation to price, asset value, and shareholder returns.

Crossarms may be constructed from wood, laminated softwood, steel, aluminium or composite fibres. Some pole top structure designs do not require crossarms at all (e.g. Single Wire Earth Return (SWER) systems). The majority of the crossarm population is constructed from wood. Wood crossarms are susceptible a wide variety of environmental damage including termite attack, rot and decay, flammability, and splitting due to weathering, all of which can increase the likelihood of catastrophic failure. The current strategy is to transition away from wood crossarms in favour of alternatives such as composite crossarms or constructions with no crossarm for standard designs.

EQL measures crossarm reliability using a three-year moving average. Overall population performance is evaluated as part of the general organisation obligations for reliability and annual Dangerous Electrical Events incidents.

EQL is working to improve its data quality, cost capture, and failure and condition monitoring capability, and actively investigating and pursuing advancements in overhead inspection, using emerging technologies that will further assist in the management of this asset class.

Work is continuing with respect to the alignment of maintenance and operating practices from legacy organisations, to drive efficiency, deliver customer outcomes, and mitigate risks across all EQL operations.

Revision History

Revision date	Version number	Description of change/revision
31/01/2019	1	Document Initial release
27/11/2020	2.01	Added V1 End Notes; Updated Action Lists to reflect those in Consolidated Action List; minor edits found during V1 review resolved. Added Document Endorsement Table back in. Updated references to ESCOP to be 2020. Updated Owners and Stakeholders. Added Asset Criticality section. Added Risk Valuation section. Added basic budgets into Section 9.4 and 9.5. Add some comments highlighting a need for Action Reviews
20/1/2021	2.02	Updated for V2 of document.
14/7/2022	3	Updated for V3 of document
01/12/2023	4	Updated with current state of strategies and data

Document Approvals

Position title	Date
GM Asset Maintenance	Jan 2024
Chief Engineer	Jan 2024

Stakeholders/Endorsements

Title	Role
Manager Asset Strategy	Endorse
Manager Poles and Pole Top Structures	Endorse

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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 Distribution Network Service Providers (DNSPs):

- Energex, covering the area defined by the Distribution Authority for Energex Corporation Limited, and
- Ergon Energy, covering the area defined by the Distribution Authority for Ergon Energy Corporation Limited.

Energy Queensland 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, as a result of 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 demonstrate the responsible and sustainable management of pole top structures on the EQL network. The objectives of this plan are to:

1. Deliver customer outcomes to the required level of 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 Asset Management Plan 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.

This Asset Management Plan is guided by the following legislation, regulations, rules and codes:

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

This Asset Management Plan forms part of EQL's strategic asset management documentation, as shown in Figure 1. It is part of a suite of Asset Management Plans, 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 pole top structures, at all voltage levels, predominately focusing on the following assets:

- Crossarms including wood, composite, steel, laminated and aluminium.
- Insulators including porcelain, glass, and composite.
- Pole mounted surge arrestors.

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 Asset Management Plan has a strong linkage to other overhead assets including poles, lattice towers, and overhead conductor. These plans should be considered together.

Many customers, typically those with high voltage connections, own and manage their own network assets including pole top structures and insulators. EQL does not provide condition and maintenance services for third party assets, except as an unregulated and independent service. This AMP relates to EQL owned assets only and excludes any consideration of such commercial services.

1.3 Total Current Replacement Cost

Pole top structures are relatively low individual cost assets; however, the very high volume of these assets in the network makes them a significant component of the overall asset base. Based upon asset quantities and replacement costs, EQL pole top structures have an undepreciated replacement value of approximately $3.87 billion. This valuation is the gross replacement cost of the assets, based on the cost of modern equivalents, without asset optimisation or age assigned depreciation. Figure 2 provides an indication of the relative financial value of EQL pole top structures compared to other asset classes.

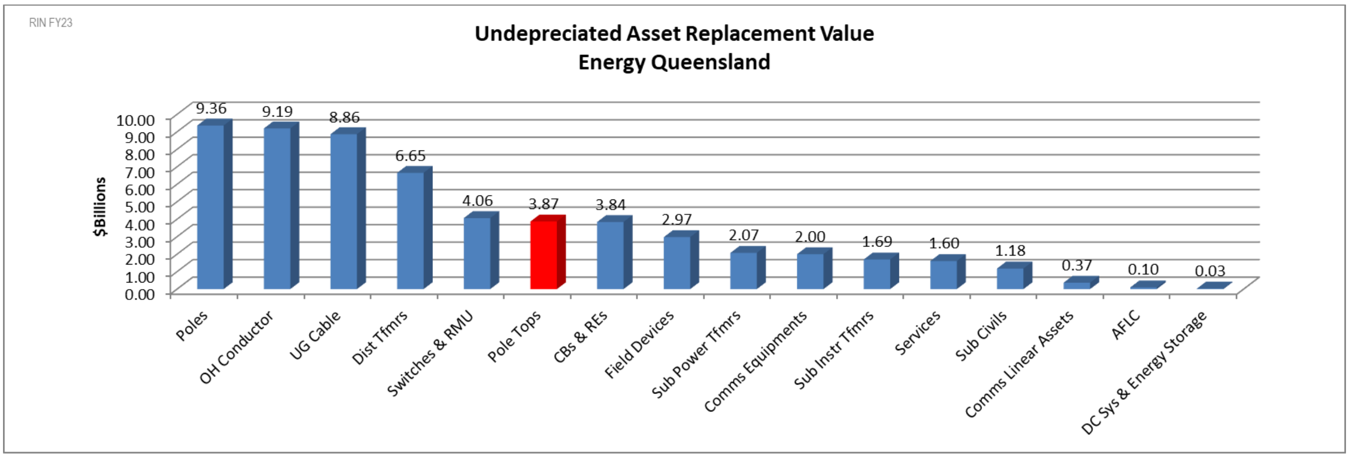

Figure 2: EQL – Total Current Asset Replacement Value

1.4 Asset Function and Strategic Alignment

Pole top structures support the overhead network which delivers electricity to customers across Queensland. Pole top structures are a distributed asset class, located in all terrains and environments, urban areas, and remote rural areas.

Table 1 provides a summary of the relationship between EQL's asset management objectives and the pole top assets covered in the scope of this Asset Management Plan.

Relevant Asset Management Objectives	Relationship of Asset to Asset Management Objectives
Ensure network safety for staff, contractors, and the community	Managing integrity and condition of poles tops is a key factor in managing safety hazards and compliance to legislative and regulatory obligations.
Meet customer and stakeholder expectations	Continued pole top serviceability supports network reliability and promotes delivery of a standard quality electrical service.
Meet customer and stakeholder expectations	The performance of poles tops 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	Failure of poles tops can result in significant risk to public safety, disruption of the electricity network, and disruption of customer amenity. Understanding asset performance allows optimal investment to achieve intended outcomes. Prudent management of these 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 current standards and future requirements.

Table 1: Asset Function and Strategic Alignment

1.5 Owners and Stakeholders

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

Responsible Party	Role
Queensland Government	Development of legislative framework and environment for operation of EQL 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

Responsible Party	Role
	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, 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 EQL under its Distribution Authorities 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 of many 110kV to 330kV transmission grid assets and 74 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

Pole top structures refer to the structures, insulators, and hardware at the top of a pole that supports and positions conductors and other pole top equipment such as air break switches.

Crossarms are predominately used as part of the pole top. Some pole top designs utilise insulators and steel brackets directly attached to the pole instead of crossarms.

Transformer platforms, surge arrestors, and raiser brackets also form part of the pole top structure. Raiser brackets are treated in a similar fashion to crossarms for the purposes of maintenance.

2.1.1 Crossarms

Crossarms are used to support electrical conductors as well as to provide physical and electrical separation between them. Where crossarms form part of the pole top, they are categorised by material which includes wood, laminated wood, composite fibre, steel, and aluminium. Wood crossarms are predominately made out of hardwood timber. Lightweight laminated softwood plantation timber crossarms have also been used. Due to delamination issues which compromise the structural strength and integrity of the asset, all regions ceased installing laminated crossarms between 2000 and 2005.

Composite crossarms use thermosetting resin binders including epoxies, vinyl esters, polyurethane, or phenolic compounds, combined with glass fibre reinforcement applied by a pultruded or filament winding process. This product has significant promise with regard to longevity and electrical performance and is relatively lightweight. Second generation composite crossarms are also coated with a membrane of thermoplastic polymer alloy, which has excellent electrical insulation and tracking resistance properties. Composite crossarms tend to deform or bend rather than break when conductors are impacted by either vegetation or a third party. This results in a generally improved safety performance, as conductors remain suspended at height as opposed to falling to ground.

