OVERHEAD AND UNDERGROUND SERVICE MAINS FAILURE RISK MITIGATION

Case for investment FY23
(Pre-optimisation)

December 2022

Investment Title	Condition based replacement of overhead and underground service mains
Project # / Code	
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Pre RIT-D	☐
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Other	☐

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Author:

Digitally signed by Shane Worthington
DN: cn=Shane Worthington, c=AU, o=Endeavour Energy,
email=shane.worthington@endeavourenergy.com.au
Date: 2022.12.21 13:57:11 +11'00'

Shane Worthington

Asset Investment Engineering Specialist

Endorsed by:

David Mate

Asset Performance Manager

Approved by:

Digitally signed by Peter Langdon
DN: cn=Peter Langdon, c=AU, o=Endeavour Energy, ou=Asset Planning and Performance,
email=peter.langdon@endeavourenergy.com.au
Date: 2022.12.22 08:23:30 +11'00'

Peter Langdon

Head of Asset Planning and Performance

Contents

1. Executive Summary

1.1 Recommendation

This case for investment (CFI) recommends investment into the replacement of Endeavour Energy owned overhead and underground service mains across the distribution network during the FY23-FY29 period to address the safety, reliability and bushfire risks associated with the failure of these assets whilst in service.

It is noted that this CFI is recommending these investments to be included into the portfolio risk-based asset investment planning and optimisation process during the period of FY23 – FY29.

The total cost of proposed proactive replacement overhead service mains is estimated to be $0.31 million in real FY23 terms, however due to relatively low volume of proposed overhead service main replacements being spread over a large geographical area, it is recommended that no proactive investment into overhead service main replacement be undertaken during FY23 – FY29, instead the risk associated with overhead service mains is to be controlled under a reactive replacement program.

There are no proposed proactive replacements for underground service mains during FY23-FY29.

Within this recommended program of works, each asset has been assessed individually for the risk it presents. Furthermore, this is an on-going program with no material change proposed across the asset type and the highest cost credible option at each site falls below the threshold for application of the Regulatory Investment Test for Distribution (RIT-D) (currently $6.0 million). Therefore, the RIT-D is not applicable to this on-going program.

An allowance of $9.13 million is proposed for the replacement of overhead services and $3.21 million for the replacement of underground services that fail unexpectedly and in a non-repairable manner during the FY23 - FY29 period, giving a total proposed investment of $12.34 million.

1.2 Identified need

Endeavour Energy is responsible for approximately 849,000 service mains, comprising of approximately 447,000 overhead (OH) service mains and approximately 402,000 underground (UG) service mains.

The possible consequences of a service main failure include:

- Safety impacts: Injury or fatality due to electric shock resulting from a failed service neutral in both overhead and underground services. Additionally, overhead services can cause injury to people due to being struck as a result of a fallen overhead service, this also carries the risk of electric shock leading to serious injury or fatality.
- Reliability impacts: Failure of an overhead or underground service main resulting in extended loss of supply while the service main is repaired or replaced.
- Bushfire impacts: Overhead service mains making contact with the ground or other structures may ignite a bushfire due to arcing/sparking of the live conductor.
- No significant environmental, financial or regulatory compliance consequences have been experienced or are anticipated for future failures of a service main.

1.3 Options analysis

There are no credible non-network solutions for replacing the functionality of overhead and underground service mains given their relatively low replacement cost and their identified need in Endeavour Energy's network.

For overhead service mains the only option available for addressing the failure risk of individual overhead service mains in a proactive planned manner which is considered to be credible is retirement followed by the replacement of the service main with a modern equivalent conductor type.

Table 1 below summarises the outcomes of the cost-benefit assessment for the overhead service main replacement of Endeavour Energy's fleet of 447,000 overhead service mains compared to the counterfactual case. The summary shows the impact of investment in the replacement of overhead service mains whose net present value (NPV) of intervention reaches its maximum value in the FY23 - FY29 period.

Table 1 - Option economic evaluation summary

Option	Option type	Volume of inter-ventions	Residual risk ($M)	PV of benefits ($M)	PV of investment ($M)	NPV ($M)	Rank	Comments
Run-to-failure	Counter-factual	-	144	-	-	-	2	Excessive risk
1. Replace overhead service main	Network	784	139	4.86	0.29	4.57	1	Preferred option

There are no proposed proactive replacements for underground service mains during FY23-FY29.

1.4 Recommended option

Due to the relatively low volume of proposed proactive overhead service main replacements being spread over a large geographical area, it is recommended that no proactive investment into overhead service main replacement be undertaken during FY23 – FY29, instead the risk associated with overhead service mains is to be controlled under a reactive replacement program and the assets identified as being cost justified for proactive replacement be flagged in the system (e.g. defected) for replacement if other works are being done in the area.

As there are no proposed proactive replacements for underground service mains during FY23-FY29, it is also recommended that a reactive replacement program be undertaken for underground service mains.

1.5 Budget

The total funding required for overhead services that are likely to fail in service is $9.13 million and the total funding required for underground services that are likely to fail in service is $3.21 million, giving a total for the recommended funding of $12.34 million.

