5.13.C

Project justifications for overhead conductors replacement programs

Content

1 INTRODUCTION

1.1 Overhead conductors on our network

Ausgrid has 32,009 km of overhead conductors on the network. The conductor operating voltages range from low voltage (LV) operating at 240V through to sub-transmission conductors operating at 132kV. These overhead conductors are located in all of Ausgrid's network supply area and are supported by more than 446,000 poles. The length of overhead conductor for each operating voltage is:

- 19,153km of LV overhead conductors (excluding overhead services)
- 9,914km of 11kV and 22kV overhead conductors
- 123km of SWER (single wire earth return) overhead conductors
- 1,235km of 33kV overhead conductors
- 481km of 66kV overhead conductors
- 1,102km of 132kV overhead conductors.

1.2 Changes in technology

Older types of overhead conductors are uninsulated 'bare mains', typically made from copper. Some overhead conductors have also been made from steel. Steel conductors were typically used for electrification schemes in rural or remote areas as it could be strung over large distances with a minimal number of poles to support it – this expedited electrification. Technology advances have resulted in the following changes:

- Insulated coverings on LV conductors – polyvinyl chloride (PVC) coverings were installed from the 1950s to the 1990s but have been superseded with cross-linked polyethylene (XLPE) coverings
- Aluminium conductors – these were introduced in the 1960s due to their lower weight and cost compared to copper conductors. For long spans (long distances between poles), some aluminium conductors have steel strands wound into them to provide additional strength (known as 'ACSR')
- Insulated coverings on 11kV conductors – XLPE coverings have been installed from the 1990s to reduce the safety and loss of supply risks associated with the public or vegetation making contact with overhead conductors or conductors clashing together
- Bundled conductors – these were introduced in the 1990s and reduce the safety risks associated with the public or vegetation making contact with overhead conductors. They have primarily been used on LV circuits however small quantities have also been used for 11kV.

In addition to the technology changes described above, Ausgrid has progressively been increasing the functionality of the LV overhead conductors in line with changes in street lighting technology and to meet the needs of our customers.

1.3 Working out what and when we need to replace

Ausgrid undertakes inspections and condition assessments of overhead conductors to determine the appropriate treatment option when condition issues are identified. The different overhead conductors have known failure modes, which informs assessment criteria for treatment. However, condition monitoring is not always effective as degradation can occur on the top of the conductor. Ausgrid therefore also targets conductors for replacement with known failures.

1.4 Summary of programs

In total, we expect to spend $104.9 million replacing or reconfiguring approximately 13% of the overhead conductor population and replacing 492 earth electrodes during the 2019-24 regulatory period. Ausgrid has a 'run to failure' approach for other overhead conductors and equipment which are not demonstrating condition issues and these are replaced following failure (refer to Part K (Reactive programs) for further details).

The following programs are discussed in further detail below:

- Overhead conductor replacement ($36.9 million)
- Reconfiguration of dedicated low voltage circuits ($42.9 million)
- Overhead wiring community concerns ($18.7 million)
- Low mains risk mitigation ($5.6 million)
- Earthing electrode replacement ($0.7 million).

2 OVERHEAD CONDUCTORS

2.1 Program description

The conditional and planned replacement programs for overhead (OH) conductors address known risks associated with condition or design issues. These programs are outcomes of OH conductor inspections and condition assessments. Degradation of OH conductors result in safety risks to the public, customers and workers if:

- The overhead conductors fail and fall to the ground
- The overhead conductors fail and are suspended at a reachable distance from ground
- The overhead conductors start a fire.

The three main programs related to the replacement of OH conductors are:

- Steel mains (km) (REP_04.02.01)
- High voltage overhead mains (ACSR/Quince) (km) (REP_04.02.46)
- Refurbish 33kV overhead feeders (km) (REP_05.02.07-4).

These programs are continuing from the current regulatory period. Ausgrid expects to spend $35.6 million replacing 940km of 11kV and 22kV overhead conductors as well as $1.3 million replacing 15km of 33kV overhead conductors during the 2019-24 regulatory period. Other conductor replacement work is being undertaken as described in this document (including Part K for reactive conductor replacement).

2.2 Background

The primary function of OH conductors is to safely distribute electricity from sub-transmission supply points to customers. Ausgrid has approximately 32,000km of overhead conductors on the network operating at voltages ranging from 240V to 132kV. Conductor types targeted in the overhead conductor programs are detailed in Table 1.

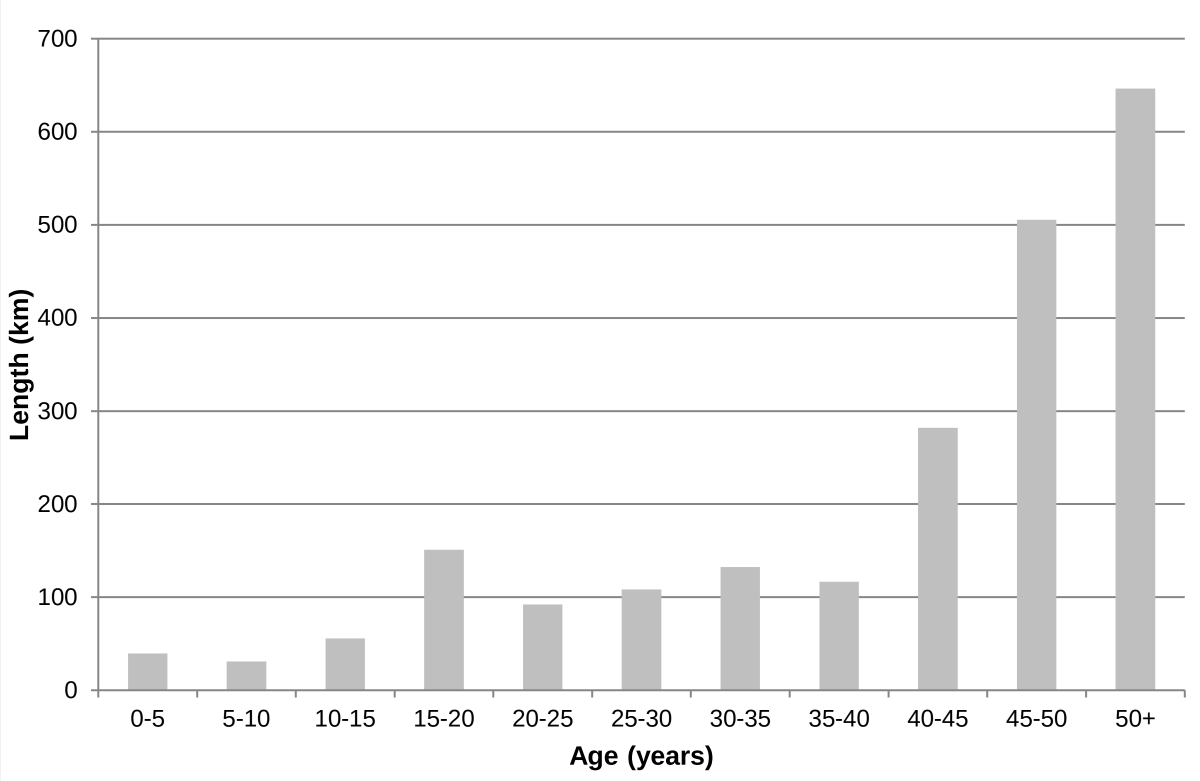
Table 1. Targeted overhead conductor type information

Asset	Overview
Small sized 11kV Steel Mains and ACSR	Steel mains were typically installed under a 'Rural Electrification Scheme' established in the 1950s as they were inexpensive and could traverse large distances due to their tensile strength, thereby reducing the number of pole installations required. ACSR is a technology advance on steel mains and is still being installed. Aluminium is used because of improved current-carrying capacity and reduced weight compared to steel however steel strands are required to provide tensile strength for large spans. Corrosion of steel strands in both of these conductor types pose risks to the public, customers and workers. They predominantly operate at 11kV, however small sections may operate at 22kV or 12.7kV on SWER feeders.
33kV overhead conductors	The circuits which these conductors are installed on supply zone substations and major industrial locations. These overhead conductors can be made from copper, aluminium alloys or ACSR. They are located in urban areas, industrial areas, commercial areas, national parks and areas which are bushfire prone. Some 33kV circuits have condition issues due to their operating environment and age, or have inherent design issues due to how they were originally constructed.

