Pole Top Assembly
FAILURE RISK MITIGATION

Case for investment FY23
October 2022

Endeavour Energy

Contents

Investment Title	**Condition based replacement of pole top assemblies**
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Portfolio	Repex
CFI Date	17/10/22
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1. Executive Summary

This case for investment (CFI) recommends investment into the renewal of pole top assemblies on Endeavour Energy owned poles across the distribution and sub-transmission network during the FY23-FY29 period to address the safety, reliability, bushfire and financial risks associated with the failure of these assets whilst in service.

Endeavour Energy has an in-service pole population of approximately 311,000 poles with 387,820 pole top assemblies. The fleet strategy outlined within this CFI does not include Endeavour Energy owned poles and associated earthing nor services. Nor does the CFI explore hardware associated with transmission tower structures.

All pole top assemblies are subject to routine inspection and treatment typically every 5.5 years dependent on pole type. Over the past 4 years, Endeavour Energy replaces on average approximately 5,873 pole top assemblies per annum based on its condition. In addition to this there has also been approximately 3,247 insulators or hardware components replaced on poles over the same period.

For the purpose of this evaluation, pole top assemblies have been evaluated as a grouped entity which includes the cross arms (timber, composite and steel), cross arm brace and hardware, insulators (disc, post, pin/strain, Inline/long rod) and insulator associated hardware. The characteristics of pole top assemblies have been sub-grouped at three voltage levels: low voltage assemblies (≤1000V), high voltage assemblies (11kV and 22kV), transmission assemblies (≥33kV).

The most common functional failure of an assembly occurs when the cross arm has insufficient strength to support the load applied to it or failed to maintain the structural integrity to support associated hardware such as insulators, king bolts or braces.

Pole top assemblies can also fail due to other external impacts some of these include vehicle collisions and trees falling across the line. The cost of consequence associated with assisted failures has been excluded from the assessment undertaken within this CFI.

The three defined categories of assemblies have different characteristics in regard to the pattern of functional failures. These characteristics has been defined by analysing incidents records within Endeavour Energy's Outage Management System (OMS). The average unassisted functional failures per annum for each assembly category are as follows: low voltage assemblies: 17, high voltage assemblies: 48 and transmission assemblies: 1.5.

The possible consequences of a pole top assembly failure include:

- Safety impacts: Injury to people due to falling components from an assembly failure. Injury could be to pedestrian's, workers and/or drivers on the road. There is also the risk of electrocution from fallen live conductors resulting in serious injury or a fatality.
- Reliability impacts: Failure of a pole top assembly may cause conductors to clash, fall to the ground or rest on a crossarm resulting in extended loss of supply while the network is re-configured to isolate, sectionalise and repair the affected area.
- Financial impacts: In some events the assembly failure can result in a pole top fire which can result in the pole structure needing to be replaced.
- Bushfire impacts: Conductors making contact with the ground or other structures may ignite a bushfire due to arcing/sparking of the live conductor.
- No significant environmental or regulatory compliance consequences have been experienced or are anticipated for future failures of a pole top assembly.

Pole top assemblies are identified for proactive intervention at the time when the net present value of the intervention reaches its maximum value.

The assessment conducted as part of this CFI into the proactive replacement of low voltage and transmission pole top assemblies 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 these assembly classifications within this CFI at this time for optimisation.

However, high voltage pole tops assemblies have been identified for proactive intervention at the time when the net present value of the intervention reaches its maximum value. Where this occurs in the period of FY23 – FY29, the interventions have been included in this program. As a result, it is proposed that 6,393 pole top assembly replacements are carried out during FY23 – FY29.

The net present value (NPV) of the proposed proactive replacement option is unique to each high voltage pole top assembly and varies from $3,606 to $37,825 with an average of $13,080 across the 6,393 assets for intervention during the period as proposed. The total NPV of the proposed program is $59.16 million in real FY23 terms.

The benefit to cost ratio (BCR) for each pole top assemblies varies from 2.8 to 27.6 with an average of 9.2 across the 6,393 assembly replacements proposed.

The total cost of these works is estimated to be $7.67 million in real FY23 terms, and it is recommended that the program be approved for consideration in the FY23 Portfolio Investment Plan (PIP) for optimisation.

A further 3,807 high voltage pole top assemblies are NPV positive and provide their maximum NPV across the second half of the 10-year investment period (FY30-FY34 period) and are also put forward for optimisation. These 3,807 investments total a further $4.57 million (in real FY23 terms) giving a total investment for optimisation of $12.24 million.

There are a further 38,886 pole top assemblies for an estimated replacement value of $42 million that are NPV positive but do not achieve NPV maximum prior to the conclusion of the investment period (FY34) at the time of completing this economic assessment. These sites have not been considered within this CFI for optimisation.

In addition, reactive modelling for the FY23-FY29 period has forecast approximately 39,500 pole top assemblies and approximately 18,000 assembly components across all three voltage levels to reach a state of functional or conditional failure (e.g. found to be in a poor condition indicative of imminent failure and/or no longer capable of performing its function). To accommodate this eventuality, it is proposed that additional funding of $52.6 million in real FY23 terms be made available for reactive pole top assembly replacement during the FY23 – FY29 period. It is to be noted that pole top assemblies proposed for proactive retirement as part of this CFI have been excluded from the reactive modelling across this period.

This recommendation is made on the basis that the preferred solution represents the highest economic value (economic benefit) compared to other credible network and non-network options.

2. Purpose

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

This case for investment (CFI) recommends reactive intervention for pole top assemblies that that may functionally fail unexpectedly or conditionally fail during the FY23-FY29 period.

The fleet strategy outlined within this CFI only focuses on pole top assemblies on Endeavour Energy owned poles and structures. This CFI does not consider poles, structures, and conductors. The CFI also does not consider tower structures and associated supporting hardware.

3. Identified needs and or opportunities

3.1 Background

The function of a pole top assembly is to provide the mechanical support and electrical insulation for network overhead conductors attached to poles and structures. More specifically they facilitate the suspension of the network on pins or suspension insulators, to allow the termination or suspension of various network conductor segments.