2. Purpose

The purpose of this document is to seek endorsement of the case for investment (CFI) for managing the risks posed by aged service mains throughout Endeavour Energy's network.

This CFI is recommending these investments to be included into the portfolio risk-based asset investment planning and optimisation process during the period of FY23 – FY29.

This case for investment (CFI) recommends reactive intervention for overhead and underground services that may functionally fail unexpectedly or conditionally fail during the FY23-FY29 period.

This CFI will be grouped together with any other related CFI's and rolled up into an asset class plan (ACP) to provide an overall view of the asset classes performance at a macro level. ACP's will also be fed into system strategy documentation to view the CFI / ACP in the context of the entire network (e.g. by feeder, substation and/or region) to understand its contribution to the overall networks performance.

3. Identified needs and or opportunities

3.1 Background

The basic function of a service main is to supply electricity to residential, commercial and industrial customers by providing a connection between the low voltage distribution network and the customer's premises.

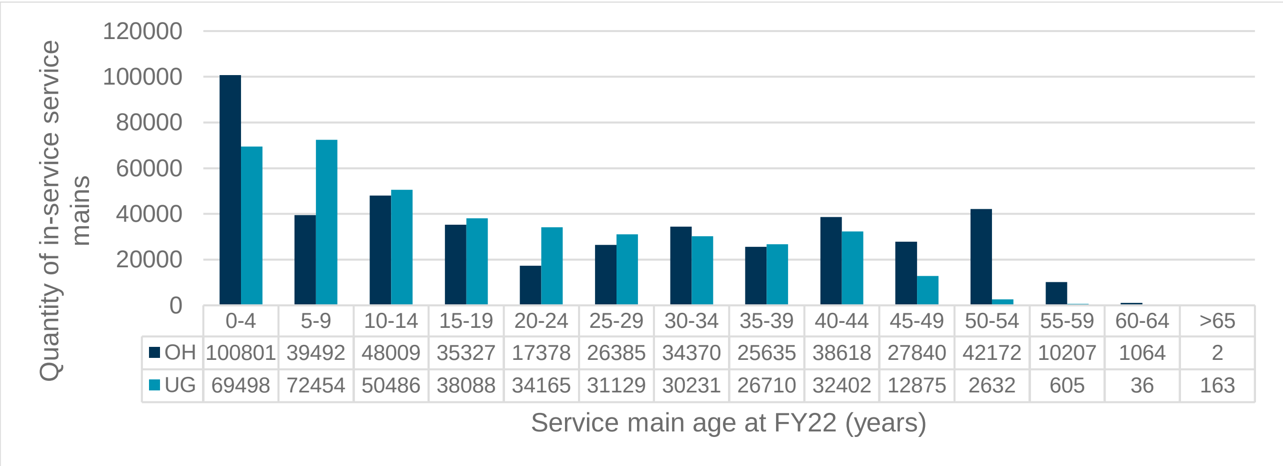
Endeavour Energy is responsible for approximately 849,000 service mains, comprising of approximately 447,000 overhead (OH) service mains and approximately 402,000 underground (UG) service mains. Overhead service mains were largely installed prior to the late 1970's when underground supply to residential developments became predominant.

The Service and Installation Rules of New South Wales states that all new overhead service mains must be insulated with cross-linked polyethylene (XLPE) material however older overhead service mains may consist of polyvinyl chloride (PVC) insulated conductors or bare conductors. The most common type of XLPE insulated overhead service mains is low voltage aerial bundled conductor (LV ABC).

Similarly, the Service and Installation Rules of New South Wales states that all new underground service mains must be XLPE insulated however older underground service mains may consist of PVC insulated cable, paper insulated lead alloy sheathed steel wire armoured and served (PLYSWS) cable or concentric neutral solid aluminium (CONSAC) cable.

Endeavour Energy's overhead and underground service main age profile can be seen in Figure 1 below.

Figure 1 - Endeavour Energy service main age profile



	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	>65
OH	100801	39492	48009	35327	17378	26385	34370	25635	38618	27840	42172	10207	1064	2
UG	69498	72454	50486	38088	34165	31129	30231	26710	32402	12875	2632	605	36	163

3.2 Risks and identified need

The primary mode of failure for both overhead and underground service mains is the failure of the connectors at either the point of attachment/connection point at a customer's installation or at the connection point to the low voltage distribution network. Failed connectors result in fluctuating voltages and/or loss of supply to the installation but of particular concern is the loss of the neutral connection which can lead to electrical shock hazards in the installation.

As overhead service mains age, the outer insulation of the service wire deteriorates due to the exposure to ultraviolet (UV) radiation. This is generally indicated by cracked or brittle insulation. This deterioration of insulation, which results in bare conductors and connectors, presents a further risk of electrical shock hazard for the customer and their workers.

Other factors that contribute to service mains failures include climate and environmental conditions as well as past local design and installation practices.

The functional failure of a service main occurs when the service main is unable to perform its required function as a consequence of the condition of the asset, this may be a failure causing disruption to the supply of electricity or a failure of any component of the service main installation that requires immediate rectification, such as an open circuit neutral service connector.

