SUBSTATION BUILDING AND AMENITIES FAILURE RISK MITIGATION

Case for investment FY23:
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Endeavour Energy

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1. Executive Summary

This case for investment (CFI) recommends the provision of capital for the reactive refurbishment or replacement of substation building and civil assets that fail within the FY23-FY29 period.

The recommendation is made on the basis that under the current reactive intervention strategy for this asset class, reactive refurbishment/replacement of civil assets based on conditional failure provides a higher economic benefit than other credible options considered.

The civil assets addressed by this case for investment include:

- Control buildings (excluding the roofs which have their own program of refurbishment/replacement)
- Driveways and access roads
- Retaining walls
- Stormwater and drainage systems; and
- Switchyard surfaces

Failure of building and civil assets can include physical failures, collapse, or essential service interruptions that may result in a loss of served power, personal injury and or environmental and financial impacts. The primarily risk associated with a civil asset failure is the inconvenience caused by loss of access and amenity, and the subsequent impact on the ability of network operational activities to be undertaken in a safe and timely manner.

The possible consequences of a civil asset failure include:

- Safety Impacts: Injury to people due to slip, trip and fall hazards resulting from the failure of driveways, retaining walls and switchyard surfaces. There is also a risk of electrocution if electrical pits become flooded and increased step and touch potential associated with the reduction in resistivity of switchyard surfaces due to gravel loss or drainage failure.
- Reliability impacts: Failure of civil assets may restrict access and mobility around network sites, impacting response times for crews to attend faults and outages.
- Financial impacts: The additional costs associated with clean-up after a failure and the repair/replacement of any assets, equipment or vehicles which are damaged or affected.
- Environmental Impacts: Costs for remediation of erosion caused by the failure of a civil asset or fines for pollution incidents deemed to result from environmental negligence.
- Bushfire Impacts: No significant bushfire consequences have been experienced or are anticipated for future failures of civil assets.

Civil assets 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 civil assets 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 within this CFI at this time for optimisation.

The business as usual (BAU) scenario for addressing the risk of a civil asset failure is reactive intervention to refurbish or replace assets based on “conditional failure”. Conditional failure is indicated by poor condition such as extensive and advanced corrosion or damage. (The civil asset is still functional but close to failing functionally). While conditional failure of civil assets present little immediate risk, a cascading failure can materialise following the functional failure of individual assets. For example, a stormwater or drainage systems failure can impact the stability of surrounding structures and lead to the premature failure of further assets.

This CFI demonstrates the risks exposed by the BAU scenario are low, and on this basis, proactive refurbishment/replacement is not warranted as this will give similar low levels of residual risk to the BAU, but at higher levels of investment. The highest economic value is provided by the BAU reactive intervention solution and is therefore the preferred option for addressing risks associated with building and civil asset failures. Continued investment into the reactive intervention strategy is recommended in this CFI.

Based on observed historical conditional failure data of civil assets, it is forecast that approximately 17 driveways or access roads, 17 switchyard surfaces, 14 stormwater or waste systems and 7 retaining walls will require reactive refurbishment/replacement across the FY23 – FY29 period.

To accommodate this eventuality, it is proposed that funding of $6.65 million in real FY23 terms be made available for reactive civil asset refurbishment during the FY23 – FY 29 period. A contingency has not been proposed as the unit rates used in this forecast are based off mean values of costs accrued from Endeavour Energy's historical interventions.

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.

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 aging building and civil assets including roads, driveways, switchyard surfaces, retaining walls and drainage networks at zone and transmission substations and switching stations.

This case for investment (CFI) recommends the provision of capital for the reactive refurbishment or replacement of substation building and civil assets that experience conditional failure within the FY23-FY29 period.

3. Identified needs and or opportunities

3.1 Background

Endeavour Energy currently has 203 sub-transmission sites across the network, ranging in age from new to 67 years of age. Each substation site employs a range of civil assets including buildings, driveways, access roads, retaining walls, stormwater and drainage systems and surfaced areas to provide safe access and protect primary plant and equipment.

Building and civil assets which are in poor condition pose risks to the safe and reliable operation of the network. Failure of civil assets become more likely with age, presenting an ongoing challenge to the serviceability of the substation, as assets reach their end of life and require refurbishment or replacement.

For a substation to remain serviceable, the roads, driveways, switchyard surfaces, retaining walls and drainage networks must also be maintained in a serviceable condition. This requires ongoing capital investment that matches the rate of deterioration of the assets. Timely replacement of deteriorating assets can contribute to the availability and reliability of the network.