Ausgrid has approximately 2,160km of small sized steel mains and ACSR (those with cross sectional area less than 30mm^2) operating at voltages from 11kV to 22kV. Approximately

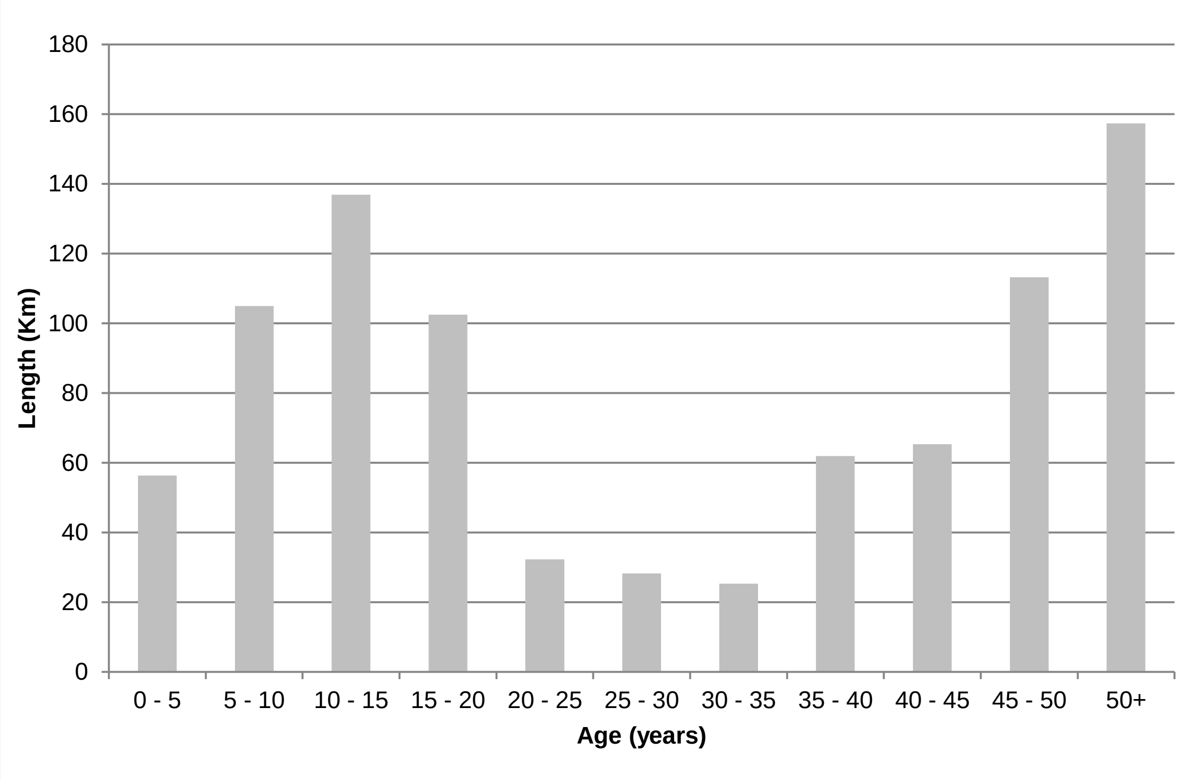
75% of this total length is located in bushfire prone areas. The average age of these overhead conductors is 37 years, with 53% over their standard technical life of 45 years. The age profile of these overhead conductor types is shown in Figure 1.

Figure 1. Age profile of steel mains and ACSR (as at June 2017)]



Ausgrid has 1,235km of overhead conductors operating at 33kV. The average age of these overhead conductors is 36 years, with 41% over their standard technical life of 45 years. The age profile of these overhead conductor types is shown in Figure 2.

Figure 2. Age profile of 33kV overhead conductors (as at June 2017)



The need to replace the identified types of overhead conductors has been triggered by the risks associated with their known failure modes and their inherent design. These risks are compounded by the aging asset population, noting that a significant portion of the asset population is already over 45 years old.

2.3 Risks – Consequence and likelihood

The key consequences related to overhead conductors are shown in Table 2.

Table 2. Consequences from loss of function for overhead conductors

Consequences	Description
Harm to the public, communities and workers	Contact with failed live electrical conductors which have fallen to the ground or are suspended at a reachable height may cause injury (physical injury, electric shock or burns) or a fatality (electrocution).
	Fires (including bushfires) caused by vegetation contact with live electrical conductors which may cause injury (burns) or a fatality.
	Safety issues as a result of loss of supply are detailed below.
Damage to property	Contact between live electrical conductors and buildings, infrastructure or vehicles / watercraft may cause arcing, fires or physical damage.
	Buildings, property or critical infrastructure may be damaged by fires caused by failed electrical conductors or equipment.
Damage to the environment	The natural environment may be damaged by fires caused by failed electrical conductors or equipment.
Loss of supply	Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and

Consequences	Description
	communication systems, critical infrastructure and vulnerable customers including those on life support systems.
	Failures associated with these conductor types may result in large numbers of supply interruptions and penalties or intervention by our regulator.

The consequences and likelihood of overhead conductor failure can increase due to factors including:

- Its inherent design – for example, the use of steel, and the small number of strands, has led to increased failures for steel mains / ACSR due to the smaller cross sectional area
- Being in areas with high pedestrian / vehicle activity or in close proximity to schools
- Supporting circuits which supply critical customers, infrastructure or economic hubs
- Being in areas prone to bushfire or high winds / lightning
- Being in areas that are salt affected (coastlines) or highly polluted.

The failure modes associated with these types of overhead conductors are generally deteriorating in nature and therefore present an increased likelihood over time. All OH conductors may also fail due to physical impact (for example, by vegetation, vehicles or persons) or weather conditions. The predominant failure modes for the identified types of overhead conductors are shown in Table 3.

Table 3. Key failure modes by identified OH conductor types

Pole Type	Key Failure Modes
Steel mains and ACSR	Conductor corrosion due to exposure to weather or pollution.
	Broken conductor strands (known as ‘stranding’) caused by corrosion or fatigue from conductor movement (swaying).
	Conductor failure due to corrosion or fatigue from conductor ‘sway’ over the life of the service.
	Conductor mechanical damage due to contact with vegetation, buildings or vehicles.
33kV overhead conductors	Conductors clashing together due to insufficient separation during their original construction, weather (wind, storms or lightning), vegetation contact, ‘through faults’ or third party impacts.
	Conductor stranding caused by fatigue from conductor movement (swaying).or conductor clashing.
	Conductor failure due to fatigue, conductor clashing, weather (wind, storms or lightning), vegetation contact, ‘through faults’ or third party impacts.

The failure modes associated with steel mains are widely known within the electricity industry. Major fire events in Victoria in 2009 (the 'Black Saturday' bushfires) resulted in many fatalities. The Victorian Bushfire Royal Commission (VBRC) was established to investigate these major fire events, including the role that electricity networks played in causing fires. Failure of network assets were identified as causing five of the fires (and over 115 fatalities) involved with this major event.

The VBRC made recommendations for the replacement of steel mains and other network asset types which were subsequently mandated by legislation and enforced by the Victorian industry safety regulator. While the recommendations from the VBRC were specific to Victoria, including its environmental and network operating context, Ausgrid noted the recommendations and, among other actions, initiated the steel mains replacement program due to the reasonably foreseeable risks associated with that conductor type.

In the period from 1/7/2013 to 30/6/2017, there were:

- Over 420 failures of steel mains and ACSR (including 32 functional failures). Additional failures were caused by falling vegetation or third party damage
- 60 failures of 33kV conductors (including 24 functional failures). Additional failures were caused by pole top structure issues, falling vegetation or third party damage.

The low level of functional failures compared to conditional failure reflects the robust inspection process for overhead conductors to assess their condition and to then repair or replace them prior to functional failure.

Ausgrid's asset management practices for overhead conductors provide an understanding of their condition and therefore the likelihood of failure. Detecting failures before they occur and applying treatments maintains overhead conductors in a serviceable condition, limiting the likelihood of failure and mitigating the potential consequences described above.

2.4 Treatment analysis

Assessment of the treatment options considered for the identified overhead conductor types is shown in Table 4.

Table 4. Treatment options for managing overhead conductors

Treatment option	Treatment overview
1 Repair the overhead conductors	Undertake repairs to the overhead conductors as condition issues are identified. Indicative repair costs range from approximately \$3,000 to more than \$20,000 per repair.
2 Replace the overhead conductors like for like	Replace the identified types of conductor with the same technology. Indicative replacement costs are approximately \$38,000 per km for 11kV conductors and \$89,000 per km for 33kV conductors.
3 Replace the overhead conductors with new technology	Replace the identified types of conductor with insulated conductors. Indicative replacement costs are approximately \$80,000 per km for 11kV conductors.

Repairs (Option 1) are an operational expense associated with maintaining the assets and may be done where deemed practical and efficient, or as a short term fix until planned replacement can be undertaken. Repairs may involve re-joining broken or stranded conductors or 'piecing in' conductor between poles. Repairs do not return the assets to an 'as new' condition and do not address risks associated with the inherent design issue with steel mains and ACSR conductors (i.e. the use of steel strands). Where assets have advanced degradation they may be beyond repair and will need to be replaced – this is typical for steel mains and ACSR. Repairs add additional points of failure and do not remove the inherent risks associated with steel mains and ACSR designs, however they may be applied, where appropriate, for 33kV conductors.

Ausgrid believes the replacement of steel mains and ACSR is the only viable treatment option when condition issues caused by corrosion of steel strands are identified. Where this occurs, it is typically also found in numerous other locations along an individual circuit because the conductors were mostly installed at the same time and have the same operating context (including environmental factors which cause the corrosion). Steel mains and ACSR are predominantly replaced with larger diameter ACSR (Option 2) however some conductors may be replaced with semi-insulated conductor (known as ‘covered conductor thick’ or ’CCT’) in heavily vegetated areas (Option 3). CCT requires installation of more poles (and an associated increase in cost) as it cannot span the large distances that ACSR is able to cross. The choice between Option 2 or Option 3 is considered during the design stage of each replacement project.