There are on average 190 unassisted functional failures of overhead services per annum and an average of 109 unassisted functional failures of underground services per annum. These functional failures are directly related to the condition of the service mains where the failure of the service main has resulted in an extended outage incident recorded within Endeavour Energy's Outage Management System (OMS) / Advanced Distribution Management System (ADMS).

The possible consequences of a service main failure include:

- Safety impacts: Injury or fatality due to electric shock resulting from a failed service neutral in both overhead and underground services. Additionally, overhead services can cause injury to people due to being struck as a result of a fallen overhead service, this also carries the risk of electric shock leading to serious injury or fatality.
- Reliability impacts: Failure of an overhead or underground service main resulting in extended loss of supply while the service main is repaired or replaced.
- Bushfire impacts: Overhead service mains making contact with the ground or other structures may ignite a bushfire due to arcing/sparking of the live conductor.
- No significant environmental, financial or regulatory compliance consequences have been experienced or are anticipated for future failures of a service main.

4. Consequence of nil intervention

4.1 Consequence of no intervention

The nil intervention option involves no capital expenditure for the replacement of overhead and underground services, therefore if a service main were to fail, it would not be replaced. Due to the defined service level of service mains within the network, this option is not feasible due to negative impact and consequences of failure for each service main as noted in section 3.2 above and hence the no intervention option for service mains is not considered for this CFI.

4.2 Counterfactual (business as usual)

The business as usual (BAU) “counterfactual” scenario includes overhead and underground service mains remaining in-service until it either functionally or conditionally fails and then replacement of the service main after failure, providing its service is still required. Nil proactive capital intervention is carried out.

The scope of works under the BAU include:

- Maintenance:
  - All overhead service mains are subject to routine inspection and treatment, with typical overhead line inspection periods being every 5.5 years in accordance with MMI0001 [1] where defects such as loss of insulation, faulty connectors or tension clamps are identified and repaired within a certain timeframe.
  - Underground services are not routinely inspected however defects relating to the underground service connections may be identified during routine column and pillar inspections that occur every 5 years in accordance with MMI0003 [2]. The underground service main cable and the connections at the customer’s main switchboard are not inspected.
- Repair of any minor damage such as replacement of faulty service tension clamps, replacement of faulty service connectors at the pole, pillar, column or at the customer’s point of attachment and the re-sleeving of insulation if required.
- Reactive replacement after failure.

Currently, “functional failure” refers to the inability of the service main to perform its required function as a consequence of the condition of the asset:

- Failures disruptive to the supply of electricity.
- Failure of any component of the service main installation that requires immediate rectification, such as an open circuit neutral service connector.

Conditional failures occur when a service main fails to meet the minimum serviceable requirements as outlined in MMI0002 [3]. Conditional failures can occur due to:

- Burnt or damaged service connectors.
- Damaged or missing insulation.
- Service mains not securely attached to hardware.

When a service main is deemed to have conditionally failed, a defect is raised, and the defect is repaired either through repair of the individual components or replacement of the entire service main within a specified timeframe based on its priority.

Over the past 5 years, Endeavour Energy has replaced on average approximately 2800 overhead service mains per annum based on its condition, at an average annual intervention cost of $1.25 million ($FY23 real) and replaced an average of 110 underground service mains per annum based on its condition, at an average annual intervention cost of $0.12 million ($FY23 real).

For the purpose of this assessment only costs that have occurred due to a functional failure has been considered. A summary of the risk presented by the counterfactual case is shown in Table 2 and Table 3 below. All costs are in real FY23 terms and are present values (PV). A discount rate of 3.26% has been used throughout the economic evaluation.

Table 2 - BAU risk cost summary for overhead service mains

Risk category	PV of residual risk ($M)	Risk proportion (%)
Safety	18	13
Reliability	48	33
Bushfire	66	46
Reactive capital replacement costs	12	8
Total	**144**	**100**

As noted in Table 2 above, the residual risk presented by the BAU case totals $144 million. The residual risk value presented by each overhead service main ranges from $26 to $96,412 and averages $322 across the fleet of 447,300.

Table 3 - BAU risk cost summary for underground service mains

Risk category	PV of residual risk ($M)	Risk proportion (%)
Safety	15	9
Reliability	64	37
Reactive capital replacement costs	91	54
Total	**170**	**100**

As noted in Table 3 above, the residual risk presented by the BAU case totals $170 million. The residual risk value presented by each underground service main ranges from $108 to $107,907 and averages $425 across the fleet of 401,474.

5. Options considered

5.1 Risk treatment options

Before assessing the network intervention option, consideration has been given to a range of alternative approaches which could possibly contribute to addressing the risk presented by service mains. These approaches are summarised in Table 4 below.

