HV distribution combination switchgear failure risk mitigation

Case for investment FY23 - FY29
(Pre-optimisation)

August 2022

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1. Executive summary

1.1 Recommendation

This case for investment (CFI) recommends investment in replacement of *11kV and 22kV HV distribution combination switchgear* across the network during the period of FY23 – FY29 to address the safety, reliability and financial risks associated with this equipment failing 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. Any proposed asset interventions in this CFI are in addition to existing scope that has previously been released and/or currently in progress of being delivered.

The total cost of the proposed works is estimated to be $24.90 million in real FY23 terms.

Within this recommended program of works, each asset has been assessed individually for the risk it presents. Furthermore, 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.

A further allowance of $4.24 million is proposed for the replacement of HV switchgear that fail unexpectedly and in a non-repairable manner during the FY23 - FY29 period giving a total proposed investment of $29.14 million.

1.2 Identified need

Ground mounted HV distribution switchgear is primarily composed of two technology types of insulation medium; epoxy resin-cast (4,851) and SF6 (9,883) insulated. HV Resin type switches exhibit higher potential consequence outcomes upon failure. These switch types also receive increased maintenance. Failure of a HV Resin type switch may cause significant risks for persons and property near to and possible loss of supply to customers. The possible consequences of failure include:

- Safety impacts: The main failure mode typically being seen at present is with Resin type switchgear. This is occurring through electrical discharge caused by the cable terminations via progressive partial discharge caused by environmental factors, operating conditions and age. This leads to phase to earth fault leading to uncontrolled energy discharge. The energy discharge has the potential for the fibreglass cubicle door to be expelled at a high velocity, for fire to engulf the substation and spread and subsequently pose a potential risk to members of the public and/or Endeavour employee in the case of operation;

- Reliability impacts: HV feeder supply is effected from a HV switchgear failure and subsequently while the network is re-configured to isolate and sectionalise the HV switchgear. Once the failed HV switchgear has been isolated from the HV network there is further loss of LV supply from the distribution substation/s through to the customers that could not be off loaded to another local distribution substation; and

- Financial impacts: the additional costs associated with clean-up after a failure and the repair/replacement of any adjacent assets in the vicinity of the failed unit such as the distribution transformer, LV switchgear and substation housing which can also be damaged by a catastrophic failure.

- No significant environmental or regulatory compliance consequences have been experienced or are anticipated for future failures of a HV switchgear units. The use of SF6 continues to be discussed across the organisation / industry and a risk value on the use of the insulation medium may be introduced in the future, however at this stage no value has been assigned to the use of SF6.

1.3 Options analysis

There are no credible non-network solutions for replacing the functionality of a *11kV and 22kV HV distribution combination switchgear* unit given their relatively low replacement cost and the amount of energy that flows through them on a continual basis.

For *11kV and 22kV HV distribution combination switchgear* the only option available for addressing the failure risk of individual HV switchgears in a proactive planned manner which is considered to be credible is retirement followed by the replacement of the switchgear with a modern equivalent switchgear.

Table 1 below summarises the outcomes of the cost-benefit assessment for the HV switchgear replacement of Endeavour Energy's fleet of 14,743 HV switchgear compared to the counterfactual case, which includes operating the HV switchgear until failure (run-to-failure) and then replacing them. The summary shows the impact of investment in the replacement of HV switchgear 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	-	613	-	-	-	2	Excessive risk
1. Replace HV Switchgear (SF6 equivalent)	Network	904	570	43.0	23.1	19.9	1	Preferred option

The use of SF6 technology is becoming increasingly reviewed due to its potential environmental impact (as it leaks from equipment). As the organisation, industry and globe continue to focus on options to reduce the use of SF6 technology, alternative options and the cost / benefit of each will continue to be monitored.

1.4 Recommended option

Recommended option is Option 1 for the replacement of 904 HV distribution combination switchgear with a modern equivalent SF6 technology, subject to project optimisation.

The NPV of the proposed interventions is unique to each HV distribution combination switchgear and varies from $4,866 to $130,941 with an average of $22,018 across the 904 assets proposed for intervention during the period. The total NPV of the proposed program is $19.9 million.

The benefit to cost ratio (BCR) for each HV switchgear site varies from 1.1 to 5.8 and averages 1.8 across the 904 HV distribution combination switchgear interventions.

1.5 Budget

The total cost of the proactive replacement works is estimated to be $24.90 million in real FY23 terms.

The additional funding required for HV switchgear that is likely to fail in service is $4.24 million giving a total for the recommended funding of $29.14 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 *11kV and 22kV HV distribution combination switchgear* throughout the distribution network.

This case for investment (CFI) recommends the proactive intervention for the retirement and subsequent replacement of the identified HV distribution combination switchgear during FY23-FY29 and provision of additional capital for the reactive replacement of HV distribution combination switchgear that may fail unexpectedly during the period.

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.

This CFI will be grouped together with any other related CFI's (e.g. LV distribution switches, and distribution transformers etc) 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

Endeavour Energy has a fleet of 14,734 individual HV distribution combination switchgear units of fuse-switch, switch combination or circuit breaker types in-service installed in padmount, cottage, kiosk, indoor substations and switching stations. Ground mounted HV distribution switchgear is primarily composed of two technology types of insulation medium; epoxy resin-cast and SF6 insulated. Some vacuum interrupters also exist.