Functions of the major civil assets are:

1. Driveways and access roads – provide safe access to the substation for workers, delivery partners, heavy vehicles and emergency services.
2. Switchyard gravel – increase resistance and reduce ground potential rise - step and touch voltage, prevent vegetation growth and provide an adequate surface for all-weather access to the switchyard.
3. Retaining walls – retain sloping ground to provide for level and well drained switchyard surfaces.
4. Stormwater and drainage network – collect surface and ground water, directing it away, thereby keeping substation buildings and switchyard ballast drained, protecting the site from becoming sodden and unstable.
5. Building components – support, enclose and protect the substation primary plant and equipment.

In accordance with Substation Maintenance Instruction SMI 100 [1], all zone and transmission substations and switching stations are inspected on a bi-annual cycle. SMI 106 [2], includes inspection of both the internal and exterior of the buildings for evidence of damage or corrosion, and inspection of switchyards to monitor the effectiveness of site drainage, identify water leaks and monitor vegetation growth. These inspections provide the opportunity for the condition of civil assets to be noted and allow for a “conditional failure” (ie: the asset is in poor condition) to be reported.

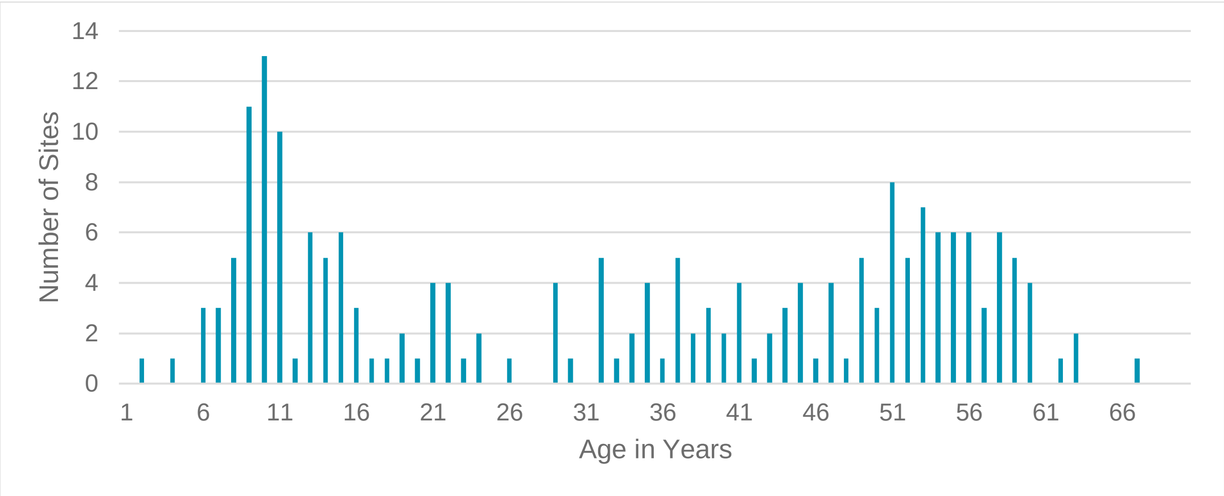
Condition information is gained from inspection reports carried out during routine inspections and targeted condition audits and assessments. Endeavour Energy then programs maintenance or proposes capital works when required by the observed condition and potential risks.

Maintenance works carried out in accordance with Substation Maintenance Instruction SMI-106 include preventative maintenance and minor repairs, however capital works carried out under program TS024 – *Substation building and amenities refurbishment*, have included:

- Refurbishment of driveways and access roads
- Repair and renewal of stormwater and drainage systems
- Re-applying gravel to switchyard surfaces; and
- Refurbishment or replacement of building components (doors, windows, ceilings, walls, flooring, security and fire systems)

The age of Endeavour Energy's fleet of zone and transmission substations and switching stations range in age from new to 67 years old. This is shown in **Error! Reference source not found.** below.

Figure 1: Age profile of Endeavour Energy sub-transmission sites



3.2 Risks and identified need

The primary risk associated with a substation civil asset failure is the limited access or amenity, and subsequent impact on the ability of network operational activities to be undertaken in a safe and timely manner.