Pole top assemblies includes the following hardware/equipment to support conductors under tension on poles: cross arms (timber and steel), cross arm brace and hardware, insulators (disc, post, pin/strain, inline/long rod) and insulator associated hardware. The major component of an assembly is the cross arm. The significant majority of cross arms are wood (98-99%) with steel and composite also being used in smaller numbers making up the estimated remaining 2% of the population. Steel crossarms are only used in transmission overhead construction.

Endeavour Energy's owns approximately 311,000 poles with 387,820 pole top assemblies used from service voltage levels through to distribution and transmission voltages that range from 230V to 132kV.

For the purpose of this evaluation assemblies have been categorised into five distinct classifications as shown in Table 1 below.

Table 1 - Asset type summary - pole top assemblies

Assembly classification			No. of units (out of scope)	No. of units (in scope)
1.	Low voltage assembly (230 - 415V)		-	197,220
2.	High voltage assembly (11 – 22kV)		-	142,430
3.	Transmission assembly	Transmission assembly (33 - 132kV)	1,561	25,904
		Overhead earth wire assembly (33 -132kV)	986	8,147
Sub-total			***6,358***	***373,701***
4.	Optical pilot ground wire (OPGW) assembly		4,331	-
5.	Other pilot assembly		7,241	-
Sub-total			***11,572***	-
Total			**387,820**	

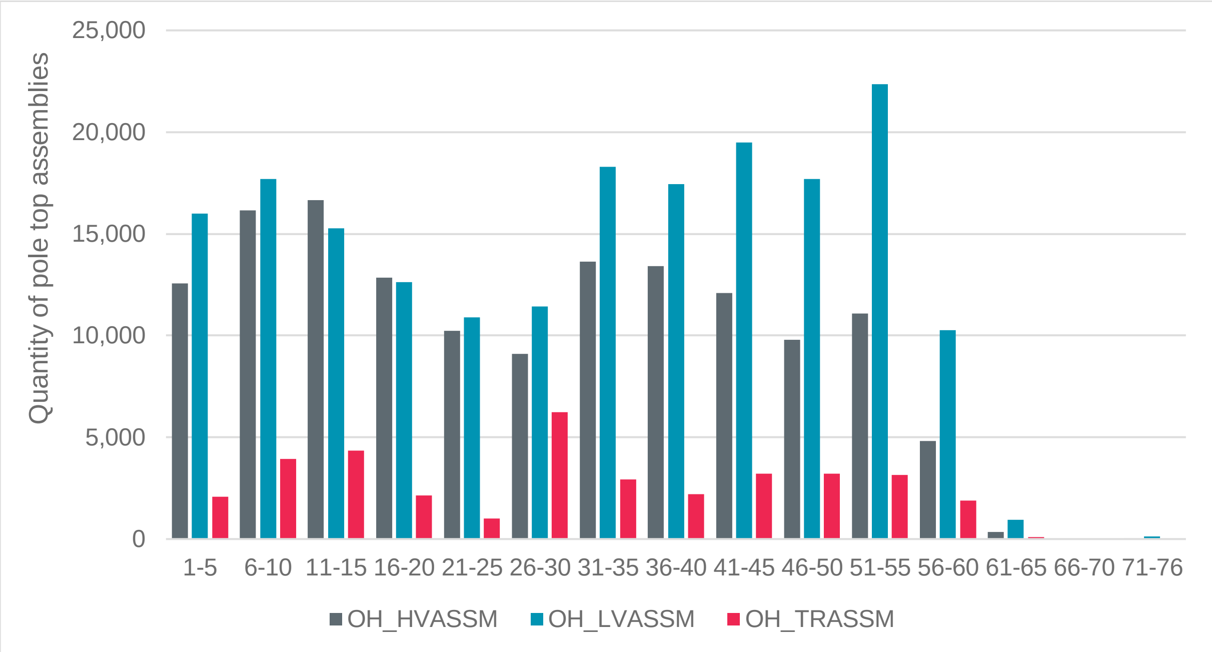
This case for investment evaluates 373,701 pole top assemblies associated with three classifications: low voltage, high voltage and transmission voltages (inclusive of overhead earth wire).

In accordance with MMI0001 am17 - *Pole and Line Inspection and Treatment Procedures*, pole top assemblies are inspected on a 5 ½ year cycle. MMI0002 - *Distribution Defect Handbook* governs the identification of conditional failures their categorisation and prioritisation.

In designated bushfire areas, a yearly aerial inspection is carried out on pole top assemblies in accordance with MMI0034 - *Pre-summer bushfire inspections*. Condition failures identified during this process follow the prioritisation process as stipulated in MMI0002. Typical conditional failures include cross arm deterioration and leaning or loose insulators and hardware.

The age profile of the in-service pole top assemblies is shown in figure 1 below.

Figure 1: Endeavour Energy pole top assembly age profile (FY22)



3.2 Risks and identified need

The functional failure of an assembly typically occurs when the cross arm has insufficient strength to support the load applied to it or failed to maintain the structural integrity to support associated hardware such as insulators, king bolts or braces.

Common failure modes include, leaning insulators due to crossarm hole elongation and loose hardware due to crossarm degradation (including hole elongation). In addition to this, insulators also conditionally fail due to cracks and chips in the insulation medium.

It has been noted that the functional failure of hardware such as insulators, braces and bolts are related to the functional and conditional failure of the cross-arm component. It is generally understood that the deterioration of cross arms where they have drilled (elongation of holes) leads to the loosening and or leaning of insulator pins and hardware.

Further when replacing the cross arm, the associated hardware of insulators, bolts and braces are typically retired and replaced also.

Assisted failure events such as vehicle collisions, trees falling across the line and bushfire has been excluded from the assessment undertaken within this CFI.

Across the three voltage classes, there are on average a combined 66.5 unassisted functional failures per annum for pole top assemblies.