Ausgrid believes the replacement of 33kV OH conductors like for like (Option 2) is the appropriate treatment option when condition issues are not able to be repaired or are endemic on any particular circuit. Where conductor replacement is undertaken, the pole top structures they are supported by are also assessed and replaced where appropriate. Replacement removes the inherent risks associated with superseded designs and return asset condition to new.

2.5 Options

The program options available when considering overhead conductor management strategies are summarised in Table 5. These options are based on the need to undertake work on Ausgrid’s assets when their condition is assessed to be unsafe if left as-is.

Table 5. Program options for managing overhead conductors

Program need options	Option overview
1 Reactive Treatment	Implement treatment, such as replacement when the line fails.
2 Conditional Treatment	Implement treatment to replace overhead conductors when inspections or condition assessments identify that they have deteriorated to the point of conditional failure based on a set of criteria.
3 Planned Treatment	Implement treatment such as replacement of the overhead conductor at the standard technical life of 45 years.

The consequence of an identified OH conductor type falling poses serious safety risks to the public, customers, workers and the community as described above. Due to these risks, an approach that only manages these assets in a reactive manner (Option 1) is unacceptable. This option would defer capital expenditure in the short term, but would not adequately manage the existing risks associated with the identified OH conductor types. As these risks accumulate over time, this could lead to a significant uplift in public safety incidents, reactive replacement work and an accompanying step change in capital expenditure. Due to the significant and ageing population of the existing assets, overcoming this in the future would require a significant increase in capital expenditure.

Planned replacement (Option 3) does not take into consideration the actual condition of the OH conductor and the additional spatial factors which may increase the risk. In Ausgrid’s case, given the asset age profile, this option would likely result in an up-lift in capital replacement which is not reflective of current performance and risk requirements.

Additionally for Option 3, some OH conductors, depending on factors such as their operating environment, adjacent vegetation and other spatial considerations, may fail earlier than 45 years and so the risk of increased failure remains. Planned replacement is therefore not considered the preferred approach due to the increased costs and risks.

Ausgrid's preferred approach is to manage the risks associated with the identified OH conductor types by undertaking an assessment of each OH conductor to determine its condition and then to prioritise its treatment (Option 2). This approach addresses the risks associated with the known failure modes for these conductors rather than the long term sustainability of the asset population (average age) and provides a balance between risks and costs so far as is reasonably practicable. Where the condition of OH conductors does not warrant treatment, no treatment is undertaken.

For 33kV conductors, all condition issues on individual 33kV feeders are assessed to determine the most efficient 'packaging' and timing of conductor replacement on a 'per feeder' basis – this approach is considered a 'refurbishment' of the feeder because not all overhead conductors on the feeder are replaced. Other assets with condition issues on the feeders (for example, pole top structures) may also be packaged as separate components of these feeder refurbishment projects.

These programs address the overhead conductor types with known condition issues, however any other type of overhead conductor may also fail. Ausgrid inspects all overhead conductors on a regular maintenance cycle to ensure their continued safe operation and has processes in place to prioritise any identified condition issues for repair or replacement based on their risk. Refer to Part K of this document for details in regard to reactive replacement requirements for other overhead conductors.

2.6 Costing and volumes

The forecast replacement quantities of steel mains and ACSR have been based on historical identification of conditional failures as well as the size and age of the remaining asset population. This forecast is expected to sustainably manage the risks associated with an ageing asset population and involves replacement in a prioritised order so those of highest risk are completed first.

For 33kV overhead conductors, sectional replacement requirements are determined by a condition assessment of the feeder following asset inspections. The condition assessments are reviewed to determine the appropriate program of works required per feeder (i.e. conductor replacement and pole top structure replacement). The forecast for the replacement program has been based on historical identification of conditional failures, asset population and condition information, as well as known feeder condition issues. The forecast excludes any works covered by Area Plan projects or reactive replacement.

Replacement expenditure (repex) analysis of 11kV conductors undertaken by Ausgrid shows close alignment between forecast and benchmark volumes while the implied unit cost is lower than the benchmark. Ausgrid has had much focus on reducing costs associated with steel mains and ACSR replacement in recent years and this is reflected in the unit cost which is better than the Australian Energy Regulator (AER) repex benchmark.

Repex analysis of 33kV conductors undertaken by Ausgrid shows that the quantity forecast to be replaced is significantly below the benchmark volume, however the unit cost is above the benchmark unit cost. The replacement being undertaken is primarily in urban areas and the poles, which the 33kV circuits are on, typically also have 11kV and LV circuits attached. This context requires additional traffic control and outages on the lower voltage circuits to enable replacement to be undertaken safely – these challenges contribute to the forecast unit cost being higher than the AER benchmark.

The 2019-24 summary forecast for these replacement programs is shown in Table 6. The costs shown are direct costs only. The forecast equates to replacement of 1.9% of the 11kV and 22kV OH conductor population annually (reflecting our intention to mitigate the risks associated with steel mains by the end of that period) and 0.2% of the 33kV OH conductor population annually. Replacement of ACSR and refurbishment of sub-transmission feeders will continue to be targeted in subsequent periods due to the size of the asset population and expected increasing volume of identified condition issues as the asset population continues to age.

These programs form part of the overall investment being proposed for the replacement of overhead conductors. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details on the overall investment proposed for this asset category during 2019-24.

Table 6. Forecast for OH conductors

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Steel mains replacement					
Volumes for replacement (km)	120	120	120	120	120
Unit cost	$37,436	$37,203	$37,070	$36,972	$36,812
Total costs ($m)	**$4.49**	**$4.46**	**$4.45**	**$4.44**	**$4.42**
ACSR/Quince conductor replacement					
Volumes for replacement (km)	60	60	70	75	75
Unit cost	$39,745	$39,495	$39,355	$39,254	$39,086
Total costs ($m)	**$2.74**	**$2.37**	**$2.76**	**$2.94**	**$2.93**
Refurbishment of 33kV OH feeders					
Volumes for replacement (km)	3	3	3	3	3
Unit cost	$89,889	$89,439	$89,238	$89,129	$88,883
Total costs ($m)	**$0.27**	**$0.27**	**$0.27**	**$0.27**	**$0.27**

3 RECONFIGURATION OF DEDICATED LOW VOLTAGE CIRCUITS

3.1 Program description

Ausgrid has initiated a program to reconfigure supply arrangements for dedicated LV overhead circuits supplying street lights by improving the functionality of the LV network. This program has been introduced to mitigate public safety risks associated with superseded circuit configurations.

Ausgrid has one program related to this replacement:

- Dedicated LV circuit reconfiguration program (DOC_11.03.73).

This program commenced in 2017/18 and will continue into subsequent regulatory periods. This program is expected to reconfigure 2,900km of overhead mains at a total cost of $42.9 million during the 2019-24 regulatory period.

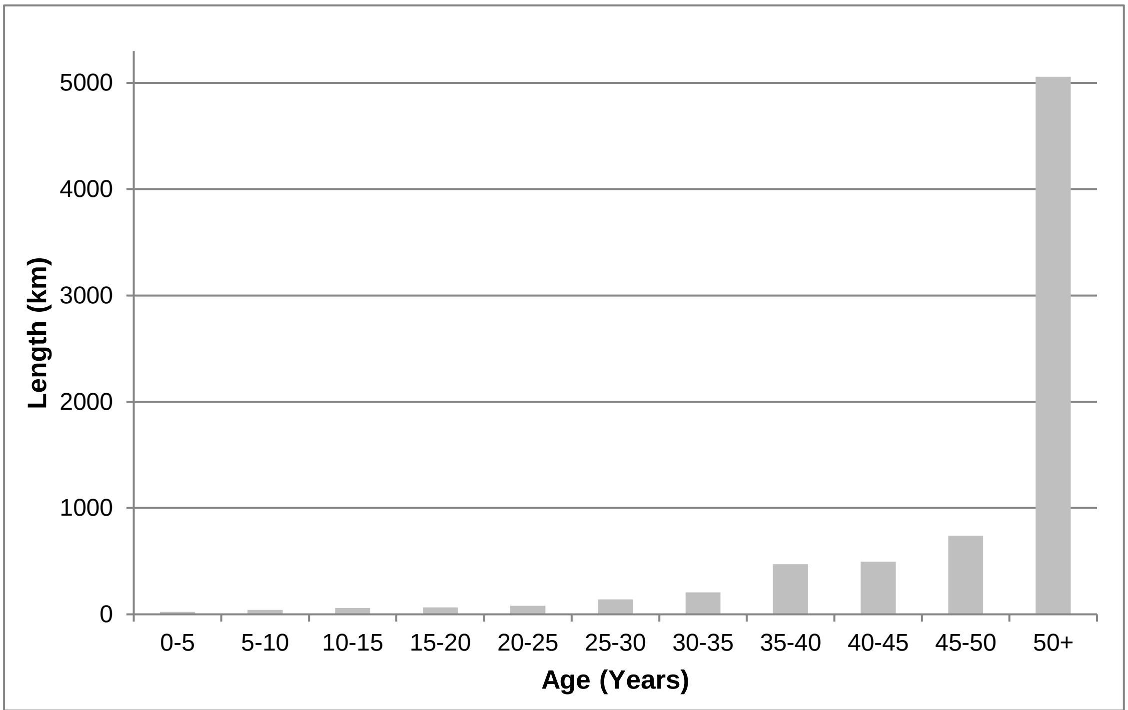
3.2 Background

Ausgrid's LV distribution network was originally designed with separate dedicated street light circuits which utilised small diameter conductors and a control mechanism to turn the circuit on at night time through centralised control. The primary function of dedicated circuits is to safely supply electricity to street lights. These circuits were generally constructed above LV circuits with bare conductors.