While conditional failure of civil assets present little immediate risk, they can progress rapidly to a functional failure which can then readily cascade to further functional failures. For example, a stormwater or drainage failure can reduce the subgrade stability of surrounding structures, undermining the bearing capacity of retaining walls or switchyard structures etc, and lead to the premature failure of further assets.

Building and civil assets can be expected to fail at an increasing rate the older they become due to wear and tear, exposure to environmental conditions, corrosion and erosion. The serviceable life of an asset is affected by a complex interaction of factors including material characteristics, utilisation, environmental factors, construction and maintenance methods.

The failure of assets usually progress from initially being "conditional", ie: the appearance of cracks, corrosion or wear and tear etc, and then degrade to a "functional failure" over time. Typical failure indicators, causes and impacts are detailed in Table 1.

Table 1: Summary of civil asset failure modes

Asset type	Failure mode	Cause of failure	Consequences of failure
Driveways and roads	Cracking, pot-holes, rutting, stripping and ravelling	Poor drainage, over loading, material fatigue, ground settlement, construction joint failure, ingress of moisture over time.	Safety impact – slip, trip and fall hazard. Financial impact – vehicle damage Reliability impact - Increased response times due to access restrictions Environmental impact – erosion and sediment issues
Switchyard gravel	Contamination, erosion, gravel loss, reduced depth, rutting	Poor drainage, poor subgrade compaction, heavy vehicle movements	Safety impacts - Reduced resistivity, increased step and touch potential, trip hazards. Reliability impact - Increased response times due to access restrictions Financial impact – rehabilitation costs, equipment repair Environmental impact – erosion, vegetation growth.
Stormwater and waste systems	Collapsed, blockage, leakage, deterioration	Pipe damage, tree roots, heavy vehicle movements, ground settlement, joint failure, material fatigue	Safety impacts - flooding of cable pits and trenches, electrical hazards, increased step and touch potential Financial impact - damage to civil structures Reliability impact - Increased response times due to access restrictions Environmental impact - erosion and polluted water leaving site
Retaining walls	Bearing failure, over-turning, cracking, deterioration	Poor drainage, ground settlement, poor subgrade compaction, material fatigue	Safety impact – slip, trip and fall hazard. Financial impact - damage to civil structures, clean up costs Reliability impact - Increased response times due to access restrictions Environmental impact - erosion and or turbid water leaving site
Building components	Wear, distortion, corrosion, deterioration, damage, malfunction	Age, wear and tear, exposure to environmental conditions	Safety impact - loss of amenity, reduced risk mitigation. Financial impact – clean-up costs Reliability impact - Increased response times due to access restrictions Environmental impact – disposal of hazardous materials

A common failure mode of a substation driveways or access roads is cracking and pot holing following an ingress of moisture which undermines the sub-base material, resulting in reduced load bearing capacity and failure of the road surface. This type of failure can present a trip hazard for personnel working onsite or required to attend at night. If left to deteriorate further an increasing risk of vehicle damage when driving over deep pot-holes could result. A recent example of this failure mode is shown in Figure 2 below

Figure 2: Driveway surface deterioration at Minto ZS

Substation switchyards are surfaced with high resistivity gravel to reduce ground potential rise and protect workers from step and touch potential while working on live equipment. Switchyard gravel also provides drainage and prevents vegetation growth. The gravel loss shown in Figure 3, demonstrates a switchyard surface conditional failure.

Figure 3: Smithfield ZS switchyard gravel depth < 20mm

Common signs that a retaining wall is failing include cracking in the wall, bulging or deflection of the face, or tilting of the wall. Examples of retaining wall conditional failure are provided in Figure 4 below.

Figure 4: Retaining walls in poor condition at Figtree ZS and Colo Heights generator station

It is noted, the failing blockwork wall at Colo Heights generator station is an example of premature failure due to poor quality of materials and workmanship.

4. Consequence of nil intervention

4.1 Consequences of nil capital intervention

The nil capital intervention scenario involves not carrying out any capital works. This would see all civil assets deteriorate to functional failure and not be refurbished or replaced.

The consequences of this would include:

- Access into sites would eventually become non-trafficable. Work program delivery would be impacted as operational activities become limited to pedestrian movements.
- Increased safety risk resulting from reduced site amenity and stability.
- Additional costs associated with amendment to work methods.
- Potential fines should sanitary and pollution mitigation systems be allowed to fail.

Although maintenance works would still be carried out, this would not prevent the deterioration of assets which occurs over time due to wear and tear and exposure to the elements.