Steel crossarms were anticipated to provide longer life and avoid the risks resulting from catastrophic failure of wood crossarms. These arms are typically used where high strength and reliability is required, such as over railway crossings. While effective in terms of strength, steel crossarms are significantly heavier than other crossarms and so present other risks in terms of manual handling and electrical conductivity. Energex briefly trialled aluminium crossarms as a lightweight alternative to steel, however, the unit cost of aluminium crossarms was found to be uneconomical.

Not all pole top construction types use crossarms. Some use brackets, while others use bolts or insulators directly attached to the pole. Examples include low voltage aerial bundled cable (LV ABC), single wire earth return (SWER), and trident constructions.

2.1.2 Insulators

Insulators are used to attach and support overhead conductors to their supporting structures. The accessories used to secure the conductor to the insulator are covered under the Overhead Conductor Asset Management Plan.

The material and type of insulator used is application specific and is influenced by pollution, power frequency and switching surge voltage, lightning performance, and mechanical load. Insulators are manufactured from glass, porcelain, or composite polymer materials such as ethylene propylene diene monomer (EPDM) or silicon rubber.

Pin type insulators are typically constructed of porcelain and are mounted vertically to the crossarm via a threaded stud. The conductor passes through a groove in the head of the insulator and is fixed in place with a suitable tie accessory.

Line post insulators are of similar construction to pin type; however, they can be mounted vertically or horizontally, either to the crossarm or directly to the pole using a gain base. Depending on the application, the conductor may be fixed in place with ties or secured with additional hardware. Line post insulators at 66kV and above are typically constructed of composite polymer material.

At distribution voltages and higher, suspension type insulators may also be used. These insulators were historically constructed using strings of individual toughened glass or ceramic discs connected in series. Additional hardware is connected to support the conductor. The arrangement of suspension insulators at a termination dead-end is referred to as strain insulators. There is a preference to use composite materials for suspension and strain type constructions, due to their lighter weight and resistance to vandalism. Composite, long rod insulators are constructed using a central member or “core” of solid high-density, axially aligned, glass-fibre-reinforced, epoxy resin rod. The housing and sheds are moulded from suitable elastomer which is stabilised against the effects of ultraviolet and other solar radiation.

2.1.3 Surge Arrestor

A surge arrestor (also referred to as a lightning arrestor) is a protective device connecting a live conductor on an electrical system and earth. Its function is to limit the magnitude of transient overvoltage applied to the system equipment primarily due to lightning induced surges. Surge arrestors are sealed units with a long service life and are essentially maintenance free. They are a standard stock item and are replaced on failure. Where surge arrestors form part of the pole top structure, they are maintained alongside other pole top assets.

2.2 Asset Quantity and Physical Distribution

Pole tops are not recorded as separate assets in the legacy corporate systems, so comprehensive information on age, date of installation, material and condition is incomplete. Table 3 presents the quantity of pole top structures by type based on available data (see Sections 2.1.1 and 2.1.2 for further detail).

<table>
<tr><th>Pole Top Grouping</th><th>Pole Top Type</th><th>Energex</th><th>Ergon Energy</th><th>EQL Total</th></tr>
<tr><td rowspan="3">Crossarms</td><td>Wood</td><td>252,575</td><td>1,151,903</td><td rowspan="3">1,751,512</td></tr>
<tr><td>Laminated</td><td>5,908</td><td></td></tr>
<tr><td>Composite</td><td>222,835</td><td>118,291</td></tr>
<tr><td rowspan="4">Pole Top Other</td><td>Steel</td><td>116,730</td><td rowspan="3">300,000</td><td rowspan="3">427,876</td></tr>
<tr><td>Aluminium</td><td>835</td></tr>
<tr><td>Other</td><td>10,311</td></tr>
<tr><td>SWER</td><td>161</td><td>242,940</td><td>243,101</td></tr>
<tr><td colspan="2">Total</td><td>609,355</td><td>1,813,134</td><td>2,422,489</td></tr>
</table>

Table 3: Pole Top Structures Quantity

2.2.1 Crossarms

Crossarm data has been derived for each region based on the below information. As this data is partially derived, errors and inaccuracies may present.

Ergon Energy:

The installation year is determined for crossarms which have been replaced since 2009, by using the total volume replacement information of the AER’s Category Analysis RIN data. Before 2009, the pole top age profile data is used to infer the installation year, and to derive an age estimate for the pole top.

Detailed breakdown of crossarm quantity data into material type is not available. Please refer to 9.2 for more details on supporting data requirements.

SWER quantities are based on the number of SWER poles. This may result in a small underestimation of crossarm due to a number of duplex and triplex SWER lines. Other pole top data is inferred by using the voltages recorded for each pole top that is not indicated to have crossarms attached.

Energex:

Data on age brackets and material types have been developed based on actual data and derived age estimates, using a consistently applied methodology taking into consideration:

- Available crossarm asset data in the asset register.
- Pole type, age, and voltage level.

SWER quantities are based on the number of poles that corporate data indicates have SWER attached.

2.2.2 Insulators

EQL has a large and diverse population of insulators, with very little corporate data on the type and age of these assets.

Condition information on insulators is not collected, although defects are identified and recorded during routine visual inspections.

Most pole top types include insulators as part of the design. An exception to this is LV ABC. Total numbers of pole tops presented in this document can, therefore, be used to give a general indication of numbers of insulators. The number of insulators required per pole top structure is generally reflected by the voltage and type of pole top structure.

2.3 Asset Age Distribution

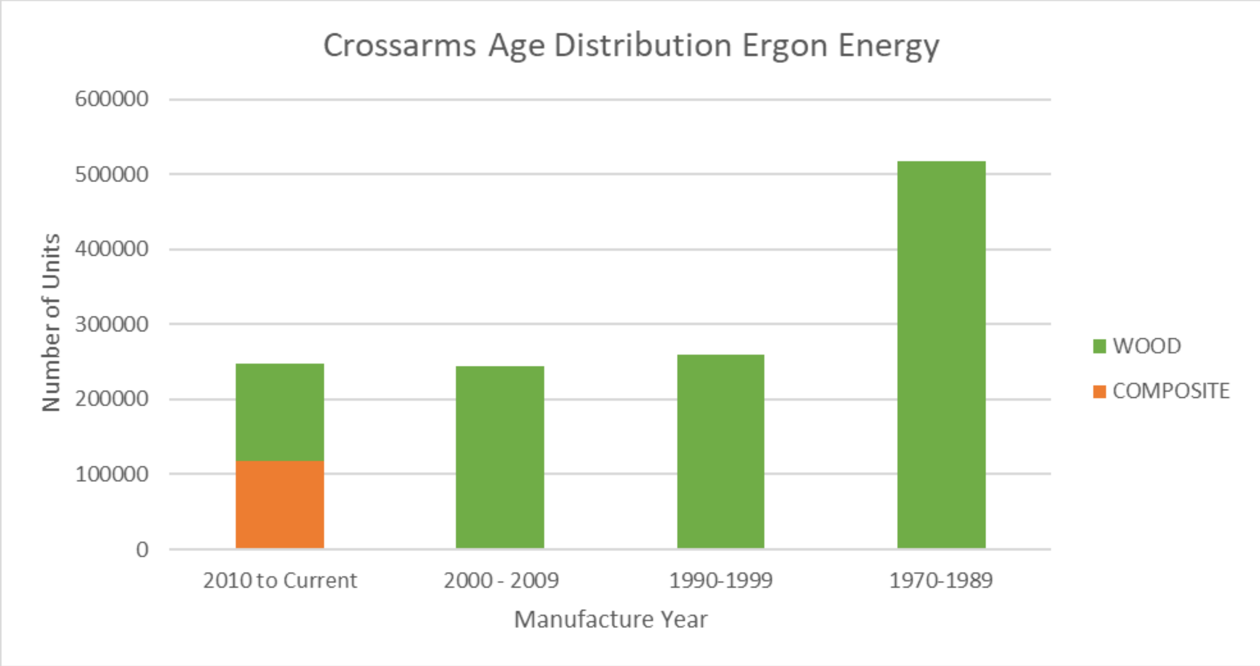

Figure 3: Ergon Energy Pole Top Age Profile

Figure 3 shows the derived age profile for the Ergon Energy pole top population. The majority of the crossarm population presented are wood. Note that data prior to 2009 is subject to substantial uncertainty because year of installation records of individual crossarms do not exist.

