# LEGISLATIVE COUNCIL
# Question Without Notice

## Tuesday, 29 November 2022

**C1388. Hon Dr Steve Thomas to the Parliamentary Secretary representing the Minister for Energy**

I refer to the 2022 Western Power Annual Report which on page 108 has Total Property, Plant and Equipment listed at a capital value of $11.977 billion as at the 30th of June 2022, and I ask:
1) How much of the $11.977 billion is represented by:
a) Poles
b) Cables
c) Substations, and
d) Transformers, And
2) Given that the estimated useful life of substations, transformers, poles and cables is 45 to 50 years, what proportion of each of these categories is over 50 years old?

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**Answer**

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1) a & b) $8.9 billion
c) $1.6 billion
d) $0.23 billion

2) Western Power publishes an annual State of the Infrastructure Report which provides amongst other things a snapshot of the age profile, condition and risk of key transmission and distribution assets.

I table the most recent edition of the State of the Infrastructure Report for the Member.

Bill Johnston

# State of the Infrastructure Report 2020/21

7 December 2021

# Contents

# Introduction

### *Purpose*

The primary purpose of this report is to provide stakeholders with information about the performance and state of the Western Power Network ('the network'), with a particular focus on operational safety. This supports improvements in the quality, transparency and alignment of decision making by all stakeholders.

We first published annual performance and asset data in this format in 2011/12 in response to one of the recommendations of the Parliamentary Standing Committee on Public Administration (Report 14 - Unassisted Failure) in January 2012. The report is updated and published annually, maintaining a consistent and independently verifiable source of performance data.

### *Scope*

The report covers the period 1 July 2020 to 30 June 2021 ('the reporting period') and provides:

- an overview of the operational safety performance of the network with respect to the key impact areas of public safety, property damage and the environment over the reporting period
- a snapshot of the age profile, condition and risk of key transmission and distribution network assets as at 30 June 2021, with a comparison of the same data from previous years.

The report does not present detailed information on strategies, treatment plans or network investment programs. These are captured in a range of other Western Power reports.

### *Context*

Our objective is to provide customers with safe, reliable and efficient access to the electricity network. We focus on providing agreed levels of service at the lowest practical cost, while minimising harm to the public, our workforce, the environment and damage to property.

We manage the electricity network in line with an asset management system. The asset management system meets the requirements of Australian Standard for Electricity Network Safety Management Systems **(AS5577)**, and is certified to **ISO55001:2014**, an International Standard on Asset Management.

The asset management system is aligned with the requirements set by the Economic Regulation Authority of Western Australia **(ERA)** and is recognised for its maturity as 'leading practice' by independent auditors. The mix of asset management capability, technological capability, and a culture of innovation and continual improvement enables us to deliver on our business objectives.

An integral part of providing an electricity network service, is the investment on asset treatment programs (inspection, repair, maintenance and replacement) centred around identifying and mitigating safety risks on the network asset including poles, towers, conductors and substations. This risk-based approach complies with AS5577 and includes consideration of the asset condition and the potential of the asset to cause a safety or reliability consequence if failure occurs. Under this approach, it is important to note the number of failures of a particular asset may vary without a change in the underlying risk.

# 1. Executive summary

The report focuses on three key areas:

1. public safety performance
2. environmental performance
3. asset performance and condition.

Asset performance and condition are included as indicators of potential future public safety and environmental performance, although it should be noted that outcomes in these areas are also influenced by factors beyond our control, such as:

- the operating conditions for the network
- interaction with the network by members of the public
- interaction with the network by flora and fauna
- external environmental conditions.

Consistent with our focus on operational safety, this report presents information only on those assets assessed as presenting the highest levels of risk to public safety and the environment.

Performance in 2020/21 in each of these areas (including overall asset state) was materially consistent with the 2019/20 report, in the context of normal year-on-year variability arising from external factors.

## 1.1 Public safety performance

We report on public safety performance using a range of agreed measures by our safety regulator, Building and Energy. This includes the frequency of public safety incidents.

A total of 152 public safety incidents were recorded during the reporting period (see Table 1.1).

**Table 1.1: Public safety**

| Public safety incident type | | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|---|
| A discharge of electricity from the network that causes the electric shock, injury or death of a person or the death of livestock | Human fatality | 0 | 0 | 0 | 0 | 0 |
| | Human injury | 2 | 2 | 0 | 2 | 4 |
| | Livestock fatality | 3 | 5 | 3 | 0 | 2 |
| | Electric shock, no injury | 155 | 122 | 157 | 187 | 146 |
| An incident caused by the network, other than a fire, that causes damage to property other than to the network | | 3 | 1 | 0 | 2 | 0 |
| A fire caused by the network that causes damage to property other than to the network | | 10 | 2 | 1 | 1 | 0 |
| **Total** | | **173** | **132** | **161** | **192** | **152** |

The increase in human injuries during the year was primarily (three of the four) due to third party contact with our network.

## 1.2 Environmental performance

We report on environmental performance using a range of measures. These include the frequency of hydrocarbon leaks from our network assets and vehicle fleet, as summarised in Table 1.2. During the reporting period, 725 such incidents were recorded.  A spike was observed in the 'Other' cause category due to numerous assets being affected by the Wooroloo bushfire and Tropical Cyclone Seroja.

We are also required to report significant environmental incidents to our regulators. During the 2020/21 financial year, six environmental incidents from network causes were reported (four related to oil spills, two related to fauna), all managed in liaison with the Department of Water & Environmental Regulation and the Department of Biodiversity, Conservation & Attractions.

**Table 1.2: Environmental hydrocarbon leak incidents by cause**

| Environmental hydrocarbon leak incidents by cause | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Network asset failure | 674 | 656 | 680 | 621 | 616 |
| Vehicle fleet | 20 | 22 | 27 | 38 | 18 |
| Human factors | 6 | 14 | 14 | 11 | 13 |
| Other (includes weather, fauna and third-party impacts) | 13 | 27 | 22 | 26 | 78 |
| **Total** | **713** | **719** | **743** | **696** | **725** |

## 1.3 Asset performance and condition

The network includes both overhead and underground construction and comprises millions of diverse individual assets such as poles, towers, overhead wires, underground cables, switchgear, transformers, protection equipment and security fencing. These are of various ages and at different stages of their lifecycles, which are subject to a broad range of environmental and operating conditions.

A sound understanding of the condition (or health) of an asset provides insight into its likelihood of failure. This knowledge, along with consideration of the potential consequences of failure, permits an assessment of the risk that asset poses. This in turn, informs strategies and plans for maintenance and renewal activities. The key risks considered in these activities are:

- safety risks, including initiation of fires, electric shocks and physical impacts
- service risks, including reliability of supply and power quality
- environmental risks, including hazardous substance leaks and fires.

A significant component of the report is dedicated to providing an overview of the assessed performance and condition of the key classes of network assets, as well as their associated high-level risk assessment.

Table 1.3 provides the summary view for 2020/21. While the condition of assets varies significantly with type and location, the overall position at the network level is largely unchanged from the 2019/20 State of the Infrastructure Report.

**Table 1.3: Summary of key asset class risk ratings**

| Risk area | Consequence type | Number of asset classes with risk rating – 2020/21 | | | | |
|---|---|---|---|---|---|---|
| | | Extreme | High | Medium | Low | No material risk |
| **Safety** | Fire | 0 | 3 | 8 | 8 | 0 |
| | Electric shock | 0 | 7 | 7 | 4 | 1 |
| | Physical impact | 0 | 4 | 9 | 5 | 1 |
| **Service** | Reliability | 0 | 0 | 14 | 4 | 1 |
| | Power quality | 0 | 0 | 8 | 5 | 6 |
| **Environmental** | Environmental | 0 | 3 | 10 | 4 | 2 |
| **Total** | | **0** | **17** | **56** | **30** | **11** |

### 1.3.1 Year-on-year comparisons

Explanatory commentary is only provided where there is significant variance between the current year and previous years. In comparing year-on-year performance, it is important to note there can be significant variability for a number of reasons, including:

- the general state of assets, which influences failure rates and the frequency with which defects are found
- the geographic diversity of the network, which influences whether a failure results in an incident
- year-on-year variability in environmental factors (e.g. the frequency and intensity of storms and lightning events, fuel loads and summer weather conditions) and public interference with the network.

This variability may occur without a change in the underlying risk.

Previous year's performance data in the report reflects the data collection, investigation and classification methods available at the time unless specifically noted.

## 1.4 Future-proofing the network

We're proud to be at the forefront of innovation and technology, embracing new generation, distribution and management options to ensure the network meets the needs of Western Australians into the future.

Current and future technology advancements are and will continue to enable Western Power to develop new solutions to connect people to safe, reliable electricity at the lowest sustainable cost. In order to manage the risk of the existing asset base, while enabling the transformation to the power system of the future, we tailor our asset management strategies to strike an optimum balance of investment in mitigating risk and realisation of these opportunities for our community.

We're well on the way to transforming the grid with significant progress made during the past year. Some of the recently completed and ongoing innovative projects are:

- Community battery installation
- Stand-alone power systems (SPS)
- Kalbarri microgrid
- Advanced metering infrastructure including Service connection condition monitoring (SCCM)
- Smart streetlights
- Perenjori microgrid
- Flexibility Services Pilot
- Project Symphony

# 2. Public safety performance

We report on public safety performance using a range of agreed measures by our safety regulator Building & Energy. This includes the frequency of public safety incidents.

As summarised in Table 2.1, a total of 152 public safety incidents were recorded during the reporting period, with no fatalities. This equates to a 12-month average of 13 incidents per month.

**Table 2.1: Public safety**

<table>
<tr><th colspan="2">Public safety incident type</th><th>2016/17</th><th>2017/18</th><th>2018/19</th><th>2019/20</th><th>2020/21</th></tr>
<tr><td rowspan="4">A discharge of electricity from the network that causes the electric shock, injury or death of a person or the death of livestock</td><td>Human fatality</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Human injury</td><td>2</td><td>2</td><td>0</td><td>2</td><td>4</td></tr>
<tr><td>Livestock fatality</td><td>3</td><td>5</td><td>3</td><td>0</td><td>2</td></tr>
<tr><td>Electric shock, no injury</td><td>155</td><td>122</td><td>157</td><td>187</td><td>146</td></tr>
<tr><td colspan="2">An incident caused by the network, other than a fire, that causes damage to property other than to the network</td><td>3</td><td>1</td><td>0</td><td>2</td><td>0</td></tr>
<tr><td colspan="2">A fire caused by the network that causes damage to property other than to the network</td><td>10</td><td>2</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td colspan="2">Total</td><td>173</td><td>132</td><td>161</td><td>192</td><td>152</td></tr>
</table>

The increase in human injuries during the year was primarily (three of the four) due to third party contact with our network.

Table 2.2 summarises public safety performance against other key indicators.

**Table 2.2: Safety performance indicators**

| Safety performance indicator | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Unassisted wood pole failures (distribution) | 327 | 367 | 116 | 188 | 48 |
| Unassisted wood pole failures (transmission) | 6 | 17 | 5 | 19 | 1 |
| Unassisted phase conductor failures (distribution) | 298 | 285 | 234 | 192 | 160 |
| Unassisted conductor failures (transmission) | 0 | 1 | 0 | 0 | 0 |
| Ground fire incidents | 128 | 150 | 194 | 186 | 117 |

The lower numbers of unassisted asset failures and ground fire incidents for 2020/21 were attributed primarily to favourable weather conditions during the year. Weather affects both the likelihood of an asset failure and the likelihood of that failure converting to a ground fire. Note that the large number of pole failures from Tropical Cyclone Seroja are classified as 'assisted' and therefore do not contribute to the numbers above.

# 3. Environmental performance

We report on environmental performance using a range of measures. These include the frequency of hydrocarbon leaks from our network assets and vehicle fleet, as summarised in Table 3.1. During the reporting period, 725 such incidents were recorded. A spike was observed in the 'Other' cause category due to numerous assets being affected by the Wooroloo bushfire and Tropical Cyclone Seroja.

We are also required to report significant environmental incidents to our regulators. During the 2020/21 financial year, six environmental incidents from network causes were reported (four related to oil spills, two related to fauna), all managed in liaison with the Department of Water & Environmental Regulation and the Department of Biodiversity, Conservation & Attractions.

**Table 3.1: Environmental hydrocarbon leak incidents by cause**

| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Network asset failure | 674 | 656 | 680 | 621 | 616 |
| Vehicle fleet | 20 | 22 | 27 | 38 | 18 |
| Human factors | 6 | 14 | 14 | 11 | 13 |
| Other (includes weather, fauna and third-party impacts) | 13 | 27 | 22 | 26 | 78 |
| **Total** | **713** | **719** | **743** | **696** | **725** |

To reduce the risk of soil and ground water pollution from incidents, all new equipment installed in Western Power substations containing more than 1,000 litres of oil are designed to meet the requirements of AS2067:2016 for oil containment. Table 3.2 summarises the status of transmission bunds, which are progressively upgraded to the current standard to continually reduce the risk of a major incident. A review against current standards in 2020/21 financial year has identified further non-compliant bunds that have been added to the program of work.

**Table 3.2: Status of transmission oil-containment bunds**

| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Bund draining to a holding tank, polymer filter or interceptor | 227 | 220 | 221 | 231 | 233 |
| Containment bund draining to soil | 128 | 120 | 120 | 113 | 110 |
| Portable bund (rapid response asset) | 4 | 4 | 4 | 4 | 4 |
| No bund | 13 | 14 | 14 | 13 | 19 |
| **Total** | **372** | **358** | **359** | **361** | **366** |

# 4. Asset performance and condition

## 4.1 Introduction

The network includes both overhead and underground construction and comprises millions of diverse individual assets, such as poles, towers, overhead wires, underground cables, switchgear, transformers, protection equipment and security fencing. These are of various ages and at different stages of their lifecycle, which are subjected to a broad range of operating conditions (including varying environmental exposure).

A sound understanding of the condition (or health) of an asset provides insight into its likelihood of failure. This knowledge, along with consideration of the potential consequences of failure, permits an assessment of the risk that asset poses. This, in turn, informs strategies and plans for maintenance and renewal activities. The key risks considered in these activities are:

- safety risks, including initiation of fires, electric shocks and other consequences (such as physical impacts)
- service risks, including reliability of supply and power quality
- environmental risks, including hazardous substance leaks and fires.

This portion of the report provides an overview of the assessed performance and condition of the key classes of network assets, as well as their associated high-level risk assessment. It has been revised for this report to incorporate additional asset classes and risk information, reflecting our increasing maturity in risk-based asset management. Some asset classes have been removed as they do not pose significant safety, service or environmental risks.

Table 4.1 provides the summary view for 2020/21. While the condition of assets varies significantly with type and location, the overall position at the network level is largely unchanged from the 2019/20 State of the Infrastructure Report.

**Table 4.1: Summary of key asset class risk ratings**

| Risk area | Consequence type | Number of asset classes with risk rating – 2020/21 | | | | |
|---|---|---|---|---|---|---|
| | | Extreme | High | Medium | Low | No material risk |
| **Safety** | Fire | 0 | 3 | 8 | 8 | 0 |
| | Electric shock | 0 | 7 | 7 | 4 | 1 |
| | Physical impact | 0 | 4 | 9 | 5 | 1 |
| **Service** | Reliability | 0 | 0 | 14 | 4 | 1 |
| | Power quality | 0 | 0 | 8 | 5 | 6 |
| **Environmental** | Environmental | 0 | 3 | 10 | 4 | 2 |
| **Total** | | **0** | **17** | **56** | **30** | **11** |

## 4.2 Network elements

We hold transmission and distribution licences for the construction, management and operation of two distinct networks:

1. the **transmission network**, which transports electricity between generators, transmission terminal stations and zone substations.
2. the **distribution network**, which transports electricity between zone substations and individual customers

These elements are made up of many different types of assets, including 19 key asset classes that are discussed further in this report. For the purpose of reporting the state of the network assets, these are grouped as follows:

- structures (distribution and transmission)
- conductors (distribution and transmission)
- distribution plant and equipment
- transmission plant and equipment
- public lighting
- easements (distribution and transmission)
- network buildings (distribution and transmission).

## 4.3 Assessment methodology

The assessment for each asset group consists of the following:

- Summary of the asset classes within the group and the purpose(s) they serve in the network.
- **Failure modes and consequences** – a brief discussion of the high-level failure modes of the asset classes that contribute to key risks, including a summary of the associated failure mechanisms.
- **Age and condition profile** – a summary of the expected service life of the asset classes and the associated age profile. This recognises that as an asset ages, the frequency and severity of defects tend to increase, progressively reducing its serviceability until intervention (repair or replacement) is required in accordance with our risk-based asset management strategy. Where relevant, additional condition information is included.
- **Expected service life** – this is the nominal period during which the asset is expected to serve its intended functional purpose safely, with an appropriate level of maintenance, repair or refurbishment (that is not disproportionate to the replacement cost). It takes into consideration the actual performance of the asset and the cumulative deterioration of the asset over time.
    - The expected service life of an asset typically exceeds its design life. Exceeding expected service life does not mean an asset is unsafe or will fail immediately, however the frequency and severity of defects and the likelihood of in-service failure are expected to increase. Expected service life is typically less than mean replacement life, as we replace many assets on-condition and prioritise according to our risk-based approach to asset management.
- **Failure performance** – a summary of recent historical performance for the failure modes of interest. Unless otherwise noted, this reflects "unassisted" failures.

- **Risk assessment** – the current risk assessment against the key risk areas in accordance with our network risk assessment criteria.