The possible consequences of an assembly failure include:

- Safety impacts: Injury to people due to an impact from a pole top assembly failure including pedestrian's and/or drivers on the road or workers if the pole fails during the process of line construction on the pole or in the immediate vicinity. There is also the risk of electrocution from fallen live conductors resulting in serious injury or a fatality.
- Reliability impacts: may cause conductors to clash or insulation to break down resulting in extended loss of supply while the network is re-configured to isolate, sectionalise and repair the affected area.
- Financial impacts: the failure of an assembly can often lead to conductors resting on the cross arm or pole causing ignition of a fire. The fire can often cause damage to an extent requiring the pole and assembly to be replaced. It is possible that an assembly failure could also lead to damage of third-party property such as vehicles or other property.
- Bushfire impacts: Conductors making contact with the ground or other structures may ignite a bushfire due to arcing/sparking of the live conductor.
- No significant environmental or regulatory compliance consequences have been experienced or are anticipated for future failures of an assembly.

Figure 2 below, provides the number of historical conditional failures each year.

Figure 3 below, provides the number of historical functional failures each year.

Figure 2 : Annual conditional failures by assembly type

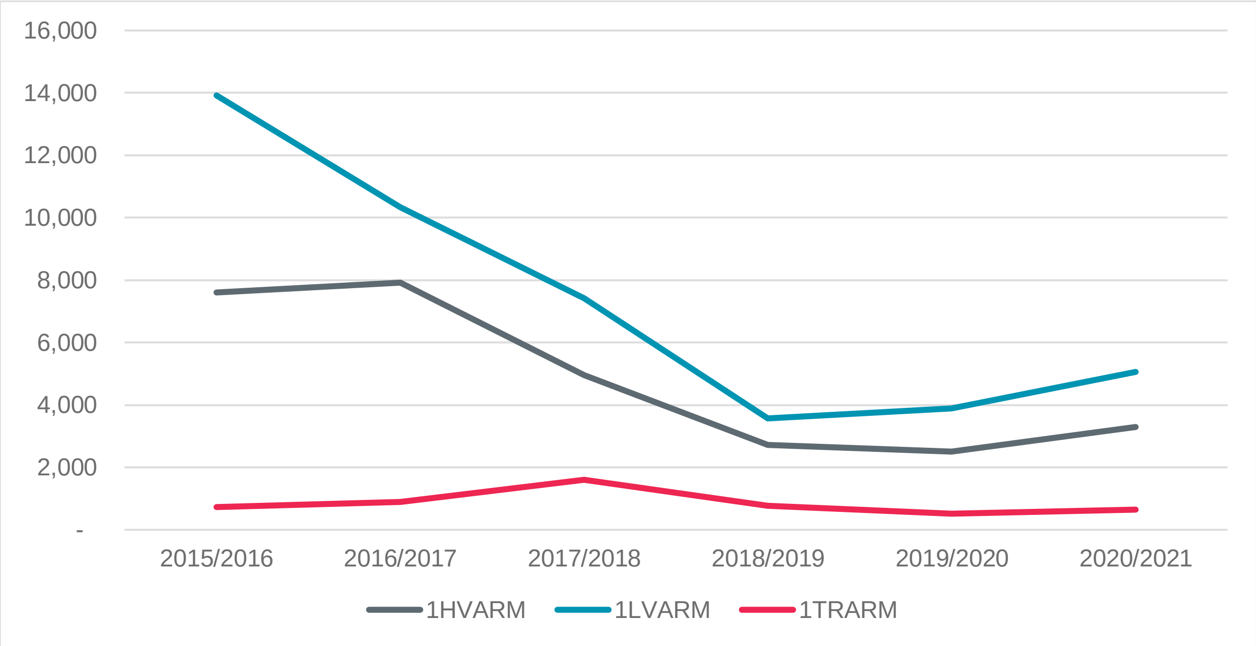
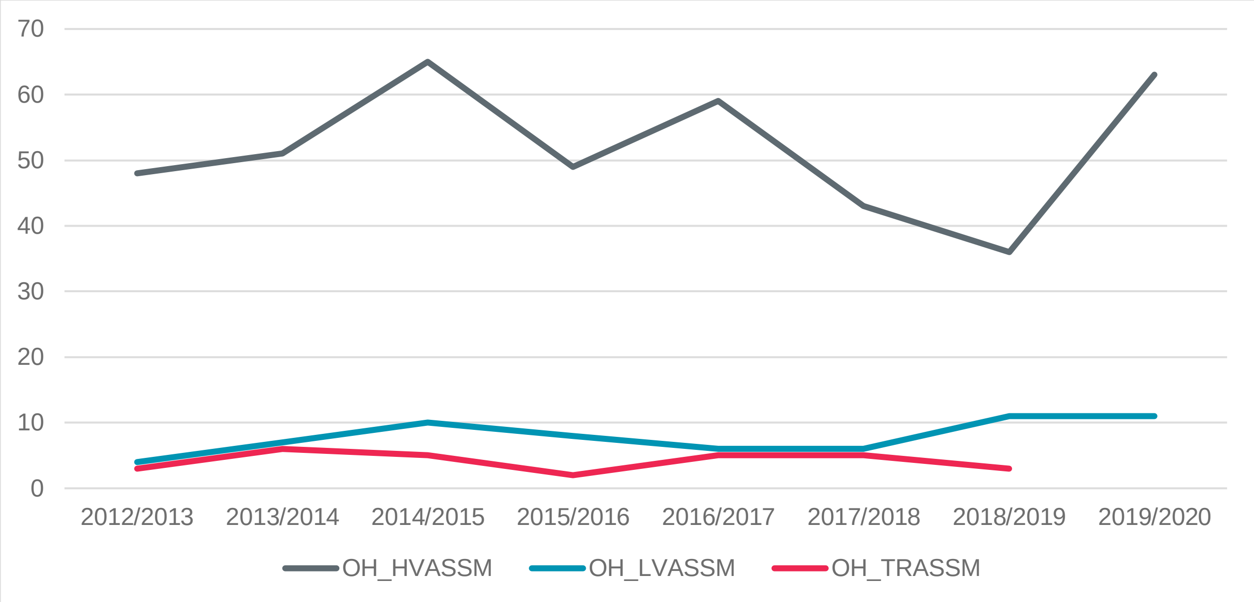


Figure 3 : Annual functional failures by assembly type



4. Consequence of nil Intervention

4.1 Consequence of nil capital intervention

The nil intervention option involves no capital expenditure for the replacement of assemblies. If an assembly were to fail, it would not be replaced or reinstated.