On the basis that substations are required for the safe and reliable operation of the network, the nil capital intervention scenario is not practicable and will not be considered further in this CFI.

The risk of asset failure generally follows a probability of failure (PoF) curve. Based on the age at failure for past failures, a Weibull distribution curve can be developed to describe the probability of failure for the existing fleet of assets.

Table 2 provides the probable age of failure for each major civil asset. The forecast number of failures for each asset is expected to increase based on the age profile and assessed mean life of the asset.

Table 2: Weibull distribution for civil assets

Asset type	Mean no. annual failures	Forecast no. of failures	Expect mean life
Driveways and roads	1.6	2.5	63
Switchyard gravel	0.6	2.5	63

Asset type	Mean no. annual failures	Forecast no. of failures	Expect mean life
Stormwater and waste systems	0.9	2.0	68
Retaining walls	0.3	1.0	77
Building components	-	-	50

4.2 Counterfactual (business as usual)

The business as usual (BAU) scenario includes regular inspection of sub-transmission sites and taking action to maintain and or carry out capital works to refurbish or replace civil assets when assessed as reaching a state of conditional failure. Nil proactive capital intervention is carried out, but action is taken before the assets fail functionally, provided the service is still required.

The scope of works under the BAU include:

- Inspection and maintenance
  - On a bi-annual cycle, Endeavour Energy inspects the condition of all substation sites and programs maintenance.
  - Maintenance works are carried out in accordance with SMI-106, which includes inspection of buildings for evidence of damage or corrosion, and switchyards to monitor the effectiveness of site drainage, identify water leaks and monitor vegetation growth.
- Reactive action for either the refurbishment or replacement of civil assets, typically before the occurrence of a major failure.

The risks associated with the BAU approach include:

1. That a conditional failure will not be identified before it escalates to a functional failure;
2. The conditional assessment of civil assets can be complex and there is a risk that an asset is in worse condition than assessed and therefore timely intervention is not programmed; and
3. An asset identified as having reached conditional failure deteriorates rapidly and fails before it can be refurbished or replaced.

Table 3 below summarises the risks associated with the BAU case to give the consequences of failure (CoF) for a civil asset once it has been identified as a conditional failure.

Various failure modes, likelihood and consequence elements make up the risk cost.

Table 3: BAU risk costs

Risk category	risk ($M)	Risk proportion (%)
Safety	0.13	0.5
Environmental	0.06	0.3
Financial	0.12	0.5
Reliability	0.79	3.2
Reactive capital replacement costs	23.72	95.5

Risk category	risk ($M)	Risk proportion (%)
Total CoF	**24.82**	**100**

As shown in Table 3, the risk presented by the current BAU approach, is very low. On this basis, proactive refurbishment / replacement solutions for civil assets are not warranted as these will give similar low levels of residual risk to BAU, but at higher levels of investment, resulting in lower overall value. Therefore, the current reactive intervention strategy for addressing substation civil asset failures remains the preferred approach.

5. Options Considered

5.1 Risk treatment options

A range of options have been considered to address the risk presented by civil assets being assessed as an alternative to network investment. These approaches are summarised in Table 4 below.

Table 4: Civil asset risk treatment options

Option	Assessment of effectiveness	Conclusion
Additional maintenance to extend the life of the existing asset	Current maintenance practises include minor or temporary repairs. It is not considered to be economically efficient to extend the maintenance practices to include re-construction or bulk replacement etc. However, current maintenance standards could be reviewed to ensure early identification of failure modes.	No technically feasible solution
Reduce the load on the asset through network reconfiguration, network automation, demand management or other non-network options	The risk of civil asset failure is independent of substation supply load. Due to the primary function of civil assets, there is no non-network option to replace the functionality.	No technically feasible solution
Implementing operational controls such as limiting or restricting access.	These controls can be put in place to mitigate the safety risks to workers, however will likely increase response times for crews to attend faults and outages, impacting network availability.	Not economically feasible.
Staged replacement to maintain option value and reduce the consumer's long-term service cost	Proactive and reactive refurbishment or replacement programs to ensure the extension of life for civil assets at network sites	Recommended approach for further consideration.

5.2 Non-network options

Civil assets including buildings, driveways, switchyard surfaces, retaining walls and drainage networks provide the amenity for safe and reliable network operations within sub-transmission sites. With minimal risk presented by the current BAU approach to managing these assets, nil proactive intervention is required and therefore consideration of non-network solutions which could replace the functionality is also not required.