HV distribution combination switchgear allow isolation and segmentation of the network for the purpose of providing targeted access on other parts of the network to carry-out, asset maintenance and repairs.

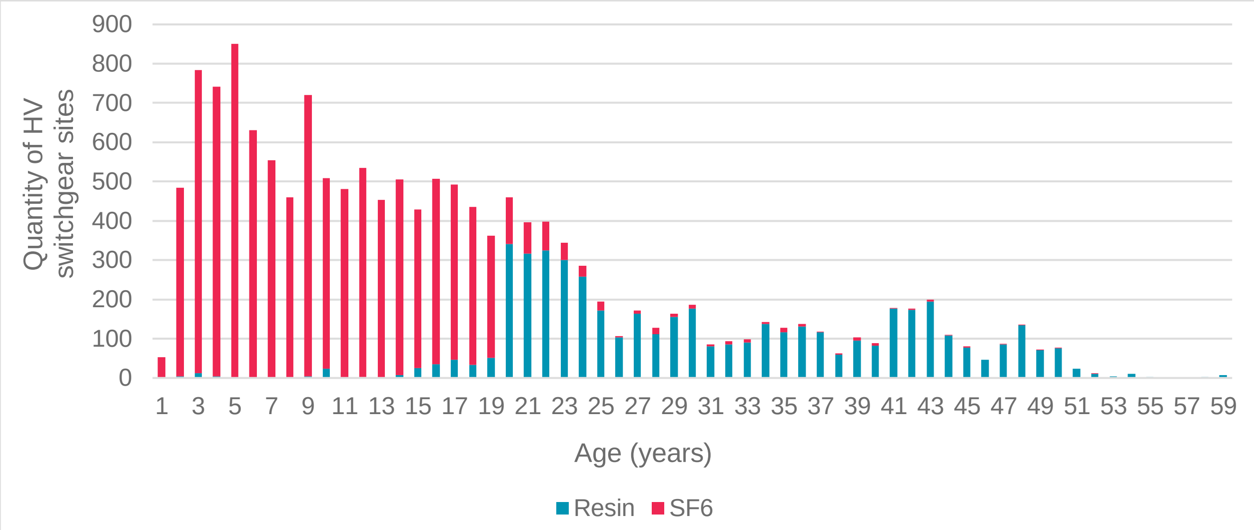
Magnefix MD4 epoxy insulated switchgear has been used as the predominant switchgear technology in most of the underground network since the 1960's. Since early 2000's metal clad SF6 switchgear has been more predominately used with all installations and replacements from 2011 being mandatory SF6 replacements. The use of SF6 technology is continuing to be reviewed across the organisation / industry and as other technology options become viable, alternative intervention options will be considered and re-evaluated.

There are variations to this with oil switchgear introduced for 11kV networks and indoor substations earlier than 1995. However, Oil insulated switchgear was targeted for replacement through *DS316 – HV oil switchgear replacement program*. DS316 was accelerated following incidents in other DNSP networks and since 2009 approximately 260 oil circuit breakers or switch-fuse units have been replaced or retired across 85 distribution substations. This program was completed in the FY18.

The most recent ongoing program is *DS307 – Holec MD4 Epoxy HV Switchgear Replacement* for the replacement of defective HV Resin type switchgear units with metal-clad switchgear from the current supply contract.

The age profile of the fleet of 14,734 HV distribution switchgear sites is shown in Figure 1 below.

Figure 1 – Individual HV distribution combination switchgear age profile



3.2 Risks and identified need

The majority of distribution substations built from the 1970's through early 2000's were built with Resin type switchgear (Magnefix MD4 HV Switchgear) which is currently installed in 4,851 sites. Due to the prevalence of Resin type HV switchgear throughout the network, the observed failure modes and rate of ageing, there is a growing risk with this HV switchgear. Failure of a HV Resin type switch may cause significant risks for persons and property near to and possible loss of supply to customers.

The possible consequences of failure include:

- Safety impacts: The main failures are typically being seen at present is with resin type switchgear. This is occurring through electrical discharge caused by the cable terminations via progressive partial discharge caused by environmental factors, operating conditions and age. This leads to phase to earth fault leading to uncontrolled energy discharge. The energy discharge has the potential for the fibreglass cubicle door to be expelled at a high velocity, for fire to engulf the substation and spread and subsequently pose a potential risk to members of the public and/or Endeavour employee in the case of operation;
- Reliability impacts: HV feeder supply is effected from a HV switchgear failure and subsequently while the network is re-configured to isolate and sectionalise the HV switchgear. Once the failed HV switchgear has been isolated from the HV network there is further loss of LV supply from the distribution substation/s through to the customers that could not be off loaded to another local distribution substation; and
- Financial impacts: the additional costs associated with clean-up after a failure and the repair/replacement of any adjacent assets in the vicinity of the failed unit such as the distribution transformer, LV switchgear and substation housing which can also be damaged by a catastrophic failure.
- No significant environmental or regulatory compliance consequences have been experienced from the failure of a HV switchgear units and have not been included within this assessment. The use of SF6 continues to be discussed across the organisation / industry and a risk value on the use of the insulation medium may be introduced in the future, however at this stage no value has been assigned to the use of SF6.