### 4.3.1 Data quality

The network asset data used to support decisions has been collected over many decades. Although its quality and completeness vary across asset classes, due to historical variability in type and method of collection, we have invested considerable effort to ensure it is adequate to assess risk and prioritise investment. This effort continues through improvements in technology and collection, storage and validation processes.

The previous year's report reflects the data collection, investigation and classification methods available at the time unless specifically noted.

### 4.3.2 Risk based asset management

We manage the electricity network in line with an asset management system. The asset management system meets the requirements of Australian Standard for Electricity Network Safety Management Systems **(AS5577-2013)**, and is certified to **ISO55001:2014**, an International Standard on Asset Management.

The asset management system is aligned with the requirements of the Economic Regulation Authority of Western Australia **(ERA)** and is recognised for its maturity as 'leading practice' by independent auditors. The mix of asset management capability, technological capability, and a culture of innovation and continual improvement enables us to deliver on our business objectives.

Our ability to address all network risks in the short term is constrained by a range of factors, such as the volume and geographic dispersion of assets, funding and works delivery capacity. The risk-based prioritisation of network investment is therefore critical to optimising risk outcomes within these constraints.

As discussed in the introduction to this report, the risk-based approach is a key element of our certified asset management system. It includes consideration of the asset condition and the potential of the asset to cause a safety or reliability consequence if failure occurs. Under this approach, it is important to consider the number of failures of a particular asset may vary significantly without a change in the underlying risk.

Our approach to asset management is maturing continuously to support a robust, defensible and transparent prioritisation of risks. We maintain a continuous dialogue with key external stakeholders to build understanding and confidence in the asset knowledge, tools and systems used to develop and support our investment decisions.

The reader should expect to see this report evolve over time so that it continues to provide an aligned and transparent view of operational safety risks, including specific asset failure modes and condition information that is indicative of likelihood of failure.

## 4.4 Structures

This group includes the following key asset classes:

- distribution structures (poles, cross-arms, foundations, stay systems and insulators)
- transmission structures (poles, towers, cross-arms, foundations, stay systems and insulators).

For these asset classes, the asset components of poles and cross-arms are identified as having the greatest potential to adversely impact public safety or reliability of the network.

Note: Communications structures are not discussed in this section. While these assets are exposed to the same environmental stresses as other structures, and hold mains powered equipment, they do not support network conductors. They are also typically located in sparsely populated areas and pose less significant risks to the public.

Poles and towers support overhead lines and equipment in the transmission and distribution networks. Poles are categorised and managed according to their material type (wood, concrete or metal) and network type (transmission or distribution). Towers are only installed in the transmission network.

### 4.4.1 Failure modes and consequences

High level failure modes of highest risk for structures are:

- structural failure leading to fire (from fallen conductors), electric shock (from fallen/low conductors), physical impact or reliability impacts
- leakage current across insulators leading to fire or reliability impacts.

#### *Structural failure*

Structures are exposed to the environment throughout their lifecycle, leading to progressive degradation in strength that can result in failure below the design load, typically in high winds.

A range of conditions contribute to structural failure, including:

- environmental conditions, particularly wind direction/strength
- design factors such as material (including wood species) and diameter
- external damage, particularly fire damage and vehicle impacts
- defects in wooden components such as knots, splits, rot and insect (primarily termite) damage
- defects in metal or concrete components such as cracking, rust, metal fatigue and concrete cancer.

Structural failure is managed through regular inspection and on-condition replacement of high-risk assets.

#### *Leakage current*

Leakage current is electrical tracking from an energised conductor at the top of an insulator through an earth connection across an insulator surface. This electrical tracking can be caused by defective insulators or insulator surfaces being contaminated with pollution, in conjunction with surface moisture from sources such as mist, dew or light rain. These pollution and weather conditions can vary significantly from year to year. Leakage current is the major cause of pole top fires in the network, and these fires can spread to the ground or cause network outages.

A range of conditions contribute to leakage current failures, including:

- environmental conditions, particularly salt/pollution and wind direction/strength
- design factors such as insulator and fastener type
- defects such as cracked insulators or loose fastener.

Leakage current is managed through a combination of regular inspection, risk-based proactive treatments (siliconing and insulator washing) and on-condition replacement of high-risk assets.

### 4.4.2 Age and condition profile

Expected life for structures varies widely with the materials. Based on AS/NZS 7000:2016 (Table D4) untreated unreinforced hardwood poles have an expected service life of 15-25 years and softwood poles have an expected service life of 45-55 years. Non-wood poles and towers have expected service lives ranging from 55 to 100 years. The cross-arms used in the network have expected service lives of 40 years (wood) and 50 years (steel).

The age profile of the network's 786,266 distribution poles is shown in Figure 4.1. Of these, 618,102 are wood poles, of which 135,730 are identified for treatment (replacement, reinforcement or removal) in accordance with our risk-based asset management strategy.

**Figure 4.1: Age profile – distribution poles**

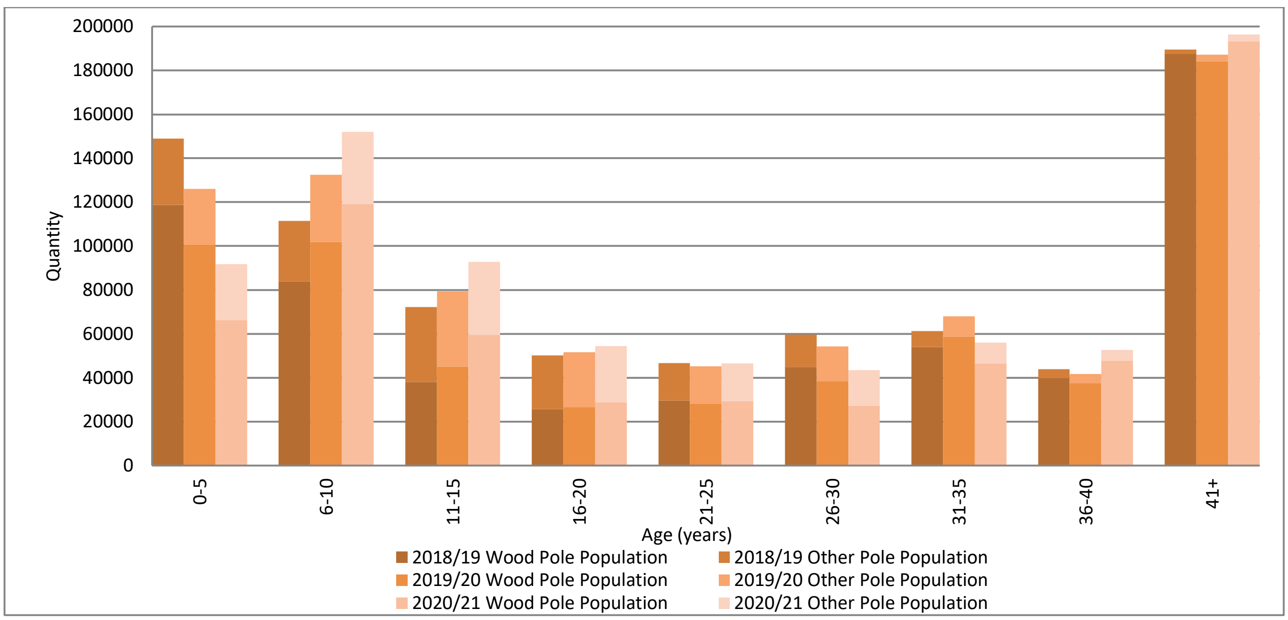



Figure 4.2 (following page) shows the volumes of distribution wood poles that are and are not identified for treatment. In addition, 159 metal poles, and 11 concrete poles have been assessed as having conditions requiring replacement in accordance with our strategy for managing assets of this type, and our risk-based approach to asset management.

**Figure 4.2: Serviceability profile by age – distribution wood poles**

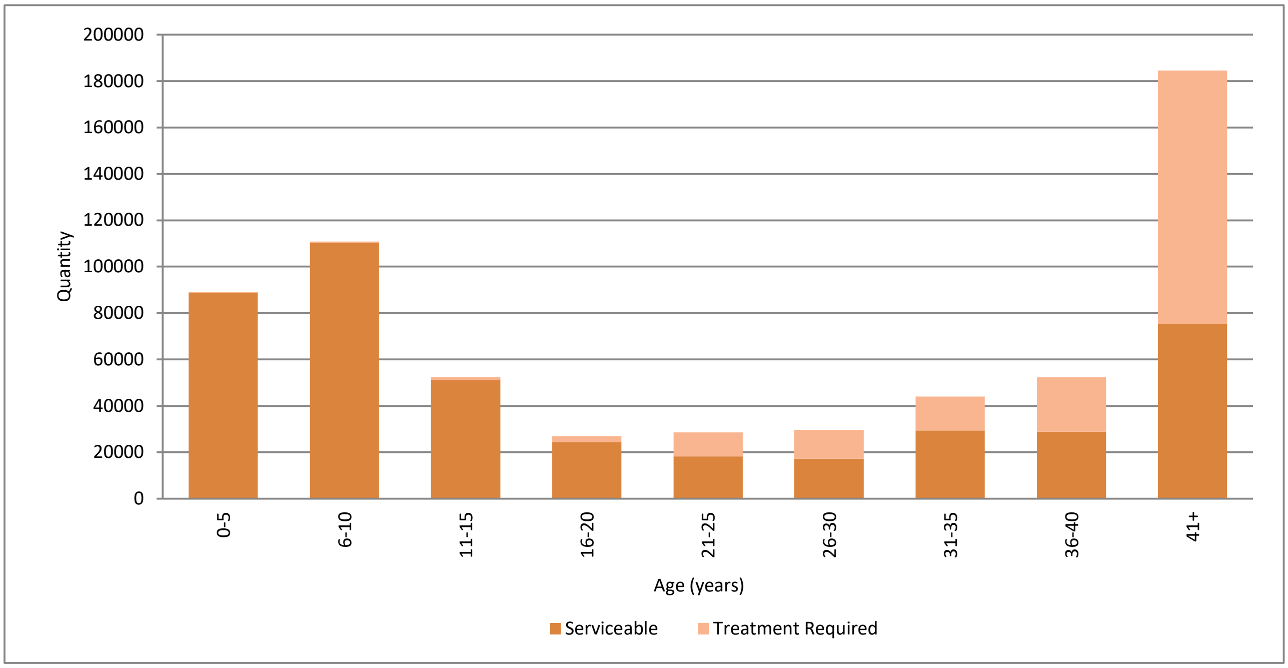
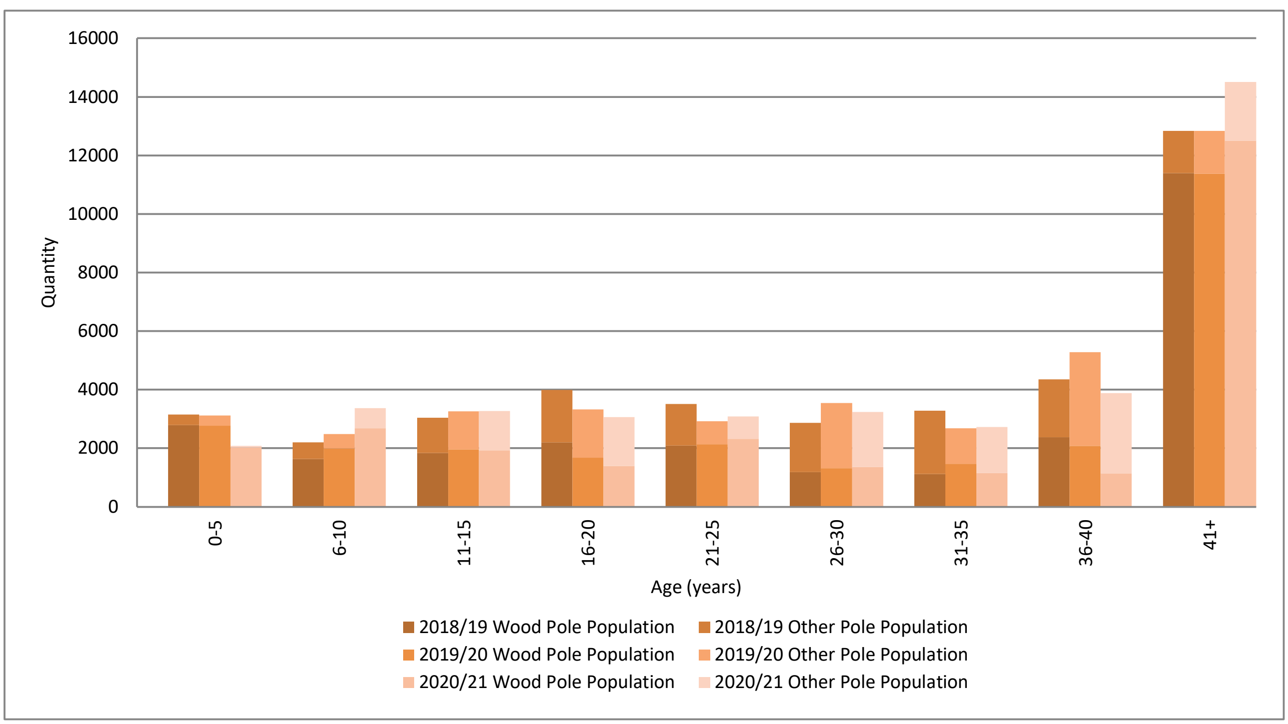


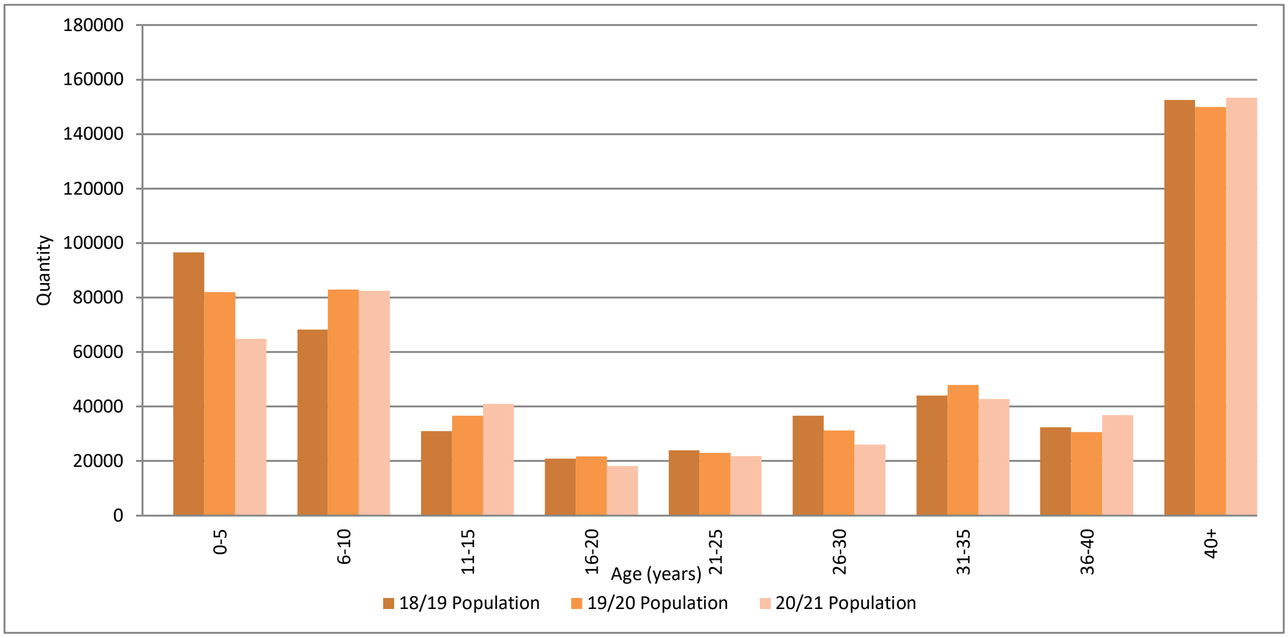

Figure 4.3 shows the age profile of the total population of 39,239 transmission structures at the end of the reporting period. A total of 26,505 are wood poles (including auspoles), of which 8,938 are identified for treatment (removal, replacement or reinforcement) in accordance with our risk-based asset management strategy. The number of poles requiring treatment has reduced this year due to both the program of work and a strategy review that implemented more nuanced triggers for proactive treatment.

**Figure 4.3: Age profile - transmission structures**



The age profile of the network's 477,009 distribution cross-arms is shown in Figure 4.4. Of these, approximately 239,000 are hardwood timber, 177,000 steel and 61,000 composite materials. Installation dates for cross-arms are not recorded and the total numbers have reduced this year due to a data improvement activity. The condition of cross-arms is assessed through routine inspection, with 24,189 cross-arms assessed as being due for replacement is in accordance with our strategy for managing assets of this type, and our risk-based approach to asset management.

**Figure 4.4: Age profile - distribution cross-arms**




### 4.4.3 Failure performance

Table 4.2 summarises failure performance for structures for this reporting period and preceding reporting periods.

Note: No failures of towers or non-wood structures have been recorded in recent years.