Ausgrid has 19,153km of LV overhead conductors including 6,100km of overhead conductors used on dedicated circuits which supply street lights. In the 1990s, Ausgrid stopped installing bare overhead conductors on these dedicated circuits and transitioned to the current practice to individually supply new street lights, where possible, directly from LV circuits via an integrated photo electric (PE) cell built into modern street lights. Reconfiguration of LV circuits to remove dedicated street light circuits has been progressively occurring on an ad-hoc basis since the 1990s.

The age profile of LV overhead conductors used on dedicated circuits is shown in Figure 3. 79% of these assets are more than 45 years old.

Figure 3. Age profile of LV overhead conductors on dedicated circuits (as at 30 June 2017)



The need for this LV circuit reconfiguration program is primarily driven by circuit condition and inherent design issues which have resulted in safety risks to the public, customers or workers. These risks are compounded by the ageing asset population, noting that 72% of the population is already over 45 years old.

3.3 Risks – Consequence and likelihood

The key consequences that can result from failure of overhead conductors on dedicated circuits are shown in Table 7.

Table 7. Consequences from loss of function for LV overhead conductors on dedicated circuits

Consequence	Description
Harm to the public, communities and workers	Contact with failed live dedicated circuits which have fallen to the ground or are suspended at a reachable height may cause injury (physical injury, electric shock or burns) or a fatality (electrocution). A fatality has occurred in Western Australia.
	Fires (including bushfires) caused by vegetation contact with live dedicated circuits which may cause injury (electric shock or burns) or a fatality.
	Interruptions to the dedicated circuit supply can affect a single light or larger areas (up to approximately a 10 block radius) reducing visibility for pedestrians / drivers and cause unsafe environments for the public.
Damage to property	Contact between failed live dedicated circuits which have fallen and buildings, infrastructure or vehicles may cause arcing, fires or physical damage.
	Buildings, property, critical infrastructure or natural environments may be damaged by fires caused by vegetation contact with dedicated circuits.

The failure modes associated with the conductors and components used on the dedicated circuits are generally deteriorating in nature and therefore present an increased likelihood of failure over time. The failure modes associated with the conductor can still occur whether the circuit is in use or it is redundant but has not been removed from the poles. The predominant failure modes for the LV overhead conductors used on dedicated circuits are shown in Table 8.

Table 8. Key failure modes for LV overhead conductors on dedicated circuits

Conductor type	Key Failure Modes
Dedicated low voltage conductors	Conductor corrosion due to exposure to weather or pollution.
	Broken conductor strands (known as 'stranding') caused by corrosion or fatigue from conductor movement (swaying).
	Conductor failure due to corrosion or fatigue from conductor 'sway' over the life of the service.
	Conductor mechanical damage or failure due to contact with vegetation, buildings or vehicles.

Failure of the control mechanism used for dedicated circuits (photoelectric (PE) cells, control relays or switching contactors) can also occur due to exposure to the elements, age related degradation, vegetation contact or third party impact (to conductors, poles or other components). Failure of the control mechanisms results in all street lights on a dedicated circuit not operating.

The consequences and likelihood of a dedicated circuit failure can increase due to factors including:

- Its inherent design (small diameter conductors and a common control mechanism)
- Constructed below LV conductors (more likely to be struck by vehicles) or above LV conductors (failed conductors can fall onto the live LV conductor)
- Being in areas that are prone to high winds / lightning, are salt affected (coastlines) or highly polluted, or are in areas with vegetation near or above the network
- Being in areas with high pedestrian / vehicle activity, in close proximity to schools and shopping centres, or in areas with high crime rates
- Being in areas prone to bushfire
- Low likelihood of failure detection, particularly for redundant circuits.

The need for this LV circuit reconfiguration program is primarily driven by overhead conductor condition and inherent design issues associated with the dedicated circuits which have resulted in safety risks to the public, customers or workers when they fail and:

- Remain live in a position where contact can be made with the conductor
- Fallen conductors are in contact with energised LV conductors
- Lighting levels are insufficient for drivers of vehicles and other persons at night.

A fatality occurred in Western Australia in 2011 when a member of the public made contact with a fallen conductor on a dedicated circuit[1]. The conductor which failed was constructed above bare LV conductors – when the conductor failed, it fell against the bare LV conductors underneath and remained live. Other members of the public were injured during their

[1] Government of Western Australia, Department of Commerce, EnergySafety, Electrical Incident Safety Report, Western Australia 2010-11, p.8

attempt to assist with this emergency. The heighted risk with this dedicated circuit was attributed to;

- The small diameter street lighting conductors (which increases the likelihood of failure)
- The dedicated circuit being constructed above bare LV conductors
- A low likelihood of detecting failures on dedicated circuits because disruptions to electricity supply to customers do not generally occur and therefore are not reported.

Ausgrid's dedicated circuits are of similar construction to those in Western Australia which caused this fatality. The risk of a fatality occurring under similar circumstances within our operating context is therefore 'reasonably foreseeable'.

In the period from 1/7/2013 to 30/6/2017, there were more than 2,300 failures of conductors on dedicated circuits (including 389 functional failures and 49 third party damage incidents). The low level of functional failures compared to conditional failure reflects the robust inspection process for overhead conductors (including those on dedicated circuits) to assess their condition and to then repair or replace them prior to functional failure. If the failures or third party damage were not identified and were therefore unattended, the public safety risk would be significant.

Ausgrid's asset management practices for overhead conductors (including dedicated circuits) provide an understanding of their condition and therefore the likelihood of failure. Detecting failures before they occur and applying treatments maintains overhead conductors in a serviceable condition, limiting the likelihood of failure and mitigating the potential consequences described above.

3.4 Treatment analysis

Assessment of the treatment options considered for overhead conductors on dedicated circuits is shown in Table 9.

Table 9. Treatment options for managing dedicated circuits

Treatment option	Treatment overview
1 Repair the dedicated circuits	Undertake repairs to the dedicated circuit and components as condition issues are identified. Indicative repair costs range from approximately $1,200 to $5,000 per repair.
2 Reconfigure the dedicated circuits	Reconfigure the dedicated circuits so street lights are individually supplied from the LV distribution network. Indicative reconfiguration cost is approximately $15,000 per km.
3 Replace the dedicated circuits	Replace the existing dedicated circuits and their components with new dedicated circuits using modern equivalents. Indicative replacement costs are approximately $50,000 per km.
4 Replace the dedicated circuits with new underground dedicated circuits	Replace the existing overhead dedicated circuits with new underground dedicated circuits. Indicative replacement costs are approximately $1,000,000 per km.

Repairs (Option 1) are an operational expense associated with maintaining the assets and may be done as a short term fix until planned replacement can be undertaken. Repairs do not return the assets to an 'as new' condition and do not address the known failure modes and safety risks associated with the inherent design issue of the dedicated circuits. This option also does not address the age of the population or redundant assets still installed on poles.

Reconfiguring the dedicated circuits (Option 2) addresses the safety risks associated with contact with failed dedicated conductors or reduced lighting levels at night due to failed control mechanism components. This option addresses the age of the dedicated circuit population and removes redundant assets. Utilising the existing LV distribution network removes life cycle costs associated with operating dedicated circuits (as well as reducing vegetation management requirements in particular circumstances) and expedites reconfiguration. Efficiencies can be gained by undertaking circuit reconfiguration in conjunction with the upgrading of street lighting services.

Replacing the dedicated circuits with the modern equivalent components (Option 3) reduces the safety risks in the short term however does not resolve the inherent safety risks associated with the design of the dedicated circuits. This option also does not remove the life cycle costs associated with operating these dedicated circuits

Relocating overhead dedicated circuits underground (Option 4) addresses the safety risks associated with contact with failed dedicated conductors or reduced lighting levels at night due to failed control mechanism components if the lights are replaced with the individual PE cell control. This option also addresses the age of the dedicated circuit population and removes redundant assets. This option is significantly more expensive and takes significantly longer (significantly deferring risk mitigation) to implement than the previous options due to the requirement to undertake this work in established population areas.

Ausgrid believes the reconfiguration of dedicated circuits (Option 2) is the most appropriate treatment option as it addresses the safety risks associated with contact with failed dedicated conductors or reduced lighting levels at night due to failed control mechanism components and includes removal of redundant assets which still pose safety risks.

3.5 Options

The program options for managing the dedicated circuits are summarised in Table 10. These options are based on the need to undertake work on Ausgrid's assets when their condition is assessed to be unsafe.