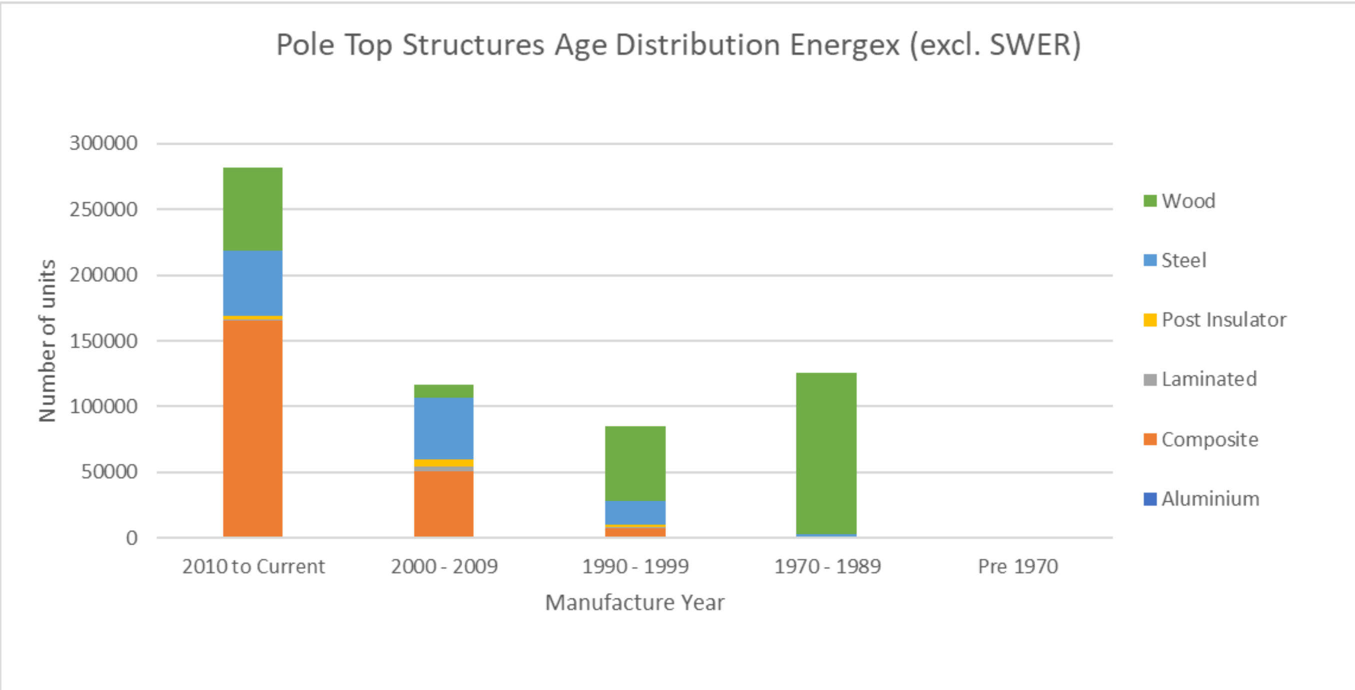

Figure 4: Energex Pole Top Age Profile

Figure 4 shows the derived age profile for the Energex pole top structures population. Similar to Ergon Energy data, the profile data is derived and subject to substantial uncertainty.

2.4 Population Trends

The following sections describe the general asset population trends of different assets covered in this AMP.

2.4.1 Wood Crossarms

Prior to 1990, overhead distribution (LV, 11kV and 22kV) feeders were constructed exclusively with hardwood timber crossarms.

In the early to mid-1990s, all regions introduced the practice of painting the top surface of wood crossarms to prevent moisture collecting on the top of the crossarm and accelerating rot.

Use of wood crossarms for common construction types is no longer the preferred option due to the wide range of environmental factors that influence the useful life and difficulties in manual handling. Wood crossarms are used only for some legacy constructions and non-standard constructions.

2.4.2 Composite Crossarms

All regions introduced the first generation of composite crossarms around 2005/2006.

In Energex, the first trials of 100 x 100mm composite crossarms were LV and 11kV intermediate constructions (pin and post). Composite crossarms were later extended to 11kV strain and termination constructions (these crossarms required a larger 125 x 125mm arm). Installation location wasn't limited by proximity to the coast, as composite fibres are less susceptible to deterioration by coastal environments than other materials. The extra strength capability of composite crossarms was utilised in design practices.

In Ergon Energy, composite crossarms were installed at a range of voltages with the first being installed at 110kV to replace timber wishbone constructions. Composite crossarms for high voltage constructions were not installed within 5km of the coastline. Strength requirements of crossarms were based on equivalent wood strength, allowing for interchangeability with wood crossarms if required.

The second generation of composite crossarms, coated with a membrane of thermoplastic polymer alloy, which has excellent electrical insulation and tracking resistance properties, was introduced around 2009/2010.

Across the Energex and Ergon Energy networks, composite crossarms are the now the standard type of crossarm used for new constructions and replacements, with some exceptions for some legacy and non-standard constructions where there are limitations that prevent their use.

2.4.3 Steel Crossarms / Pole top brackets

In the late 1990s all regions began using steel 11kV, 22kV trident constructions to replace wood pin insulator constructions. Typically these designs utilise insulators and steel brackets directly attached to the pole instead of crossarms. Energex replaced timber crossarms with steel crossarms on 11kV and 33kV, shackle and termination constructions.

SWER (Single Wire Earth Return) pole tops also typically utilise a steel bracket and insulator attached directly to the pole.

Energex briefly trialled aluminium crossarms as a lightweight alternative to steel, however, the unit cost of aluminium crossarms was found to be uneconomical.

2.4.4 Laminated Crossarms

The introduction of laminated softwood plantation timber crossarms occurred in the late 1990's in Energex and in the early 2000's in Ergon Energy. Due to delamination issues which lead to loss of mechanical strength, all regions ceased installing these crossarms, Energex in the early 2000's, and Ergon Energy in 2005.

2.4.5 Post / Clamp Constructions

Post insulator and clamp suspension constructions do not use crossarms at all. Post insulator constructions such as vertical offset and vertical delta arrangements typically use an insulator that is directly attached to the pole. Other pole top constructions, such as LV ABC, use a clamp that is typically attached by a bolt to the pole.

2.5 Asset Life Limiting Factors

The following tables describe the key factors that influence the life of Pole Top Structures and as a result, have a significant bearing on the programs of work implemented to manage the lifecycle.

2.5.1 Crossarms

Table 4 details the life limiting factors associated with wood, composite, and steel crossarms, as well as pole top metallic hardware.

Factor	Influence	Impact
Age	Deterioration of strength over time. Wood crossarm splitting due to age.	Reduction in the remaining life
Environment	Outdoor, corrosive or coastal environments, ultra-violet radiation, high rainfall areas, and environmental factors such as lightning, resulting in degradation of the crossarm and other pole top components. Wood crossarms are susceptible to termite attack, fungal fruiting bodies, rot and decay, and splitting due to weathering. Environmental influences make composite crossarms more prone to tracking and blooming. Steel and other pole tops metallic hardware are susceptible to corrosion.	Reduction in the remaining life, defects and failures

Factor	Influence	Impact
Design	Wood crossarm design can result in burning due to leakage currents – leakage mitigation such as gang nail plates are used to reduce this issue. Laminated wood crossarms present a greater risk of premature failure due to their design. Delamination leads to rot forming between laminations. Composite crossarm tracking and blooming issues resulting from environmental influences detailed above have been mainly associated with first generation crossarms. Design of the second generation crossarms has reduced this issue. Steel crossarms and other pole top metallic hardware can have compromised strength due to weld cracks.	Defects and failures

Table 4: Crossarms Life Limiting Factors

2.5.2 Insulators

Table 5 details the life limiting factors associated with insulators.

Factor	Influence	Impact
Age	Deterioration of strength over time.	Reduction in the remaining life.
Environment	Outdoor, corrosive or coastal environments and environmental factors such as lightning can result in flashover, corrosion, and degradation of the physical asset and components. Composite insulators are also susceptible to damage by birds and ultra-violet radiation.	Reduction in the remaining life, defects and failures.
Design	Network design and other influences can result in vibrations that can cause damage to the insulators. Porcelain insulators are susceptible to cement growth, resulting in cracking and moisture ingress and subsequently corrosion of metal components.	Defects and failures.
External factors	Insulators offer ready-made target practice opportunities	Defects and failures.

Table 5: Insulators Life Limiting Factors

3 Current and Desired 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 will be managed, consistent with corporate asset management policy, to achieve all legislated obligations and any specifically defined corporate key performance indicators and to support all MAT key result areas as reported in the Statement of Corporate Intent (SCI).

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 risks associated with this asset class will be managed to be 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 population will be managed consistently based upon generic performance outcomes, with an implicit aim to achieve the intended and optimised life cycle costs 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, reliability, and financial expectations. Problematic assets such as very high maintenance or high safety risk assets in the population will be considered for early retirement.

Assets of this class will be managed by population trends, inspected regularly, and allowed to operate as close as 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 minimise overall replacement cost and customer impact.

3.2 Legislative Requirements

Regulatory performance outcomes for this asset include compliance with all legislative and regulatory standards, including the *Electrical Safety Act 2002 (Qld)*, the *Electrical Safety Regulation 2013* (Qld), and the Queensland Electrical Safety Codes of Practice.