Due to the asset hierarchy child relationship with poles, this strategy would also require the associated pole to be retired thus rendering the adjacent poles and feeder to also be redundant. Under a nil intervention scenario, the risk costs would increase exponentially over time as other supporting elements in the network also failed and were not replaced. The primary function of the network would not be able to be met under this scenario.

This option is not feasible due to negative impact and consequences of failure. The no intervention option for assemblies is not considered nor modelled for this CFI.

4.2 Counterfactual (business as usual)

The business as usual (BAU) “counterfactual” scenario includes an assembly remaining in-service until it conditionally or functionally fails. Alternatively, it also includes the scenario where the assembly is retired in conjunction with the failure or augmentation of the associated pole (assuming the service of pole is still required). Nil proactive capital intervention is carried out.

The scope of works under the BAU include:

- Maintenance: All assemblies are subject to routine inspection with typical overhead line inspection periods being every 5.5 years. Defects are identified as an output of the inspection cycle.
- Reactive Intervention: the refurbishment or replacement of pole top assembly components or whole assembly, typically before the occurrence of a major failure. Defects are identified rectified in accordance with prioritisation assignment.

Conditional failures as outlined in *MMI0001 Pole and Line Inspection and Treatment Procedures [1]*, include:

- Rotting or termite damaged cross arms
- Elongated crossarm mounting holes causing leaning, loose insulator and bolts.
- Splitting or distorted cross arms.
- Misaligned cross arm due to braces that are damaged or loose.
- Corroded/bent insulator pins, chipped or damaged insulators.

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 and below. The data has been presented in the three categorised voltage levels to highlight the variability in risk proportion across these categories. 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 LV Assembly Risk cost summary

Risk category LV Assembly	PV of residual risk ($M)	Risk proportion (%)
Safety	3	20
Reliability	6	48
Financial	0	0
Bushfire	2	19
Reactive capital replacement costs	2	14
Total	**13**	**100**

As shown in Table 2, the residual risk presented by the BAU case totals $13 million. The residual risk value presented by an assembly failure ranges from $11 to $3,543 and averages $66 across the low voltage assembly population.

Table 3 : BAU HV Assembly Risk cost summary

Risk category HV Assembly	PV of residual risk ($M)	Risk proportion (%)
Safety	7	2.3
Reliability	273	89
Financial	1	0.3
Bushfire	20	7
Reactive capital replacement costs	6	2
Total	**307**	**100**

As shown in Table 3, the residual risk presented by the BAU case totals $307 million. The residual risk value presented by an assembly failure ranges from $50 to $37,825 and averages $2,143 across the high voltage assembly population.

Table 4 : BAU TR Assembly risk cost summary

Risk category TR Assembly	PV of residual risk ($M)	Risk proportion (%)
Safety	2.0	37
Reliability	2.2	40
Financial	0.02	0.4
Bushfire	0.5	9
Reactive capital replacement costs	0.8	15
Total	**5.5**	**100**

As shown in Table 4, the residual risk presented by the BAU case totals $5.5 million. The residual risk value presented by an assembly failure ranges from $26 to $3,809 and averages $154 across the transmission assembly population.

5. Options Considered

5.1 Risk treatment options

A range of options have been considered to address the risk presented by assemblies being assessed as an alternative to network investment. These approaches are summarised in Table below.

Table 5 - Pole top assembly risk treatment options

Option	Assessment of effectiveness	Conclusion
Additional maintenance to extend the life of the existing asset	The equipment making up the composition of pole top assemblies are all considered to be consumable equipment. Based on the cost of the consumables the labour involved for any maintenance intervention would be similar to that involved for replacement. Maintenance costs would be comparable to replacement costs with no practical maintenance options.	No practical holistic or economical feasible solution in isolation that would be recommended to be applied to population as a whole.
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
Replacement to maintain option value and reduce the consumer's long-term service cost	Replacement of pole top assembly	Recommended approach for further consideration.

5.2 Non-network options

Due to the nature of the asset and its primary functionality to support overhead conductors, there are no credible wholescale non-network solutions which could replace their functionality.

It is possible that small scale isolated remote area power supply solutions could be considered for small load areas on a spur. These would be considered based on the replacement of the feeder conductor and pole structures rather than the replacement of individual pole top assemblies. In this regard this non-network option would not be considered practical or economical for the replacement of pole top assemblies as a single unit in isolation.

5.3 Credible network options

The following network options have been considered in the intervention of a pole pop assembly.

Table 6 - Credible network options - assembly intervention

Option	Intervention Solution	Credible	Description
1	Proactive Replacement (like for like)	Credible	Replacement of asset based on risk and condition. Where alternate product or options exist, these will we determined at time of retirement

For the purpose of this asset assessment replacing like for like will be utilised as the recommended credible network solution. Option 1 will be considered as the only credible network solution to be discussion in the paper from this point forward.

5.3.1 Pole top assembly replacement

Under this option, the intervention includes the retirement and disposal of the existing pole top assembly and replacement with new pole top assembly of similar type and functionality.

The replacement unit rate per each pole top assembly, is listed below:

- LV Assembly – $1,000.
- HV Assembly – $1,200; and
- TR Assembly – $2,000.

These values are an estimate based on the mean cost for pole top assembly renewal over the past 10 years.

5.4 Economic Evaluation

5.4.1 Option 1 Proactive replacement

5.4.1.1 Low Voltage Assembly Outcome

The Endeavour Energy Network has approximately 197,000 low voltage pole top assemblies. Analysis of failure modes identified there is approximately 17 functional failures per year.

The assessment conducted as part of this CFI into the proactive replacement of low voltage pole top assemblies compared to the current BAU asset management approach 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 this assembly classification within this CFI at this time for optimisation.