From FY13 onwards Endeavour Energy has experienced on average 24 functional failures of HV Resin type units per year due to defective equipment, with approximately 40% of these resulting in catastrophic failure. As this asset class continues to age it is expected that with no intervention this level of failure will continue to increase over time.

Maintenance procedures are in place to control this risk but is only partially successful leaving the switchgear with a risk of catastrophic failure.

The bulk of the fleet of HV SF6 type units are considered a relatively young asset at present and are showing minimal functional failures events recorded.

Refer Appendix C for further detail of the assessed failure consequences.

4. Consequence of nil intervention

4.1 Consequences of nil capital intervention

The nil intervention case involves not carrying out any capital works. Therefore, HV distribution combination switchgear would be operated until they experienced a functional failure and then retired and not replaced if they could not be returned to service after a post-fault maintenance intervention.

The consequences of this would include:

- The consequences of failure for each HV distribution combination switchgear as noted in 3.2 above; and
- Non-repairable failures lead to extended loss of supply while alternate arrangements are made;
- HV switchgear units are components of ground-based distribution substations and as such, their retirement will remove a critical function of the parent distribution substation;
- Where suitable alternative network supply is not available, portable generators will remain in use for an extended period;
- Potential for overload of adjacent substations during peak periods requiring generator support; and
- Loss of redundancy for adjacent substations will lead to customer outages during planned and unplanned work on those substations.

Note that the impact of these consequences depends on the ongoing integrity of the surrounding network to allow failed switchgear units to be partially offloaded for perpetuity. 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. These exponential additional risk costs have not been modelled or included in the assessments as part of this CFI.

On this basis, the reactive replacement of HV distribution combination switchgear which fail will be undertaken, subject to an assessment of the ongoing need for the asset, and the nil intervention case will not be considered further in this CFI.

4.2 Counterfactual (run to failure)

The counterfactual scenario includes operating the HV distribution combination switchgear until they suffer a non-repairable functional failure or a conditional failure after which they are replaced with a modern equivalent asset providing the service provided by the HV distribution combination switchgear is still required. Nil proactive capital intervention is carried out.

The scope of works under the BAU include:

- Maintenance:
  - All HV switchgear types: All HV switchgear in padmount, ground, and indoor/kiosks substations are inspected and tested for partial discharge (PD) every three years in accordance with substation maintenance instruction SMI101 Minimum requirements for maintenance of distribution equipment
  - HV Resin Type only: Major maintenance (10 yearly)
  - Repair of any minor damage such as switch caps, operating mechanisms, topping up of epoxy wet boxes; and
- Reactive replacement after failure.

Functional failure refers to the inability of the HV switchgear to perform its required function following:

- Failures disruptive to the supply of electricity;
- Catastrophic failures of equipment or subcomponents such as the cable termination;
- Failure of the switchgear to operate (or be operated) when required; or
- Failure of the switchgear to perform its rated duty.

Conditional failures are units which exceed the partial discharge limits, noticeable degradation of the epoxy insulation, observable discharge across the insulation, signs of tracking current or have other defects which persist after maintenance, are typically scheduled for replacement in accordance with substation maintenance instruction SMI212 HV switch and switch fuse units.

For the purpose of assessing risk, all HV switchgear which are currently approved for replacement and whose works are in progress have been removed from the fleet of assets. Therefore, the BAU risk includes only the risk presented by assets not currently approved for replacement.

A summary of the risk presented by the run to failure case is shown in Table 2 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 – Run-to-failure risk cost summary

Risk category	PV of residual risk ($M)	Risk proportion (%)
Safety	25	4
Reliability	378	62
Financial	33	5
Reactive capital replacement costs	177	29
Total	**613**	**100**

As noted in Table 2 above, the residual risk presented by the run-to-failure case totals $613 million. The residual risk value presented by each HV distribution combination switchgear ranges from $0.01 million to $0.37 million and averages $0.04 million across the fleet of 14,734.

The higher risk values are considered to be excessive and indicate the need for the higher risk HV distribution combination switchgear to be retired in order to mitigate the risk. On this basis, options for intervention should be considered to provide for the continuation of the service required of these HV distribution combination switchgear.

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 the HV switchgear. These approaches are summarised in Table 3 below.