**Table 4.2: Failure performance – structures (quantity, percentage of total population)**

| Failure mode | 2016/17 | | 2017/18 | | 2018/19 | | 2019/20 | | 2020/21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Qty | % | Qty | % | Qty | % | Qty | % | Qty | % |
| Structural failure – unassisted wood pole failures (distribution) | 327 | 0.05 | 367 | 0.06 | 116 | 0.02 | 188 | 0.03 | 48 | 0.01 |
| Structural failure – unassisted wood pole failures (transmission) | 6 | 0.02 | 17 | 0.06 | 5 | 0.02 | 19 | 0.08 | 1 | <0.01 |
| Structural failure – unassisted cross-arm failures (distribution) | 270 | 0.05 | 391 | 0.08 | 226 | 0.04 | 158 | 0.03 | 122 | 0.02 |
| Leakage current resulting in unassisted pole top fire (total) | 361 | 0.04 | 253 | 0.03 | 350 | 0.04 | 498 | 0.10 | 247 | 0.04 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Leakage current resulting in unassisted pole top fire (with ground fire) | 45 | <0.01 | 17 | <0.01 | 90 | 0.01 | 101 | 0.02 | 28 | <0.01 |

The lower numbers of unassisted asset failures and ground fire incidents for 2020/21 were attributed primarily to favourable weather conditions during the year. Weather affects both the likelihood of an asset failure and the likelihood of that failure converting to a ground fire. Note that the large number of pole failures from Tropical Cyclone Seroja are classified as “assisted” and therefore do not contribute to the numbers above

#### 4.4.4 Risk assessment

**Table 4.3: Risk assessment – distribution structures**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | High | Distribution structures pose a high fire risk as there is a very large population of assets situated in areas classified as extreme or high bushfire risk zones. Failure of these assets is known to have initiated ground fires. |
| | Electric shock | High | Distribution structures pose high electric shock risk, as there is a very large population of assets in close proximity to streets, pedestrian pathways and public spaces. In addition, the distribution network does not have the same level of fault protection as the transmission network. There have been incidents of electric shock reported from failed distribution structures. |
| | Physical impact | High | Distribution structures pose high physical impact risk as there is a very large population of assets in close proximity to streets, pedestrian pathways and public spaces. Failure of these assets has historically resulted in physical impact events. |
| **Service** | Reliability | Medium | Distribution structures pose medium reliability risk as failures typically cause a service interruption to hundreds of customers. |
| | Power quality | No material risk | Distribution structures pose no material power quality risk. |
| **Environmental** | Environmental | Medium | Distribution structures pose high environmental risk as they can cause fires and asset failure can result in the release of oil from pole top transformers. |

**Table 4.4: Risk assessment – transmission structures**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Medium | Transmission structures pose medium fire risk due to wide easements and fast-acting protection. |

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| | Electric shock | Medium | Failure of a transmission structure can cause electric shock by contact with steel structures temporarily live or contact with low conductors following structure failure. This is considered to be medium risk as transmission lines have fast-acting protection, limiting the potential exposure . |
| | Physical impact | Medium | Transmission structures pose medium physical impact risk. Due to their size, they have a potential to cause major injury, but lines typically have wide easements, thus reducing the likelihood of consequence from failure. |
| **Service** | Reliability | Medium | Transmission structures pose medium reliability risk due to higher levels of redundancy in the transmission network design. |
| | Power quality | Low | Failure of a transmission structure may lead to frequency variations resulting in a slight impact to power quality. This is considered to be low risk as there have been no recorded power quality issues caused by structural failure. |
| **Environmental** | Environmental | Medium | Transmission structures pose medium environmental risk due to the potential for a failed transmission structure to cause a ground fire that may result in environmental damage. |

## 4.5 Conductors

This group includes the following key asset classes:

- distribution overhead conductors (phase conductors, earth wires and associated accessories)
- distribution underground cables (cross-linked polyethylene (XLPE)/ paper-insulated cables and associated accessories, including joints and terminations)
- service connections (overhead, underground and hybrid)
- transmission overhead conductors (phase conductors, earth wires and associated accessories)
- transmission underground cables (XLPE/ fluid-filled cables and associated accessories, including joints, terminations and pressurising equipment).

Note: Communications assets such as pilot cable and optical fibre are not discussed in this section. Pilot cables can have significant potential voltage induced from network conductors, but these are rare events and pose less significant risk to the public.

Conductors carry electrical current from generators to consumers across the transmission and distribution networks. Earth wires provide protection from lightning strikes and other faults and accessories connect, support or protect the conductors.

### 4.5.1 Failure modes and consequences

High level failure modes of highest risk for conductors are:

- conductor failure (breakage) leading to fire (from fallen conductors), electric shock (from fallen/ low conductors) or reliability impacts

- overhead conductor clashing leading to fire (from droplets of molten metal)
- substandard clearances leading to fire or electric shock
- service connection failure leading to electric shock (from exposed conductors or loss of neutral integrity)
- insulation failure of underground cables leading to reliability impacts
- oil leaks from fluid-filled cables leading to environmental and reliability impacts.

### *Overhead conductor failure*

Overhead conductors are exposed to the environment throughout their lifecycle, leading to progressive degradation in strength, primarily from corrosion and mechanical fatigue. This can result in failure below the design load, typically in high winds.

A range of conditions contribute to conductor failure, including:

- environmental conditions, particularly salt/ pollution and wind direction/ strength
- design factors such as material, gauge (wire diameter) and insulated/bare wire
- operational loading.

Conductor failure is managed through regular inspection and on-condition replacement of high-risk assets.

### *Overhead conductor clashing*

Phase conductors require a minimum separation distance between each other and earth conductor/s. Conductor clashing can occur if the separation distance is sufficiently reduced, to permit electric current to travel along an unintended path between the conductors. This failure mode is largely limited to the distribution network, due to the larger separation distances designed into the transmission network.

A range of conditions contribute to conductor clashing, including:

- environmental conditions, such as wind direction/strength and high ambient temperatures
- design factors such as the distance between adjacent poles (‘bay’ length) and conductor separation
- third party interference
- defects such as pole lean or conductor sag that reduce conductor tension
- operational loading.

Conductor clashing is managed through regular inspection and fault response. We continue to investigate asset characteristics (such as protection signatures), that correlate with increased likelihood of unassisted conductor clashing, permitting more effective prioritisation of treatment works.

### *Substandard clearance*

Overhead conductors crossing roadways and navigable waterways are required to provide a minimum clearance height to ensure safe passage beneath them.  This primarily affects distribution conductors, due to the higher construction standards for transmission assets.

A range of conditions contribute to substandard clearances, including:

- environmental conditions, such as high ambient temperatures
- design factors such as the distance between adjacent poles (‘bay’ length)

- defects such as pole lean or conductor sag that reduce clearances
- operational loading.

Substandard clearance is managed through survey to identify non-compliant crossings. Identification of substandard road crossings will be improved by the surveying methods used. Remediation options include re-tensioning or lifting conductors on existing poles, installing new taller poles or installing additional intermediate poles, with treatment prioritised by risk.

Under normal configuration and operation conditions, the construction standards in transmission lower the risk of substandard clearance. However, one of the tools available to Western Power to facilitate the adaptation of the transmission network to cater for the changing energy needs of Western Australia is uprating overhead lines. When lines are uprated, the line is subjected to additional stresses that increase conductor sagging and consequently reduces conductor clearances. Before uprating transmission lines, Western Power models the behaviour of the line when operating at limit conditions to identify and treat potential intermittent substandard clearances before allowing the line to be uprated.

### *Service connection failure*

Service connections are inherently located in close proximity to the public, and any failures have the potential to lead to electric shock through either exposure of conductors or loss of neutral integrity.

A range of conditions contribute to service connection failures, including:

- substandard installation and repair practices
- abnormal stresses (e.g. damage from vehicles, vegetation)
- age degradation, particularly corrosion and degradation of insulation material.

Service connection failure is managed through inspections in response to customer reports. We are currently implementing condition monitoring by leveraging advanced metering technology to identify and treat failed service connections before electric shock incidents occur.

### *Insulation failure*

Insulation on underground cables can degrade due to environmental stresses, with potential to cause network outages. This affects XLPE and paper-insulated underground cables.

A range of conditions contribute to insulation failures, including:

- third party damage
- insect damage (primarily termites)
- mechanical fatigue in metallic (lead alloy) sheaths
- age degradation of insulation material.

Insulation failure is managed through routine inspection (transmission cables only) and reactive maintenance (all cables).

### *Oil leak*

Fluid-filled cables comprise paper insulation impregnated with fluid (oil), which is maintained at a positive pressure within the cable by means of a reservoir and pressurisation equipment at each end of the cable. This oil represents an environmental hazard if it leaks from the cable.

A range of conditions contribute to oil leaks, including:

- third party damage
- defects in cable accessories (terminations and straight joints)
- mechanical fatigue in metallic (lead alloy) sheaths.

Oil leaks are managed by monitoring oil consumption and on-condition inspection and repair of leaking cables. We are no longer installing fluid-filled underground cables, and we are progressively decommissioning existing 66kV fluid-filled cables from the network. We are also running a trial for the use of a leak detection method that is expected to improve accuracy in detecting the leak location, thus improving treatment efficiency.

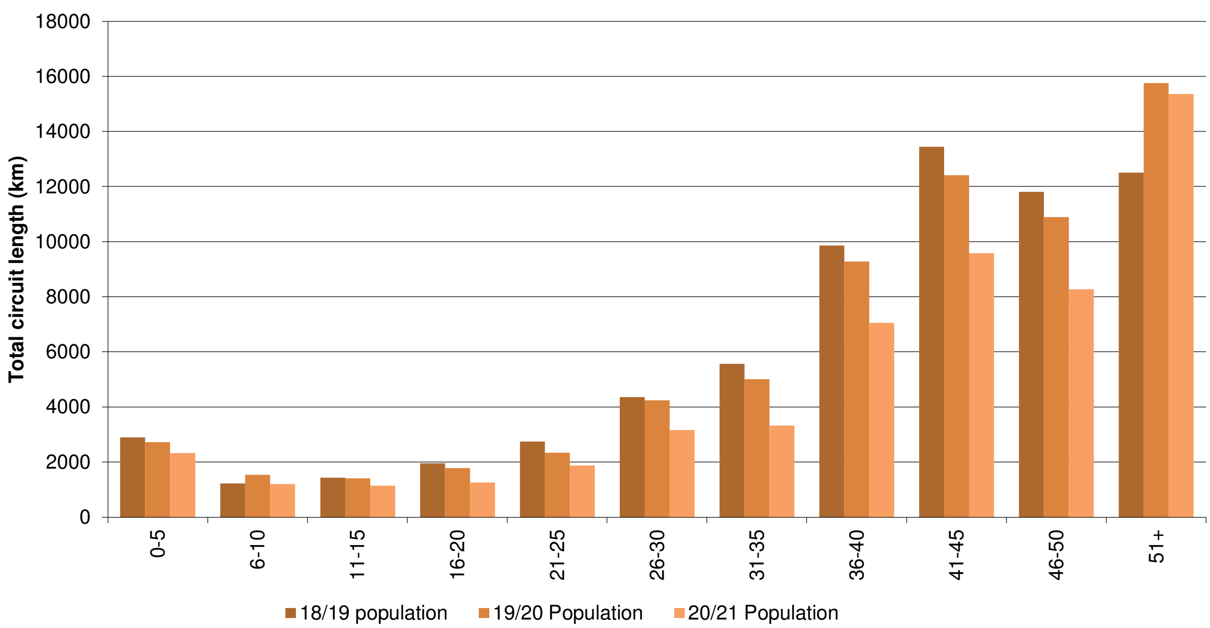
### 4.5.2 Age and condition profile

The expected service life of transmission overhead conductors is 60 years. Expected service lives have not been defined for other conductor asset classes, but the mean replacement lives (typically higher than expected service life) for distribution overhead is 70 years, 30-32 years for service connections, 30 years for distribution underground and 40 years for transmission underground. For comparison, the mean replacement life for transmission overhead conductors is 80 years.

Of the network's population of 65,964 km of distribution overhead conductor (high voltage: 57,283 circuit km; low voltage: 8,681 circuit km), 3,769 km was assessed as presenting a higher likelihood of failure, with 567 km located in high population centres or high or extreme bushfire risk zones.

As shown in Figure 4.5, approximately 61 per cent of the network's distribution overhead conductor population is more than 40 years old. Distribution overhead conductor age data is derived using estimation algorithms.

**Figure 4.5: Age profile – distribution overhead conductors**




The estimated population of service connections is shown in Table 4.5.

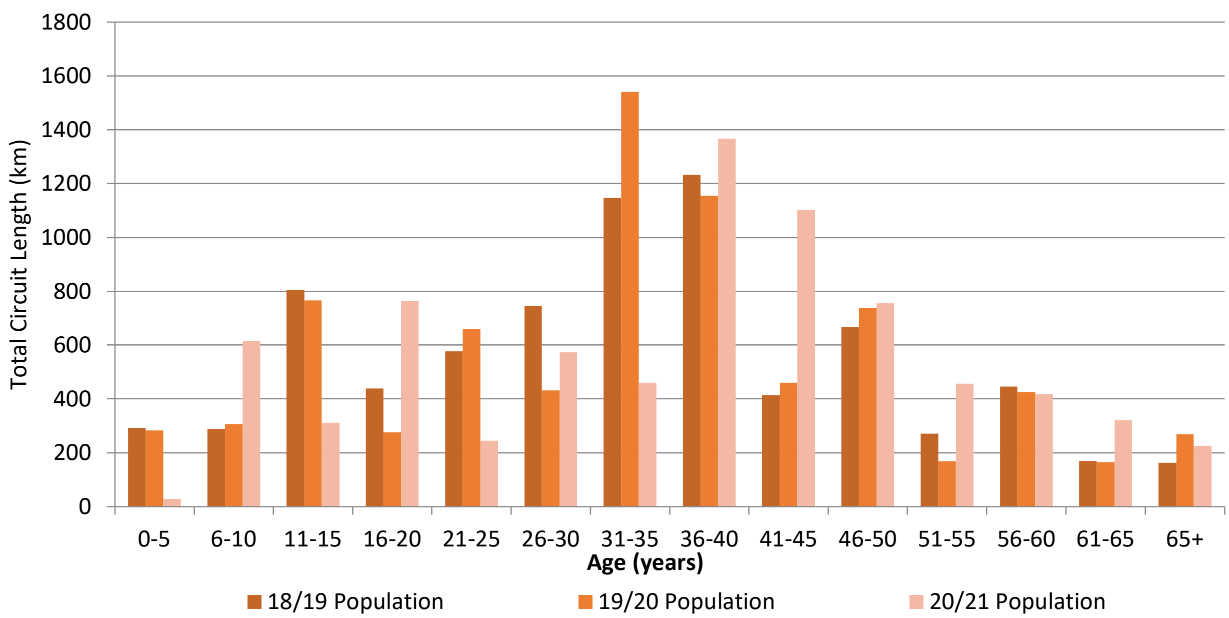
**Table 4.5: Asset population – customer service connections**

| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Overhead customer service connections | 362,092 | 358,382 | 354,771 | 350,763 | 343,907 |
| Pillars | 335,423 | 344,257 | 351,646 | 357,543 | 364,081 |

The reduction in the reported population of overhead customer service connections is due to a combination of improved data accuracy, and the progressive removal of these assets from the network through the undergrounding of these connections.

The overall age profile of transmission overhead conductors is shown in Figure 4.6. Only a small percentage of the transmission conductor population has exceeded the expected service life.

**Figure 4.6: Age profile – transmission overhead conductors**




At the end of the reporting period, the 52km of energised cable that makes up the underground transmission network includes 9.3km of fluid filled cables, 82 per cent of which have exceeded their mean replacement life. Approximately 9 per cent of XLPE cable is beyond mean replacement life. Overall, 38.5 per cent of the transmission underground cable network is beyond mean replacement life. No graph is presented for this information due to the limited population of assets.

### 4.5.3 Failure performance

Table 4.6 summarises failure performance for conductors for this reporting period and preceding reporting periods.

**Table 4.6: Failure performance – conductors**

| Failure mode | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Unassisted conductor failure – overhead distribution conductors (total) | 298 | 285 | 234 | 192 | 160 |
| Unassisted conductor failure – overhead distribution conductors (with ground fire) | 7 | 18 | 18 | 3 | 3 |
| Unassisted conductor failure - overhead transmission conductors (total) | 0 | 1 | 0 | 0 | 0 |
| Unassisted conductor clashing – distribution conductors (total) | 66 | 81 | 35 | 137 | 120 |
| Unassisted conductor clashing – distribution conductors (with ground fire) | 4 | 3 | 2 | 5 | 6 |
| Unassisted overhead service connection failure (with electric shock) | 74 | 40 | 61 | 91 | 73 |
| Unassisted underground service connection failure (with electric shock) | 15 | 29 | 40 | 40 | 29 |
| Unassisted insulation failure – underground cable sheath failures | 12 | 8 | 11 | 8 | 7 |
| Unassisted oil leak – cables requiring additional top-ups | 3 | 4 | 3 | 3 | 3 |
| Unassisted oil leak – volume of oil leaked (litres) | 505 | 954 | 408 | 360 | 510 |

Note: Historical transmission cable insulation failures and oil leaks have been amended to align with new methodology for monitoring and reporting.

Of the Network's 237,220 conductor road crossings, 123,394 have been surveyed and 12,882 crossings are reported to have substandard ground clearances of varying degree. The number of surveyed road crossings and substandard clearances incorporates the findings from the first LiDAR survey of the network in the 2018/19. A second LiDAR survey of the network commenced in 2020/21 and its data will be used to update and reassess crossings and clearances.