The Electrical Safety Act 2002 (Qld) s29 imposes a specific duty of care upon Ergon Energy and Energex, which are prescribed Electrical Entities:

1) An electricity entity has a duty to ensure that its works—
    a. are electrically safe; and
    b. are operated in a way that is electrically safe.
2) Without limiting subsection (1), the duty includes the requirement that the electricity entity inspect, test and maintain the works.

There are no specific legislative or regulatory performance standards defined for pole top assets.

3.3 Performance Requirements

EQL has a strategic objective to ensure a safe and reliable network for the community. Performance targets associated with these asset classes, therefore, aim to reduce in service failures to levels which deliver a safety risk outcome which is considered so far as is reasonably practicable (SFAIRP) and as a minimum, maintains current performance standards.

Asset failures occur where the programs in place to manage the assets do not identify and rectify an issue prior to it failing in service. Failures typically result in or expose the organisation to risk and represent the point at which asset related risk changes from being proactively managed to retrospectively mitigated.

While there are no specific Serious Electrical Incidents (SEI) or Dangerous Electrical Events (DEEs) targets, EQL is committed to reducing these indicators in compliance with our electrical safety obligations under the regulations.

The frequency and duration of outages are also tracked to ensure ongoing compliance with minimum service standards set forth under 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

The following are the current level of performance of crossarm.

Figure 5 presents the Ergon unassisted crossarm failure along with its reliability performance. The Ergon unassisted crossarm failure has been increasing over the years. The only exception of low failure rate of crossarm in the year 2014/15 was likely due to variation on data collection.

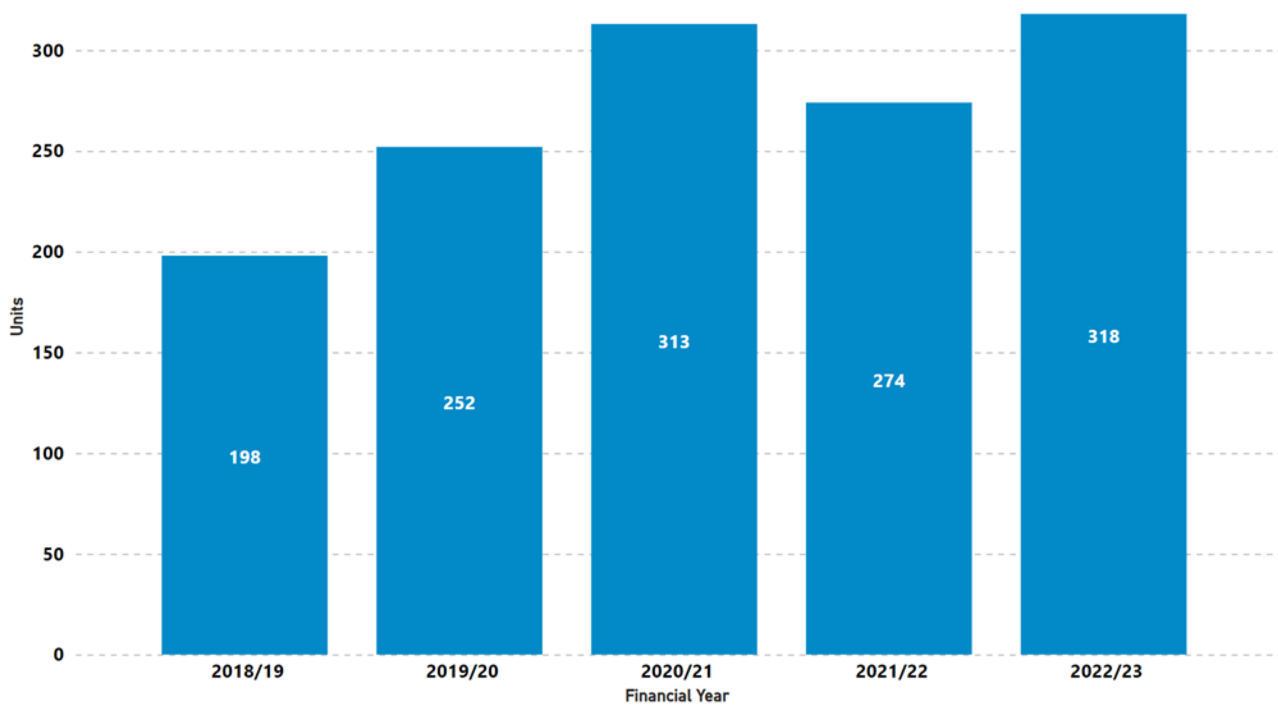

Figure 5: Unassisted Crossarm Failures – Ergon Energy

Figure 6 presents the crossarm reliability performance which is improving in the Energex region. Overall Energex unassisted crossarm failure has been on a gradual decline.

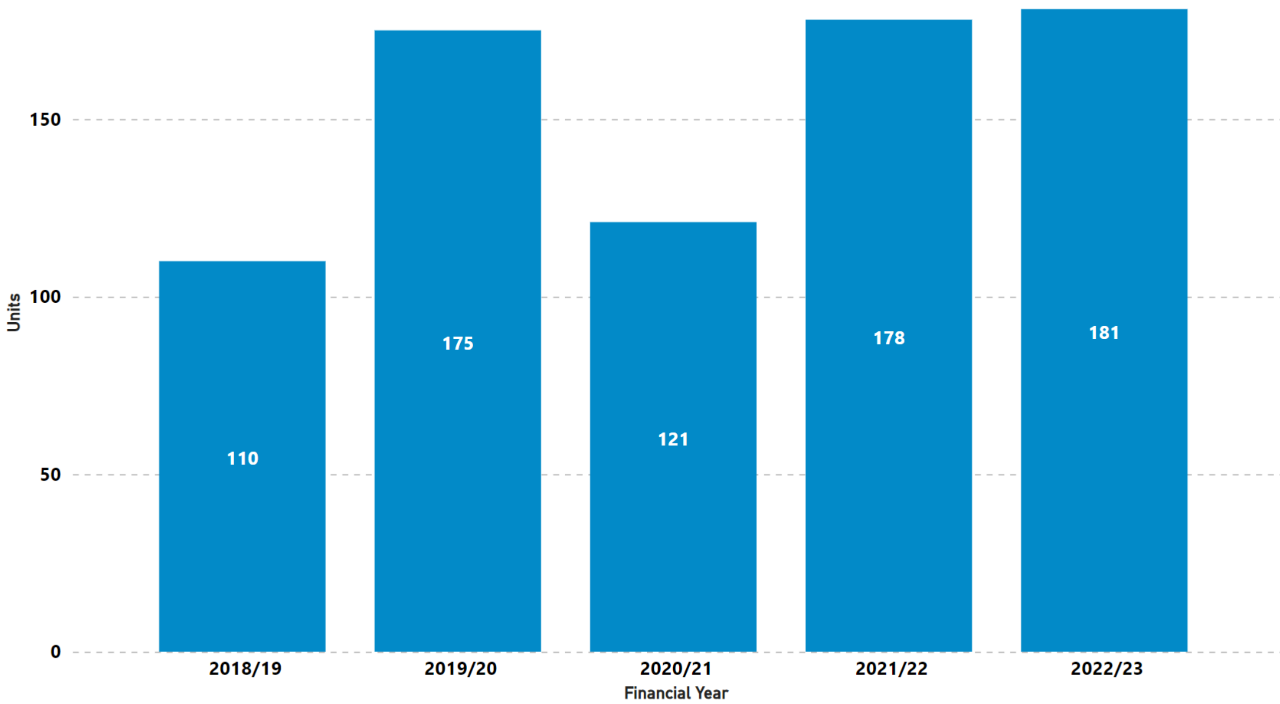

Figure 6: Unassisted Crossarm Failures – Energex

Figure 7 and Figure 8 demonstrates the number of defects identified on EQL poles. Identified defects are scheduled for repair according to a risk-based priority scheme. The P0, P1 and P2 defect categories relate to priority of repair from P0 requiring immediate rectification through to P2 where the normal planning processes are employed for rectification.

Recognising differences in data recording systems, work order processing systems, and the asset management strategies employed by the two legacy organisations, EQL has been actively working to merge the actual information being managed. Acknowledging that 60% of EQL poles are in the Northern and Southern Regions, and 40% of EQL poles are in the South East Region, the average number of defects per pole is already quite similar between the legacy regions, reflecting some early integration success in asset management approach.