Table 3 – HV distribution combination switchgear risk treatment options

Option	Assessment of effectiveness	Conclusion
Additional maintenance to extend the life of the existing asset	Maintenance procedures unable to further extend the life of HV distribution switchgear. The ongoing management and maintenance of Resin type is approximately 288% higher than the modern SF6 technology equivalent. This is primarily attributed to the ongoing 10-yearly major overhaul performed on Resin type as an outcome of failure-modes & effects analysis. Whilst the current inspection program has some success at identifying defects prior to a functional failure, the failure mode appears to deteriorate quickly, with a number of sites that have functionally failed having inspection completed within 12 months prior. Current practices / maintenance activities still result in on average 24 catastrophic failures p.a.	No technically feasible solution in isolation

Option	Assessment of effectiveness	Conclusion
Reduce the load on the asset through network reconfiguration, network automation, demand management or other non-network options	The risk of failure is independent of load. A minor reduction in the consequences of failure could be achieved by transferring load from any of the distribution substations. These HV links facilitate flexibility in switching of the distribution network to minimise the extent of customer outages and the duration of outages during planned and unplanned works on the network and limit the extent of outages after faults. The switchgear also provides a means of creating three and four-way joints in underground cables on the distribution network. Further, there are no practicable non-network solutions for replacing the function of HV switchgear.	No technically feasible solution
Implementing operational controls such as limiting access, remote switching protocols etc	Operating controls are already in place for the operation of Resin type switchgear during fault conditions. 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 and reliability, neither of which can be affected by practicable controls.	Controls only the safety risk elements for workers

5.2 Non-network options

HV distribution combination switchgear units' function as connection and isolation points for distribution substations as well as facilitating fault protection for the substation.

HV distribution combination switchgear is comprised of links to isolate the incoming and outgoing HV cables and a fuse to protect the distribution transformer (when installed in a substation).

The links facilitate flexibility in switching of the distribution network to minimise the extent of customer outages and the duration of outages during planned and unplanned works on the network and limit the extent of outages after faults. The switchgear also provides a means of creating three and four-way joints in underground cables on the distribution network.

There are no credible non-network solutions capable of replacing their functionality under the assumption that the substation is required. Upon functional or conditional failure of an HV distribution combination switchgear unit, the future requirement of the distribution substation should be considered on a site-specific basis prior to undertaking replacement of the asset.

Therefore, network options should be considered which include intervention to address the identified need.

5.3 Credible network options

Option	Description	
Proactive Replacement (with SF6 technology)	Replacement of HV distribution combination switchgear based on condition with SF6 technology. SF6 technology may also be connected to the SCADA network for remote and/or automated operation.	Credible option considered and has progressed for further assessment

Replacement of HV distribution combination switchgear units based on condition is considered a credible network option.

5.3.1 HV distribution combination switchgear replacement

Under this approach (option 1), the intervention includes the complete replacement of the HV distribution combination switchgear (with metal-clad switchgear from the current supply contract) in a planned proactive manner to allow for the retirement of the existing HV distribution combination switchgear.

An average nominal cost of $27,500 for replacement of each HV switchgear has calculated using the past five years of cost. This has been based on actual costs of previously delivered works and includes:

- Project Management;
- Design;

- Materials;
- Labour and plant; and
- Traffic management.

5.4 Economic evaluation

5.4.1 Option 1 – HV distribution combination switchgear replacement

The proposed program under Option 1, identifies 904 HV distribution combination switchgear 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 $570 million and provides a benefit of $43.0 million compared to the counterfactual case. The PV of the cost of Option 1 is $23.1 million and the NPV overall is $19.9 million.

The NPV of the proposed interventions is unique to each HV distribution combination switchgear and varies from $4,866 to $130,941 with an average of $22,018 across the 904 assets proposed for intervention during the period.

The benefit to cost ratio (BCR) for each HV switchgear site varies from 1.1 to 5.8 and averages 1.8 across the 904 HV distribution combination switchgear interventions.

Table 4 below provides a summary of the residual risk presented by this option. Refer Appendix A for details of the HV switchgear identified for intervention during the FY23 – FY29 period under this option.

Table 4 – Option 1 residual risk summary

Risk category	PV of residual risk ($M)	Risk proportion (%)
Safety	2	4
Reliability	352	62
Financial	31	5
Reactive capital replacement costs	165	29
Total	**570**	**100**

5.5 Evaluation summary

Table 5 below summarises the outcomes of the cost-benefit assessment the HV Switchgear replacement options for Endeavour Energy's fleet of 14,734 compared to the BAU (run-to-failure) case. The summary shows only the impact of investment in the HV switchgear whose NPV of intervention reaches its maximum value within the FY23 - FY29 period.

Table 5 – 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	-	613	-	-	-	2	Not preferred as shows excessive levels of risk
1. Replace HV Switchgear	Network	904	570	43.0	23.1	19.9	1	Preferred option as it reduces risk and provides a positive NPV.

Each intervention in the proposed program provides a positive NPV which also reaches its maximum value during the FY23- FY29 period and therefore provides the highest value compared to the BAU (run-to-failure) and to other timings for the interventions.

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 project. Refer Appendix C 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 in order 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 6 below.