### 4.5.4 Risk assessment

**Table 4.7: Risk assessment – distribution overhead conductors**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | High | Distribution conductors pose high fire risk, as there is a very large population of assets situated in areas classified as extreme or high bushfire risk zones. Failure of these assets is known to have initiated ground fires. |
| | Electric shock | High | Distribution conductors pose high electric shock risk, as there is a very large population of assets in close proximity to streets, pedestrian pathways and public spaces. In addition, the distribution network does not have the same level of fault protection as the transmission network. There have been incidents of electric shock reported from failed distribution conductors. |

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| | Physical impact | High | Distribution conductors pose high physical impact risk, as travelling vehicles coming into contact with fallen or low conductors could lead to a collision and potential injuries. While unlikely, such events are known to have occurred. . |
| Service | Reliability | Medium | Distribution conductors pose medium reliability risk, as a failure can cause a service interruption to hundreds of customers. |
| | Power quality | Medium | Distribution conductors pose medium power quality risk as a loss of a phase leads to voltage variations. |
| **Environmental** | Environmental | Medium | Distribution conductors pose medium environmental risk as they can initiate fires, which typically would lead to minor environmental damage (loss of flora/fauna) with short term effects. |

**Table 4.8: Risk assessment – distribution underground cables**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Medium | Distribution underground cables pose a medium fire risk as fires have been known to originate from cable termination failures or through fauna/flora interference at the termination. Based upon historic evidence, the expected level of public injury from these fires is expected to be minor (e.g., minor burns or smoke inhalation) and is unlikely. |
| | Electric shock | Medium | Distribution underground cables pose a medium electric shock risk, with historic evidence of shocks caused by neutral integrity issues on LV cables/accessories, and as a result of direct contact with cables through excavation. These incidents typically lead to electric shocks with no injury. Shocks with more severe consequences can occur but are assessed as less likely. . |
| | Physical impact | Medium | Distribution underground cables pose a medium physical impact risk, as there is potential for failure of cable pits or pit lids which could lead to a member of the public tripping over or falling into a pit. There is also the potential for joints to fail explosively at access pits exposed to the public, although there is no recent history of this. |
| **Service** | Reliability | Medium | Distribution underground cables pose medium reliability risk as a failure can cause an extended service interruption to hundreds of customers. |
| | Power quality | Medium | Distribution underground cables pose medium power quality risk as neutral integrity issues can cause localised PQ issues for downstream customers (e.g. dimming and/or flickering lights). These effects are typically localised and affect a small number of customers. |
| **Environmental** | Environmental | Low | Distribution underground cables pose low environmental risk, as they can cause ground fires leading to environmental damage, which is assessed to typically be localised with short term effects. |

**Table 4.9: Risk assessment – Distribution service connections**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Low | Distribution service connections pose a low fire risk as they are typically insulated. |
| | Electric shock | High | Service connections pose high electric shock risk as certain failure modes on these assets result in voltage being present on metallic items to which the customer is exposed, e.g. plumbing. Most electric shock incidents of this nature are of minor consequence. However, more serious incidents could occur but are unlikely. |
| | Physical impact | Low | Service connections pose low physical impact risk as impact with a suspended asset is unlikely and a fallen asset presents a low probability of physical impact risk. |
| **Service** | Reliability | Low | Service connections pose low reliability risk as individual failures can cause an outage for a small number of customers. |
| | Power quality | Low | Service connections pose low power quality risk as the effects are typically transitory and affect a small number of customers. |
| **Environmental** | Environmental | No material risk | Service connections pose no material environmental risk, as they do not contain hazardous substances capable of leaking and very rarely cause fires. |

**Table 4.10: Risk assessment – transmission overhead conductors**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Medium | Failure of a transmission OH conductor can lead to a live conductor on the ground or clashing between live conductors. These events can lead to the ignition of ground fires and consequently serious injury or fatality, particularly in high or extreme fire risk zones. The risk is considered medium due to wide easements on transmission lines and fast-acting protection. |
| | Electric shock | Medium | Transmission overhead conductors pose medium electric shock risk, due to the combined probability of direct contact with live conductors and induction shocks. The inherent risk is reduced through fast acting protection and high design standards. |
| | Physical impact | Medium | A failed conductor can fall on property, vehicles or people causing serious injury. It can also cause injury by vehicles contacting low conductors resulting in a traffic accident. The risk is considered medium as a series of events would need to happen in a specific sequence for this risk to eventuate. |
| **Service** | Reliability | Low | Transmission overhead conductors pose low reliability risk due to higher levels of redundancy in the transmission network design. |
| | Power quality | Low | Transmission overhead conductors pose low power quality risk due to high design standards. |

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Environmental** | Environmental | Low | Transmission overhead conductors pose low environmental risk, as they do not contain hazardous substances capable of leaking and very rarely cause fires. |

**Table 4.11: Risk assessment – transmission underground cables**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Low | Transmission underground cables pose a low fire risk as fires have been known to originate from cable termination failures on rare occasions. |
| | Electric shock | No material risk | Transmission underground cables pose no material electric shock risk as they are isolated from the public and workers. |
| | Physical impact | No material risk | Transmission underground cables pose no material physical impact risk as they are isolated from the public and workers. |
| **Service** | Reliability | Low | Transmission underground cables pose low reliability risk, as a failure can cause a service interruption to hundreds of customers, but most cables are in areas of the network with sufficient redundancy historical data indicates cable failures rarely result in supply loss or any type of system instability. |
| | Power quality | No material risk | Transmission underground cables pose no material power quality risk due to the high design standards and low failure rates. |
| **Environmental** | Environmental | High | Transmission underground cables pose high environmental risk as they contain pressurised oil with a history of leakage. |

## 4.6 Distribution plant and equipment

This group includes the following key asset classes:

- distribution transformers (pole and ground mounted transformers and auto transformers)
- ring main units (RMUs)
- distribution overhead high voltage (OH HV) switchgear (reclosers, sectionalisers, load break switches, pole top switch disconnectors, HV disconnectors and drop out fuses).

Note: There are additional distribution plant asset classes (reactive plant, voltage regulators, surge arrestors and low voltage switchgear), that are not discussed in this section as these assets do not pose significant risks given current condition and failure performance.

Distribution plant and equipment enables the conversion of voltages and switching of the distribution network. This enables reliable supply of power to consumers.

### 4.6.1 Failure modes and consequences

High level failure modes of highest risk for distribution plant and equipment are:

- distribution transformer failure leading to fire, electric shock, reliability impacts or environmental impacts (leaking oil)
- ring main unit failure leading to physical impact or environmental impacts (oil or gas leaks)
- pole top switch disconnector failure leading to fire, physical impact or reliability impacts
- recloser failure leading to reliability impacts
- sectionaliser failure leading to reliability impacts
- dropout fuse failure leading to fire or reliability impacts.

### *Distribution transformer failure*

Distribution transformers convert high voltages in the distribution network to the lower voltage levels required for customer connections. They are oil-filled and have the potential to explode or leak, particularly if highly loaded.

This section considers only distribution transformers equal or larger than 100 kVA, as these have a greater impact in the event of failure and therefore represent a higher risk.

A range of conditions contribute to distribution transformer failure, including:

- age degradation, particularly corrosion and degradation of insulation material
- external damage (lightning)
- defects in components (bushings, turrets)
- operational loading.

Distribution transformer failure is managed through network modelling to predict transformer overload and regular inspection, with on-condition replacement of high-risk assets.

### *Ring main unit failure*

Ring main units are ground mounted HV switchgear that enable switching, isolation and protection of the distribution underground network. In addition to high voltage, they can contain SF6 gas or oil for insulation and have potential to leak or explode. These units are typically located in populated areas due to their role.

A range of conditions contribute to ring main unit failure, including:

- Environmental conditions (particularly water ingress)
- Substandard installation and repair practices
- Operational loading.

Ring main unit failure is managed through regular inspection and on-condition replacement of high-risk assets.

### *Pole top switch disconnector failure*

A pole top switch disconnector **(PTSD)** is a ganged (3-phase) manually operated load break device, used to provide switching, isolation and bypass functionality on the high voltage overhead distribution network. It is exposed to the environment throughout its life, may be infrequently operated and can fail in either the open or closed position.

A range of conditions contribute to pole top switch disconnector failure, including:

- infrequent operation
- age degradation, particularly corrosion and degradation of insulation material.

PTSD failure is managed through routine inspection and on-condition replacement of high-risk assets. Depending on condition, failed units may remain in service, with reduced operational flexibility.

### *Recloser failure*

A recloser is an automatic protection/switching device installed to detect and isolate faults on a line. It automatically attempts to restore power, i.e. reclose, after a fault is detected to minimise outages from transitory events.

A range of conditions contribute to recloser failure, including:

- defects such as loose connections and low gas levels
- age degradation, particularly corrosion and degradation of external connections.

Recloser failure is managed through routine inspection and on-condition replacement of high-risk assets. Depending upon condition, failed units may remain in service with reduced operational flexibility, potentially affecting reliability.

### *Sectionaliser failure*

A sectionaliser is an automatic isolation device usually used in conjunction with a recloser to isolate and help to identify the faulted section/s of line.

A range of conditions contribute to sectionaliser failure, including:

- defects such as oil leaks
- age degradation, particularly corrosion and degradation of insulation.

Sectionaliser failures is managed through routine inspection and on-condition replacement of high-risk assets. Depending upon condition, units that fail to operate may remain in service with reduced operational flexibility, potentially affecting reliability.

### *Dropout fuse failure*

Dropout fuses protect distribution assets and distribution line segments by de-energising faulted portions of the network when subjected to a fault current.

In contrast with all other asset types reported, dropout fuses create a risk through normal operation, in which a quantity of molten metal is expelled. This is managed using fire-safe fuses in high and extreme fire risk zones. Dropout fuse failures include all of the following:

1. the fuse failing to release (hang-up) under fault conditions
2. the fuse releasing when no fault current is present
3. fire-safe fuses releasing molten material with potential to start fires.

A range of conditions contribute to dropout fuse failure, including:

- manufacturer and design
- age degradation, particularly corrosion.

Dropout fuse failure is managed as an emergency response activity.

### 4.6.2 Age and condition profile

The expected service life for distribution plant and equipment is 35 years for distribution transformers, 30 years for pole top switch disconnectors, 25 years for reclosers, 35 years for sectionalisers and 35 years for dropout fuses. Expected service life has not been defined for ring main units, but the mean replacement life (typically higher than expected service life) is 31-57 years depending on the specific type.

Nine per cent of distribution transformers (≥ 100 kVA) have exceeded the expected service life of 35 years, while continuing to provide reliable service. Figure 4.7 shows the age profile of distribution transformers.

**Figure 4.7: Age profile – distribution transformers (≥ 100 kVA)**

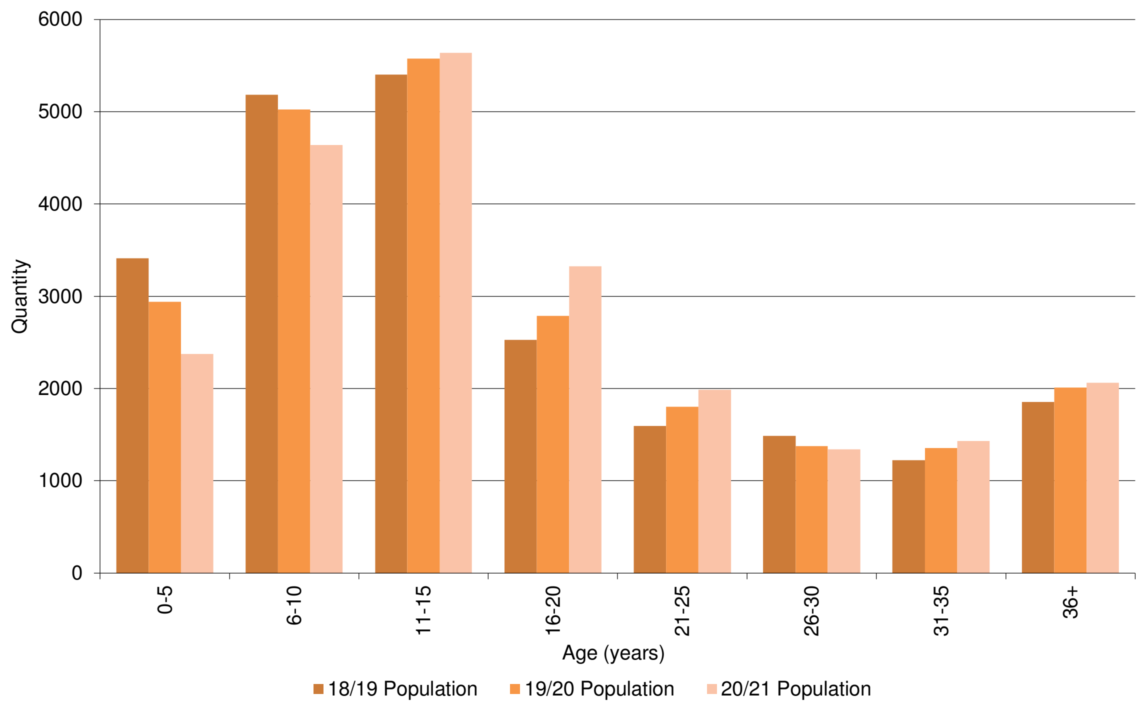
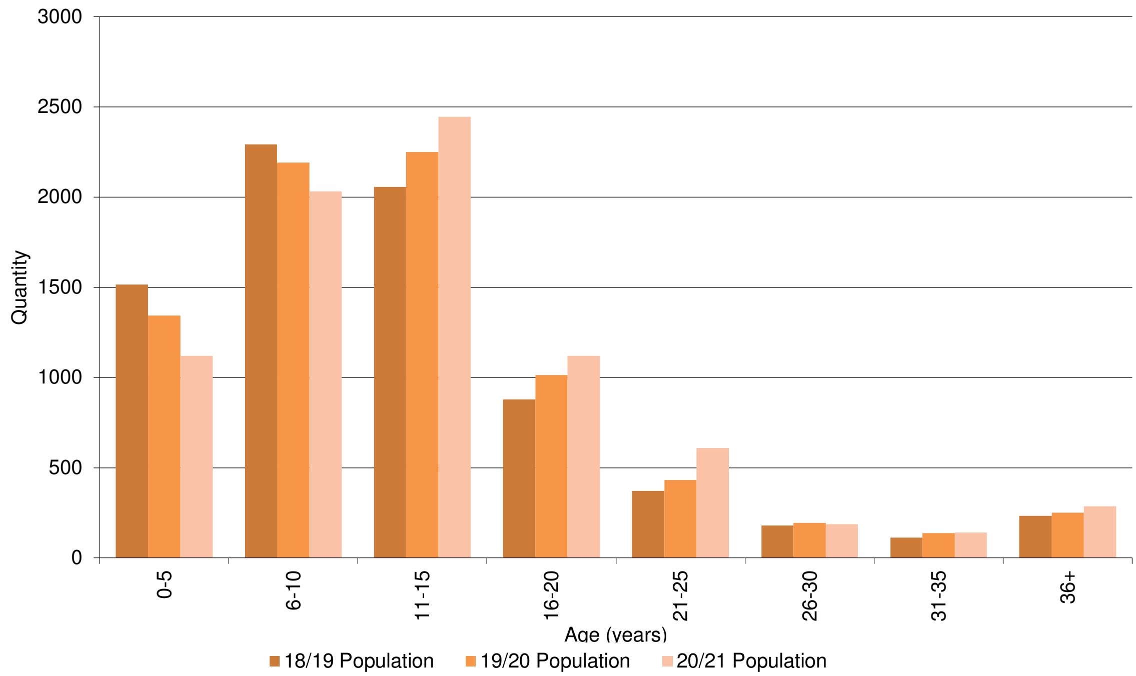


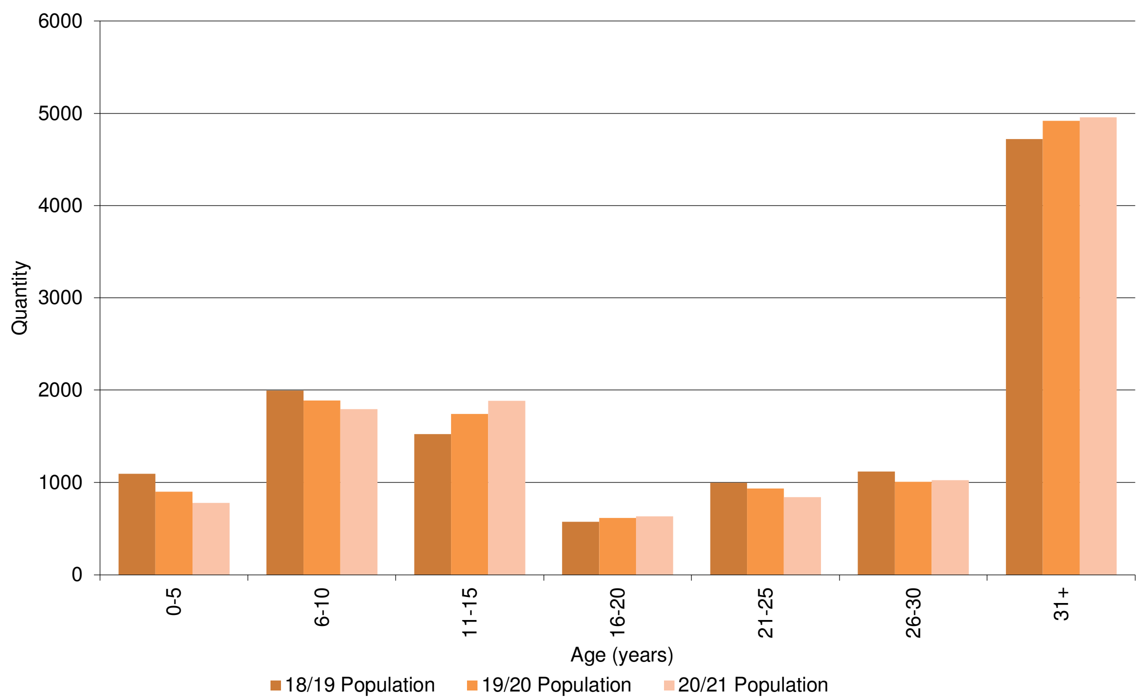

Figure 4.8 shows the age profile of ring main units.