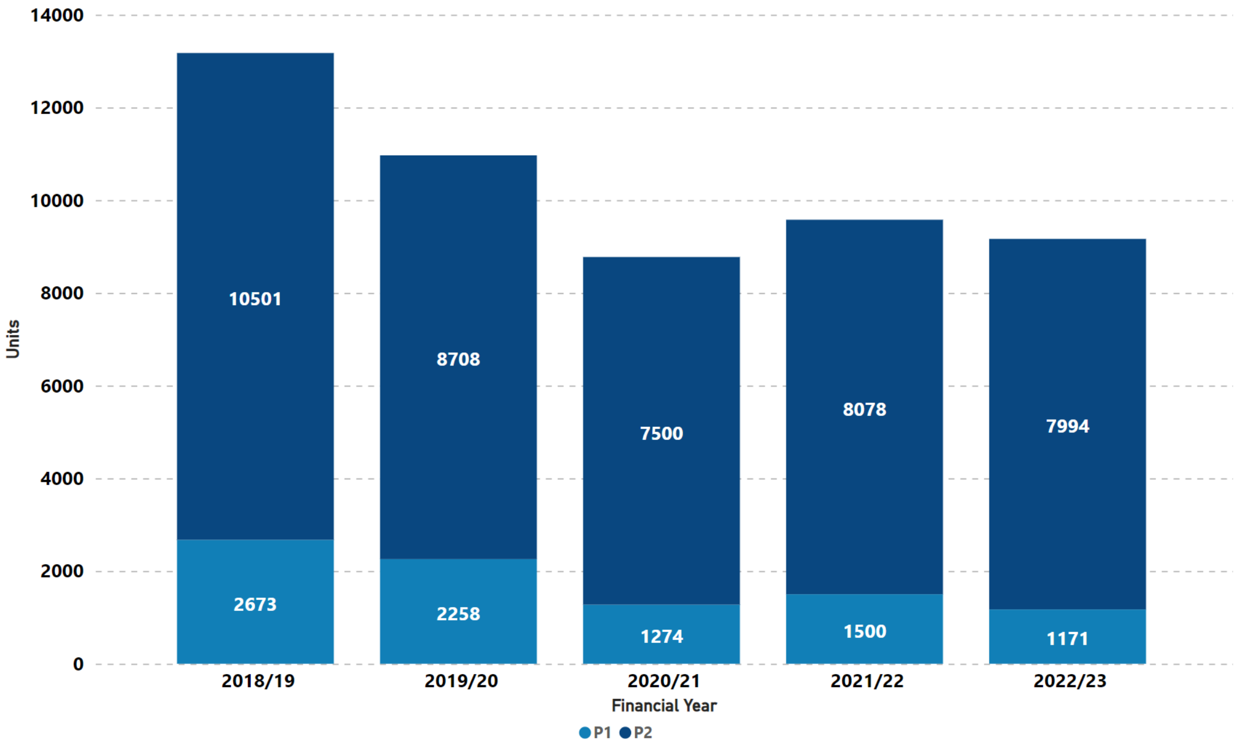

Figure 7: Crossarm Defects – Ergon Energy

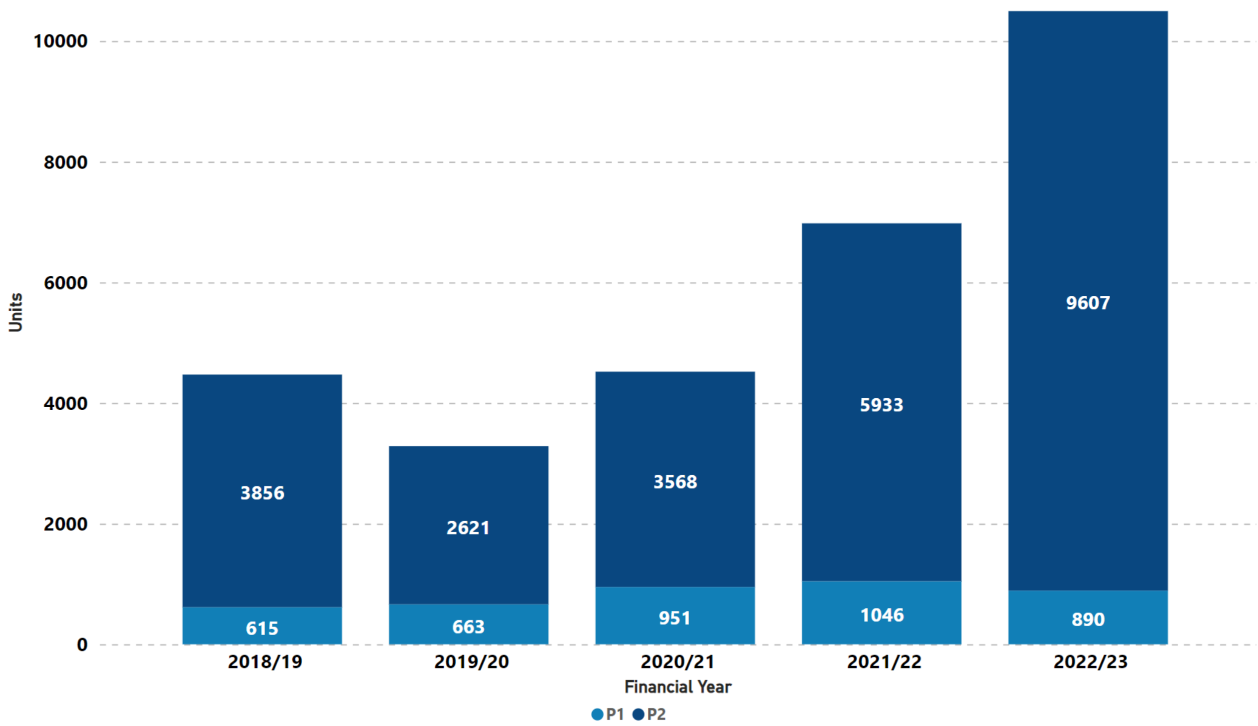

Figure 8: Crossarm Defects – Energex

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, they have employed Net Present Value (NPV) modelling. This commitment is in line with their efforts to minimize the impact on customer prices.

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

4 Asset Related Corporate Risk

As detailed in Section 3.2, Queensland legislation details that EQL has a Duty to ensure its works are electrically safe. This safety duty requires that EQL take action so far as is reasonably practicable (SFAIRP) to eliminate safety related risks, and where it is not possible to eliminate these risks, to mitigate them SFAIRP[1]. Risks in all other categories are managed as low as reasonably practicable (ALARP).Figure 9, Figure 10, Figure 11 and Figure 12 detail threat-barrier diagrams for pole top structures. Many threats cannot be controlled (e.g. third party damage), although EQL undertakes a number of actions to mitigate safety threats SFAIRP. Failure of a pole top structure presents public and staff safety risk in several ways, most notably:

- Bringing energised electrical conductors to easily accessible heights, risking public contact, shock, and electrocution
- Heavy objects physically falling, risking physical harm to anyone in the vicinity.

EQL's legislative duty to ensure its works are electrically safe (SFAIRP) results in proactive and pre-emptive replacement strategies, focussing inspection, maintenance, refurbishment, and replacement works upon failure prevention and mitigation.

The asset performance standards described in Section 3.3 detail EQL's achievements to date in respect of this safety duty. The following sections detail the ongoing asset management journey necessary to continue to achieve high performance standards into the future.