Table 4 – Service main risk treatment options

Option	Assessment of effectiveness	Conclusion
Additional maintenance to extend the life of the existing asset	Existing maintenance include replacement of service connectors and the re-sleeving of insulation on overhead service mains and whilst both methods may extend the life of these service mains these maintenance activities are not effective in managing risk for the entire service main population.	No technically feasible solution
Reduce the supply load on the asset through network reconfiguration, network automation, demand management or other non-network options	The risk of failure is independent of supply load. Due to the primary function of service mains, there is no credible non-network option to replace their functionality.	No technically feasible solution
Implementing operational controls such as limiting access, remote switching protocols etc.	These controls are in place to limit the safety risks presented by this equipment to workers, but the principal risk that drives the need for intervention is safety to the public, bushfire and reliability, which cannot be affected by practicable controls.	Controls only the safety risk elements for workers

Option	Assessment of effectiveness	Conclusion
Replacement to maintain option value and reduce the consumer's long-term service cost	Replacement of service main.	Recommended approach for further consideration

5.2 Non-network options

Due to the nature of the asset and its primary functionality being connecting customers to the low voltage distribution network, there are no credible non-network solutions which could replace their functionality and therefore network options have been considered to address the identified need.

5.3 Credible network options

Table 5 - Credible network options – service main intervention

Intervention option	Description	Conclusion
Proactive replacement	Replacement of asset based on risk and condition. • Overhead service mains will be replaced with LV ABC. • Underground service mains will be replaced with XLPE insulated cable.	Credible option and has progressed for further assessment

Replacement of overhead and underground service mains based on condition is considered a credible network option.

5.3.1 Service main replacement

Under this option, the intervention includes a scoping exercise targeting suburbs with high numbers of proposed proactive replacements followed by the complete replacement of the service main in a planned proactive manner to allow for the retirement of the existing asset.

A unit rate of $400 for the replacement of an overhead service main has been assumed for this assessment based on historical replacement of overhead service mains between FY17-FY21. This unit rate assumes a high density of work in an area and the associated efficiencies that come with this.

A unit rate of $2,985 for the replacement of an underground service main has been assumed for this assessment based on the typical labour and material cost for this type of work due to limited historical replacement data of underground service mains.

Both unit rates include:

- Project management;
- Design;
- Materials;
- Labour and plant; and
- Traffic management

5.4 Economic evaluation

5.4.1 Option 1 – Proactive replacement

This option identifies 784 overhead service mains whose NPV at time of proposed replacement is positive and reaches a maximum value during the FY23 – FY29 period. This option presents a residual risk of

$139 million and provides a benefit of $4.86 million compared to the counterfactual case. The PV of the cost of the option is $0.29 million and the NPV overall is $4.57 million.

The NPV of the proposed interventions is unique to each overhead service main and varies from $299 to $64,156 with an average of $5,834 across the 784 assets proposed for intervention during the period. The total NPV of the proposed program is $4.6 million.

The benefit to cost ratio (BCR) for each overhead service main varies from 1.9 to 161.4 and averages 16.9 across the 784 overhead service main interventions.

Table 6 below provides a summary of the residual risk presented by this option.

Table 6 - Option 1 residual risk summary

Risk category	PV of residual risk ($M)	Risk proportion (%)
Safety	18	13
Reliability	46	33
Bushfire	64	46
Reactive capital replacement costs	11	8
Total	**139**	**100**

The assessment into the proactive replacement of underground service mains yielded no economically feasible interventions within the FY23 – FY29 investment period or the following period FY30-FY34. Therefore, proactive replacement scope has not been submitted for underground service mains within this CFI at this time for optimisation.

5.5 Evaluation Summary

Table 7 below summarises the outcomes of the cost-benefit assessment the overhead service main replacement options for Endeavour Energy's fleet of assets compared to the BAU case. The summary shows only the impact of investment in overhead service mains with maximum NPV of intervention within the FY23 – FY29 period. As shown, the option which includes proactive overhead service main replacement provides a greater benefit than BAU as it results in a lower residual risk value, therefore this option is preferred.

Table 7 - Option comparison economic summary for overhead service main replacement

Option	Option Type	Volume of inter-ventions	Residual risk ($M)	PV of benefits ($M)	PV of investment ($M)	NPV ($M)	Rank	Comments
Run-to-failure	Counterfactual	0 Proactive	144	-	-	-	2	Excessive risk
1. Replace overhead service mains	Network Solution	784 Proactive	139	4.86	0.29	4.57	1	Preferred Option

As shown in Table 7, proactive overhead service main replacement provides a higher NPV overall and will deliver the highest overall value and is therefore the preferred option.

This section is not applicable to underground service mains as no proactive scope is being considered.

5.6 Economic evaluation assumptions

There are a wide range of assumptions of risk, their likelihoods and consequences which support the cost benefit assessment associated with this evaluation.

Refer to Appendix A for details of these assumptions.

5.7 Scenario assessment

A scenario assessment has been carried out on the various elements of the risk and cost assumptions used in the economic analysis to test the robustness of the evaluation.

Three scenarios have been assessed:

- Scenario 1 – discourages investment with low benefits and high capital costs.
- Scenario 2 - represents the most likely central case based on estimated or established values.
- Scenario 3 - encourages investment with the high benefits with low capital costs.