5.4.1.2 Transmission Assembly Outcome

The Endeavour Energy Network has approximately 36,598 transmission pole top assemblies. Analysis of failure modes identified there is approximately 1.5 functional failures per year.

The assessment conducted as part of this CFI into the proactive replacement of transmission pole top assemblies compared to the current BAU asset management approach 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 this assembly classification within this CFI at this time for optimisation.

5.4.1.3 High voltage assembly outcome

This option identifies 6,393 high voltage assemblies 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 $240 million and provides a benefit of $66.0 million compared to the counterfactual case. The PV of the cost of the option is $7.2million and the NPV overall is $59.1 million.

Table 5 below provides a summary of the residual risk presented by this option.

Refer Appendix B for details of the HV assemblies identified for intervention during the FY23 – FY29 period under this option.

Table 5 : Option 1 residual risk summary

Risk Value Measure	Proactive Intervention ($M)	Proportion (%)
Bushfire	$16	6.7
Financial	$0.4	0.2
Safety	$5.2	2.2
Reliability	$213.5	89
Reactive Replacement	$4.9	2
Total	**$240**	**100**

5.5 Evaluation Summary

Table 6 below summarises the outcomes of the cost-benefit assessment the pole top assembly replacement option for Endeavour Energy's fleet of 373,701 compared to the BAU case. The summary shows only the impact of investment in HV pole top assemblies with maximum NPV of intervention within the FY23 - FY29 period.

Table 6 Option summary

Option	Volume of interventions	Residual risk ($M)	PV of benefits ($M)	PV of investment ($M)	NPV ($M)	Rank	Comments
Network: BAU	0	307	-	-	-	2	BAU
Network: Proactive Replacement HV Assembly	6,393	240	66.3	7.2	59.1	1	Preferred option

As shown in Table 6, HV pole top assembly replacement provides a higher NPV overall and will deliver the highest overall value and is therefore the preferred option.

5.6 Economic evaluation assumptions

There are a 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 Sensitivity and scenario analysis

A scenario assessment has been carried out on the various elements of the risk and cost assumptions used in the economic analysis in order to test the robustness of the evaluation. The sensitivity analysis has been conducted on the high voltage assembly only.

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 7 below.

Table 7 - 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 β 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 β parameter (decreases the mean time to failure for the asset)

The impact of the recommended option (Option 1) NPV is shown in Table 8 below and the resultant spread of replacement years to give the maximum NPV for each of the 6,393 high voltage pole top assembly units identified for replacement under the preferred option is shown in Figure 4.

Table 8 - NPV of scenario analysis HV Assembly for the preferred option (Option 1)

Scenario Analysis of HV Assemblies	NPV of preferred option ($M)
Scenario 1 – Low benefits, high costs	20.5
Scenario 2 – Central risks and costs	59.2
Scenario 3 – High benefits, low costs	125.9
Average	**68.5**

Each scenario reduces the risks posed by the 142,430 HV Pole Top Assembly units with an average NPV of $68.5 million across the three scenarios analysed.

Figure 4 : Option 1 - maximum NPV replacement years for the three sensitivity scenarios

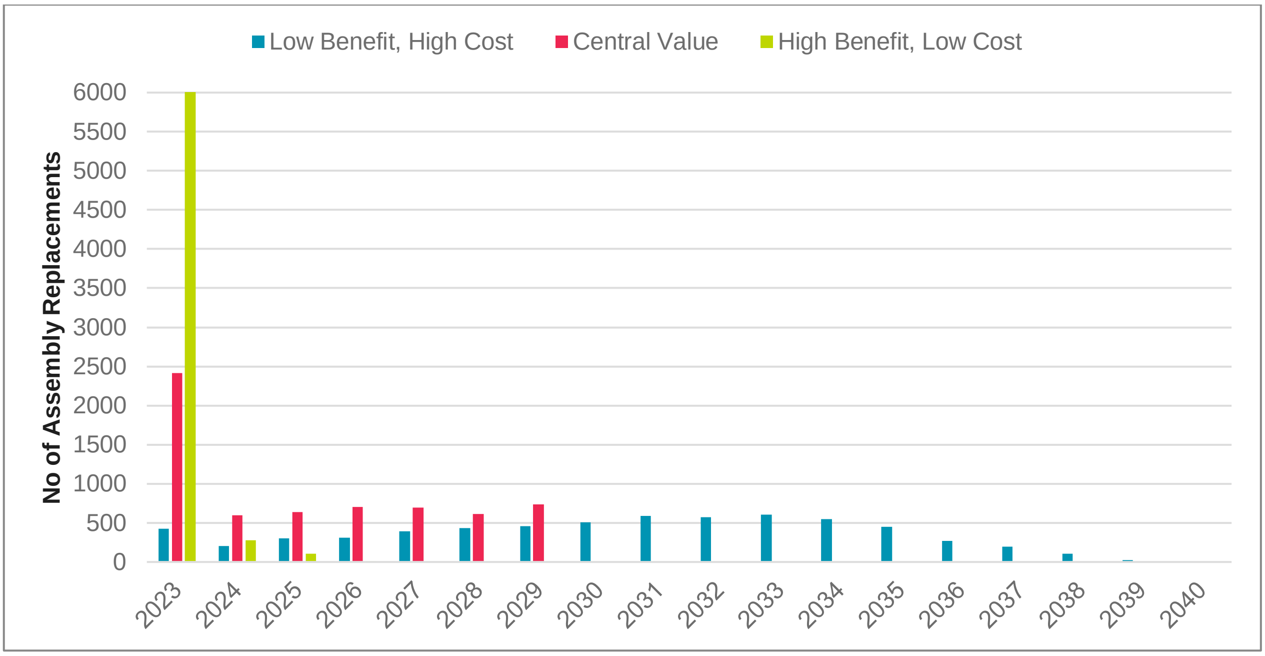


Figure 4 shows that across the three sensitivity scenarios, the timing of the maximum NPV of the recommended 6,393 replacements are skewed towards FY23, which is the earliest year that the works can now be practically carried out.