[1] QLD Electrical Safety Act 2002 s10 and s29

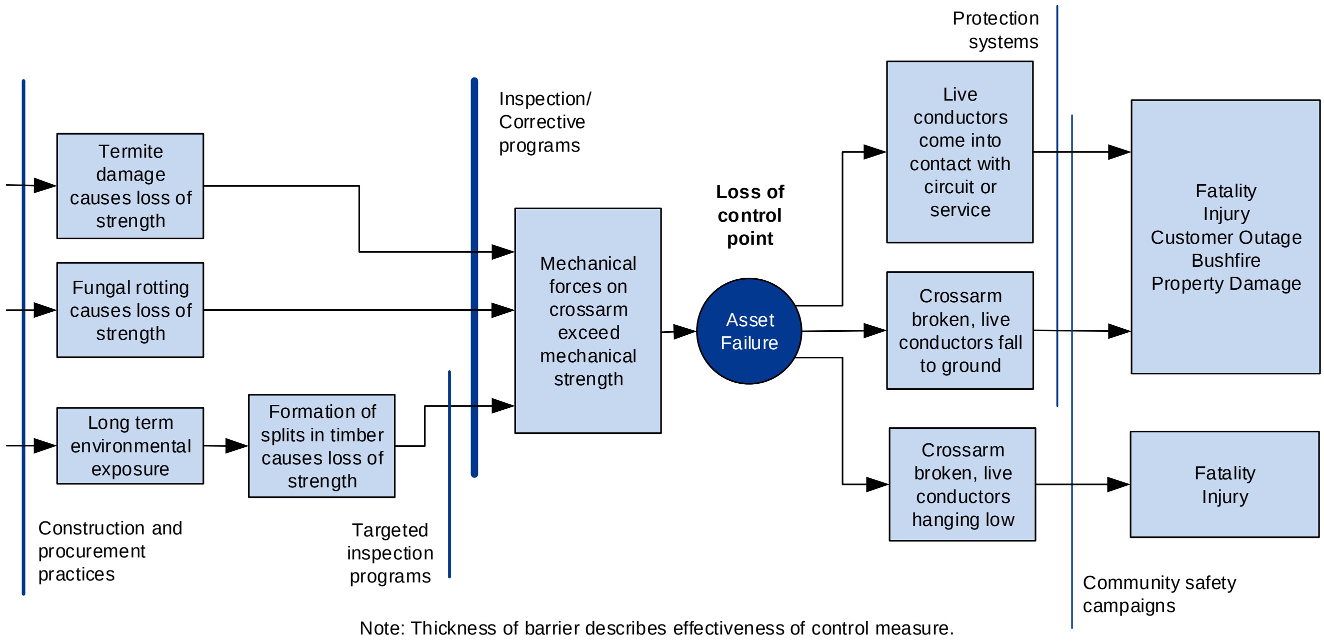

Figure 9: Threat Barrier Diagram for Wood Crossarms

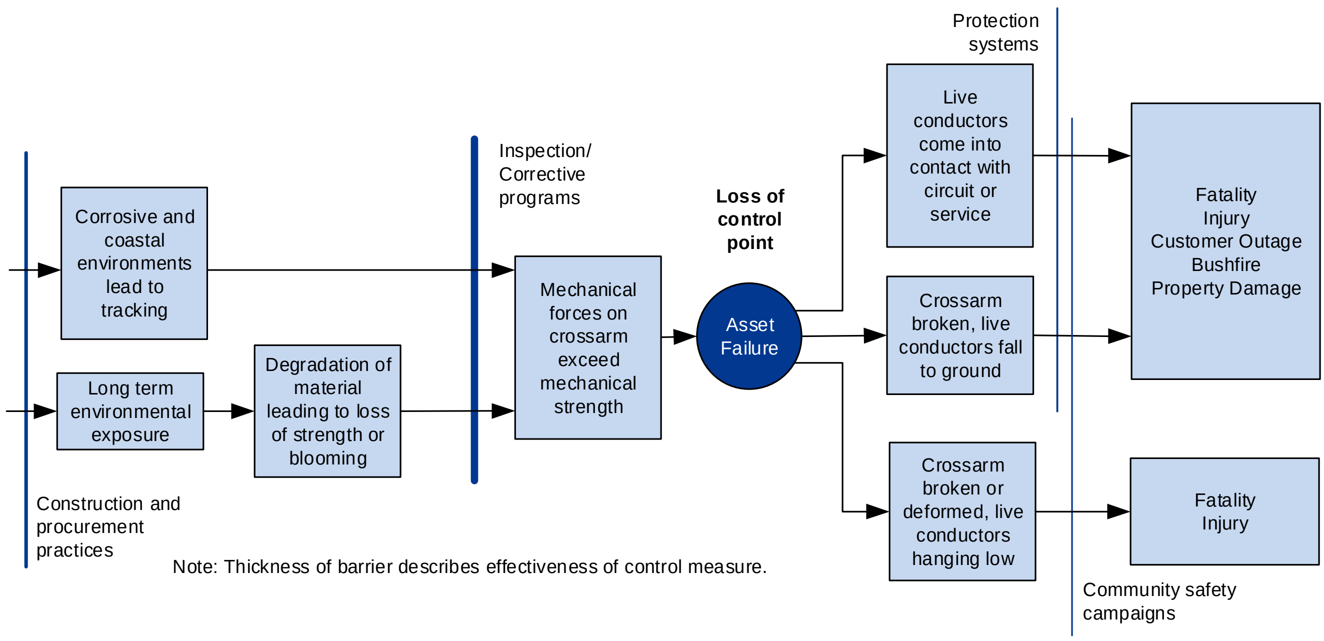

Figure 10: Threat Barrier Diagram for Composite Crossarms

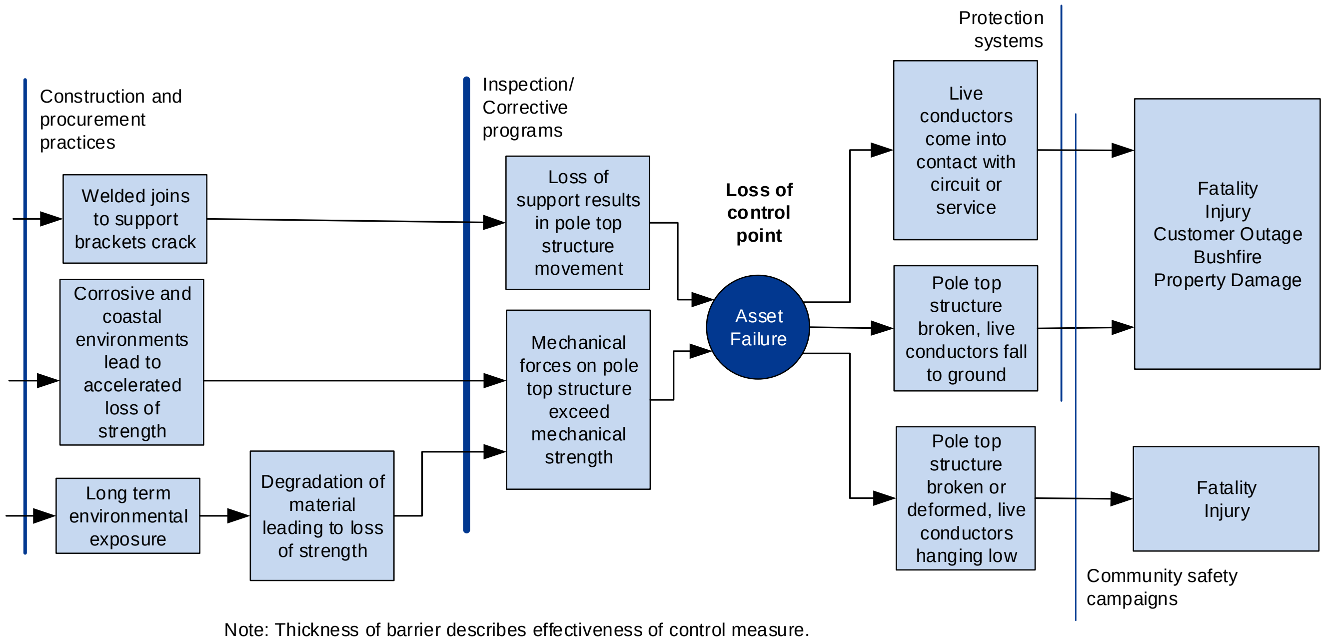

Figure 11: Threat Barrier Diagram for Steel Crossarms and Other Pole Top Metallic Hardware