The values for each of the variables used for each scenario are shown in Table 8 below.

Table 8 – Summary of scenarios investigated

Variable	Scenario 1 – low benefits, high capital costs	Scenario 2 – central values	Scenario 3 – high benefits, low capital costs
Capital cost	10% increase in the estimated network capital costs	Estimated network capital costs	10% decrease in the estimated network capital costs
Value of risk (combination of consequence of the failure risk and the likelihood of the consequence eventuating)	10% decrease in the estimated risk and benefit values	Estimated risk values	10% increase in the estimated risk and benefit values
Weibull distribution end-of-life failure characteristic	10% increase in the Weibull scale parameter (increases the mean time to failure for the asset)	Estimated Weibull parameters based on available failure data and calibrated to observed failure rates	10% decrease in the Weibull scale parameter (decreases the mean time to failure for the asset)

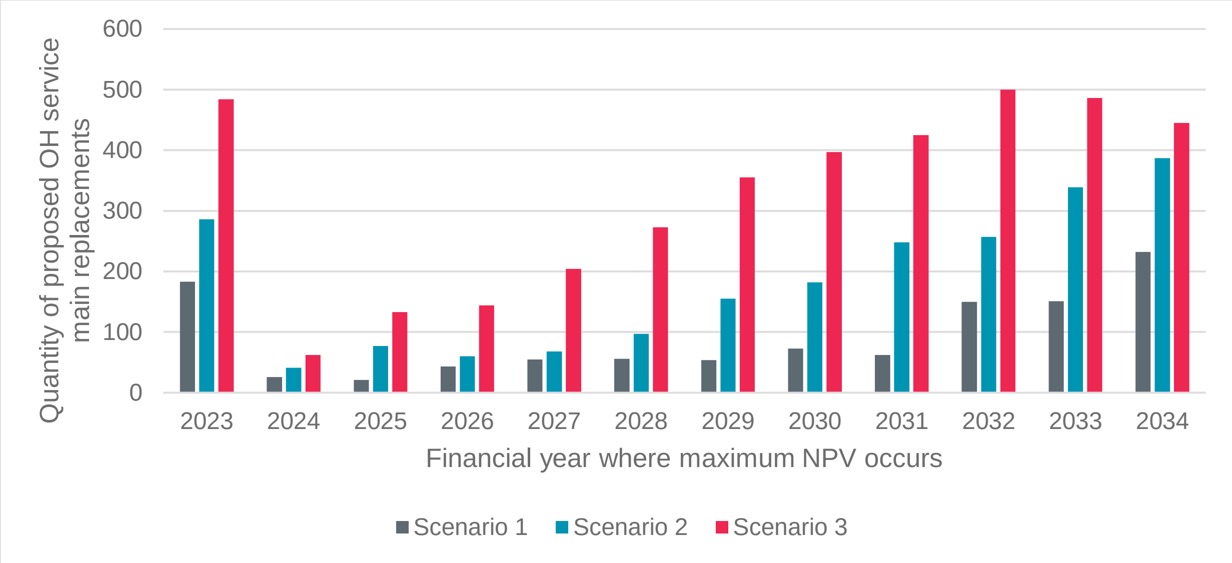
The impact on the NPV for the proactive replacement option is shown below in Table 9 and the resultant spread of replacement years to give the maximum NPV for each of the 784 overhead service mains identified for replacement under the preferred option is shown in Figure 2.

Table 9 – NPV of scenario analysis for the preferred option

Scenario	NPV of preferred option ($M)
Scenario 1 – Low benefits, high costs	2.32
Scenario 2 – Central risks and costs	4.57
Scenario 3 – High benefits, low costs	9.68
Average	**5.52**

Each scenario reduces the risks posed by the 784 overhead service mains with an average NPV of $5.52 million across the three scenarios analysed.

Figure 2 - Option 1 - maximum NPV replacement years for the three sensitivity scenarios



Further analysis found when individually adjusting, capital cost and value risk inputs, each had minimal contribution to the proposed financial year that the assets maximum NPV occured. In this assessment, sensitivity lies around the Weibull end-of-life element. This assessment has been able to rely on historical failure data over the FY12-FY21 period to assist in determining the Weibull parameters.

Figure 2 shows that across the three sensitivity scenarios, the timing of the maximum NPV of the recommended 784 replacements spikes in FY23 before dropping in FY24 and increasing towards FY34, indicating that a number of overhead services are beyond their maximum NPV prior to FY23.

This section is not applicable to underground service mains as no proactive scope is being considered.

6. Preferred option details

6.1 FY23-FY29 scope and timing

The preferred option for overhead service mains is option 1, which includes the proactive replacement of 784 overhead service mains during FY23 – FY29, however due to the relatively low volume of proposed overhead service main replacements being spread over a large geographical area, it is recommended that no proactive investment into overhead service main replacement be undertaken during FY23 – FY29, as the applied unit rate would not be applicable for a low-density project implementation. Instead, the risk associated with overhead service mains is to be controlled under a reactive replacement program as outlined in section 6.3.2 and the assets identified as being cost justified for proactive replacement be flagged in the system (e.g. defected) for replacement if other works are being done in the area. This way the unit rate used for justification would be applicable and allow the reduction in risk to be achieved prior to conditional / functional asset failure.