Table 10. Program options for managing dedicated circuits

Program need options	Option overview
1 Reactive Treatment	Implement treatment such as reconfiguration when the dedicated circuit fails.
2 Conditional Treatment	Implement treatment to reconfigure when inspections and condition assessments (based on a set of criteria) identify that the dedicated circuits have deteriorated to the point of conditional failure.
3 Planned Treatment	Implement treatment such as reconfiguration at a fixed time and, where feasible, in conjunction with the upgrade to street lighting services for Councils.

The consequence of an overhead conductor on a dedicated circuit falling poses serious safety risks to the public, customers, workers and the community as described above. Due to these risks, an approach that only manages these assets in a reactive manner (Option 1) or following identification of condition issues (Option 2) is unacceptable. These options would defer capital expenditure in the short term, but would not adequately manage the existing reasonably foreseeable risks associated with the dedicated circuits. As these risks accumulate over time, this could lead to a significant uplift in public safety incidents, reactive replacement work and an accompanying step change in capital expenditure. Due to the significant and ageing population of the existing assets, overcoming this in the future would be expected to require a significant increase in capital expenditure.

The preferred option is the planned reconfiguration of dedicated circuits (Option 3). This option mitigates the inherent and reasonably foreseeable safety risks associated with the dedicated circuit configuration and can be implemented expediently using the existing LV network to provide a balance between the risks and costs for the significant asset population so far as is reasonably practicable. Additional benefits of circuit reconfigurations include the potential for reduced vegetation management requirements and reduced pole top construction life cycle costs.

3.6 Costing and volumes

Due to the safety risks associated with dedicated circuits Ausgrid initiated an accelerated program during 2017/18 to reconfigure the LV network to remove these reasonably foreseeable risks. Ausgrid is currently negotiating street light replacement with customers (i.e. Councils) – it is expected that approximately 100,000 older street lights will be replaced with modern street lights which utilise LED technology following these negotiations and during the 2019-24 regulatory period. The upgrade of the street lighting service for Councils presents an opportunity to reconfigure the dedicated circuit arrangements concurrently. Aligning these street light upgrades and circuit reconfiguration will result in operational efficiencies.

As this program is still in its infancy, the program unit rate and delivery is still being established, however indicative estimates are shown in the forecast table below. This work is predominantly undertaken by internal staff, however it is also carried out by external resources and accredited service providers in association with contestable projects.

Repex modelling for overhead conductors operating at <1kV undertaken by Ausgrid shows that the unit cost for this program is lower than the benchmark unit cost, however the forecast volume is significantly higher than the AER benchmark volume. The unit cost is lower because the dedicated circuits are predominantly being reconfigured (as opposed to being replaced) using existing LV conductors. The volume of LV circuits being reconfigured is significantly higher than the benchmark due to the accelerated program Ausgrid is undertaking to mitigate the 'reasonably foreseeable' safety risks associated with the dedicated circuits.

The 2019-24 summary forecast for this replacement program is shown in Table 11. The costs shown are direct costs only. Approximately 9.5% of the dedicated circuit population is to be reconfigured each year due to the reasonably foreseeable public safety risks and average age of these assets. The accelerated program commenced in 2017/18 and is expected to continue at similar volumes until its targeted completion at the end of the 2024-29 regulatory period.

This program forms part of the overall investment being proposed for the replacement of overhead conductors. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details in regard to the overall investment proposed for this asset category during 2019-24.

Table 11. Forecast for dedicated LV circuit configuration

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Dedicated LV circuit reconfiguration					
Volumes for reconfiguration (km)	580	580	580	580	580
Unit cost	$14,937	$14,840	$14,797	$14,774	$14,721

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Total costs ($m)	**$8.66**	**$8.61**	**$8.58**	**$8.57**	**$8.54**

4 OVERHEAD WIRING COMMUNITY CONCERNS

4.1 Program description

Ausgrid has been working closely with stakeholders, including local councils, to improve the way vegetation near overhead conductors and poles is managed in urban areas. Ausgrid undertakes vegetation management to mitigate safety risks to the public, customers and workers associated with vegetation making contact with overhead conductors. A common theme from stakeholders was the need for Ausgrid to forge more effective partnerships with local Councils to improve our vegetation management strategies and to ultimately align them with the strategies and priorities of our customers while still ensuring safe and reliable operation of the network. Current vegetation management practices have resulted in outcomes in urban areas which are perceived by communities as inappropriate and have led to:

- Widespread media coverage of community concerns and complaints
- Political intervention (local and state government)
- Reputational risks to the Ausgrid brand.

In response to the stakeholder feedback, Ausgrid has initiated a program to address community concerns in regard to vegetation management:

- Overhead wiring community concerns (REP_04.02.49).

This new program is expected to commence in 2019. Ausgrid expects to spend $18.7 million during the 2019-24 regulatory period to improve our urban area network configuration.

4.2 Background

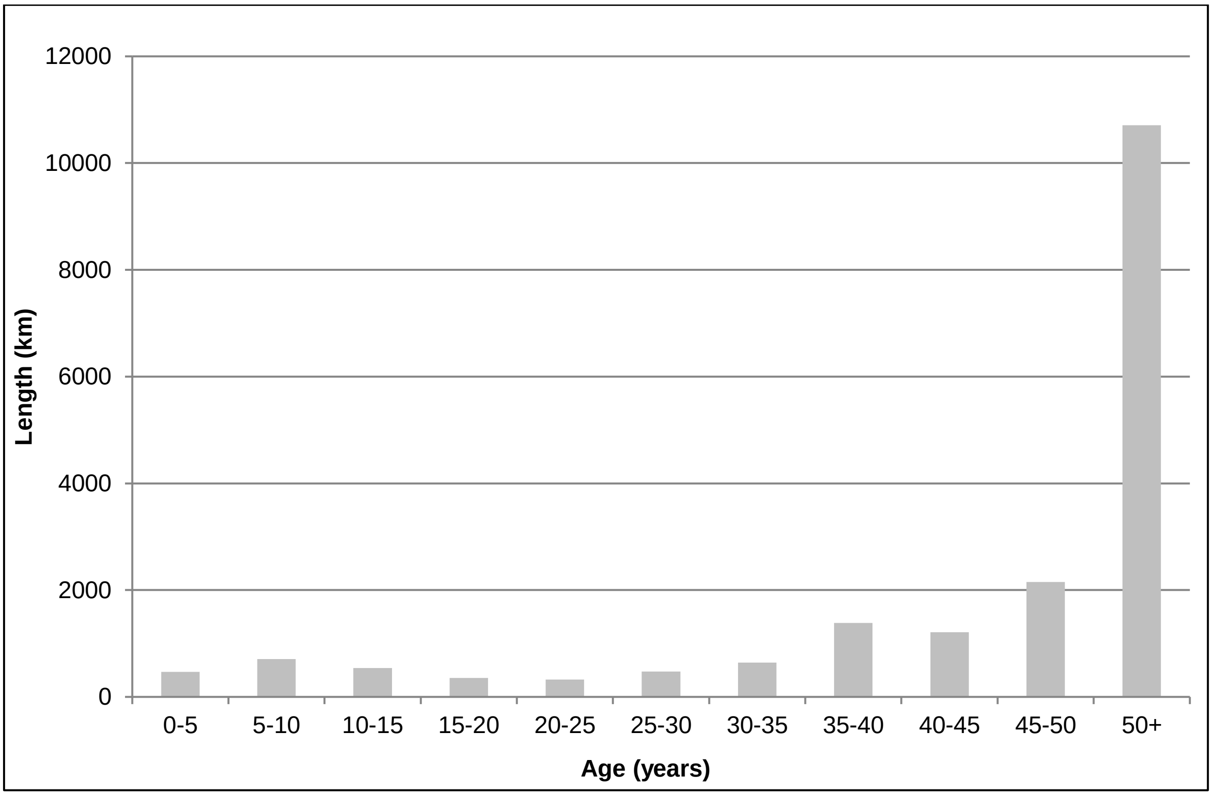
Redevelopment of urban areas has resulted in increased population densities. The traditional single dwelling on a ‘quarter acre block’ has been superseded by medium density housing (duplex) or high density housing (multi-story apartments). Where people cultivated and enjoyed their own gardens and trees in the past, the increasing housing density has reduced (or eliminated) the size of private yards and shifted community expectations for gardens and trees from their own property to public lands. There is growing awareness of the economic and social benefits of trees and the important role they play in the liveability of urban areas.

There is a cost for trees being near the electricity network. Trees can damage, interfere with or come within safety clearances to the electricity network. These issues result in safety risks to the public (including if a person were to climb a tree), customers and workers, as well as loss of supply risks. These risks cannot be left untreated. Ausgrid is required under legislation to ensure that the electricity network is safe and reliable. One aspect of meeting this requirement is to manage vegetation in close proximity to overhead conductors.

Ausgrid spends more than $40 million a year in operating expenditure managing vegetation near the network. Ausgrid recognises the benefits of trees as essential green infrastructure and trims trees in accordance with the vegetation safety clearances specified in NSW industry guidelines. These guidelines include an allowance for regrowth between trimming cycles.

The age profile of all LV overhead conductors is shown in Figure 4.