**Figure 4.8: Age profile - ring main units**



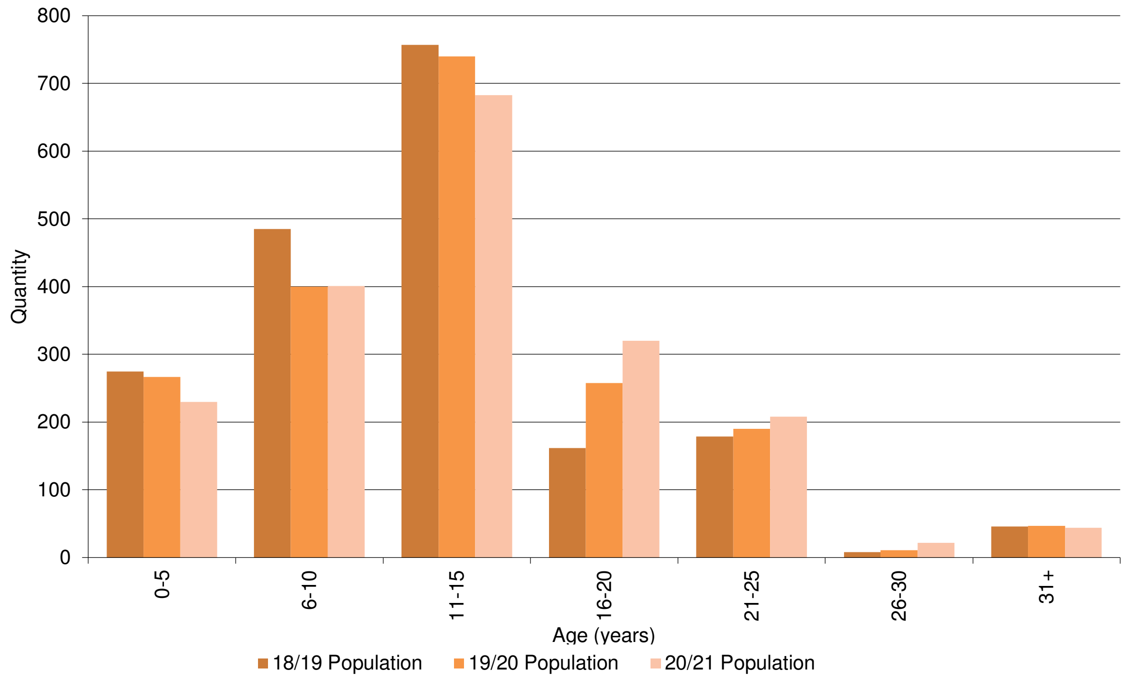

Approximately 42 per cent of pole top switch disconnectors have exceeded their 30-year expected service life. Fewer assets of this type have been installed over the last 20 years, with reclosers and sectionalisers now preferred options for overhead switchgear. Figure 4.9 shows the age profile of pole top switch disconnectors.

**Figure 4.9: Age profile – pole top switch disconnectors**



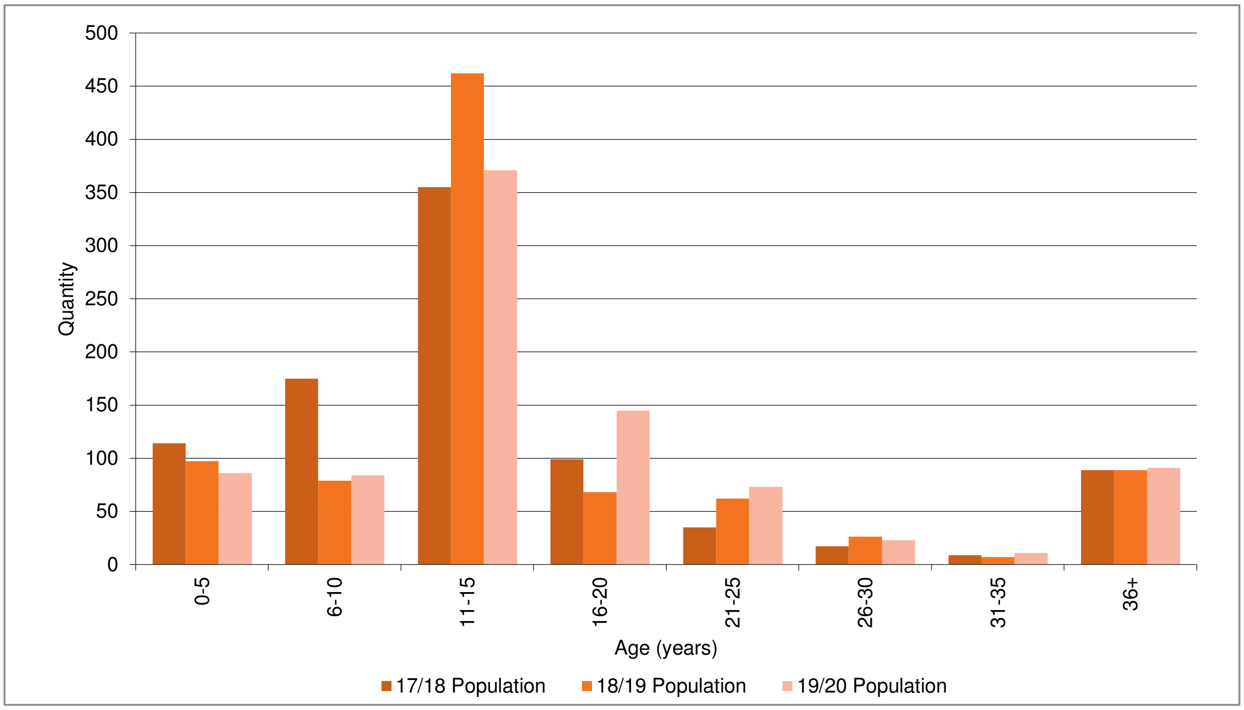
The majority of reclosers were installed in the last 20 years, in preference to pole top switch disconnectors, with a small number of reclosers having exceeded their expected service life of 25 years. Figure 4.10 shows the age profile of reclosers.

**Figure 4.10: Age profile – reclosers**




The majority of sectionalisers have been installed over the last 20 years, with a small number having exceeded their expected service life of 35 years. Figure 4.11 shows the age profile of sectionalisers.

**Figure 4.11: Age profile – sectionalisers**




A large proportion of dropout fuses have exceeded their 35-year expected service life, while continuing to provide reliable service. Figure 4.12 shows the age profile of dropout fuses.

**Figure 4.12: Age profile - dropout fuses**

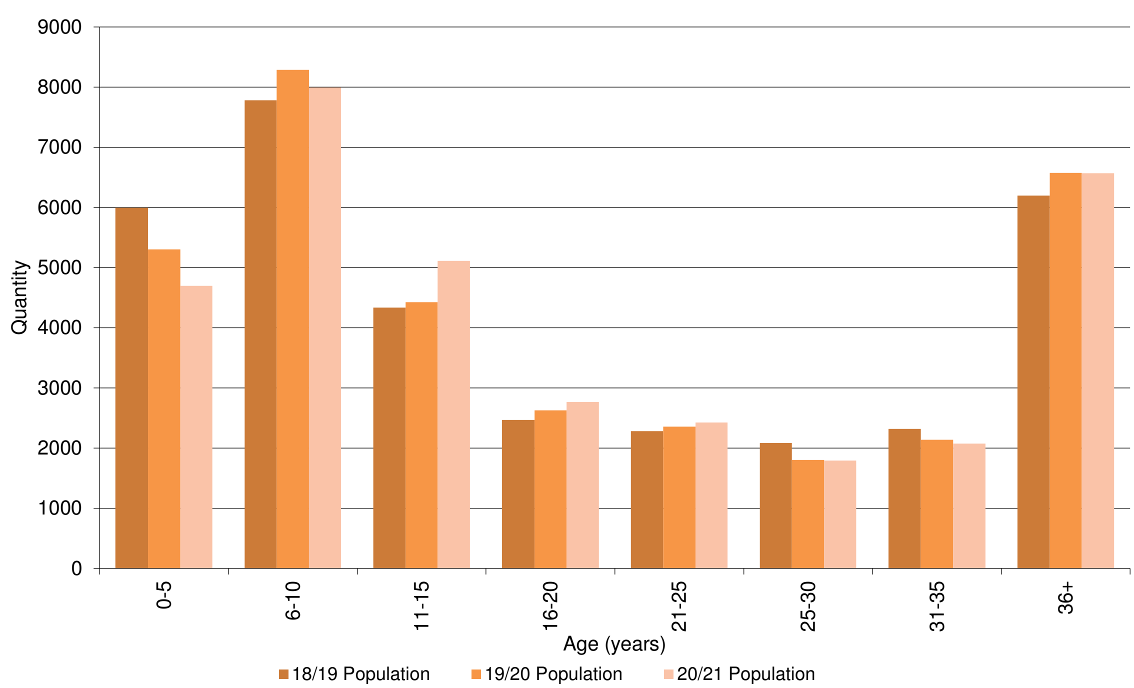



Table 4.12 summarises the population of distribution plant and equipment requiring replacement due to assessed conditions. Ring main units are not included due to their low average age.

**Table 4.12: Assets with conditions identified for replacement – distribution plant and equipment (quantity, percentage of total population)**

| Asset class/type | 2016/17 | | 2017/18 | | 2018/19 | | 2019/20 | | 2020/21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Qty | % | Qty | % | Qty | % | Qty | % | Qty | % |
| Assets with conditions identified for replacement – distribution transformers | 400 | 1.8 | 259 | 1.2 | 313 | 1.4 | 320 | 1.4 | 367 | 1.6 |
| Assets with conditions identified replacement – pole top switch disconnectors | 289 | 2.4 | 300 | 2.5 | 181 | 1.5 | 184 | 1.5 | 223 | 1.9 |
| Assets with conditions identified for replacement – reclosers | 126 | 6.7 | 113 | 5.9 | 108 | 5.6 | 99 | 5.2 | 91 | 4.8 |
| Assets with conditions identified for replacement – sectionalisers | 78 | 8.8 | 75 | 8.4 | 69 | 7.8 | 69 | 7.8 | 60 | 6.8 |
| Assets with conditions identified for replacement – dropout fuses | 3,612 | 10.8 | 3,395 | 10.1 | 3,252 | 9.7 | 3,151 | 9.4 | 3,025 | 9.1 |

### 4.6.3 Failure performance

Table 4.13 summarises failure performance for distribution plant and equipment during this reporting period and the preceding reporting periods.

**Table 4.13: Failure performance – distribution plant and equipment**

| Failure mode | 2016/17 | | 2017/18 | | 2018/19 | | 2019/20 | | 2020/21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Qty | % | Qty | % | Qty | % | Qty | % | Qty | % |
| Unassisted distribution transformer failure (≥100kVA) | 56 | 0.3 | 126 | 0.6 | 127 | 0.6 | 121 | 0.5 | 125 | 0.5 |
| Unassisted ring main unit failure | 4 | <0.1 | 7 | 0.1 | 5 | <0.1 | 5 | <0.1 | 4 | <0.1 |
| Unassisted pole top switch disconnector failure | 67 | 0.6 | 114 | 0.9 | 40 | 0.3 | 68 | 0.6 | 51 | 0.4 |
| Unassisted recloser failure | 25 | 1.3 | 16 | 0.8 | 25 | 1.3 | 20 | 1.0 | 12 | 0.6 |
| Unassisted sectionaliser failure | 34 | 3.8 | 13 | 1.5 | 26 | 2.9 | 19 | 2.1 | 1 | 0.1 |
| Unassisted dropout fuse failures | 241 | 0.7 | 205 | 0.6 | 290 | 0.9 | 313 | 0.9 | 248 | 0.7 |

### 4.6.4 Risk assessment

**Table 4.14: Risk assessment – distribution transformers**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Medium | Distribution transformers pose medium fire risk as they have potential to explode and start fires, but have very low historic rates of such events. |

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| | Electric shock | High | Distribution transformers pose high electric shock risk, as they inherently contain electrical energy, and failure can result in electric shocks downstream of the transformer. |
| | Physical impact | Low | Distribution transformers pose low physical impact risk, as all assets have potential to explode or fall from poles, but historic rates of such events are very low. |
| **Service** | Reliability | Medium | Distribution transformers pose medium reliability risk, as failure generally results in an outage for up to several hundred customers and can also overload other assets. |
| | Power quality | Medium | Distribution transformers pose medium power quality risk as failure can affect power system frequency and voltage. |
| **Environmental** | Environmental | High | Distribution transformers pose high environmental risk, as they contain moderate to large quantities of insulating oil and have been known to leak. |

**Table 4.15: Risk assessment – ring main units**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Low | Ring main units pose low fire risk as they have potential to explode and start fires, but are typically located in low/moderate fire risk zones and have very low historic rates of such events. |
| | Electric shock | Medium | RMUs pose medium electric shock risk as they contain hazardous voltages and a large proportion are installed in public spaces. This includes high traffic areas such as schools and shopping centres. RMUs include earthing and enclosures to protect against shocks and the historic rate of failures leading to shocks is very low. |
| | Physical impact | Medium | Ring main units pose medium physical impact risk, as they have potential to explode and are typically located in populated areas to service the distribution underground network. |
| **Service** | Reliability | Medium | Ring main units pose medium reliability risk, as failure can lead to outages for up to several hundred customers and can also overload other assets. |
| | Power quality | No material risk | Ring main units pose no material power quality risk as their operation does not impact power quality. |
| **Environmental** | Environmental | Medium | Ring main units pose medium environmental risk as they contain small quantities of insulating oil or gas and have been known to leak. |

**Table 4.16: Risk assessment – distribution OH HV switchgear**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Medium | Distribution OH HV switchgear poses medium fire risk, as failure has potential to cause sparks or extend fault clearance times, and the assets are installed across all fire risk zones but has low historic rates of such events. |
| | Electric shock | Medium | Distribution OH HV switchgear poses medium electric shock risk, as failure has the potential to extend fault clearance times, and the assets are installed across all public safety risk zones, but has very low historic rates of such events. |
| | Physical impact | Low | Distribution OH HV switchgear poses low physical impact risk, as failure potentially includes explosion or falling debris, and the assets are installed across all public safety risk zones, but has very low historic rates of such events. |
| **Service** | Reliability | Medium | Distribution OH HV switchgear poses medium reliability risk as failure can cause outages or extend duration for up to several hundred customers. |
| | Power quality | Medium | Distribution OH HV switchgear poses medium power quality risk as failure can allow faults to propagate to customer premises. |
| **Environmental** | Environmental | Medium | Distribution OH HV switchgear poses medium environmental risk, as some asset types contain small quantities of oil or gas and have been known to leak. |

## 4.7 Transmission plant and equipment

This group includes the following key asset classes:

- power transformers
- switchboards
- outdoor circuit breakers
- instrument transformers.

Note: There are additional transmission plant asset classes (disconnectors and earth switches, surge arrestors, protection and control systems, reactive plant, auxiliary DC systems and auxiliary AC systems) that are not discussed in this section as these assets do not pose significant risks given current condition and failure performance.

Transmission plant and equipment includes the equipment used in terminal stations and zone substations to:

- convert higher voltages to lower voltages
- allow switching of the transmission network.

*Important note on risk assessment for this asset system*

In any network, the most extreme failure of energised transmission plant and equipment can result in explosion, with the potential to cause injury or death to anyone in close proximity. In assessing the risks associated with assets of this type, it must be emphasized that:

- failures of this type are rare
- this type of equipment is generally contained within a fenced perimeter, minimising public safety risk
- the safety risk to Western Power employees and contractors is mitigated by widespread use of remote operation, supported by appropriate work practices and training
- the most critical assets will be targeted for online condition monitoring to allow time for Western Power to react (turn off) in case of partial discharge in the asset.
- in the majority of cases, protection systems isolate these assets from the network to minimise further damage to other assets.

### 4.7.1 Failure modes and consequences

High level failure modes of highest risk for transmission plant and equipment are:

- power transformer failure leading to physical impact, reliability impacts, power quality impacts, network stability or environmental impacts
- switchboard failure leading to physical impact, reliability impact or power quality impact
- circuit breaker failure leading to physical impact, reliability impact or power quality impact
- instrument transformer failure leading to physical impact, reliability impacts, power quality impacts or environmental impacts.

### *Power transformer failure*

Power transformers are major substation assets that convert voltage levels on the transmission network. They are often fitted with an on-load tap changer to maintain voltage levels within the required limits.

A range of conditions contribute to power transformer failure, including:

- age degradation, particularly of cellulose in the paper insulation of the windings and external components (such as cooling equipment, tap changers, bushings)
- operational loading.

Power transformer failure is managed through online monitoring, regular testing and inspection, scheduled refurbishment and on-condition repair or replacement of high-risk assets.

### *Switchboard failure*

Transmission indoor main switchboards (SWBD) and gas insulated switchgear (GIS) provide switching and isolation between the transmission and distribution networks.

A range of conditions contribute to switchboard failure, including:

- environmental, electrical and mechanical stresses
- corrosion, gas/oil leaks, insulation deterioration, dust and other pollutants,
- degradation of pitch used as an insulator at busbar connections, exposed distribution cable ducts allowing moisture ingress, environments with high levels of humidity
- older non-arc fault containment designs, poor cable terminations, faulty switchgear closing mechanism, poor cable terminations, poor switch room structural integrity and inadequate lighting.

Switchboard failure is managed through online monitoring, regular testing and inspection, scheduled refurbishment and on-condition repair or replacement of high-risk assets.

### *Circuit breaker failure*

Circuit breakers are installed at terminal stations, switching stations and zone substations to interrupt supply to specific network sections when abnormal conditions are detected. This maintains system security and allows switching operations to be performed, in addition to protecting other network assets from damage and ensuring the safety of personnel.