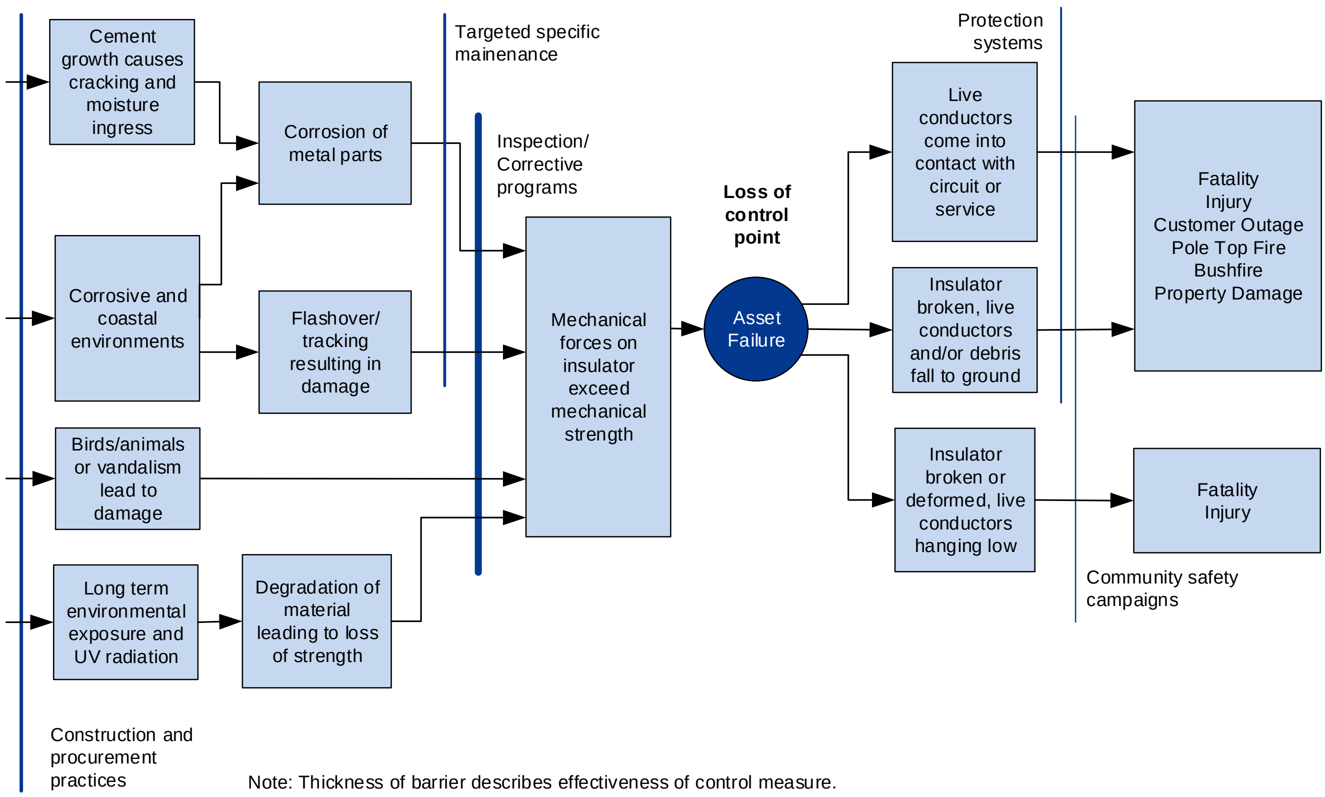

Figure 12: Threat Barrier Diagram for Insulators

5 Health, Safety & Environment

The increasing use of light weight composite crossarms over wooden or steel crossarms has alleviated some of the manual handling requirements presented by the heavier crossarms. While these crossarms are lighter, they do present a fibreglass blooming issue, creating an irritant while working at heights. This has only been experienced in first generation composite crossarms and handling techniques have been put in place to mitigate this issue.

Similarly, the use of composite insulators has significant manual handling benefits over the equivalent porcelain line post or string of porcelain or glass disc insulators. Upon failure, composites do not shatter on impact, reducing the laceration risk to nearby personnel or the public.

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 Laminated Crossarm Condition

Over the years, it was identified that laminated crossarms experienced accelerated loss of strength due to failure of or leaching of the lamination glue. Unfortunately, the location of these crossarms were not recorded as they were not considered as a specific asset when they were installed.

Laminated crossarms are removed from service based on external visual inspection. Prior to 2017, feedback from field crews undertaking the replacements highlighted that in many circumstances the external deterioration has not been reflective of the internal condition and that the crossarm could have potentially remained in service for longer. Testing was arranged on several laminated crossarms removed from service to determine the residual strength of the crossarm with the aim of improving the visual condition triggers for initiating corrective replacement actions.

In early 2017, an inspection "defect" definition was created, assigning P1 or P2 replacement priority for all laminated crossarms in "wet tropics locations", and visual condition based P1 or P2 replacement priority or C3 (monitor only priority) for elsewhere.

Since 2018/19, approximately 7,000 laminated crossarms have been replaced across the Ergon Energy network and 1,500 across the Energex network due to deteriorated condition.

6.2 Narrow Trident Constructions

Narrow trident construction uses short steel arms and brackets to hold the insulators that in turn support the conductors. This construction was introduced as an alternative to using wooden crossarms and as a less visually-intrusive construction for the public. The narrow spacing of the conductors associated with this construction presents a significant risk of clashing which in turn can lead to sparks and molten metal failing to ground and potentially causing a bush fire. Narrow trident constructions in bushfire prone areas have been replaced because of these risks.

The remaining areas of narrow trident constructions are now being monitored for reliability performance.

6.3 Use of Stainless Steel Hardware

Some locations along the Queensland coastline and on the islands that EQL supplies, metallic components on the pole top such as bolts, washers, crossarm brackets and insulators, are subjected to salt spray leading to premature deterioration.

Energy Queensland deployed guidelines for the use of stainless steel components on pole tops in 2019 however there has been confusion about the application in different scenarios. EQL is investigating a prudent and clearer way to define where stainless steel components should be used instead of traditional, less expensive galvanised components. This includes consideration of where the pole and crossarm are in their lifecycle to maximise the benefits of using stainless steel components and to minimise the number and frequency of truck rolls to replace these components.

7 Emerging issues

Defect and failure trends are monitored to identify emerging issues and improvements to processes. There are no identified emerging issues associated with pole tops. Issues to date are being managed through maintenance and replacement programs.

7.1 Economic Limitations for Ergon Energy

In the 2019/20, Ergon Energy increased its pole replacements program leading to increased pole top replacements.

Figure 13 highlights the crossarm replacement history and proposed forecasts. Due to the increasing failure rate of Ergon's crossarm, it is proposed to gradually increase the forecast replacement rate to improve the reliability performance of crossarm in the regions.

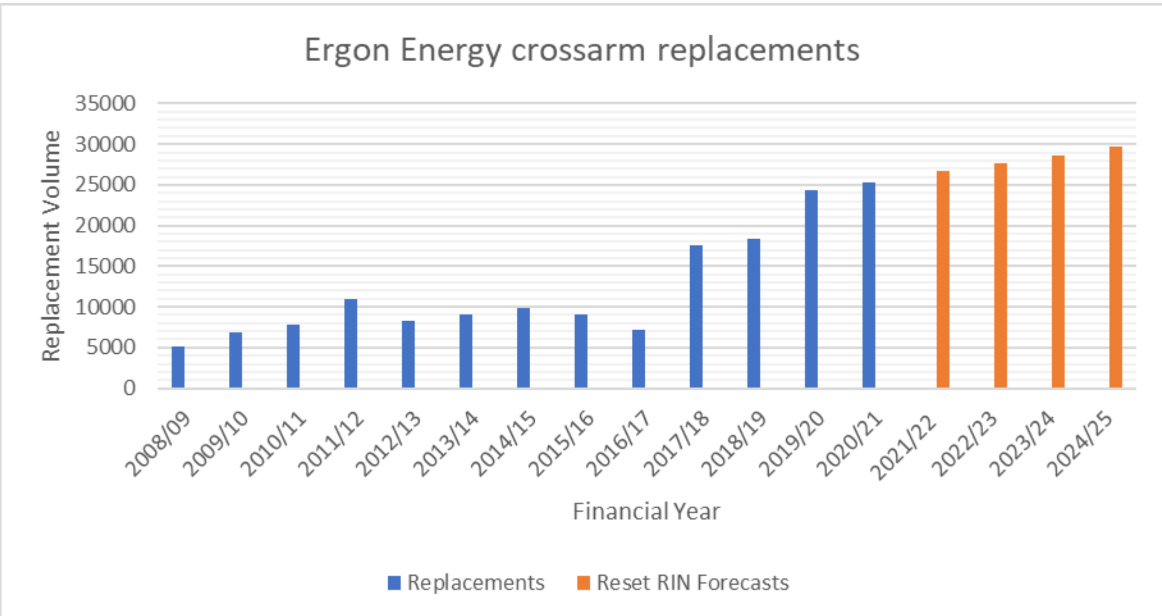

Figure 13: Ergon Energy Annual Crossarm Replacement Volumes and Forecasts

The proposed increased forecast faced a limitation due to competing business priorities and resource constraints. Progresses have been made to provide further focus on inspection to ensure a more targeted crossarm replacement program could be formulated.

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 Future Technologies to Deliver Inspection Capability

The use of high resolution imaging, artificial intelligence and machine learning to determine defect classification has been proven to provide Energy Queensland with an efficient, effective, and economic solution for condition monitoring of pole top structures and other overhead assets. The pole top detailed inspection program has been implemented using technologies such as aerial helicopter inspection and unmanned aerial vehicles (UAV) that are able to provide adequate detailed imagery for condition assessment using image processing and machine learning solutions to determine the condition rating, supplemented by minimal human intervention. The use of these aerial images and assessment processes has led to improvements in the identification of pole top structures that need replacement that otherwise are difficult to detect from a ground based inspection.

8.2 Future Technologies as an Alternative to Replacement

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

Energy Queensland continues to investigate technology-based techniques and applications to provide an alternative to like-for-like replacement to deliver greater risk reductions at lower cost.

There are ongoing regulatory hurdles to be overcome before some of these alternatives become more viable.

8.3 Health Index and Risk Monetisation

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

- Developed a Weibull distribution based analysis 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 their efforts to minimize the impact on customer prices.
    - A cost benefit analysis has been conducted to confirm that the pole top replacements are prudent capital investments.

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

EQL actively manages pole tops using a condition-based approach including:

- Visual inspection of physical condition from ground level.
- Aerial visual inspection carried out from helicopters/aircraft.
- Pole top inspection carried out from elevated work platform or climbing.

Physical defects identified through inspection are repaired or the asset is replaced. Failed assets are replaced on failure.

9.2 Supporting Data Requirements

Pole tops (including crossarms and insulators) are not recorded as individual assets in the corporate system. They are also not uniquely identified in the field. Information such as age, date of installation, material and condition is therefore problematic to monitor in an ongoing fashion. This asset class is therefore managed on a population performance basis.