Table 6 – Summary of scenarios investigated

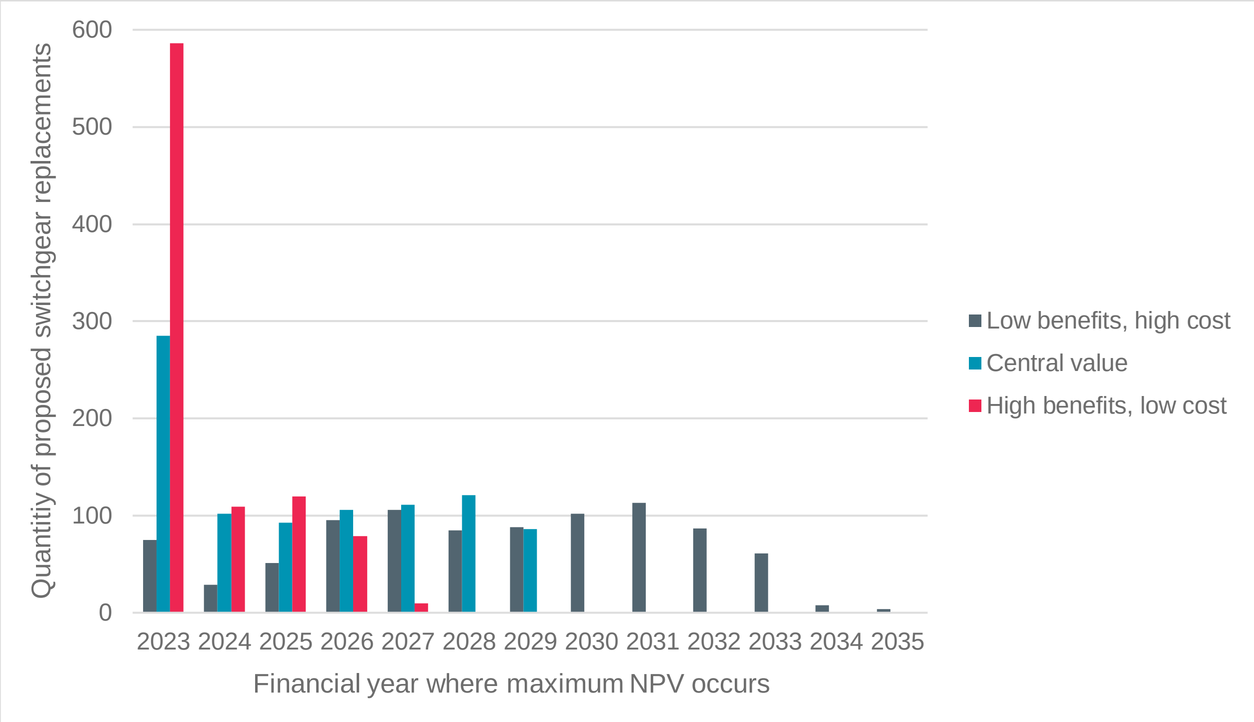
Variable	Scenario 1 – low benefits, high capital costs	Scenario 2 – central values	Scenario 3 – high benefits, low capital costs
Capital cost	5% increase in the estimated network capital costs	Estimated network capital costs	5% decrease in the estimated network capital costs
Value of risk (combination 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	5% 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	5% decrease in the Weibull β parameter (decreases the mean time to failure for the asset)

The impact on the preferred option (Option 1) NPV is shown in Table 7 below and the resultant spread of replacement years to give the maximum NPV for each of the 904 HV switchgear units identified for replacement under the preferred option is shown in Figure 2.

Table 7 – NPV of scenario analysis for the preferred option (Option 1)

Scenario	NPV of preferred option ($M)
Scenario 1 – Low benefits, high costs	10.9
Scenario 2 – Central risks and costs	19.9
Scenario 3 – High benefits, low costs	31.6

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 approximately 170 assets that ran-to-failure over the FY12-FY21 period to assist in determining the Weibull parameters.

Figure 2 above also shows that across the three sensitivity scenarios, the timing of the maximum NPV of the recommended 904 replacements are skewed towards FY23 out suggesting an appropriate level of investment for Option 1, which is the earliest year that the works can now be practically carried.

6. Preferred option details

6.1 FY23 – FY29 scope and timing

The preferred option is Option 1, which includes replacement of 904 HV switchgear units during FY23 – FY29. These asset replacements are in addition to existing scope that has previously been released and/or currently in progress of being delivered, as these have been removed from the analysis.

The overall cost of the proposed program is estimated to be $24.9 million (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 FY19-FY21 mean values with individual site's costs evening out to the mean across the program.

Note: All HV switchgear which are currently approved for replacement and whose works are in progress have been removed from the fleet of assets. Therefore, the proposed investments within this CFI only includes assets not currently approved for replacement.

6.2 Additional scope and timing

A further 605 HV distribution combination switchgear sites provide are NPV positive their maximum NPV within a 10-year forecast period (FY30-FY34). These 605 investments total a further $16.6 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 8 below.

All costs are in real FY23 terms.