Circuit breakers can either be installed as standalone outdoor units or within switchboards. This failure mode considers outdoor circuit breakers only.

A range of conditions contribute to outdoor circuit breaker failure, including:

- environmental conditions, particularly humidity
- defects including oil or gas leaks
- age degradation, particularly wear of moving parts and degradation of insulation material
- operational loading, especially operations under fault conditions
- number of operations, especially under fault conditions.

Outdoor circuit breaker failure is managed through online monitoring, regular testing and inspection, scheduled refurbishment and on-condition repair or replacement of high-risk assets.

### *Instrument transformer failure*

Instrument transformers measure network voltage or current at specific locations for protection, control and operational purposes. Instrument transformers include current transformers **(CT),** voltage transformers **(VT),** capacitive voltage transformers **(CVT)** and combined units.

A range of conditions contribute to instrument transformer failure, including:

- environmental conditions, particularly pollution and humidity
- defects such as oil leaks
- age degradation, particularly degradation of insulation material
- operational loading.

Instrument transformer failure is managed through online monitoring, regular testing and inspection, scheduled refurbishment and on-condition repair or replacement of high-risk assets.

## 4.7.2 Age and condition profile

The expected service lives of transmission plant and equipment are 40 years for power transformers, 45 years for circuit breakers and switchboards, and 40 years for instrument transformers.

Figure 4.13 shows the age profile of power transformers.

**Figure 4.13: Age profile – power transformers**

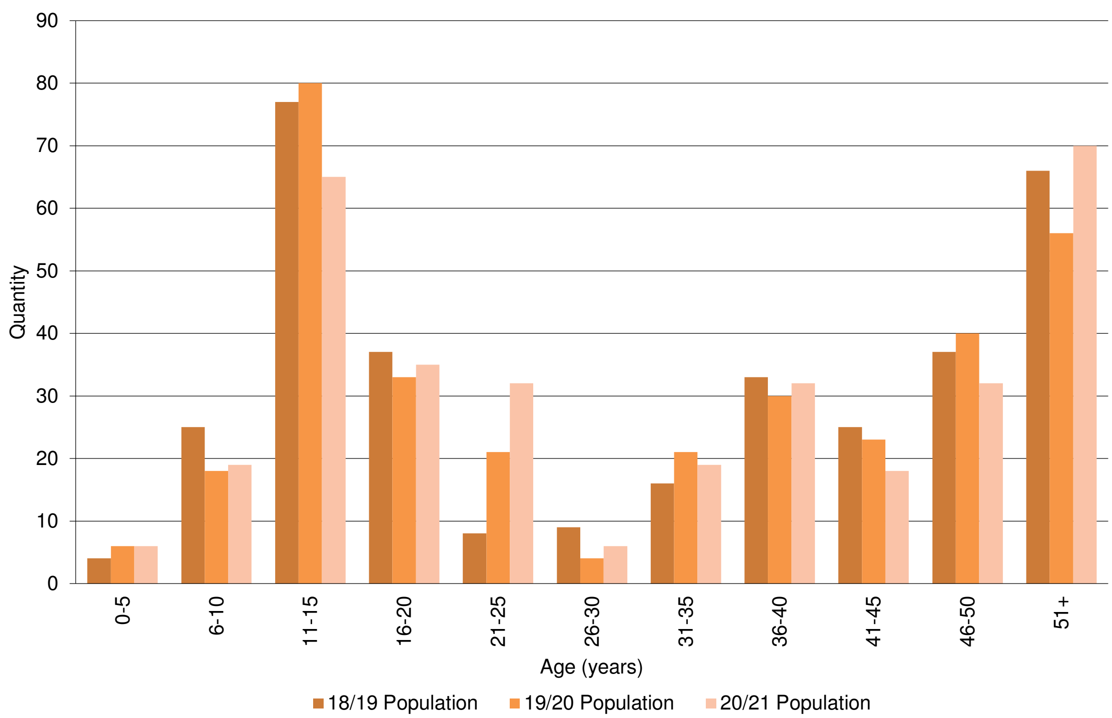


Figure 4.14 shows the age profile of switchboards.

**Figure 4.14: Age profile – switchboards**

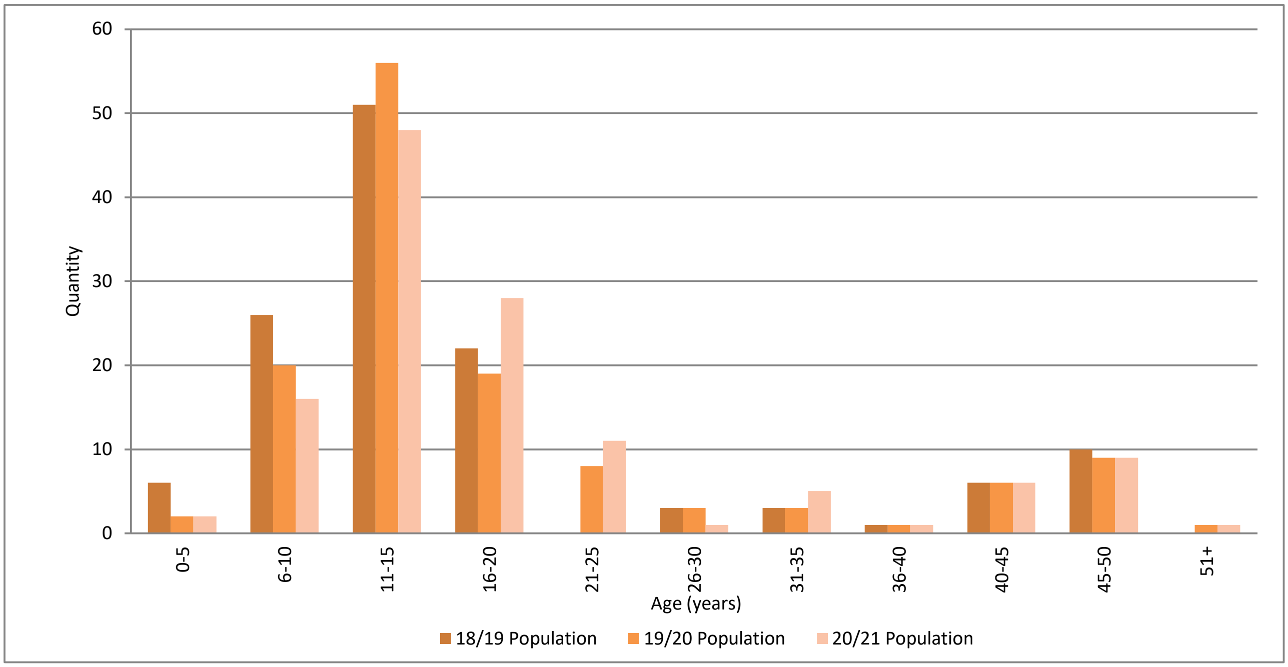



Figure 4.15 shows the age profile of circuit breakers, grouped by interrupting medium.

**Figure 4.15: Age profile – circuit breakers (grouped by interrupting medium)**

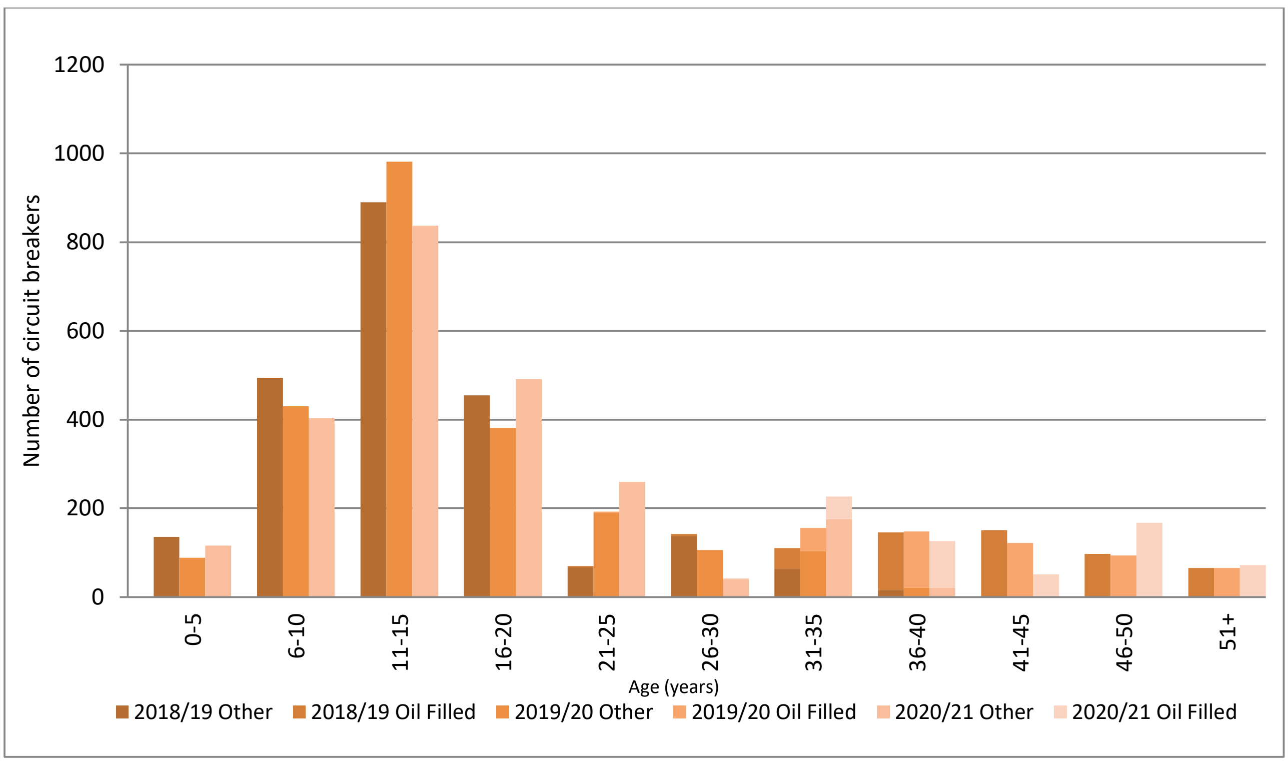


Figure 4.16 shows the age profile of instrument transformers.

**Figure 4.16: Age profile – instrument transformers**

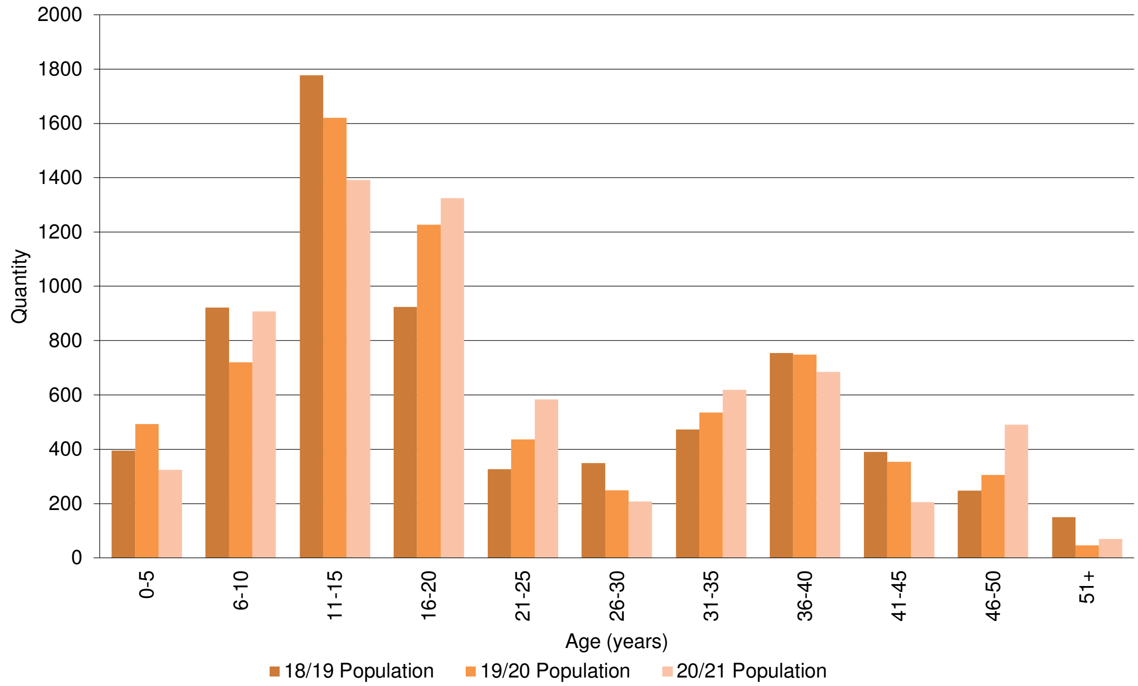



Table 4.17 summarises the proportion of the population that has exceeded this asset type's expected service life of 40 years.

**Table 4.17: Assets exceeding expected service life – transmission plant and equipment**

| | 2016/17 | | 2017/18 | | 2018/19 | | 2019/20 | | 2020/21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Qty | % | Qty | % | Qty | % | Qty | % | Qty | % |
| Assets exceeding expected service life – power transformers | 125 | 36.7 | 119 | 35.7 | 128 | 38.0 | 119 | 35.8 | 120 | 35.9 |
| Assets exceeding expected service life – switchboards | 4 | 3.1 | 4 | 3.1 | 10 | 7.8 | 10 | 7.8 | 10 | 7.8 |
| Assets exceeding expected service life – circuit breakers (indoor/ outdoor) | 159 | 5.6 | 181 | 6.5 | 163 | 5.9 | 160 | 5.8 | 240 | 8.6 |
| Assets exceeding expected service life – instrument transformers | 775 | 11.5 | 719 | 10.8 | 787 | 11.7 | 705 | 10.5 | 765 | 11.2 |

Table 4.18 summarises the population of transmission plant assets identified for refurbishment or replacement due to assessed conditions.

**Table 4.18: Assets with conditions requiring replacement or refurbishment – transmission plant and equipment (quantity, percentage of total population)**

| | 2016/17 | | 2017/18 | | 2018/19 | | 2019/20 | | 2020/21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Qty | % | Qty | % | Qty | % | Qty | % | Qty | % |
| Assets with conditions identified for replacement – power transformers | 36 | 10.6 | 38 | 11.4 | N/A | N/A | 33 | 9.9 | 20 | 6 |
| Assets with conditions identified for refurbishment – power transformers | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 55Error! Bookmark not defined. | 17 |
| Assets with conditions identified for replacement – switchboardsError! Bookmark not defined. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 3Error! Bookmark not defined. | 2 |
| Assets with conditions identified for refurbishment – switchboardsError! Bookmark not defined. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 7Error! Bookmark not defined. | 5 |
| Assets with conditions identified for replacement – outdoor circuit breakers | 259 | 9.1 | 222 | 8.0 | N/A | N/A | 256 | 9.3 | 246 | 19.4 |
| Assets with conditions identified for replacement – instrument transformers | 146 | 2.2 | 117 | 1.8 | N/A | N/A | 285 | 4.9 | 428 | 6.3 |

### 4.7.3 Failure performance

Table 4.19 summarises failure performance of transmission plant and equipment in this reporting period and preceding reporting periods in relation to asset failures (failures that cause a supply interruption and require asset replacement).

**Table 4.19: Failure performance – transmission plant and equipment**

| Failure mode | 2016/17 | | 2017/18 | | 2018/19 | | 2019/20 | | 2020/21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Qty | % | Qty | % | Qty | % | Qty | % | Qty | % |
| Unassisted power transformer asset failure | 0 | 0 | 1 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unassisted switchboard asset failure | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unassisted outdoor circuit breaker asset failure | 3 | 0.1 | 0 | 0 | 1 | <0.1 | 0 | 0 | 0 | 0 |
| Unassisted instrument transformer asset failure | 31 | 0.5 | 2 | <0.1 | 1 | <0.1 | 2 | <0.1 | 0 | 0 |

Table 4.20 provides a view of the functional failures of these key transmission plant assets, where a "functional failure" is a failure requiring asset repair rather than replacement. Functional failures provide a

more accurate representation of transmission plant asset performance. Transmission plant asset failures are rare, while functional failures are relatively common and often have an impact on reliability and capacity. Performance is managed internally by, amongst other targets, maintaining the number of functional failures in line with historical performance.

Functional failures in the transmission network started to be captured through work order type count from 2017/18 onwards (some assets only started in 2018/19). In this version of SOTI, both tables are presented. From SOTI 2021/22 onwards, only the functional failure table will be presented and asset failures will be summarised in a paragraph.