Therefore, there is no proactive scope for overhead or underground service mains being considered as part of this CFI.

6.2 Additional scope and timing

This section is not applicable to this CFI as no proactive scope is being considered.

6.3 Investment summary

6.3.1 Planned proactive works

A summary of the proactive investment proposed is shown in Table 10 below. All costs are in real FY23 terms.

Table 10 - Summary of planned proactive investment

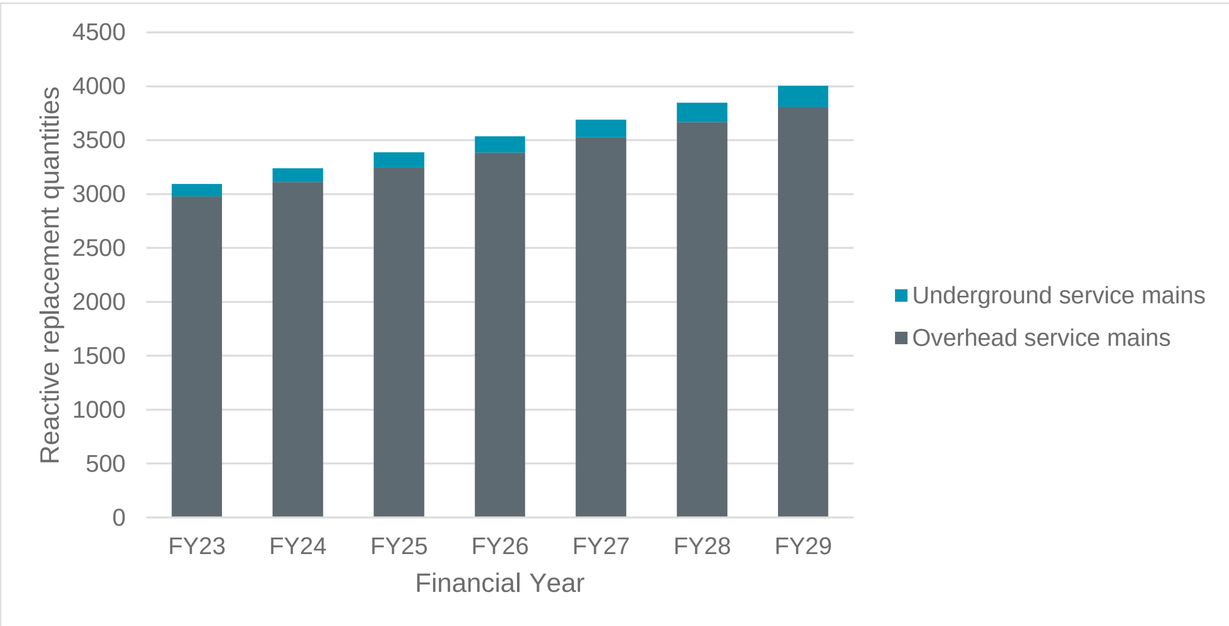
Intervention type	Unit rate ($)	Quantity of retirements	Total replacement costs ($M)
OH Service Main Replacement (NPV Max FY23-FY24)	400	327	0.13
OH Service Main Replacement (NPV Max FY25-FY29)		457	0.18
OH Service Main Replacement (NPV Max FY30-FY34)		1,413	0.57
Total		**2,197**	**0.88**

6.3.2 Reactive investment

Reactive modelling for the FY23 -FY29 period has forecast approximately 23,700 overhead service mains and approximately 1,070 underground service mains will reach a functional or conditional failed state (e.g. found to be in a poor condition indicative of imminent failure and/or no longer capable of performing its function). An additional 790 overhead services identified for proactive replacement will be included in the reactive forecast for overhead service mains bringing the total reactive forecast for overhead service mains to 24,490 for the FY23 – FY29 period.

Figure 3 below shows the forecast trend of reactive investment likely to be required for the replacement of overhead and underground service mains between FY23-FY29, including the additional proactive scope as mentioned in section 6.3.1.

Figure 3 - Forecast reactive replacement quantities of overhead and underground service mains FY23-FY29



A reactive replacement cost, which takes account of the likelihood of damage to adjacent equipment but excludes the economic costs of a service main failure, has been averaged across the fleet of service mains to give an annual forecast of reactive funding requirements.

To accommodate this eventuality, it is proposed that funding of $9.13 million (in real $FY23 terms) be made available for reactive overhead service main replacement during the FY23 – FY29 period and that a further funding of $3.21 million (in real $FY23 terms) be made available for reactive underground service main replacement during the FY23 – FY29 period.

Table 11 below, summarises the proposed reactive funding forecast.

All costs are in real FY23 terms.