Corporate data systems hold the initial construction type of each pole top attached to a pole. This is not generally updated if a pole top is replaced unless the replacement goes through a design process. The construction type gives insight into the type of crossarms and insulators used on the pole top. Pole tops are generally replaced at least once in the lifetime of the pole; therefore initial construction data is not always reflective of the in-service pole top asset. Traditionally, pole tops were replaced like for like, but with improvements in composite materials, most high voltage poletops are now replaced with composite versions. Where possible, low voltage (LV) construction types that have typically included a wood crossarm are now replaced with LV ABC instead of like-for-like.

Limited pole top data is stored against the pole which, is identified as an individual asset in the corporate system. Pole top replacement work orders are also associated with the pole. This information is utilised to infer/determine the age of the pole top and its condition.

EQL is investing in a new asset management system and consideration is being given to the inclusion of pole top structures as a unique asset class in the equipment data model. System limitations may prevent this from proceeding due to the volume.

The new asset management system will also include a common field data collection system which will result in consistent data collection and condition information across the Ergon Energy and Energex networks.

9.3 Acquisition and Procurement

Asset creation is driven by the upgrade of existing lines and replacement activities.

Pole top structures selected for use are dependent on the current construction standards for that voltage and the requirements of the individual design.

There are no current issues with the supply of pole top structures.

9.4 Operation and Maintenance

Operation and maintenance include planned and corrective maintenance. Operation and maintenance procedures are supported by a suite of documentation which 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.

The following sections provide a summary of the key aspects of the operation and maintenance of pole top structures as they relate to the management of the asset lifecycle.

EQL is continuing the process of alignment of maintenance practices between regions where it is prudent and efficient. This alignment will occur over a number of years to maintain compliance with maintenance tolerances during any transition. Alignment of maintenance practices and data collection is partially tied to the implementation of the new enterprise asset management system.

9.4.1 Preventive maintenance

The maintenance standards for overhead pole lines and overhead tower lines provide detail of the preventive maintenance programs and associated activities relating to pole top structures. Pole top structures are referred to as part of the crossarm assembly.

Associated maintenance activities include:

- In-service condition assessments:
  - Ground inspection
  - Aerial inspection of targeted wood pole top structures based on age and performance criteria utilising high resolution imagery and artificial intelligence technology
  - Wood pole top inspection in high rainfall areas based on age and rainfall criteria – Ergon Energy.
- Other specific maintenance
  - LiDAR (light detection and ranging)
  - Insulator cleaning.

Routine in-service condition assessments of pole tops are carried out to identify any unacceptable safety risk to personnel and the general public, to detect any defects requiring action, and to collect condition data for performance/risk analysis and replacement programs. Maintenance activity frequencies are provided in the Maintenance Activity Frequencies document.

Defects found during routine inspection or maintenance activities are risk assessed, classified and prioritised in accordance with the Lines Defect Classification Manual (LDCM). An example of this is the replacement of laminated crossarms. Known augmentation and replacement plans are considered prior to carrying out repairs or replacement.

Wood pole top inspection programs are also carried out in the wet tropic areas. These inspections are carried out by climbing the pole, with aid of an EWP to identify reduced strength crossarms. prudent.

Insulator cleaning may be performed on sub-transmission and transmission lines where there has been a history of contamination and flashover, although to date, it has not been found to be cost effective.

Maintenance tasks are contained in the following Maintenance Standard documents:

- Maintenance Standard for Overhead Tower Lines.
- Maintenance Standard for Overhead Pole Lines.

Pole tops are typically inspected as part of Pole inspections, with a frequency of the order of 5 years. The annual number of pole top inspections are around 282,000 for Ergon Energy and 111,000 for Energex. Refer to the Asset Management Plans for Poles for more details of the Works Programs.

9.4.2 Corrective maintenance

Corrective maintenance is generated from preventive maintenance programs, ad-hoc inspections and public reports.

Any corrective or forced action identified must be remediated by an authorised crew. Asset inspectors who carry out the overhead and underground line inspections are not authorised to perform any maintenance on pole tops. Asset inspection crews who carry out the EWP or climbing pole top inspections are authorised to perform chemical treatments at the time of inspection.

Where customer notification or ad-hoc inspections identify issues, rectification occurs through scheduled corrective maintenance.

For forced and corrective maintenance, pole tops are repaired if cost-effective, or replaced with like-for-like to the current standard.

9.4.3 Spares

EQL does not currently have a documented spares strategy for this asset. A minimum warehouse stock level of this asset is maintained based on historical usage and known future requirements.

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

All defects identified through the Overhead Line Inspection Program, the Line Patrol Program, and the Wood Pole Top Inspection Programs are remediated as part of the Defect Refurbishment Program.

9.5.2 Replacement

Pole top assemblies are replaced based upon condition, consistent with the requirements specified under the Asset Inspection and Defect management process. Pole top replacements may also occur in association with other works such as network augmentation or associated network asset replacement programs.

Where individual insulators have failed in service, it is common practice to inspect the remaining pole top assembly, as it is likely to be of a similar age and condition. Insulators are typically replaced with the crossarm unless they are relatively new and assessed as being in good condition.

9.6 Disposal

There are no special requirements for the disposal of pole top structures. Pole top structures are disposed of according to business disposal guidelines.

10 Program Requirements and Delivery

The programs of maintenance, refurbishment, and replacement required to outwork the strategies of this AMP are documented in Network Program Documents 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 site or feeder, to provide delivery efficiency and reduce travel costs and overheads. The Network Program Documents provide a description of works included in the respective programs as well as the forecast units.

Program budgets are approved in accordance with Corporate Financial Policy. The physical and financial performance of programs is monitored and reported on a monthly basis 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 in either legacy organisation, and therefore authorised/approved for use by EQL, that supports this Management Plan.

Legacy Organisation	Document Number	Title	Type
EQL	2948464	Standard for Classifying the Condition of Network Assets	Standard
EQL	2928929	Standard for Maintenance Acceptance Criteria	Manual
EQL	12357714	Network Schedule of Maintenance Activity Frequency	Procedure
EQL	2933369	Standard for Overhead Pole Lines	Standard
EQL	2933327	Standard for Overhead Tower Lines	Standard
Energex	2938244	Standard for Distribution Line Design Overhead	Manual
Ergon Energy Energex	-	Overhead Construction Manual	Manual
EQL	S032	Standard for Inspecting Poles	Standard
EQL	S033	Standard for Treating Poles	Standard
EQL	S038	Standard for Ground Based Pole Top Inspections	Standard
EQL	S056	Standard for Inspecting Private Property Poles	Standard
Ergon Energy	2929522	Standard for Pole Top Inspections	Standard
EQL	2945509	Standard for Managing Line Asset Defects	Standard
Energex	00629	Asset Inspection Tablet for Pole Inspection Use	Standard
Ergon Energy	2868921	Line Asset Inspection and Earthing Data Capture	Standard
Ergon Energy	2911238	Pole Structure Reference Guide	Standard
Ergon Energy	2928883	Standard for Wood Pole Serviceability Assessment	Standard
EQL	WCS5.1	Poles, Inspect and Treat	Specification
EQL	WCS5.1A	Poles, Inspect and Treat - Assessment	Specification
EQL	WCS5.6	WCS5.6 Poles, Ground Based Overhead Assessment	Specification
EQL	WCS5.6A	WCS5.6 Poles, Ground Based Overhead Assessment - Assessment	Specification
EQL	3034999	Distribution Lines Refurbishment Guideline - REPEX	Procedure

Appendix 2. Definitions

Term	Definition
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 22kVnetwork, all SWER networks
Sub transmission	33kV and 66kV networks
Transmission	Above 66kV 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.
Preventive maintenance	This type of maintenance involves routine planned/scheduled work, including systematic inspections, detection and correction of incipient failures, testing of condition and routine parts replacement designed to keep the asset in an ongoing continued serviceable condition, capable of delivering its intended service.

Appendix 3. Acronyms and Abbreviations

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

Abbreviation or acronym	Definition
ABC	Aerial Bundled Conductor
AMP	Asset Management Plan
Augex	Augmentation Expenditure
CBRM	Condition Based Risk Management
DEE	Dangerous Electrical Event
EGM	Executive General Manager
EPDM	Ethylene Propylene Diene Monomer
EQL	Energy Queensland Limited
ESCOP	Electricity Safety Code of Practice (2020)
ESR	Queensland Electrical Safety Regulation (2013)
FFA	Field Force Automation
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
NER	National Electricity Rules
NFM	Network Facilities Management
POC	Point of Connection (between EQL assets and customer assets)
POEL	Privately owned Electric Line
QLD	Queensland
REPEX	Renewal Expenditure
RIN	Regulatory Information Notice
SEI	Serious Electrical Incident
SFAIRP	So Far As Is Reasonably Practicable
STPIS	Service Target Performance Incentive Scheme
SHI	Security and Hazard Inspection
SM	Small
SWER	Single Wire Earth Return