**Table 4.20: Failure performance – transmission plant and equipment**

| Failure mode | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Power transformer functional failure | N/A | N/A | 180 | 171 | 288 |
| Switchboard functional failure | N/A | 20 | 82 | 13 | 85 |
| Outdoor circuit breaker functional failure | N/A | 161 | 240 | 213 | 342 |
| Instrument transformer functional failure | N/A | NA | 25 | 18 | 30 |

### 4.7.4 Risk assessment

**Table 4.21: Risk assessment – power transformers**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Medium | Transmission power transformers pose medium fire risk, as they have potential to explode and start fires, but have very low historic rates of such events and are physically isolated within substations. |
| | Electric shock | Low | Transmission power transformers pose low electric shock risk, as they inherently contain electrical energy, but are physically isolated within substations and equipped with fast acting protection. |
| | Physical impact | Medium | Transmission power transformers pose medium physical impact risk, as they have potential to explode, but have very low historic rates of such events and are physically isolated within substations. |
| **Service** | Reliability | Medium | Transmission power transformers pose medium reliability risk, as they can drive outages for thousands of customers, affect system stability and overload other assets. Due to system design and redundancy, failures result in low historic rates of impacts. |
| | Power quality | Medium | Component malfunction (tap changer), partial failures on the primary/secondary windings (e.g. interturn shorts) can lead to voltage fluctuations with slight impacts. |
| **Environmental** | Environmental | High | Transmission power transformers pose high environmental risk, as they contain large quantities of insulating oil, varying oil bunding capacity and there are 3 power transformers where leaks are deemed possible installed in substations near environmental protected areas (plus 50 transformers with insufficient bunding and repeated leaks installed in areas without special protection). |

**Table 4.22: Risk assessment – switchboards**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Low | Switchboards pose low fire risk as they have potential to explode and start fires but are physically isolated within substation buildings. |
| | Electric shock | Low | Switchboards pose low electric shock risk, as they inherently contain electrical energy, but are physically isolated within substation buildings and equipped with fast acting protection. |
| | Physical impact | High | Switchboards pose high physical impact risk, as they have potential to explode in confined spaces with workers present but have very low historic rates of such events. |
| **Service** | Reliability | Medium | Switchboards pose medium reliability risk, as they can drive extended outages for thousands of customers and overload other assets but have very low historic rates of such events. |
| | Power quality | Medium | Switchboards pose medium power quality risk as they can affect network impedance but have very low historic rates of such events. |
| **Environmental** | Environmental | Low | Switchboards pose low environmental risk, as they contain insulating gas and have been known to leak at a slow rate. |

**Table 4.23: Risk assessment – outdoor circuit breakers**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Low | Outdoor circuit breakers pose low fire risk, as they have potential to explode and start fires but are physically isolated within substations. |
| | Electric shock | Low | Outdoor circuit breakers pose low electric shock risk, as they inherently contain electrical energy, but are physically isolated within substations and equipped with fast acting protection. |
| | Physical impact | Medium | Outdoor circuit breakers pose medium physical impact risk, as they have potential to explode with workers present, but have very low historic rates of such events. |
| **Service** | Reliability | Medium | Outdoor circuit breakers pose medium reliability risk, as they can drive extended outages for thousands of customers and overload other assets but have very low historic rates of such events. |
| | Power quality | Medium | Outdoor circuit breakers pose medium power quality risk, as they can result in instantaneous/ short duration (~20ms) voltage fluctuation from a circuit breaker mal-operation but have very low records of such events. |
| **Environmental** | Environmental | Medium | Outdoor circuit breakers pose medium environmental risk, as they contain moderate quantities of insulating oil/ gas and have been known to leak. |

**Table 4.24: Risk assessment – instrument transformers**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Low | Instrument transformers pose low fire risk, as they have potential to affect fault detection and clearing, resulting in fires elsewhere in the network, but have very low historic rates of such events. |
| | Electric shock | Low | Instrument transformers pose low electric shock risk, as they have potential to affect fault detection and clearing, resulting in shocks elsewhere in the network, but have very low historic rates of such events. |
| | Physical impact | High | Instrument transformers pose high physical impact risk, as they have potential to explode with workers present. Such events are considered unlikely. |
| **Service** | Reliability | Medium | Instrument transformers pose medium reliability risk, as they have potential to cause incorrect operation of protection relays, resulting in system disturbance and have a limited history of such events. |
| | Power quality | Medium | Instrument transformers pose medium reliability risk, as they have potential to cause incorrect operation of protection relays, resulting in system disturbance and have a limited history of such events. |
| **Environmental** | Environmental | Medium | Instrument transformers pose medium environmental risk, as they contain moderate quantities of insulating oil/gas and have been known to leak, but are located within substations. |

## 4.8 Public lighting

This group includes the following key asset classes:

- Dedicated streetlight metal poles

Note: There are additional public lighting asset classes (luminaires, streetlight underground cables and streetlight control boxes) that are not discussed in this section as these assets do not pose significant risks given current condition and failure performance.

Public lighting assets illuminate roads and public areas to enhance public safety and security. Illumination is provided by luminaires, which are typically mounted on dedicated streetlight metal poles in areas of underground power and mounted on brackets on Western Power poles (e.g. distribution wood poles) in areas of overhead power.

### 4.8.1 Failure modes and consequences

High level failure modes of highest risk for public lighting assets are:

- structural failure leading to electric shock or physical impact
- electrical failure leading to electric shock.

### *Structural failure*

Dedicated streetlight metal poles are exposed to the environment throughout their life cycle, leading to progressive degradation in strength, primarily from corrosion. This can result in failure below the design load, typically in high winds.

A range of conditions contribute to structural failure, including:

- environmental conditions, particularly salt/pollution and wind direction/strength
- design factors such as material and corrosion protection
- third party damage (usually motor vehicle impact)
- age degradation, particularly corrosion.

These assets are designed in accordance with the structural strength and frangibility requirements of Standards AS/NZS4676 and AS/NZS1158. The majority have a design such that the energy of a vehicle collision impact is dispersed to the upper half of the pole, minimising injury risk to vehicle occupants. Such requirements limit the number of design measures that can be applied to minimise the impacts of corrosion.

Structural failure is managed through routine inspection and on-condition reinforcement or replacement of high-risk assets.

### *Electrical failure*

Public lighting assets are inherently located in close proximity to the public, and any failures have the potential to lead to electric shock through exposed conductors. While the actual failure may occur in any public lighting asset class the consequence is primarily associated with dedicated streetlight metal poles if the electrical failure energises the metal surface of the pole.

A range of conditions contribute to electrical failures, including:

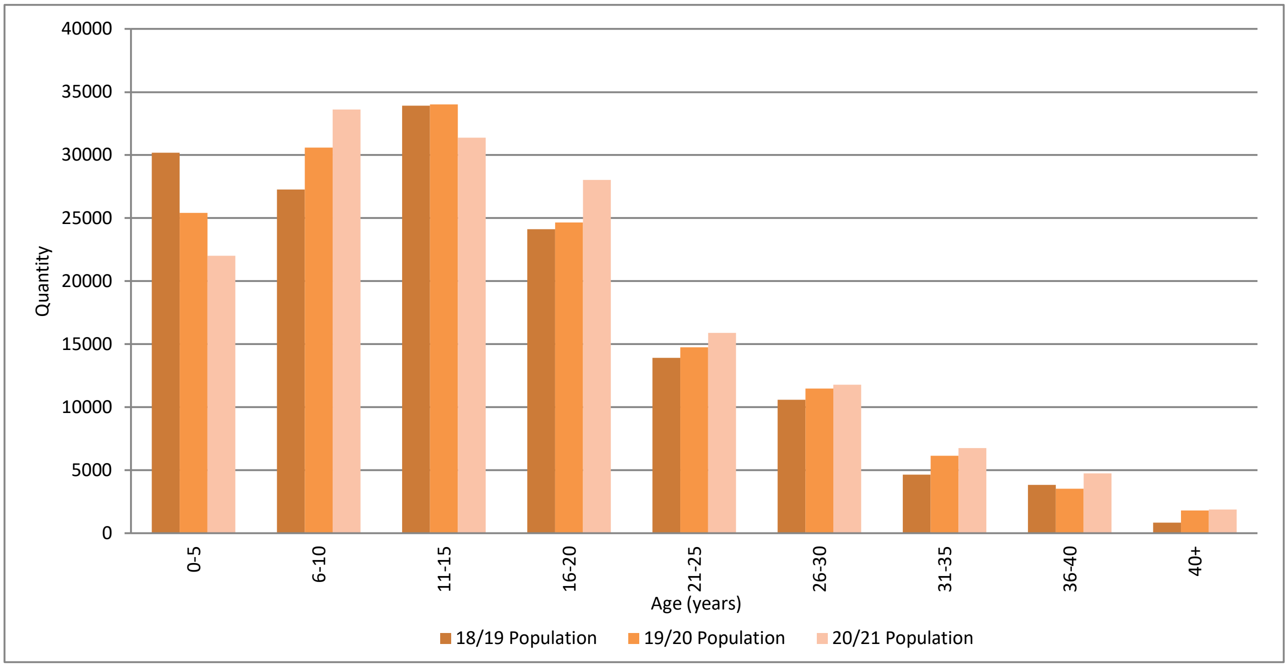
- substandard installation and repair practices
- age degradation, particularly degradation of insulation material.

Electrical failure is managed through regular inspection and repair or replacement of faulty assets.

### 4.8.2 Age and condition profile

Dedicated streetlight metal poles have an expected service life of 45 years. The age profile of the network's 156,033 dedicated streetlight metal poles is shown in Figure 4.17. Of those, 9,817 dedicated streetlight metal poles have been identified for treatment (removal, replacement or reinforcement) in accordance with our strategy for managing assets of this type, and our risk-based approach to asset management.

**Figure 4.17: Age profile – dedicated streetlight metal poles**




The network's population of these assets is increasing due to continued "gifting" of assets by Local Government Authorities (LGAs) and developers, and the replacement of overhead conductor (and the wood poles supporting them) under various undergrounding projects.

### 4.8.3 Failure performance

Table 4.25 summarises failure performance for public lighting in this reporting period and the preceding reporting periods.

**Table 4.25: Failure performance – dedicated streetlight metal poles (quantity, percentage of total population)**

| Failure mode | 2016/17 | | 2017/18 | | 2018/19 | | 2019/20 | | 2020/21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Qty | % | Qty | % | Qty | % | Qty | % | Qty | % |
| Structural collapse – unassisted failures of dedicated streetlight metal poles | 52 | 0.04 | 32 | 0.02 | 9 | 0.01 | 9 | 0.01 | 7 | <0.01 |
| Electric shocks – unassisted failures of dedicated streetlight metal poles | 1 | <0.01 | 4 | <0.01 | 6 | <0.01 | 3 | <0.01 | 3 | <0.01 |

To manage the risk of electric shock due to public lighting, Western Power improved the design of luminaire wiring as part of the release of the **LED** (Light Emitting Diode) luminaire product range.

### 4.8.4 Risk assessment

Table 4.26 provides a combined risk assessment for the key asset classes in the public lighting asset group.

**Table 4.26: Risk assessment – public lighting**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Low | Public lighting poses low fire risk as luminaires can fall to the ground and ignite a ground fire in the presence of dry vegetation. Such events have been known to occur. |
| | Electric shock | High | Public lighting pose high electric shock risk, as they are in close proximity to and expose the public to a potentially energised surface. There have been incidents of electrical shocks to the public due to asset failure. |
| | Physical impact | Medium | Dedicated streetlight metal poles pose medium physical impact risk, as their design limits structural integrity, they are located in populated urban areas and have been known to fail structurally through degradation. |
| **Service** | Reliability | No material risk | Public lighting assets are electrically isolated from customer supplies and therefore do not impact on the reliability of the network. |
| | Power quality | No material risk | Public lighting assets pose no material power quality risk as they are electrically isolated from customer supplies. |
| **Environmental** | Environmental | Medium | Luminaires pose medium environmental risk, as broken mercury globes can result in the release of mercury vapor to the atmosphere. |

## 4.9 Easements

This group includes the following key asset classes:

- transmission easements
- distribution easements.

Easements provide access to the electrical network assets and protection against encroachment from vegetation and buildings.

Note: Easements are legally protected for higher voltage elements of the transmission network only.

### 4.9.1 Failure modes and consequences

High level failure modes of highest risk for easements are:

- vegetation encroachments leading to fire, reliability impacts or environmental impacts
- building and structural encroachments leading to electric shock or reliability impacts.

***Vegetation encroachments***

Easements are defined in part to protect the electrical network from vegetation encroachments, but can fail through grow-in, fall-in or blow-in of vegetation.

A range of conditions contribute to vegetation encroachments, including:

- environmental conditions, particularly local vegetation types and rainfall

- substandard inspection and cutting practices.

Vegetation encroachments are managed through regular inspection and on-condition cutting of vegetation within the easement. High-risk vegetation (hazard trees) are monitored and may also be treated if necessary. Vegetation remediation is also managed by local governments and private landowners.

***Building and structural encroachments***

Easements are defined in part to protect the public from building or structural encroachments that could expose them to electric shock risk.

A range of conditions contribute to building and structural encroachments, including:

- changes in land use, particularly higher density developments and infill
- substandard planning permission processes to detect and prevent encroachments prior to construction
- substandard inspection processes to detect and resolve encroachments after construction.

Building and structural encroachments are managed primarily through preventive controls in building planning approvals, supported by the on-going inspection/ audit regime. We have commented on weaknesses in these defences in previous versions of this report, and we have been actively working to improve these. An initial assessment of the network has been completed and preventive treatments are being implemented, reducing both the current and future risk from this failure mode.

### 4.9.2 Age and condition profile

The concept of service life does not apply to easements and the age profile is therefore not relevant.

Table 4.27 shows the number of spans within the network identified for vegetation cutting on an annual basis.

**Table 4.27: Spans requiring treatment – easements**

| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Spans identified for cutting (distribution) | 45,955 | 43,804 | 45,024 | 51,767 | 50,248 |
| Spans identified for cutting (transmission) | 6,632 | 6,686 | 7,711 | 8,796 | 9,445 |
| Spans identified for structural encroachment rectification (distribution) | N/A | N/A | N/A | 13 | 10 |
| Spans identified for structural encroachment rectification (transmission) | N/A | N/A | N/A | 1 | 1 |

Note: The cutting data above reflects 'vegetation years', which run from April to March to assist with bushfire season preparation. Accordingly, the latest complete data is for the 2020 vegetation year, finishing in March 2021.

The increase in spans identified for cutting in recent years is believed to be the result of favourable growth conditions during these periods. Western Power is delivering the required volume of cutting to manage this risk.

Structural encroachment identification and management began following the first full network LiDAR survey in 2018/2019.

### 4.9.3 Failure performance

Table 4.28 summarises failure performance for easements in this reporting period and preceding reporting periods.

**Table 4.28: Failure performance – easements**

| Failure mode | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Vegetation encroachment – fire, shock or reliability impact (total) | 15 | 28 | 19 | 17 | 17 |
| Vegetation encroachment – fire, shock or reliability impact (distribution) | 15 | 27 | 17 | 17 | 17 |
| Vegetation encroachment – fire, shock or reliability impact (transmission) | 0 | 1 | 2 | 0 | 0 |
| Structural encroachment – fire, shock or reliability impact (total) | N/A | N/A | N/A | 0 | 0 |

### 4.9.4 Risk assessment

**Table 4.29: Risk assessment – Distribution easements**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | High | Easements pose high fire risk on the distribution network, as vegetation encroachments have potential to start fires, including within high and extreme fire risk zones. There is a large number of spans in such zones, vegetation contact with distribution network consistently causes more than 1 ground fire per month on average and exposure increases with climate change and population density. |
| | Electric shock | Medium | Easements pose medium electric shock risk on the distribution network as building encroachments can expose the public to energised assets. Historic practices to prevent or detect such encroachments have been inconsistently applied. Recent assessment post-LiDAR survey confirms extent of encroachments in the network. To date however, there have been no recorded incidents due to building or structural encroachments and the most sever encroachments are treated or managed. |
| | Physical impact | Low | Easements pose low physical impact risk, as encroachments can increase public exposure to physical impact hazards from other assets, but there is no historic record of such events. |
| **Service** | Reliability | Medium | Easements pose medium reliability risk, as there is a moderate history of vegetation encroachments and incidents driving network outages. |
| | Power quality | Low | Easements pose low power quality risk, as encroachments can lead to clashing and other power quality issues, but there is a low historic rate of such events. |

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Environmental** | Environmental | Medium | Easements pose medium environmental risk, as vegetation encroachments can start fires and there is a moderate historic rate of such events. |

**Table 4.30: Risk assessment – Transmission easements**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Medium | Easements pose medium fire risk, as vegetation encroachments have potential to start fires, including within high and extreme fire risk zones. There is a large number of spans in such zones and there is a moderate historic rate of such events. |
| | Electric shock | Medium | Easements pose medium electric shock risk on the transmission network as building encroachments can expose the public to energised assets. Historic practices to prevent or detect such encroachments have been inconsistently applied, but transmission lines generally have wider easements, minimizing the risk. Recent assessment post-LiDAR survey confirms extent of encroachments in the network and no high risk. To date, there have been no recorded incidents due to building or structural encroachments and the transmission network has fast-acting protection. |
| | Physical impact | Low | Easements pose low physical impact risk, as encroachments can increase public exposure to physical impact hazards from other assets, but there is no historic record of such events. |
| **Service** | Reliability | Medium | Easements pose medium reliability risk, as there is a moderate history of vegetation encroachments and incidents driving network outages. |
| | Power quality | Low | Easements pose low power quality risk, as encroachments can lead to clashing and other power quality issues, but there is a low historic rate of such events. |
| **Environmental** | Environmental | Medium | Easements pose medium environmental risk, as vegetation encroachments can start fires and there is a moderate historic rate of such events. |

## 4.10 Network buildings

This group includes the following key asset classes:

- Transmission substation buildings, grounds and security
- Distribution substation buildings, grounds and security
- Stand-alone communications sites.

Network buildings provide essential facilities for enclosing and securing substation or communication equipment against hazards such as physical intrusion, weather and oil leaks.

### 4.10.1 Failure modes and consequences

High level failure modes of highest risk for network buildings are:

- unauthorised access to substations leading to electric shock (from direct contact or potential rise), physical impact, reliability impacts or environmental impacts.
- structural failure leading to physical impact, reliability impacts or environmental impacts.

***Unauthorised access***

Network buildings include physical barriers (fences, doors) and detection methods (security cameras, alarms, etc) aimed at preventing or detecting unauthorised access. Failure of these assets can lead to unauthorised substation access to the general public or to unqualified staff. This may lead to accidental contact with energised assets, theft, vandalism, accidental damage or cyber-attack.