Table 11 – Reactive replacement forecast (FY23-FY29)

Description	Unit rate per reactive replacement ($)	Forecast quantity of failure interventions		Forecast reactive investment ($M)	
		FY23-FY24	FY25-FY29	FY23-FY24	FY25-FY29
OH service mains	385	6,090	17,636	2.34	6.79
OH Total FY23-FY29		**23,726**		**$9.13M**	
UG service mains	2,985	243	830	0.73	2.48
UG Total FY23-FY29		**1,073**		**$3.21M**	
OH + UG Sub-total (by FY period)		**6,333**	**18,466**	**3.2**	**9.46**
OH + UG Total FY23-FY29		**24,799**		**$12.34M**	

6.4 Scope of Works

The proposed scope of works includes the reactive replacement of both overhead and underground service mains after experiencing conditional or functional failure. Both overhead and underground services are to be replaced in accordance with the NSW Service and Installation Rules [4] as well as MCI0005 overhead constructions standards [5] and MCI0006 underground constructions standards [6].

All service main replacements must be tested in accordance with Endeavour Energy workplace instruction WSY 0037 Polarity testing and phasing of low voltage mains, services and apparatus [7] prior to the energisation of the service.

7. Regulatory investment test

Within this recommended program of works, each asset has been assessed individually for the risk it presents. Furthermore, this is an on-going program with no material change proposed across the asset type and the highest cost credible option cost at each site falls below the threshold for application of the Regulatory Investment Test for Distribution (RIT-D) (currently $6.0 million). Therefore, the RIT-D is not applicable to this on-going program.

8. Recommendation

It is recommended that over the FY23 – FY29 period, a reactive intervention strategy is to be undertaken for both overhead and underground services within the Endeavour Energy network.

The total cost of reactive investment in overhead services has been estimated to be $9.13M and the total cost of reactive investment in underground services has been estimated to be $3.21M, both in real FY23 terms.

9. Attachments

Appendix A - Summary of key risk assessment variables and assumptions

10. References

[1] Endeavour Energy, “MMI0001 Pole and Line Inspection and Treatment Procedures, Amendment 17,” November 2016.

[2] Endeavour Energy, “MMI0003 Routine external structural inspection of streetlight columns and LV pillars,” 2017.

[3] Endeavour Energy, “MMI0002 Distribution Overhead Defect Handbook,” Asset Planning & Performance, August 2021.

[4] State of New South Wales, “Service and Installation Rules of New South Wales,” Division of Energy, Water and Portfolio Strategy, NSW, July 2018.

[5] Endeavour Energy, “MCI0005 Overhead Construction Standards Manual,” 2017.

[6] Endeavour Energy, “MCI0006 Underground distribution construction standards manual,” 2016.

[7] Endeavour Energy, “WSY0037 Polarity testing and phasing of low voltage mains, services and apparatus,” November 2021.

[8] Endeavour Energy, “Company Procedure - GRM 0003 Risk Management, Amendment 13,” September 2017.

[9] Endeavour Energy, “Asset Renewal Plan FY21-FY30,” January 2020.

Appendix A - Summary of key risk assessment variables and assumptions

General variables and assumptions

Parameter	Value	Description/Justification	Source/Assumptions
Population	OH - 447,300 UG – 401,474 Total - 848,774	Number of service mains in Endeavour Energy's (EE) network as of March 2022	Endeavour Energy's Ellipse database
Average annual conditional failures	OH - 2,800 UG - 110	The expected number of conditional service main failures seen in a year. Average over the past 5 years	Endeavour Energy's defect data via Ellipse workorders
Average annual functional failures	OH - 190 UG - 109	The expected number of functional service main failures seen in a year. Average over the past 5 years	Endeavour Energy's Outage Management System
Asset age	Varies for each service main	Calendar age based on the service mains in-service date compared to the year of assessment	GIS and Ellipse asset data
Discount rate (WACC)	3.26%	Weighted average cost of capital for EE	Regulated rate. Applied to all risk and investment values used in the cost-benefit assessment
Base year of investment	FY23	All investments for budgeting purposes are expressed in real FY23 dollars	For inclusion into the FY23 PIP after optimisation
Calculation horizon	175 years	The timeframe over which the cost-benefit analysis is performed	v6.0 algorithm
Maintenance Costs	Nil	Nil	Nil
Reactive intervention cost	**OH -** $385 **UG -** $2,985	The cost associated with a reactive service main replacement	Based on actual costs of previously delivered works
Proactive intervention cost	**OH -** $400 **UG -** $2,985	The cost associated with a proactive service main replacement	Based on actual costs of previously delivered works