Table 8 – Summary of investment for optimisation

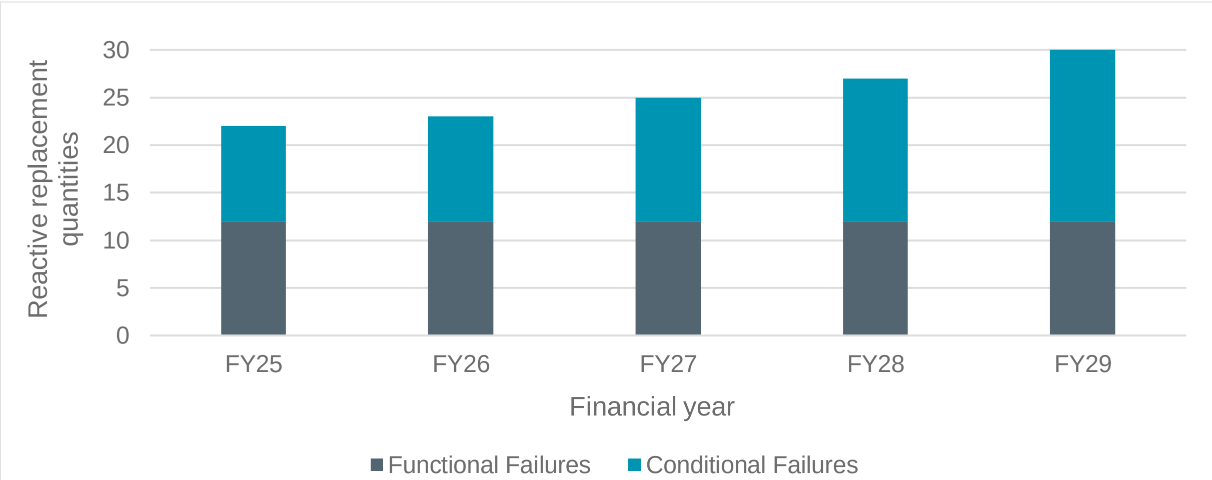
Intervention type	Unit rate ($)	Quantity of interventions	Total costs ($M)
HV Switchgear Replacement (NPV Max FY23-FY24)	27,500	387	10.65
HV Switchgear Replacement (NPV Max FY25-FY29)	27,500	517	14.25
Subtotal FY23-FY29		***904***	***24.90***
HV Switchgear Replacement (NPV Max FY30-FY34 – inclusion for optimisation)	27,500	605	16.60
Subtotal FY30-FY34		***605***	***16.60***
Totals		**1,509**	**41.50**

6.3.2 Reactive investment

Reactive modelling for the FY23 -FY29 period has forecast a further 127 HV Switchgear to 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. It is to be noted that the HV switchgear proposed for proactive retirement as part of this CFI have been excluded from the reactive modelling across this period.

Figure 3 below shows the forecast trend of reactive investment likely to be required for the replacement of failed HV distribution combination switchgear units into the future.

Figure 3 – Forecast reactive replacement quantities FY25-FY29



A reactive replacement cost, which takes account of the likelihood of damage to adjacent equipment but excludes the economic costs of a HV switchgear failure, has been averaged across the fleet of HV distribution combination switchgear to give an annual forecast of reactive funding requirements. To accommodate this eventuality, it is proposed that additional funding of $4.24 million (in real$ FY23 terms) be made available for reactive HV distribution combination switchgear replacement during the FY25 – FY29 period

Table 9 below, summarises the proposed reactive funding forecast.

All costs are in real FY23 terms.

Table 9 – Reactive replacement forecast

Regulatory control period (FY25-FY29)	Unit rate per reactive replacement ($)	Forecast quantity of failure interventions	Forecast reactive investment ($M)
Conditional Failures	27,500	67	1.84
Functional Failures	40,000	60	2.40
Total		**127**	**4.24**

6.4 Project scope of works

6.4.1 HV distribution combination switchgear replacement

HV switchgear units selected for either proactive or reactive replacement are to be replaced with metal-clad switchgear from the current supply contract and constructed in accordance with SDI183.

Repair or replacement of defective 11kV cable boxes in accordance with SMI 212 is expensed and not funded in as part of this CFI.

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 Option 1 for the proactive replacement of HV distribution combination switchgear 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.

It is further proposed, that an allowance for a further $4.24 million (in real $ FY23 terms) within the FY25-FY29 period for the reactive replacement of HV Switchgear 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. Attachments

Appendix A – Details of recommended scope for optimisation

Appendix B – Risk assessment variables

10. References

[1] Endeavour Energy, “Summer Demand Forecast 2022 - 2031,” Network Demand Forecasting Section, 2021

[2] Australian Energy Regulator, “D19-2978 - AER - Industry practice application note - Asset Replacement Planning,” AER, 25 January 2019

[3] “The Energy Charter,” theenergycharter.com.au, January 2019

[4] DS307 – Holec MD4 Epoxy HV Switchgear replacement program

Appendix A – 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 A – Details of recommended scope for optimisation.xlsx

Appendix B – Summary of key risk assessment variables and assumptions

General variables and assumptions

Parameter	Value	Description/justification	Source/assumptions
Population	14,734	Number of HV distribution combination switchgear in service in Endeavour Energy's (EE) network Resin type: 4,851 SF6 type: 9,883 (includes vacuum and unknown type where age profile suggests these are SF6 due to supply contract.	Ellipse database. Asset type HS. Combination Switchgear
Annual conditional failures	90	Defective equipment as identified and categorised as per TB 0236. Conditional failure defined as Category 2 and 3.	Historical inclusion into the DS307 program Ellipse defect workorder records Mars database
Annual functional failures	24	A functional failure is considered to be a failure of the cable termination and switchgear, causing safety, reliability, and/or financial impacts.	EE outage management system (OMS), Ellipse workorder records and anecdotal information.
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	100 years	The timeframe over which the cost-benefit analysis is performed	Risk Calculation Methodology V6.0 algorithm
Maintenance costs	$497 p.a.	Resin type: Major maintenance (10 yearly) = $3,511 Minor overhaul / inspection (3 yearly) = $439 Resin type receives on-going 10yearly major overhaul as an outcome of a failure-modes & effects analysis	Ellipse workorders
	$146 p.a.	SF6 type: Minor overhaul / inspection (3 yearly) = $439	Ellipse workorders
Planned and/or Condition based intervention costs – HV Switchgear replacement	$27,500	Replacement of existing Resin type or SF6 type switchgear with standard SF6 type	This estimate is based on actual costs of previously delivered works and includes: - Project Management - Design - Materials - Labour and plant - Traffic management Replacement Equipment type: Endeavour Energy's supply contract
Reactive intervention	$27,500	The costs of replacing a SF6 type HV switch after functional failure.	Ellipse workorders
	$40,000	Unit rate applied for the costs of replacing a Resin type HV switch after functional failure.	Ellipse workorders