5.3 Credible network options

Table 5: Credible network options – civil asset intervention

Option	Description	
Civil asset refurbishment	Refurbishment may be applied to restore civil assets which have experienced a conditional failure or a minor functional failure.	Credible option considered and has progressed for further assessment
Civil asset replacement (Like-for-like)	Under this option, the intervention includes replacement of existing civil assets to allow retirement of the failed asset.	Credible option considered and has progressed for further assessment

The option to refurbish or replace civil assets is based on the age, condition, replacement cost and consequences of failure of each asset and site. Refurbishment is considered when assessed as adequate to prolong the remaining life of the asset. For example, the topping up substation gravel would be appropriate where gravel loss has occurred within a switchyard at a non-uniform rate, as this treatment would return the asset to an "as new" or equivalent state. Generally, refurbishment is an option alongside full replacement and utilised for minor conditional failures.

Replacement of assets will provide the maximum additional life and is required whenever an asset experiences a major conditional or functional failure. This option provides certainty regarding deferral of risk. Both refurbishment and replacement form part of the same reactive intervention option with the most appropriate approach to be assessed for each asset and site.

5.4 Proactive replacement

Civil assets 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 civil assets 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 within this CFI at this time for optimisation.

5.5 Evaluation summary

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

5.6 Economic evaluation summary

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

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

6. Preferred option details

The preferred option for managing the risk posed by aging building and civil assets is reactive intervention to either refurbish or replace assets experiencing conditional failure and therefore extend the serviceable life of the network site.

6.1 FY23 – FY29 scope and timing

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

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

Civil assets 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 civil assets 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 within this CFI at this time for optimisation.

6.3.2 Reactive Investment

During the FY23 - FY29 period, it is estimated an increasing number of substation civil assets will experience conditional failure and become candidates for refurbishment or replacement.

Table 6 below provides the forecast expenditure for each of the major substation civil assets, based on mean refurbishment/replacement actual costs and the forecast number of annual failures.

Table 6: Program forecast

Asset type	Mean cost of failure ($)	Forecast annual failures	Forecast expenditure ($M)
Driveways and roads	142,000	2.5	0.35
Switchyard gravel	85,000	2.5	0.21
Stormwater and waste systems	74,000	2.0	0.15
Retaining walls	115,000	1.0	0.12
Building components	120,000	-	0.12
Total forecast			**0.95**

Based on observed historical conditional failure data of civil assets identified, it is forecast that approximately 17 driveways or access roads, 17 switchyard gravel surfaces, 14 stormwater or waste systems and 7 retaining walls will require refurbishment or replacement across the FY23 – FY29 period.

To accommodate this eventuality, it is proposed that funding of $6.65million in real FY23 terms be made available for reactive civil asset refurbishment or replacement during the FY23 – FY 29 period.

This forecast allows for project management, design, material, plant, labour and supervision. It is based on actual costs of previously delivered works when carrying out the TS024 Building and amenities refurbishment program and assumes the average refurbishment costs over the past 10 years will provide a reasonably accurate basis for similar future works. These costs may need to be updated as the process of carrying out this work is developed and refined over time.

A contingency is not proposed to be applied as the estimated costs are based on mean values with individual costs evening out over the program. Furthermore, there is considerable experience carrying out this type of work and therefore the cost estimates are considered to be reasonably firm on a program wide basis.

Figure 5: Forecast investment

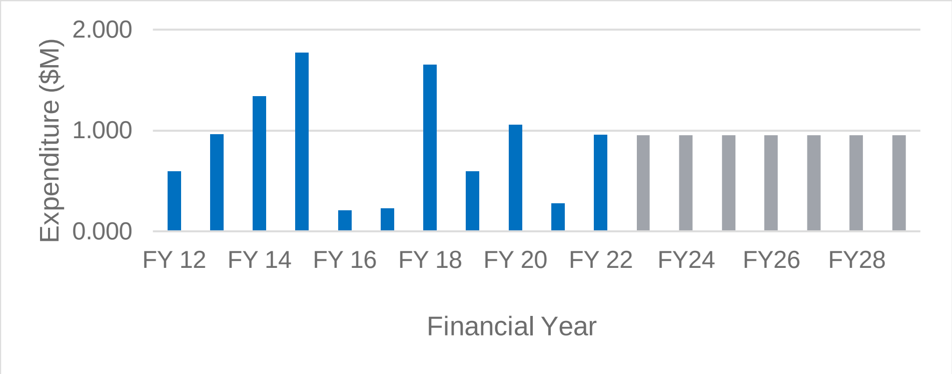


Figure 5 demonstrates the actual costs and forecast expenditure for refurbishment/replacement of civil assets at sub-transmission sites. The forecast expenditure represents an 8 percent increase on the mean annual costs over the past 10 years. This level of investment is required to address the forecast number of conditional failures considering the quantum of assets in the 50+ year range.