All high benefit, low-cost replacement cases fall within FY23 to FY25, while the low benefit, high-cost cases are spread across FY23 – FY40.

The assessment shows the maximum NPV occurs for both high benefit, low-cost and central risks and cost intervention cases within the FY23-FY29 investment period.

In addition, 40% low benefit, high-cost cases also land within in this same timeframe suggesting an appropriate level of investment for Option 1.

6. Preferred option details

6.1 FY23-FY29 scope and timing

The preferred option is option 1. This strategy recommends the proactive replacement of 6,393 high voltage pole top assemblies during the period FY23 – FY29.The overall cost of the proposed program is estimated to be $7.67million (in real $ FY23 terms). A contingency is not proposed to be applied as there are multiple sites in the program and the estimated costs are based on mean values with individual site's costs evening out to the mean across the program.

6.2 Additional scope and timing

A further 3,807 high voltage assemblies are NPV positive reaching their maximum NPV within a 10-year forecast period (FY30-FY34). These 3,807 investments total a further $4.6 million (in real FY23 terms) and have been identified as additional scope for inclusion in the investment portfolio optimisation process.

6.3 Investment summary

6.3.1 Planned proactive works

A summary of the investment proposed to be submitted for portfolio optimisation is shown in Table 9 below.

The pole top assembly replacement costs are based on historical costs associated with cross arm defect rectification. Capital programs DS418 LV Pole Top Structure Hardware (NDM-0000038), DS421 HV Pole Top Structure Hardware (NDM-000042) and TM033 Transmission Pole Top Structure (NTM-000014). Based on the volume of replacements within these capital program the unit rates applied are expected to be reasonably accurate

All costs are in real FY23 terms.

Table 9 - Summary of investment for optimisation

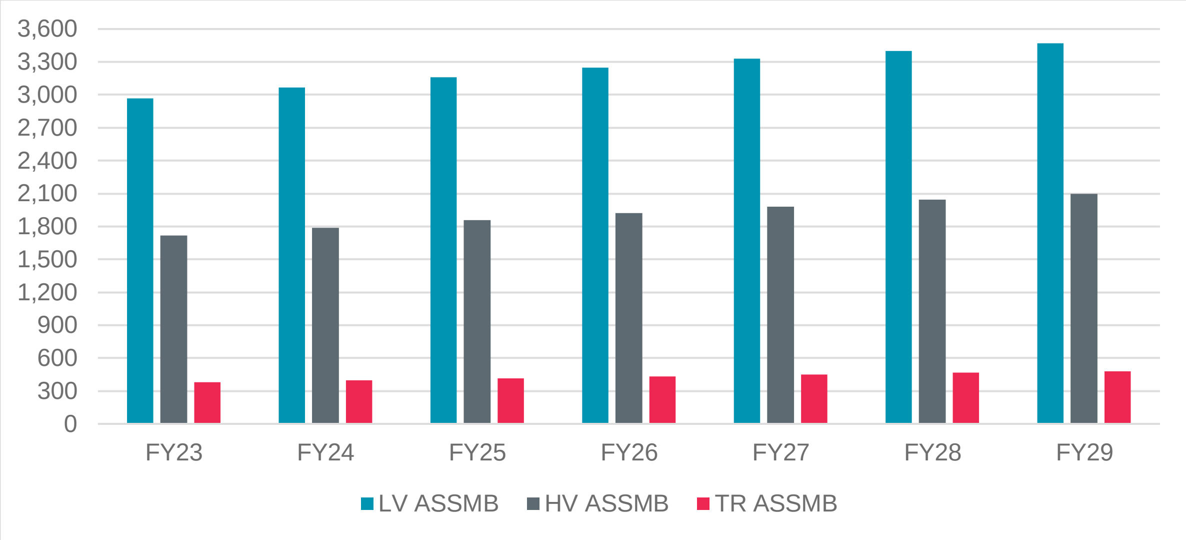
Intervention type	Unit rate ($)	Quantity of interventions	Total costs ($M)
HV Pole Top Assembly Replacement (NPV Max FY23-FY24)	1,200	3,007	3.61
HV Pole Top Assembly Replacement (NPV Max FY25-FY29)	1,200	3,386	4.06
Sub-total FY23-FY29		***6,393***	***7.67***
HV Pole Top Assembly Replacement (NPV Max FY30-FY34 – inclusion for optimisation)	1,200	3,807	4.57
Sub-total FY30-FY34		***3,807***	***4.57***
Total		**10,200**	**12.24**

6.3.2 Reactive investment

Reactive modelling for the FY23 -FY29 period has forecast a further 39,500 pole top assemblies and approximately 18,000 assembly components are to reach a state of conditional failure or functional failure (e.g. found to be in a poor condition indicative of imminent failure and/or no longer capable of performing its function). It is to be noted that the pole top assemblies proposed for proactive retirement as part of this CFI have been excluded from the reactive modelling across this period.

Figure 5 below shows the forecast trend of reactive investment likely to be required for the replacement of failed pole top assemblies into the future.

Figure 5 : Forecast conditional pole top assembly replacement quantities FY23-FY29



In addition to whole assembly (cross arm) replacements, smaller components of the assembly, insulators, bolts and braces are also discreetly replaced due to conditional and functional failures. Over the past 4 years Endeavour Energy replaced on average approximately 2,600 components of pole top assemblies at an average cost of $1.04 million per year.