Figure 4. Age profile of LV overhead conductors (as at 30 June 2017)



The need to replace some LV overhead conductors has been triggered by feedback from stakeholders in regard to aligning Ausgrid vegetation management strategies with those of the wider community while continuing to provide a safe electricity supply to customers.

4.3 Risks – Consequence and likelihood

The key consequences that can result from LV overhead conductors due to vegetation contact and misaligned vegetation management strategies are shown in Table 12.

Table 12. Consequences from loss of function for LV overhead conductors

Consequences	Description
Harm to the public, communities and workers	Contact with live electrical conductors or equipment may cause injury (physical injury, electric shock or burns) or a fatality (electrocution).
	Fires (including bushfires) caused by vegetation contact with live electrical conductors or equipment may cause injury (electric shock or burns) or a fatality.
	Safety issues as a result of loss of supply are detailed below.
Damage to property	Contact between live electrical conductors or equipment and buildings, infrastructure or vehicles / watercraft may cause arcing, fires or physical damage.
	Buildings, property, critical infrastructure or natural environments may be damaged by fires caused by vegetation contact with live electrical conductors or equipment which have reduced clearances or have fallen.
Loss of supply	Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and communication systems, critical infrastructure and vulnerable customers including those on life support systems.

Consequences	Description
	The volume of failures associated with vegetation contact with overhead conductors may result in reliability impacts and penalties / intervention by our regulator.
Increased public scrutiny and complaints	Vegetation management practices have resulted in community concerns and complaints, as well as political intervention.

Failure modes associated with vegetation contact with overhead conductors are generally deteriorating in nature and therefore present an increased likelihood over time. The predominant failure modes for vegetation contact with overhead conductors include:

- Damage to the conductor or insulation covering due to abrasion
- Conductor breakage due to vegetation contact
- Uncontrolled discharge of electricity from overhead conductors to ground.

The consequence of an overhead conductor failure due to vegetation contact in urban areas can increase if the overhead conductors:

- Are in areas with high pedestrian / vehicle activity or near schools
- Supply electricity to critical customers or infrastructure.

Vegetation management activities are undertaken near overhead conductors to mitigate safety risks to the public, customers or workers, and loss of supply risks. Stakeholders have requested that Ausgrid's current vegetation management approach be reviewed as a priority and that a more collaborative and customised approach be considered for urban environments and to address the needs of individual local Councils. While Ausgrid has improved vegetation management methodologies and reduced vegetation clearance requirements from LV overhead conductors in urban environments, further improvement is limited by:

- The existing network configuration, which primarily consists of aged LV bare mains
- The existing trees near those network components.

Ausgrid's asset management practices for overhead conductors provide an understanding of their condition and therefore the likelihood of failure and this has driven the need for vegetation management. Keeping vegetation clear of overhead conductors prevents the factors relating to vegetation contact detailed above from occurring however our need to maintain these clearances do not align with community expectations for vegetation in non-bushfire prone urban areas.

The key treatment options that may be applied where a targeted vegetation management approach for LV overhead conductors is required are described below.

4.4 Treatment analysis

Where systemic vegetation management or conductor condition issues are identified in urban areas, opportunities arise to undertake a 'redesign' of the LV network at that location. Redesigning the network with strategic vegetation management objectives in mind (as opposed to like-for-like replacement) improves outcomes for Ausgrid and the community. The treatment solutions considered for these strategic outcomes are shown in Table 13.

Table 13. Treatment options for achieving strategic outcomes

Treatment option	Treatment overview
1 Replace with bundled conductor	Replace the existing bare LV mains with LV aerial bundled conductor (LV ABC).
2 Replace with underground assets	Replace the existing LV and / or 11kV mains in associations with Council 'precinct plan' works.
3 Replace trees	Replace inappropriate tree species under LV or 11kV mains with appropriate species.

Each treatment option reduces vegetation management requirements and improves urban streetscapes to some extent. Engagement with local Councils to date has identified a willingness to align strategic objectives in regard to vegetation management improvement initiatives, and a willingness to share costs for its implementation. Ausgrid is collaboratively developing this scheme for co-funding of these improvement initiatives. In this context, the treatment option (or options) selected from the above table will be determined on a case by case scenario and will be dependent on stakeholder objectives at each location.

4.5 Options

The program options considered to achieve these strategic outcomes are summarised in Table 14. These options are based on the need to undertake work on Ausgrid's assets when their condition is assessed to be unsafe to be left as-is or when systemic vegetation management issues have been identified by stakeholders.

Table 14. Program options for achieving strategic outcomes

Program need options	Option overview
1 Reactive Treatment	Implement treatment when the overhead conductor fails.
2 Conditional Treatment	Implement treatment to redesign the network to align with the strategic objectives of stakeholders when overhead conductor condition issues are identified.
3 Planned Treatment	Implement treatment such as reconfiguration at a fixed time and, where feasible, in conjunction with the upgrade to street lighting services for Councils.

The consequence of an OH conductor falling, or vegetation contact with bare LV conductors, poses serious safety risks to the public, customers, workers and the community as described above. In addition to this, emergency like for like repairs undertaken following a failure may not align with the strategic objectives of our stakeholders. Due to these risks a treatment approach that only manages these assets in a reactive manner (Option 1) is unacceptable. If overhead conductor condition issues or vegetation management issues have been identified, negotiations would need to commence with the relevant stakeholders to verify if the location where the issue is aligns with their strategic plans. These negotiations may take time and some condition issues will need to be addressed in short timeframes if they are near the point of functional failure or vegetation is in contact with the conductors. This may result in repairs or like for like replacement being undertaken before a stakeholder response is received and further expenditure may then be required to align the network design with the stakeholder objectives. This conditional approach (Option 2) is not the optimal treatment due to the inefficiencies described above.

The preferred option is planned treatment (Option 3). This option allows a collaborative assessment of stakeholder objectives and asset condition issues to target network redesign activities at defined locations to obtain alignment between stakeholder and Ausgrid objectives. Planned treatment includes defining projects for any given year which allows efficient and collaborative 'planned' delivery of activities at these defined locations which reduces overall costs and disturbance to the public.

4.6 Costing and volumes

Ausgrid considers funding of $3.7 million per year (direct costs) adequate for the expected quantity of initiatives to be jointly funded with stakeholders. The appropriate treatment option selected from the list above will be determined on a case-by case basis after reviewing options and determining the scope of work with the relevant stakeholders.

While Ausgrid internal resources have traditionally undertaken replacement of network assets, contracted resources have been utilised for replacement of overhead conductors (primarily in association with condemned pole replacement). In addition to this, accredited service providers have installed network assets under contestable projects for many years.

Under the co-funding scheme it is expected that some functions traditionally undertaken by Ausgrid at our cost (for example, reinstatement of footpaths following works) may be undertaken by Councils at their cost where it is more efficient to do so.

The 2019-24 summary forecast for this replacement program is shown in Table 15. The costs shown are direct costs only. Negotiations are expected to commence with stakeholders during 2018/19 to establish projects which will commence during 2019/20. This forecast equates to replacement of approximately 0.1% of the LV overhead conductor population annually during the 2019-24 regulatory period.

This program forms part of the overall investment being proposed for the replacement of overhead conductors. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details on the overall investment proposed for this asset category during 2019-24.

Table 15. Forecast for overhead wiring community concerns

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Overhead wiring community concerns					
Volumes for replacement (km)	20	20	20	20	20
Unit cost	$187,975	$187,057	$186,699	$186,544	$186,098
Total costs ($m)	**$3.76**	**$3.74**	**$3.73**	**$3.73**	**$3.72**

5 LOW MAINS

5.1 Program description

Ausgrid has duty of care obligations to minimise the risk of people, property, vehicles and vegetation coming into contact with overhead conductors. Ausgrid undertakes inspections and condition assessments to identify overhead conductors which do not comply with our obligations to have sufficient clearance to the ground, roads, buildings or other infrastructure. Insufficient clearances from overhead conductors result in safety risks to the public, customers and workers if:

- People can make contact with the overhead conductors from the ground or from buildings
- Vehicles or machinery can make contact with the overhead conductors
- The overhead conductors can make contact with buildings or other infrastructure.

The two programs Ausgrid has to address the inadvertent contact risks associated with insufficient overhead conductor clearances are.

- Low mains – distribution (DOC_11.03.34)
- Low mains – transmission (DOC_11.03.35).

These programs are continuing from the current regulatory period. Ausgrid expects to spend $5.6 million in direct costs on addressing 680 overhead conductor clearance risks during the 2019-24 regulatory period, including $4.3 million to rectify low distribution mains and $1.3 million on low transmission mains.

The minimum clearance requirements that Ausgrid must comply with when overhead lines are designed, constructed and operated are set out in the Australian Standard AS7000 – Overhead Line Design ('AS7000'). AS7000 is the latest iteration of industry standards that were established many decades ago to standardise overhead conductor clearance requirements and line design. Rectifying low mains when they are identified forms an element of the strategy Ausgrid adopts in meeting its obligation to the legislation in managing the risks associated with overhead conductors so far as is reasonably practicable.