6.4 Scope of Works

The proposed scope of works allow for the refurbishment or replacement of building and civil assets at sub-transmission sites that experience conditional failure within the FY23 – FY29 period. The Delivery Design Manager is to verify the specific scope of works required for the refurbishment/replacement of each asset, however typically the scope will include all design, procurement, hiring of subcontractors, materials, plant, equipment, construction work and traffic management.

Works generally consist of the following:

- Refurbishment of driveways and access roads;
- Resurfacing of switchyard blue metal areas;
- Replacement of building components at end of life;
- Refurbishment of flood prevention and stormwater drainage systems;
- Refurbishment or replacement of failing retaining walls
- Renewal of plumbing and sewerage systems;

The scope must always include:

- WAE documentation, including update of SAP; and
- Disposal of waste.

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 a reactive program to refurbish/replace building and civil assets at sub-transmission sites that conditionally fail between the FY23 – FY29 period, be included in the PIP and proceed to the investment portfolio optimisation stage.

It is recommended that a total of $6.65 million (in real FY23 terms) be provided for refurbishment/replacement works as detailed in Table 7 below.

Table 7: Recommended reactive refurbishment/replacement funding

Intervention year	Total costs ($M)
FY23 – FY24	1.90
FY25 – FY29	4.75
Totals	**6.65**

9. Attachments

Appendix A – Assumptions and common values for investment planning
Appendix B – BAU risk costs

10. References

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

[2] Endeavour Energy, Substation Maintenance Instruction : Zone and transmission substation accomodation - SMI106 Amendment 12, 31 August 2016.

[3] Environmental Protection Authority NSW, Regulatory Policy, Parramatta, NSW: NSW Environment Protection Authority, December 2021.

Appendix A – Assumptions and common values for investment planning

General

Parameter	Value	Description/Justification	Source/Assumptions
Population	203	Number of Substations in service	Endeavour Energy's Ellipse database
Annual number of failures	1.6	Mean number of driveway and road remediation projects undertaken between 2012 & 2021.	Endeavour Energy's defect data via Ellipse workorders
Annual number of failures	0.6	Mean number of switchyard resurfacing projects undertaken between 2012 & 2021.	Endeavour Energy's defect data via Ellipse workorders
Annual number of failures	0.9	Mean number of stormwater and drainage system remediation projects undertaken between 2011 & 2021.	Endeavour Energy's defect data via Ellipse workorders
Annual number of failures	0.3	Mean number of retaining wall remediation projects undertaken between 2011 & 2021.	Endeavour Energy's defect data via Ellipse workorders
WACC	3.26%	Weighted average cost of capital	Regulated rate
Reactive intervention cost	$142,000	Mean cost of driveway and road remediation works completed under the TS024 building and amenities refurbishment program between 2012 & 2021	Based on actual costs of previously delivered works
Reactive intervention cost	$85,000	Mean cost of switchyard resurfacing works completed under the TS024 building and amenities refurbishment program between 2012 & 2021	Based on actual costs of previously delivered works
Reactive intervention cost	$74,000	Mean cost of stormwater and hydraulic system remediation works completed under the TS024 building and amenities refurbishment program between 2012 & 2021	Based on actual costs of previously delivered works
Reactive intervention cost	$115,000	Mean cost of retaining wall remediation works completed under the TS024 building and amenities refurbishment program between 2012 & 2021	Based on actual costs of previously delivered works

Weibull Parameters

Driveways and roads

Parameter	Value	Description/Justification	Source/Assumptions
$\beta_{functional}$	4.0	The shape parameter, also known as the Weibull slope, used for calculating probability of failure.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.
$\eta_{functional}$	70.0	The scale parameter used for calculating probability of failure. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.
$\gamma_{functional}$	0.0	The shift parameter used for calculating probability of failure	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.