It is proposed that additional funding of $52.58 million (in real$ FY23 terms) be made available for reactive pole top assembly replacements during the FY23 – FY29 period

Table 10 below, summarises the proposed reactive funding forecast. All costs are in real FY23 terms. **Table**

Assembly Type	Unit rate per reactive replacement ($)	Forecast quantity reactive replacements				Total forecast quantity of reactive replacement	Total forecast reactive investment ($M)
		FY23-FY24		FY25-FY29			
		Qty of units	Investment ($M)	Qty of units	Investment ($M)		
Failure type: Conditional							
Low voltage	1,000	6,033	6.03	16,602	16.60	**22,635**	**22.63**
High voltage	1,200	3,509	4.21	9,903	11.88	**13,412**	**16.09**
Transmission	2,000	780	1.56	2,244	4.49	**3,024**	**6.05**
Sub-total (Conditional)		***10,322***	***11.8***	***28,749***	***32.97***	***39,071***	***45***
Assembly component	400	5,184	2.07	12,960	5.18	**18,144**	**7.25**
Sub-total		***5,184***	***2.07***	***12,960***	***5.18***	***18,144***	***7.25***
Failure type: Functional							
Low voltage	1,000	34	0.03	85	0.09	**119**	**0.12**
High voltage	1,200	96	0.12	240	0.29	**336**	**0.41**
Transmission	2,000	3	0.01	8	0.02	**11**	**0.03**
Subtotal (Functional)		***133***	***0.16***	***333***	***0.4***	***466***	***0.56***
Total		**15,639**	**14.03**	**42,041**	**38.55**	**57,681**	**52.58**

10 – Pole top assembly reactive replacement forecast FY23-FY29

6.4 Scope of Works

6.4.1 Pole top assembly replacement

The proposed scope of works is to replace the identified pole top assembly including all components (insulator, bolts and braces) to the latest relevant network standard. Pole top assemblies shall be constructed to the requirements of the relevant standards, specifically, MCI 0005 - Overhead distribution construction standards manual [1].

7. Regulatory investment test

The project cost of the credible option(s) for each site falls below the threshold for application of the Regulatory Investment Test for Distribution (RIT-D) (currently $6.0 million) and therefore the RIT-D is not applicable to this project.

8. Recommendation

It is recommended that Option 1 for the proactive replacement of HV pole top assemblies where the intervention timing indicates that maximum NPV is between FY23-FY34, be included in the PIP FY23 and to proceed to the investment portfolio optimisation stage.

With an allowance for a further $52.58 million (in real $ FY23 terms) within the FY23-FY29 period for the reactive replacement of LV, HV or transmission pole top assemblies that reach a state of conditional failure (e.g. found to be in a poor condition indicative of imminent failure and/or no longer capable of performing its function.

9. References

[1] Energy, Endeavour, "MCI0006 - Underground distribution Construction standards manual," March 2016.

[2] Endeavour Energy, "MMI0001 Pole and Line Inspection and Treatment Procedures, Amendment 17," November 2016.

[3] Endeavour Energy, "MMI0002 - Distribiution Overhead Defect Handbook," Asset Planning & Performance, August 2021.

[4] Endeavour Energy, "MCI0005 Overhead Construction Standards Manual," 2017.

[5] Endeavour Energy, "Asset Renewal Plan FY21-FY30," January 2020.

[6] Endeavour Energy, *Substation Maintenance Instruction : Minimum requirements for maintenance of transmission and zone substation equipment - SMI 100, Amendment 14,* 31 August 2016.

[7] "MMI 0034; Pre-summer bushfire inspections," Endeavour Energy, 2016.

[8] "TB0308; Clarification on bushfire defects," Endeavour Energy, 2021.

10. Attachments

Appendix A - Summary of key risk assessment variables and assumptions

Appendix B: Details of recommended scope for optimisation

Appendix A: Summary of key risk assessment variables and assumptions

General variables and assumptions

Parameter	Value	Description/Justification	Source/Assumptions
Assembly Population	**LV Assembly** – 197,220 **HV Assembly**– 142,430 **TR Assembly –** 36,598	Number of pole top assemblies in service	Endeavour Energy's GIS database. Ages determined by GIS Job Place and Job Modify dates.
Annual Conditional Failures	**LV Assembly** – 1,455 **HV Assembly**– 623 **TR Assembly -** 205	The expected number of conditional assembly failures seen in a year based on a 10-year period (FY12-FY22)	Endeavour Energy's defect data via Ellipse workorders
Annual Functional Failures	**LV Assembly** – 17 **HV Assembly**– 48 **TR Assembly –** 1.5	The expected number of functional assembly failures seen in a year based on a 10-year period (FY12-FY22)	Endeavour Energy's Outage Management System
Maintenance Cost	**LV Assembly** – 0 **HV Assembly**– 0 **TR Assembly -** 0	The cost associated with maintenance of pole top assemblies	For the modelling of the asset class the cost of maintenance was assumed to be zero as the maintenance cost is consistent dependent on intervention strategy.
Planned Intervention Cost	**LV Assembly** – $1000 **HV Assembly**– $1200 **TR Assembly -** $2000	The cost associated with a planned assembly intervention	Based on actual costs of previously delivered works
Reactive Intervention Cost	**LV Assembly** – $1,000 **HV Assembly**– $1,200 **TR Assembly -** $2,000	The cost associated with a reactive assembly intervention	Based on actual costs of previously delivered works
WACC	3.26%	Weighted average cost of capital	Regulated rate
Indexation	2.24%	Inflation Index	Regulated Rate

Weibull Parameters

Parameter	Value	Description/Justification	Source/Assumptions
$\beta_{functional}$	**LV Assembly** - 223 **HV Assembly** - 141 **TR Assembly -** 260	The shape parameter, also known as the Weibull slope, used for calculating probability of failure for proactive investment. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Endeavour Energy's Outage Management System
$\eta_{functional}$	**LV Assembly** – 10 **HV Assembly**– 10 **TR Assembly -** 10	The scale parameter used for calculating probability of failure for proactive investment. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Endeavour Energy's Outage Management System
$\gamma_{functional}$	**LV Assembly** – 3.6 **HV Assembly**– 3.6 **TR Assembly** – 3.6	The location parameter used for calculating probability of failure for proactive investment. Developed by applying asset age to failure correlation using Endeavour Energy's	Endeavour Energy's Outage Management System
$\beta_{conditional}$	**LV Assembly** – 64 **HV Assembly**– 69 **TR Assembly -** 67	The shape parameter, also known as the Weibull slope, 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.	Endeavour Energy's Ellipse defect data
$\eta_{conditional}$	**LV Assembly** – 10 **HV Assembly**– 10 **TR Assembly -** 10	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.	Endeavour Energy's Ellipse defect data
$\gamma_{conditional}$	**LV Assembly** – 3.6 **HV Assembly**– 3.6 **TR Assembly** – 3.6	The location parameter used for calculating probability of failure for reactive forecasting. Developed by applying asset age to failure correlation using Endeavour Energy's	Endeavour Energy's Ellipse defect data

Risk Inputs

The risks presented by each asset and modelled in the cost-benefit analysis include safety, reliability, bushfire, financial and reactive replacement costs and are described and presented below.