5.2 Background

Ausgrid has over 32,000km of overhead conductors on the network operating at voltages ranging from 240V to 132kV and over 720,000 overhead service lines. Overhead lines have been constructed to comply with specified conductor clearance requirements to the ground, roads, buildings or other infrastructure however changes in their adjacent environment or asset related degradation (for example, leaning poles, broken or leaning cross arms) since they were put into service may result in clearances which are no longer compliant with those requirements. Ausgrid considers overhead conductors which have insufficient clearances to be 'low mains'.

The primary function of overhead conductors is to safely distribute electricity to customers. The need to rectify low mains has been triggered by the safety risks they pose to the public, customers and workers when they are:

- Suspended at a reachable distance from ground, a building or other infrastructure
- Suspended at a distance where vehicles or machinery may make contact
- Suspended at a distance where they may make contact with a building or other infrastructure when they are still or when they 'sway'

- Struck and fall to the ground.

Ausgrid undertakes inspection programs and condition assessments of overhead conductors to monitor their condition against known failure modes and includes identifying overhead conductors which have reduced clearances. Light Detection and Ranging (LiDAR) technology has been utilised for inspections in some parts of the network – due to the measurement accuracy of this technology, the volume of identified reduced clearance issues (to vegetation and to ground, buildings and other infrastructure) has increased significantly in recent years. Reduced clearances between overhead conductors and vegetation are predominantly mitigated by vegetation management processes as operations expenditure.

5.3 Risk – Conseuqence and likelihood

The key consequences that can result from low mains are shown in Table 16 below.

Table 16. Consequences from loss of function for low mains

Consequences	Description
Harm to the public, communities and workers	Contact with live electrical conductors may cause injury (physical injury, electric shock or burns) or a fatality (electrocution).
	Fires (including bushfires) caused by live electrical conductors which have reduced clearances or have fallen after being struck may cause injury (burns) or a fatality.
Damage to property	Contact between live electrical conductors which have reduced clearances or have fallen after being struck and buildings, infrastructure or vehicles / watercraft may cause arcing, fires or physical damage.
	Buildings, property, critical infrastructure or natural environments may be damaged by fires caused by contact with live electrical conductors which have reduced clearances or have fallen after being struck.
Litigation	Inadvertent contact with live electrical conductors causing injury, fire, property damage or loss of supply may result in litigation.

In the period from 2013/14 to 2016/17, there were over 2,800 overhead conductor low mains issues identified by inspections and condition assessments. These low mains may result in safety risks to the public, customers and workers. Reduced clearances to overhead conductors may be caused by third party activities outside of Ausgrid's control, including:

- Civil works, landscaping, agriculture or mining
- New or redeveloped buildings
- Natural events (floods, storms, ground movement, vegetation contact).

Reduced clearances to overhead conductors may also be caused by failure of network assets, including:

- Leaning poles
- Degraded or broken pole top structures
- Incorrect design or construction.

The consequences of reduced clearances to overhead conductors can increase due to:

- Being in areas with high pedestrian / vehicle activity or in close proximity to schools
- Being on circuits which supply critical customers or infrastructure

- Being in areas prone to bushfire.

Ausgrid's asset management practices detect low mains issues. Applying treatments when they are identified limits the likelihood of inadvertent contact occurring and mitigates the potential consequences. The key treatment options that are applied are detailed below.

5.4 Treatment analysis

Assessment of the treatment solutions considered for low mains is shown in Table 17. Replacing overhead conductors with underground assets to mitigate low mains risks is another option that was considered however the cost to undertake this work and the time it would take to implement and remove all low mains risks make the option not reasonably practicable.

Table 17. Treatment options for managing low mains

Treatment option	Treatment overview
1 Repair the low mains	Mitigate the low mains risk by relocating the overhead conductor to a higher position on the pole or applying additional tension to the conductors.
2 Replace the pole top structure	Mitigate the low mains risk by replacing the pole top structure with modern equivalent components.
3 Replace the entire pole	Mitigate the low mains risk by replacing the entire pole including the pole top structures.

A repair may be completed where practical and efficient. Where practical, a repair is selected as it is most readily able to be implemented as it is only a minor change to existing assets – this work is undertaken as operational expenditure.

Replacing the pole top structure is undertaken where a repair is not practical and the existing pole has sufficient height to be able to replace the pole top structure in a way that mitigates the low mains risk.

Where the existing pole does not have sufficient height to relocate conductors or replace the pole top structure to mitigate the low mains risk replacement of the entire pole becomes the only practical option available. Replacement of the entire pole may also be chosen if the condition of the pole precludes implementing repair or replacement of the pole top structure.

The appropriate treatment option to mitigate the risk is selected on a site by site basis.

5.5 Options

The treatment options available when considering low mains management strategies are summarised in Table 18 below.

Table 18. Program options for managing low mains

Program need options	Option overview
1 Reactive Treatment	Implement treatment such as mitigation of low mains following inadvertent contact.
2 Conditional Treatment	Implement treatment such as addressing low mains when inspections or condition assessments identify that conductor clearances are below requirements defined in standards.
3 Planned Treatment	Implement treatment such as replacement of overhead conductors at the standard technical life of 45 years.

Ausgrid's preferred approach is to apply a treatment solution when low mains risks have been identified by inspections or condition assessments (Option 2). When a low mains issue is identified, a risk assessment is undertaken against established criteria to determine the priority and timing of mitigation activities. The treatment solution is then selected from the options above.

This approach optimises the management of risk rather than the long term sustainability of the asset population (average age). Ausgrid believes this to be the most appropriate approach as it defers short to medium term investment for customers particularly where new technologies may lead to further efficiencies or changes in the configuration and design of the 'network of the future'.

5.6 Costing and volumes

Ausgrid has had an intense program of work based on data captured as part of the LiDAR inspections of Ausgrid's overhead mains network. Experience has shown that the volumes generated over recent years in bushfire prone areas have been decreasing as Ausgrid managers the legacy low mains issues.

Low mains risk mitigation is primarily undertaken by internal resources, however, external resources have been utilised on occasion. Internal benchmarking of Ausgrid costs is continually undertaken to drive efficiency and reduce costs.

The 2019-24 summary forecast for these replacement programs is shown in Table 19. The costs shown are direct costs only. It should be noted that each unit included in the forecast volumes will be assumed to require replacement of 100m of overhead conductor. This forecast equates to replacement of less than 0.1% of the overhead conductor population annually during the 2019-24 regulatory period.

These programs form part of the overall investment being proposed for the replacement of overhead conductors. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details in regard to the overall investment proposed for this asset category during 2019-24.

Table 19. Forecast for low mains

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Low mains – distribution					
Volumes for replacement	130	130	130	130	130
Unit cost	$6,605	$6,564	$6,545	$6,533	$6,509
Total costs ($m)	**$0.86**	**$0.85**	**$0.85**	**$0.85**	**$0.85**
Low mains – transmission					
Volumes for replacement	6	6	6	6	6
Unit cost	$43,320	$43,165	$ 43,131	$43,142	$43,095
Total costs ($m)	**$0.26**	**$0.26**	**$0.26**	**$0.26**	**$0.26**

6 EARTHING

6.1 Program description

The planned replacement program for overhead sub-transmission feeder star picket earthing electrodes addresses known condition issues associated with their design. These condition issues cause safety risks to the public, customers and workers if:

- Excessive earth potential rise occurs under normal conditions or during faults, or
- Feeder protection systems do not operate correctly.

The replacement program for star picket earthing electrodes is:

- Replace sub-transmission feeder earth electrodes program (REP_05.02.28).

This program continues from the current regulatory period and is forecast to be completed during 2019-24. Ausgrid expects to spend $0.73 million replacing 492 star picket earth electrodes during the 2019-24 regulatory period.

6.2 Background

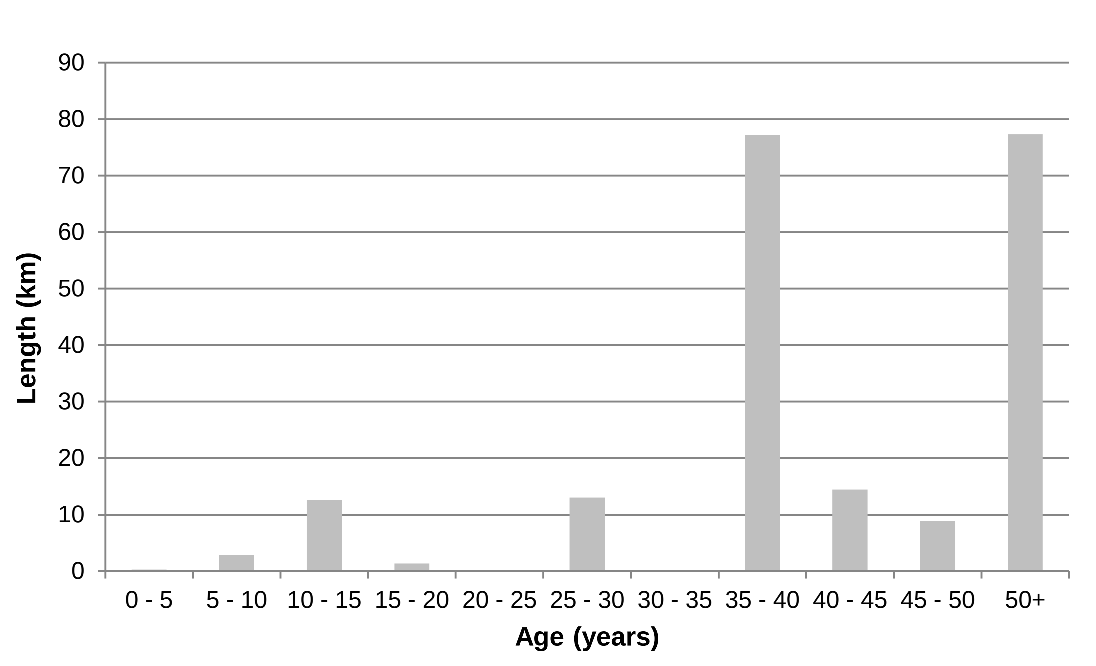
The earthing system on sub-transmission feeders is a safety critical component that must be appropriately designed and maintained in suitable condition for as long as the sub-transmission feeder it protects remains in service. These earthing systems include earth electrodes, earth conductors, earth grids, link boxes and surge arrestors. Earthing systems protect assets from being damaged by electrical faults and voltage surges as well as protect the public, customers and workers from electric shock and electrocution.