Weibull Parameters

Parameter	Value	Description/Justification	Source/Assumptions
$\mathbf{Shape}_{\mathit{conditional}}$	OH LV ABC: 3.6 OH Generic: 3.6 UG XLPE: 3.6 UG Generic: 3.6	The shape parameter, also known as the Weibull slope, used for calculating probability of failure for reactive forecasting.	The generalised wear-out function shape for a normal distribution is 3.6 and is consistent with Endeavour Energy's historical failure data.
$\mathbf{Scale}_{\mathit{conditional}}$	OH LV ABC: 62 OH Generic: 73 UG XLPE: 95 UG Generic: 152	The scale parameter used for calculating probability of failure for reactive forecasting.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data. OH LV ABC service mains have a MTTF of 56 years and average of 284 conditional failures per year. OH Generic service mains have a MTTF of 86 years and average of 11 conditional failures per year. UG XLPE service mains have a MTTF of 56 years and average of 284 conditional failures per year. OH Generic service mains have a MTTF of 137 years and average of 96 conditional failures per year.
$\mathbf{Shift}_{\mathit{conditional}}$	OH LV ABC: 0 OH Generic: 0 UG XLPE: 0 UG Generic: 0	The shift parameter which gives a failure-free period at the start of the asset's life.	As there is no guaranteed failure free period for service mains, a shift parameter of 0 has been used.
$\mathbf{Shape}_{\mathbf{functional}}$	OH LV ABC: 3.6 OH Generic: 3.6 UG XLPE: 3.6 UG Generic: 3.6	The shape parameter, also known as the Weibull slope, used for calculating probability of failure for reactive forecasting.	The generalised wear-out function shape for a normal distribution is 3.6 and is consistent with Endeavour Energy's historical failure data.
$\mathbf{Scale}_{\mathit{functional}}$	OH LV ABC: 121 OH Generic: 157 UG XLPE: 100 UG Generic: 150	The scale parameter used for calculating probability of failure for reactive forecasting.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data. Average number of functional failures per year: • OH LV ABC – 25 • OH Generic – 165 • UG XLPE – 9 • UG Generic – 100

Parameter	Value	Description/Justification	Source/Assumptions
$\text{Shift}_{functional}$	OH LV ABC: 0 OH Generic: 0 UG XLPE: 0 UG Generic: 0	The shift parameter which gives a failure-free period at the start of the asset's life.	As there is no guaranteed failure free period for service mains, a shift parameter of 0 has been used.

Bushfire risk inputs

Parameter	Value	Description/justification	Source/assumptions
Bushfire - LoC	1.1%	Likelihood that an overhead service main failure will result in a bushfire.	Based on historical fire start data.
Bushfire - CoF	Bushfire ignition risk CoC varies by location	Likelihood and consequence of bushfire start evaluated by the Bushfire Model based on the Phoenix RapidFire simulation prepared for EE's network by the University of Melbourne in 2020.	Service main spatial information input into the Bushfire FME model. The model assesses the CoC of a bushfire started by each service main. Other inputs to the model: - Vegetation LoC - CoC for Low, High, Very High, Severe, Extreme, Catastrophic fire risk days

Environmental risk inputs

Parameter	Value	Description/justification	Source/assumptions
N/A			

Financial risk inputs

Parameter	Value	Description/justification	Source/assumptions
N/A			

Safety risk inputs

Parameter	Value	Description/justification	Source/assumptions
Value of a fatality	$5,100,000	Value of statistical life (VoSL)	EE Copperleaf Value Model – based on Office of Best Practice Regulation published values
Value of injury	$255,000	5% of VoSL	EE Copperleaf Value Model – based on Office of Best Practice Regulation published values
Customer shock - LoC	20%	Likelihood of customer shock occurring after functional failure of service main	Mysafe shocks data

Parameter	Value	Description/justification	Source/assumptions
		Average customer shocks caused by faulty service neutrals = 59.6/year Average number of unassisted functional failures = 299/year	
Shock injury - LoC	0.0707%	4 major injuries out of 1131 shocks incidents over a 5 year period	Mysafe shocks data
Shock fatality - LoC	0.0177%	1 fatality out of 1131 shocks incidents over a 5 year period	Mysafe shocks data
Service main down - LoC	5%	Average number of unassisted service failures resulting in mains down = 9.6/year Average number of unassisted functional OH failures = 190/year	Estimation
Presence - LoC	0.9%	Assuming worst case energised conductor on ground = average outage time for O/H service fault = 4 hours. Assumption that a member of the public spends 1 hour per day Mon-Fri and 4 hours per day Sat-Sun in front yard near PoA.	Estimation
Service down injury - LoC	5%	No historical data for services, assumed 1 in 20 contacts results in serious injury	Estimation
Service down fatality - LoC	2%	No historical data, assumed 1 in 50 contacts results in fatality	Estimation

Reliability risk inputs

Parameter	Value	Description/justification	Source/assumptions
Load factor	70%	70% of rated load of distribution transformer	Source – studies by Protection Manager
Service load factor	Varies by distribution substation	The inverse of the number of connected customers to a distribution substation	EDI100S02 Fault Level Info
Maximum load	Varies by distribution substation	Maximum rated load of a distribution transformer	Endeavour Energy Ellipse database
VCR	Varies by distribution substation	Value of customer reliability assigned to each distribution substation based on load type/geographical location	AER published values
Duration of interruption	OH – 4 hours UG – 6 hours	Duration of time until affected customers are restored	Based on historical data from EE's Outage Management System

Produced by Asset Planning & Performance

W Endeavourenergy.com.au
E news@endeavourenergy.com.au
T 131 081

ABN 11 247 365 823

Endeavour Energy