Risk category description

Risk category	Risk description
Reliability	Loss of supply to a varying number of customers– dependent on network topology and customer demand of the feeder or pole to which the pole top assembly has failed on.
Worker Safety	Fatality or injury for a worker working on or near the network at the time of failure – dependent on likelihood of failures leading to pole top assembly failures during maintenance converting to the injury or fatality of a worker which is extremely low.
Public Safety	Fatality or injury for a member of the public because of a pole top assembly failure.
Financial	Cost of replacing additional network assets damaged because pole top assembly failure.
Bushfire	Bushfire ignition costs from a pole top assembly failure – dependent on likelihood of failures and location relative to bushfire prone lands.
Equivalent Annual Cost (EAC) of Reactive Intervention	Cost of replacement of pole top assemblies in a reactive manner after failure.
Maintenance	Cost associated with regular asset maintenance.

Reliability Risk Inputs

Parameter	Value	Description/Justification	Source/Assumptions
Load factor	0.7	Factor applied to maximum feeder loadings to represent the magnitude of load during a network outage Calculated using historic outage data	Endeavour Energy's Outage Management System
Outage duration	**LV Assembly** – 3.7 **HV Assembly**– 2.7 **TR Assembly –** 2	Calculated as the average hours lost per customer under an assembly associated outage	Endeavour Energy's Outage Management System
LoC	**LV Assembly** – 0.63 **HV Assembly**– 0.74 **TR Assembly –** 0.01	the percentage of functional failures that have resulted in outage. failures lead to a reliability risk.	Endeavour Energy's Outage Management System. For the transmission network and the inherent redundancies built in, an assumption of 1 in 100 events would lead to an outage.
VCR ($/MWh)	Varies by asset	The value customers place on having reliable electricity	Power Factory load data

		supplies under different conditions. Calculated as an average VCR across each LGA	
Load (kVA)	Varies by asset	The load distributed at each pole to each the/an assembly resides. Varies by asset type.	SME advice and GIS data

Worker Safety Risk Inputs

Parameter	Value	Description/Justification	Source/Assumptions
LoC – Injury Severity	**LV Assembly** – 0.00483 **HV Assembly**– 0.00206 **TR Assembly –** 0.02143	Likelihood that a safety related failure will result in an injury. Calculated as the no. of injuries p.a. / no. of asset related safety incidents p.a.	Endeavour Energy's historical Safety Incidents via MySafe database. No safety incidents were found to be of a consequence of a pole top assembly failure. The following assumptions were applied: LV Assembly: 2 safety incidents every 25 years HV Assembly: 2 safety incidents every 20 years TR Assembly: 2 safety incidents every 30 years
LoC – Fatality Severity	**LV Assembly** – 0.00024 **HV Assembly**– 0.00010 **TR Assembly –** 0.00107	Likelihood that a collision will result in a fatality Calculated as the no. of fatalities p.a. / no. of asset related safety incidents p.a.	Endeavour Energy's historical Safety Incidents via MySafe database had 0 fatalities in the last 10 years due to pole top assemblies No safety incidents were found to be of a consequence of a pole top assembly failure. The following assumptions were applied for each assembly category. 1 fatality every 20 injuries
CoC – Injury	$51,000	Cost of a single injury	Disproportionate factor used alongside CoC – Fatality and GNV1119 – Quantitative Determination of Reasonably Practicable Risk Control Measures when Assessing Health and Safety Risks
CoC – Fatality	$5,100,000	Cost of a single fatality	Office of Best Practice Regulation

Financial Risk Inputs

Parameter	Value	Description/Justification	Source/Assumptions
CoC – Financial	**LV Assembly** – $7,500 **HV Assembly**– $7,500 **TR Assembly -** $14,500	The cost realised when the risk of assembly failure causes pole top failure that results in pole requiring to be replaced.	Completed reactive pole replacement work orders from ellipse.
LoC – Financial	**LV Assembly** – 0.00604 **HV Assembly**– 0.023881 **TR** Assembly - 0.02571	The percentage of functional failures that have resulted in outage. failures lead to a financial risk. The financial risk is assembly failure causing pole top failure that results in pole requiring to be replaced.	Endeavour Energy's Outage Management System

Bushfire Risk Inputs

Parameter	Value	Description/Justification	Source/Assumptions
LoC – Fire Start	Varies by asset	Likelihood that an assembly failure will create a fire. Calculated as the annual no. of assembly related fires / annual no. of assembly bushfire related defect failures	Endeavour Energy's defect data via Ellipse workorders Endeavour Energy's historical fire database
LoC – Vegetation	Varies by asset	Risk reduction factor based on the asset's spatial location and its proximity to vegetation fuel sources	RFS bushfire prone land maps
LoC – Bushfire Prone Area	Varies by asset	Risk reduction factor based on the asset's spatial location and its proximity to other assets.	Value of 1 or 0 based on the number of neighbours the asset has. It is unlikely that a fire on a populated street is going to reach vegetation before being put out.
CoC – Bushfire	Varies by asset	Cost of a bushfire including costs associated with fatalities, houses lost, residential contents lost, vineyards lost, plantations lost, crops lost, powerlines lost.	Ignition simulation via Phoenix software

Appendix B: Details of recommended scope for optimisation

Scope with maximum NPV between FY23-FY34, shown in order of descending BCR, then descending NPV can be found in attached MS Excel spreadsheet:

Appendix B – CFI HV Pole Top Assembly Proactive.xlsx

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