Parameter	Value	Description/justification	Source/assumptions
Failure modes	Cable Termination	The main failure mode for HV switchgear is electrical discharge caused by the cable terminations via progressive partial discharge caused by environmental factors, operating conditions, and age. This leads to phase to earth fault leading to uncontrolled energy discharge. The energy discharge has the potential for the fibreglass cubicle door to be expelled at high velocity, for fire to engulf the substation and spread posing a threat to members of the public and or Endeavour workers in the case of an operation.	OMS data 2012 -2021 Ellipse Known failures reported by Regional staff
Asset age	Varies for each combination switchgear unit	Calendar age based on the in-service date compared to the year of assessment (2022) Where in-service date or the switchgear is not available, the in-service date is assigned based on the ages of the surrounding assets such as the distribution transformer or its supporting fitments.	Ellipse nameplate data SAP

Weibull failure probability parameters

Parameter	Value	Description/justification	Source/assumptions
α (Alpha)	Existing: - Resin type: 55years - SF6 type: 60 years Replacement: - SF6 type: 60 years	The "scale" parameter used for calculating probability of failure	Resin Type: Estimated to give a reasonable looking MTTF of around 40 years for Resin type switchgear correlates with the actual annual failure rates being experienced. SF6 Type: Estimated to give a reasonable looking MTTF of around 47 years for SF6 type switchgear and correlates with the actual annual failure rates being experienced. Weibull Curve generator_5(Version 1).xlsm
β (Beta)	4.0	The "shape" parameter used for calculating probability of failure function.	The generalised wear-out function shape for a normal distribution is 3.6. Weibull Curve generator_5(Version 1).xlsm
ψ (Gamma)	Existing: - Resin type: 10 years - SF6 type: 7.5 years Replacement: - SF6 type: 7.5 years	The "shift" parameter which gives a failure free period at the start of the asset's life.	OMS data 2012 -2021 Ellipse Known failures reported by Regional staff Weibull Curve generator_5(Version 1).xlsm

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 a serious injury	$2,249,000	44.1% of VoSL	GNV1119
Safety Public - LoC	$33	Fatality Disproportionate factor: 6.5 Cost of Consequence: $33,150,000 LoC: $1x10^{-6}$	RiskCat
	$1,560	Serious injury	RiskCat

Parameter	Value	Description/justification	Source/assumptions
		Disproportionate factor: 6.5 Cost of Consequence: LoC: $1x10^{-4}$	
	$1,560	Significant injury Disproportionate factor: 6.5 Cost of Consequence: LoC: $1x10^{-3}$	RiskCat
Safety Worker	$33	Fatality Disproportionate factor: 6.5 Cost of Consequence: $33,150,000 LoC: $1x10^{-6}$	RiskCat
	$1,560	Serious injury Disproportionate factor: 6.5 Cost of Consequence: LoC: $1x10^{-4}$	RiskCat
	$1,560	Significant injury Disproportionate factor: 6.5 Cost of Consequence: LoC: $1x10^{-3}$	RiskCat

Reliability risk inputs

Parameter	Value	Description/justification	Source/assumptions
Loss of supply to customers - LoC	100%	Functional failures result in loss of supply	OMS data 2012-2021
Load impacted	Varies based on the HV feeders and distribution substations supplied by each HV switchgear assessed.	The summer maximum demand of the substation	Spreadsheets based on 2020 Summer Maximum Demand planning report
Load factor (HV Feeder)	Site specific. Varies by asset location. 50% of summer maximum demand	Total load effected is assumed to be lost is 50% of the summer maximum demand value for the supplied substation(s) Load proportion of the each HV feeder is divided into either its Commercial % and/or its Residential %.	Source – studies by Protection Manager. Spreadsheets based on 2020 Summer Maximum Demand planning report.
Load factor (Distribution Substation)	Site specific. Varies by asset location. 7.5% of rated distribution transformer capacity	DSUB typically installed with 50% redundancy to pick up load of local DSUB if required. Latest DSNP benchmarking indicated on average EE's DSUB @ 15% utilisation 50% * 15% = 7.5%	DSUB rated transformer capacity as per Ellipse nameplate data
VCR	Varies based on the HV feeders and distribution substations supplied by each HV switchgear assessed.	Value of customer reliability for an occasional short-term outage	Values and methodology published by the AER AER – Value of Customer Reliability 18/12/20