Some sub-transmission feeders have earthing systems which utilise galvanised steel ‘star pickets’ as earth electrodes instead of properly designed copper earthing electrodes. The sub-transmission feeders identified with star picket earth electrodes are confined to a small number of feeders operating at either 66kV or 132kV in the Ausgrid Upper Hunter region. The total length of these feeders is 208km.

Ausgrid does not record earthing system asset details to such a level that individual component age is known. The average age of the earthing systems has been estimated using the age profile of the identified feeders with star picket earth electrodes. The average age of these feeders is 28 years. The age profile of the identified feeders (and inherently their associated earthing systems) is shown in Figure 5.

There standard technical life for earthing systems is aligned to the 45 years standard technical life of the identified feeders.

Figure 5. *Age profile of sub-transmission feeders with star picket electrodes (as at 30 June 2017)*



The need to replace 'star picket' earth electrodes has been triggered by their known condition and inherent design issues which prevent earthing systems performing their primary functions of:

- Controlling feeder earth potential rise (EPR) under normal or fault conditions
- Ensuring correct operation of protection systems to maintain system stability.

6.3 Risk – Consequence and likelihood

The key consequences that can result following a loss of function of star picket earthing electrodes are shown in Table 20.

Table 20. Consequences from loss of function for star picket earthing electrodes

Consequences	Description
Harm to the public, communities and workers	Excessive earth potential rise or ineffective operation of protection systems may cause injury (electric shock or burns) or a fatality (electrocution).
	Fires (including bushfires) caused by excessive earth potential rise or ineffective operation of protection systems may result in injury (electric shock or burns) or a fatality.
	Safety issues as a result of loss of supply are detailed below.
Damage to property	Contact between live electrical equipment which has failed due to excessive earth potential rise or ineffective protection system operation and buildings, infrastructure or vehicles / watercraft may cause arcing, fires or physical damage.
	Buildings, property, critical infrastructure or natural environments may be damaged by fires caused by vegetation contact with live electrical equipment which has failed due to excessive earth potential rise or ineffective operation of protection systems.
	Excessive earth potential rise may damage appliances or equipment installed within customer premises. Ausgrid may be held liable for their replacement.

Consequences	Description
Loss of supply	Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and communication systems, critical infrastructure and vulnerable customers including those on life support systems.
	Ineffective operation of protection systems may result in wide-spread supply interruptions and penalties or intervention by our regulator.

The failure modes associated with star picket earthing electrodes are deteriorating in nature and therefore present an increased likelihood over time. The predominant failure modes for star picket earthing electrodes include:

- Increased resistance to earth due to corrosion of the galvanised steel electrode
- Increased resistance to earth due to corrosion of connections to other earthing system components
- Third party damage to the earth electrode.

The consequence of a star picket earthing electrode failure can increase due to the feeder:

- Being in areas with high pedestrian / vehicle activity or in close proximity to schools
- Being in close proximity to other underground utilities (gas, fuel, telecommunications)
- Being connected to feeders which supply critical customers or infrastructure
- Being in areas prone to bushfire.

Star pickets are made from galvanised steel and are primarily designed for use in fencing applications (agriculture, roadworks etc.), not as a component of electricity network earthing systems. Conditional failures relating to corrosion of the star picket and earth connections have been identified on a small number of sub-transmission feeders and could result in safety and loss of supply risks to the public, customers and workers due to unsafe earth potential rises and ineffective operation of protection systems. The reason that this type of earthing electrode was installed when the feeders were originally commissioned instead of purposely designed copper earth electrodes is not known.

Condition or inherent design issues with other earthing system components may also cause excessive earth potential rise or ineffective protection system operation and can result in safety and loss of supply risks. Condition issues may be caused by age related degradation or third party damage to earth down leads / conductors, earth connections or earthing grids. Inherent design issues generally relate to original earthing configuration designs not meeting current network fault ratings or are due to changes in their operating environment (for example, a conductive pipeline has been installed near Ausgrid assets).

Ausgrid utilises condition information from inspections / earth resistance testing and condition assessments to determine when an earth electrode or earth system is approaching functional failure and sets criteria to define the point of conditional failure. Earthing electrodes or other earthing system components are replaced if the condition issues identified are not technically or economically able to repaired, i.e. if they are at end of life.

Ausgrid's asset management practices for earthing systems (including star picket earthing electrodes) provide an understanding of their condition and therefore the likelihood of failure. Detecting failures before they occur and applying treatments maintains earthing systems in a serviceable condition, limiting the likelihood of failure and mitigating the potential consequences described above.

The key treatment options that are applied are detailed below.

6.4 Treatment analysis

Assessment of the treatment options considered for star picket earthing electrodes is shown in Table 21.

Table 21. Treatment options for managing star picket earth electrodes

Treatment option	Treatment overview
1 Repair the earthing electrode	Undertake repairs to the earthing electrode as conditional issues are identified.
2 Replace the earthing electrode	Replace the earthing electrode only.
3 Replace the earthing system	Replacement of the entire earthing system on each pole with modern design components.

Repair of this type of earthing electrode (Option 1) is not practical due to their inherent design.

Replacing the earthing electrode (Option 2) will assist in mitigating the safety and loss of supply risks associated with star picket earthing electrodes. Replacement of this earthing system component only will not mitigate these risks if other components are in a degraded condition or of inappropriate design.

Replacing the entire earthing system (Option 3) on each pole with modern components will further mitigate the safety and loss of supply risks associated with star picket earthing electrodes and earthing system condition and inherent design issues because they are tested prior to being put into service to ensure that they are compliant with modern safety standards and current / foreseeable network fault ratings.

The preferred approach is to replace the earthing electrode (Option 2). Each pole earthing installation will be assessed prior to replacement work commencing and this assessment may identify if a full earth system replacement (Option 3) is required on any pole.

6.5 Options

The program options considered in relation to the treatment of star picket earthing electrodes are summarised in Table 22 below. These options are based on the need to undertake work on these assets when their condition is assessed to be unsafe and cannot be left as-is.

Table 22. Program options for managing star picket earth electrodes

Program need options	Option overview
1 Reactive Treatment	Implement treatment when the electrode fails.
2 Conditional Treatment	Implement treatment to treat assets when inspections identify that they have deteriorated to the point of conditional failure based on a set of criteria.
3 Planned Treatment	Implement treatment such as replacement of assets prior to functional failure.

The consequence of a star picket earthing electrode failing poses serious safety risks to the public, customers, workers and the community as described above. Due to these risks, an approach that only manages these assets in a reactive manner (Option 1) is unacceptable.

Previous inspections and testing has identified systemic condition issues with star picket earthing electrodes caused by the use of galvanised steel in their design. The preferred option is the planned replacement of star picket earthing electrodes (Option 3) as it mitigates the safety and loss of supply risks associated with the known condition issues caused by their design. Replacement will be undertaken on a 'per feeder' basis with feeders operating at 132kV to be the higher priority. All other earthing electrode types will be replaced when identified with condition issues during inspections (Option 2).

6.6 Costing and volumes

The total population of star picket earthing electrodes has been identified for replacement in this planned program. This program has been extended from the 2014-19 regulatory period and is expected to be completed during 2019-24. The forecast replacement volume is expected to sustainably manage the risks associated with the asset population and in a prioritised order so those of highest risk are completed first.

Ausgrid predominantly delivers this work utilising internal resources.

The summary replacement forecast is shown in Table 23. The costs shown are direct costs only. Although the exact quantity of existing star picket earth electrodes is not known, it is expected that known feeders with this earthing electrode type will be completed during the 2019-24 period.

This program forms part of the overall investment being proposed for the replacement of overhead conductors. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details in regard to the overall investment proposed for this asset category during 2019-24.

Table 23. Forecast for star picket earth electrodes

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Replacement of sub-transmission feeder earth electrodes					
Volumes for replacement (each)	89	100	111	116	76
Unit cost	$1,482	$1,476	$1,472	$1,470	$1,465
Total costs ($m)	**$0.13**	**$0.15**	**$0.16**	**$0.17**	**$0.11**