Gravel

Parameter	Value	Description/Justification	Source/Assumptions
$\beta_{functional}$	3.6	The shape parameter, also known as the Weibull slope, used for calculating probability of failure.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.
$\eta_{functional}$	70.0	The scale parameter used for calculating probability of failure. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.
$\gamma_{functional}$	0.0	The shift parameter used for calculating probability of failure	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.

Stormwater and waste systems

Parameter	Value	Description/Justification	Source/Assumptions
$\beta_{functional}$	3.6	The shape parameter, also known as the Weibull slope, used for calculating probability of failure.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.
$\eta_{functional}$	75.0	The scale parameter used for calculating probability of failure. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.
$\gamma_{functional}$	0.0	The shift parameter used for calculating probability of failure	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.

Retaining walls

Parameter	Value	Description/Justification	Source/Assumptions
$\beta_{functional}$	3.6	The shape parameter, also known as the Weibull slope, used for calculating probability of failure.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.
$\eta_{functional}$	85.0	The scale parameter used for calculating probability of failure. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.
$\gamma_{functional}$	0.0	The shift parameter used for calculating probability of failure	Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.

Appendix B - BAU risk costs

Risk Category	Risk description	Risk outcome	Cost of Consequence (CoC)	Likelihood of Consequence (LoC)	Consequence of Failure (CoF) ($)
Safety	Driveway or road experiences conditional failure and cause of slip, trip, fall injury or motor vehicle accident	Serious injury to personnel, pedestrian or motorist.	$2,249,100	0.025%	562
	Switchyard surface deteriorates, reduced step and touch potential protection, when substation experiences fault and is occupied	Injury or fatality of EE personnel due to exposure to step and touch potential risks	$5,100,000	0.005%	255
	Substation experiences a major stormwater, GPT, or waste system failure	Injury of EE personnel due to exposure to pathogens	$2,249,100	0.0125%	281
	Substation retaining wall fails, injuring occupant or creating hazard which may lead to injury.	Injury of EE personnel due to slip trip or fall. Injury following collapse of wall	$2,249,100	0.0625%	1406
	Injury due to failed building component	Injury of EE personnel	$2,249,100	0.01%	225
	Total safety risk				**2,729**
Environmental	Driveway or road experiences conditional failure affecting environmental control measures	Water pollution or erosion event occurs resulting in fine from EPA	$10,000	0.125%	125
	Switchyard surface experiences conditional failure affecting drainage and erosion controls	Pollution or erosion occurs resulting in fine from EPA	$10,000	0.25%	250
	Substation experiences a major stormwater, GPT, or waste system failure	Pollution or erosion occurs resulting in fine from EPA	$10,000	0.5%	500
	Substation retaining wall fails, affecting drainage and erosion controls	Pollution or erosion occurs resulting in fine from EPA	$10,000	0.125%	125
	Environmental incident due to failed building component	Pollution or erosion occurs resulting in fine from EPA	$10,000	0.001%	1
	Total environmental risk				**1,001**

Risk Category	Risk description	Risk outcome	Cost of Consequence (CoC)	Likelihood of Consequence (LoC)	Consequence of Failure (CoF) ($)
Reliability	Civil asset failure for transmission substation	No loss of supply to customers	VCR value ($/MWh)	0.0%	0
		Loss of supply to 50% of substation load	VCR value ($/MWh)	0.1%	0.0028
		Loss of supply to 100% of substation load	VCR value ($/MWh)	0.00%	0
	Total reliability risk for transmission substation (x peak load of substation)				**0.0028**
	Civil asset failure for zone substation	No loss of supply to customers	VCR value ($/MWh)	0.0%	0
		Loss of supply to 50% of substation load	VCR value ($/MWh)	0.1%	0.0028
		Loss of supply to 100% of substation load	VCR value ($/MWh)	0.0%	0
	Total reliability risk for zone substation (x peak load of substation)				**0.0028**
Financial	Driveway or road experiences conditional failure	Costs for repairs of pavement, environmental remediation and repair	$20,000	1.25%	250
	Switchyard surface experiences conditional failure	Costs for repairs of sub-base, and environmental remediation	$20,000	1.25%	250
	Substation experiences a major stormwater, GPT, or waste system failure	Costs for contamination clean up and environmental remediation	$50,000	2.5%	1250
	Substation retaining wall fails	Costs for clean up and disposal of debris	$20,000	1.87%	375
	Failure of building components	Costs for clean up	$10,000	0.5%	50
	Total financial risk				**2,175**

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