Parameter	Value	Description/justification	Source/assumptions
Duration of interruption	Restoration Stage 1: 1 hour Restoration Stage 2: 2hours Restoration Stage 3: 6hours	Outage Stage 1: HV feeder supply effected from initial failure for 1hour while fault is identified, and network configuration sectionalise the HV switchgear. Outage Stage 2: HV feeder Restored. 100% of DSUB load effected for 2hrs as LV backfeeds closed-in. Outage Stage 3: HV feeder Restored. 50% of DSUB load restored with backfeeds 50% of remaining DSUB customer effected for 6hrs HV Swgr replaced and then supply fully restored o alternate arrangements are made for supply through temporary mobile generator.	A generalised value based on a range of outages of HV switchgear assets. Assumes off-loading to reinstate supply through a combination of SCADA and manual switching.

Financial risk inputs

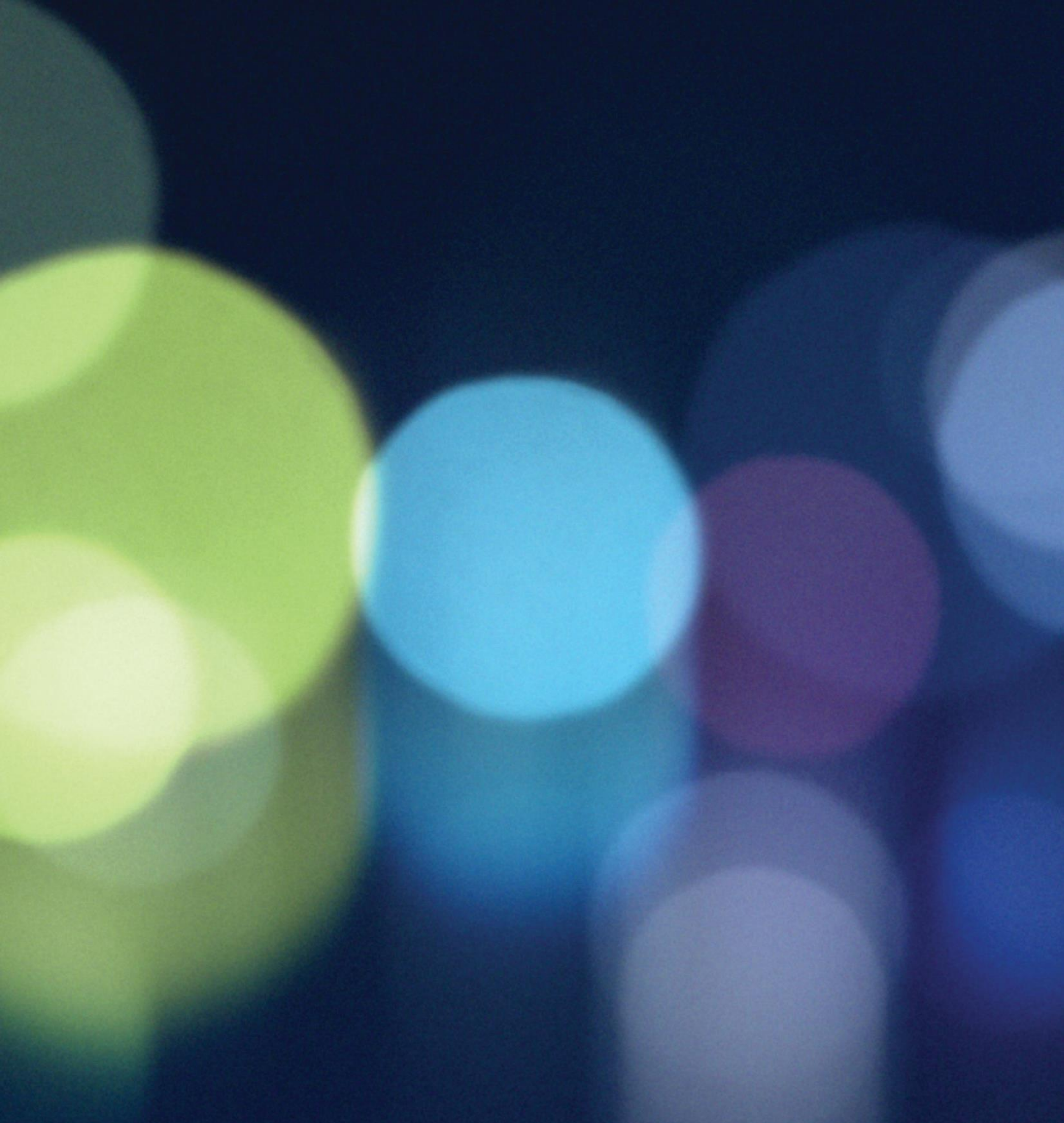
Parameter	Value	Description/justification	Source/assumptions
Financial general	$17,700	Damage cost repairs to localised equipment as the result of a functional failure of the HV switchgear.	Ellipse work orders

Bushfire risk inputs

Parameter	Value	Description/justification	Source/assumptions
N/a			

Environmental risk inputs

Parameter	Value	Description/justification	Source/assumptions
N/a			



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