A range of conditions contribute to unauthorised access, including:

- design factors such as fencing material and extent of surveillance
- external damage, particularly previous break-ins
- defects in fencing components, particularly gaps
- key management and return practices.

Unauthorised access is managed through regular inspection and on-condition treatment of high-risk assets. In addition, prioritised upgrades are undertaken on critical and high incident sites.

***Structural failure***

Network buildings are inherently exposed to the environment throughout their life cycle, leading to progressive degradation of various components, and subsequent potential for structural collapse.

A range of conditions contribute to structural failure, including:

- environmental conditions, particularly wind direction/ strength
- design factors such as building material and overall design life
- external damage, particularly fire damage and vehicle impacts
- defects in building components, including gutters.

Structural failure is managed through ad hoc reporting and on-condition treatment of high-risk assets. We are moving to a strategy of proactive inspection and on-condition treatment.

### 4.10.2 Age and condition profile

The expected service life is not generally defined for network buildings, due to the wide variability in design and construction and subsequent variability in life. An exception is security fencing, which has an expected service life of 25 years.

All transmission substation buildings are believed to be in satisfactory condition following a recent program that inspected for and remediated from structural integrity defects. The network facility strategy calls for a 5 yearly structural integrity engineering inspection of buildings that are over 40 years of age, providing confidence that satisfactory condition will be sustained.

Distribution substation building assessments are being driven by the routine inspection process and planned to be completed by the end of 2024/25. A similar 5 yearly structural integrity inspections of distribution substation buildings that are over 40 years of age is carried out to identify structural defects of aged buildings.

Each of our 155 transmission substation sites is enclosed by fencing. Many fences have combinations of different fabric types (e.g., part chainmesh and part palisade), and some zone substations have a building forming part of the boundary. Currently 97 substations fences are beyond their expected service life. Condition assessments have resulted in plans to replace four of these. A further 31 substation fences will be beyond their expected service life within 10 years. Given the impact of age on the condition of these fences, they may require treatment over that period.

### 4.10.3 Failure performance

Table 4.31 summarises failure performance for network buildings in this reporting period and preceding reporting periods. No structural failures have been observed in the reporting period.

**Table 4.31: Failure performance – network buildings**

| Failure mode | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 |
|---|---|---|---|---|---|
| Unauthorised entries – substation sites | 40 | 57 | 68 | 76 | 22 |

The reverse of the trend in unauthorised entries is believed to be mostly the result of the copper transactions licensing laws that came into effect on 01 December 2021, with a lesser contribution from Western Power's efforts to improve physical security. Western Power's intent is to continue to invest in physical security to sustain this improvement.

### 4.10.4 Risk assessment

**Table 4.32: Risk assessment – Distribution substation buildings, grounds and security**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Medium | Network buildings pose medium fire risk as structural failure could result in a fire and failures in fire detection and suppression systems could exacerbate fires initiating from electrical equipment. There is, however, no history of such events. |
| | Electric shock | High | Network buildings pose high electric shock risk, as unauthorised access can expose people to hazardous electrical equipment, particularly if the assets have been damaged due to copper theft or vandalism. There is a history of such events. |
| | Physical impact | Medium | Network buildings pose medium physical impact risk, as they have the potential for structural failure, but have no history of such events. |
| **Service** | Reliability | Low | Network buildings pose low reliability risk on the distribution network as they can drive extended outages of electrical assets, but have no history of such events. |
| | Power quality | No material risk | Network buildings pose no material power quality risk as they do not directly interact with the electrical assets. |

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Environmental** | Environmental | No material risk | Network buildings on the distribution network pose no material risk to the environment. |

**Table 4.33: Risk assessment – Transmission substation buildings, grounds and security**

| Risk area | Consequence type | Rating | Comment |
|---|---|---|---|
| **Safety** | Fire | Low | Network buildings on the transmission network pose low fire risk as structural failure could result in a fire and failures in fire detection and suppression systems could exacerbate fires initiating from electrical equipment. However, they are located within substation yards. |
| | Electric shock | High | Network buildings pose high electric shock risk, as unauthorised access can expose people to hazardous electrical equipment, particularly if the assets have been damaged due to copper theft or vandalism. There is a history of such events. |
| | Physical impact | Medium | Network buildings pose medium physical impact risk, as they have the potential for structural failure, but have no history of such events. |
| **Service** | Reliability | Medium | Network buildings pose medium reliability risk, as they can drive extended outages of electrical assets but have no history of such events. |
| | Power quality | No material risk | Network buildings pose no material power quality risk as they do not directly interact with the electrical assets. |
| **Environmental** | Environmental | Low | Network buildings pose low environmental risk as they include oil containment facilities that have the potential to release oil into the environment, including to environmentally sensitive areas. There is no history of such events. |

## 4.11 Future-proofing the network

We're proud to be at the forefront of innovation and technology, embracing new generation, distribution and management options to ensure the network meets the needs of Western Australians into the future. We're well on the way to transforming the grid with significant progress made during the past year.

Current and future technology advancements are and will continue to enable Western Power to develop new solutions to connect people to safe, reliable electricity at the lowest sustainable cost. In order to manage the risk of the existing asset base, while enabling the transformation to the power system of the future, we tailor our asset management strategies to strike an optimum balance of investment in mitigating risk and realisation of these opportunities for our community.

Some innovative projects – both recently completed and currently underway – that identify and maximise new opportunities are described below.

### 4.11.1 Community batteries

Allowing for excess solar energy to be stored and used when needed, community batteries play an important role in managing customer PV output. We currently have two types of batteries as part of the Western Power network: large network batteries that form part of a microgrid, such as the one in Perenjori in the State's Mid West, and smaller scale community batteries.

We have 13 community batteries placed in areas where the network would otherwise need upgrading to maintain power reliability and quality. We continue to partner with Synergy on a series of PowerBank community battery trials – an Australian-first for the successful integration of community batteries into an established network. The first trials, PowerBank 1 and PowerBank 2, launched in Meadow Springs and Falcon near Mandurah, and Ellenbrook in Perth's northern suburbs, in the past three years.

In March, we worked with Synergy to start PowerBank 3, the third and largest trial to date, providing up to 600 additional households with the opportunity to leverage battery storage technology and potentially lower their power bills. The 18-month trial allows household participants to take advantage of their rooftop solar PV systems by storing up to 6kWh or 8kWh of excess solar energy for later use. For the first time in the series of trials, customers are able to accrue excess energy over the course of their billing cycle, providing greater opportunity to offset peak energy consumption. PowerBanks are installed in Meadow Springs, Falcon, Canning Vale, Port Kennedy, Busselton, Two Rocks, Ashby, Yokine, Kalgoorlie, Parmelia-Kwinana and Ellenbrook.

### 4.11.2 Stand-alone power systems (SPS)

Providing reliable power supply in regional and remote areas of WA is challenging, with distance, complex terrain, diverse landscapes and extreme weather events and bushfires impacting network infrastructure.

SPS deliver significant benefits to our customers in these areas, providing reliable access to power almost regardless of location or conditions.

Each SPS functions as an energy supply unit comprised of a renewable energy source (solar PVs), a battery and back-up generation(if required), operating entirely independently of the main electricity network while still forming part of our service area.

In addition to the 58 SPS previously installed, we're installing a further 37 units as part of Cyclone Seroja network rebuild and 88 units as part of our SPS roll-out during 2021/22. The 88 units will replace about 330 kilometres of overhead powerlines and delivering significant cost savings. We continue to work with our customers to determine their energy needs, which can result in an SPS or a supply abolishment. As a result, SPS deployment numbers continually change depending on customer needs and choice.

In the medium term, the State Government has committed to deploying 1,000 SPS in the next four years across WA and we're looking to deploy 4,000 units across the network in the coming decade. Modelling has shown that if we roll out 6,000 SPS, we'll be able to decommission more than 23,000 kilometres of overhead assets, or about 17 per cent of the current network.

Large scale SPS use in WA has required regulatory changes, and our work with policy agencies and the State Government culminated in the Western Australian Parliament passing the Electricity Industry Amendment Bill 2019 (WA) in April 2020 enabling us to own, operate and provide SPS.

### 4.11.3 Kalbarri microgrid

The popular tourist town of Kalbarri receives power via a 140 kilometre rural feeder line from Geraldton, which is exposed to the elements and subject to interference that can cause extended outages. In peak tourism periods when demand on supply is at its highest, the risk of outages increases, impacting local residents and visitors.

To solve this long-standing issue, a new $15 million microgrid has been installed at Kalbarri.

The microgrid, which will connect to the main electricity network, uses renewable energy from residential and commercial solar and a wind farm to supply 5MW of peak capacity power in the event that network power is interrupted. It provides at least 2MW hours of energy storage.

Testing of the microgrid and a 40-day trial started in October 2021 and the Kalbarri community is expected to see improved power reliability later this year.

### 4.11.4 Advanced Metering Infrastructure (including Service Connection Condition Monitoring)

Western Power's installation of advanced metering infrastructure across the SWIS continues as planned, with the connection of 490,000 advanced meters to our network by 2022 on track for delivery.

The implementation of advanced metering delivers immediate benefits to customers, including: the ability for some faults to be remotely detected (eg SCCM) to improve reliability and safety; remote meter reading, leading to fewer estimated bills; usage recordings in 30-minute intervals, allowing for more detailed energy usage information; remote re-energisation, leading to faster reconnections; and the easy integration of new technologies including community batteries, microgrids, embedded networks and electric vehicles.

### 4.11.5 Smart Streetlights

In November 2020, we completed our 12-month smart streetlights trial, which involved the installation of 100 smart streetlights in the City of Melville. The trial was a resounding success, providing a range of community, operational and cost efficiency benefits to the local community. The technology now means we can dim and brighten streetlights remotely and can automatically detect and report faults for quicker repairs. LED streetlights also have a far longer lifespan than conventional streetlights and are more energy efficient, delivering significant environmental benefits.

### 4.11.6 Perenjori microgrid

September 2020 marked two years of consistent and assured community power supply for the Perenjori community thanks to the utility scale Battery Energy Storage System (BESS) established in the town. Perenjori's power supply traditionally was only fed via a long feeder line to the town, with local environmental factors causing frequent disruptions to supply.

In a world-first trial in 2018 the 1MW/hr BESS was installed directly into the local distribution network, creating a local microgrid.

Since its installation, the network battery has been used successfully to support power reliability avoiding more than 29 hours of outages for the town.

The Perenjori microgrid will remain in the town as a permanent network fixture. We'll continue to draw on the data and knowledge gained to explore opportunities that utility-scale battery integration and microgrid solutions offer for other regional communities.

### 4.11.7 Flexibility Services Pilot

As part of our drive to create a more sustainable, reliable and innovative network for the future, we partnered with WA businesses during the year to build flexibility services into the commercial and industrial customer solutions we offer.

With technology support from Schneider Electric, we designed a pilot to learn how commercial and industrial entities with large DER such as solar PV and batteries, and manageable loads like heating and cooling systems, could be enabled to better manage their generated load or supply for a financial incentive.

The focus is to demonstrate ways to effectively engage, procure and utilise customer assets to support the management of network challenges caused by excess rooftop PV generation and not enough demand to soak up supply.

Stage one ran between September 2020 to April 2021 with 10 participating partners asked to modify their energy use and generation between 10am-2pm on specific weekends.

Working with our partners we successfully enabled energy flexibility to help stabilise the grid during critical hours on weekends and holidays.

Over the course of the pilot an average 20MW of energy flexibility was achieved, a significant amount given it was the first time that partners had participated in such a program, with no benchmarks.

The results of stage one also informed the type of technologies that may support the efficient delivery of flexibility services for both the partners and the network. Stage 2 of the pilot has started.

#### 4.11.8 Project Symphony

In early 2021, we were pleased to announce with project partners Synergy and the AEMO the exciting and innovative $35.6 million Project Symphony.

The project aims to orchestrate customer distributed energy resources (DER) including rooftop solar, batteries and major appliances as a Virtual Power Plant (VPP) enabling customers to participate in a future energy market unlocking greater economic and environmental benefits for the Western Australian community

As part of the WA Government’s Distributed Energy Resources Roadmap, the project will help provide insight and understanding on how the opportunities and challenges of increasing DER can be managed to ensure a reliable, secure and affordable electricity system. It will deliver learnings on how the full capabilities of DER can provide greater choice, affordability and flexibility of energy services and products for WA households and businesses.

# A.1 Safety reporting definitions

For the purposes of this report, public safety incidents are considered to include ground fires, electric shocks, physical impacts and property damage arising from:

- Western Power Network assets (including mal-operation)
- actions by Western Power's workforce
- third-party actions in which substandard Western Power Network assets were a contributing factor.

More detailed definitions are provided for each category below.

### *Ground fire*

A ground fire is any ground fire that:

- starts in, or originates from, the electricity network
- is started by any tree, or part of a tree, falling upon or coming into contact with the electricity network
- is started by any person, bird, reptile, or other animal in, or on, the electricity network
- is started by lightning striking the electricity network or part of the electricity network
- is started by any other thing forming part of, or coming into contact with, the electricity network
- is otherwise started by the electricity network.

### *Electric shock*

An electric shock is a discharge of electricity from the network that causes the electric shock, injury or death of a person or the death of livestock. An incident where no injuries are sustained, but precautionary medical treatment is sought, is regarded as an electric shock. An incident where a reported shock was deemed to be on the customer's premises and not the Western Power Network, is not regarded as an electric shock.

### *Physical impact*

A physical impact is an incident that involves "physical" contact with electricity network assets (with or without electricity discharge), that causes injury or death of a person due to the kinetic energy/momentum of the impact. The electricity discharge through the human body is covered under the definition of electric shock and electricity discharge resulting in ground fire, is covered under the definition of ground fire.

### *Property damage*

Property damage is any incident caused by the network that results in damage to one or more consumer's installations, if the cost of rectifying the damage is likely to exceed $20,000 in aggregate.

### *Unassisted failure*

An important aspect of our failure classification process is the definition of an "unassisted failure", defined by Building and Energy as follows:

- Unassisted failure, of a pole, overhead conductor, stay wire or underground cable, means the pole breaking or collapsing, the conductor or wire breaking or the cable failing, otherwise than because of:
    a. a force exceeding the failure limit or design wind load specification in the applicable standard

b. a lightning strike, earthquake, fire or flood

c. malicious damage

d. excavation other than by a person for whom the network operator is responsible

e. any other similar occurrence beyond the control of the network operator.

To provide a consistent standard for reporting, we apply the following definition of unassisted failure to other asset classes:

- Unassisted failure of an asset, means a failure of that asset, otherwise than because of:

    a. a force exceeding the failure limit or design load

    b. a lightning strike, earthquake, fire or flood

    c. malicious damage

    d. excavation other than by a person for whom the network operator is responsible

    e. any other similar occurrence beyond the control of the network operator.

## A.2 Network asset risk rating approach

This section presents an overview of how the risk ratings have been derived for each asset group. The risk ratings have been represented by:

- **safety**, as measured in three key dimensions: Fire, electric shock and physical impact
- **service**, as measured in two key dimensions: Reliability and power quality
- **environment**, in terms of the impact of our activities and operations on the environment.

### *Risk assessment*

The risk assessment is undertaken across the population of assets represented by the asset group. Network risk assessments are conducted in accordance with Western Power's Network Risk Management Standard (NRMS).

### *Consequence*

The consequence analysis represents the most plausible consequence at the highest severity, not the worst-case scenario. The severity of consequence ranges from slight to catastrophic. These consequence severities are defined in Western Power's Enterprise Risk Assessment Criteria**.**

### *Likelihood*

The corresponding likelihood for the defined consequence severity is selected from a range of likelihood levels: Very rare, rare, unlikely, possible, likely and almost certain. These likelihood levels are defined in Western Power's Enterprise Risk Assessment Criteria.

### *Network risk matrix*

The consequence and likelihood levels are then translated to a risk rating using the risk matrix shown in Figure below.

Note: A high risk does not automatically constitute a severe consequence. A high risk may be a result of a minor consequence and an almost certain likelihood.

**Figure 0.1: Network risk matrix**

| LIKELIHOOD | | | | | |
|---|---|---|---|---|---|
| ALMOST CERTAIN | Medium | High | Extreme | Extreme | Extreme |
| LIKELY | Medium | High | High | Extreme | Extreme |
| POSSIBLE | Medium | Medium | High | High | Extreme |
| UNLIKELY | Low | Medium | Medium | High | High |
| RARE | Low | Low | Medium | Medium | High |
| VERY RARE | Low | Low | Low | Medium | Medium |
| | SLIGHT | MINOR | MODERATE | MAJOR | CATASTROPHIC |
| | CONSEQUENCE | | | | |

## A.3 List of abbreviations

| | |
|---|---|
| AA3 / AA4 / AA5 | Third / Fourth / Fifth Access Arrangement |
| AQP | Applications and Queuing Policy |
| AS/NZS | Australian and New Zealand Standard |
| CBD | Central Business District |
| CT | Current transformer |
| CVT | Capacitive voltage transformer |
| DC | Direct current |
| ERA | Economic Regulation Authority |
| kVA | Kilovolt Ampere |
| kWhr | Kilowatt Hour |
| LED | Light Emitting Diode |
| LV | Low voltage |
| LiDAR | Light Detection and Ranging |
| MVA | Megavolt Ampere |
| NCR | Normal Cyclic Rating |
| PV | Photovoltaic |
| SCADA | Supervisory Control and Data Acquisition |
| SWIS | South West Interconnected System |
| TUF | Transformer Utilisation Factor |
| VAR | Volt-Ampere Reactive |
| VT | Voltage Transformer |
| XLPE | Cross-linked polyethylene |