Revised Proposal

Attachment 5.13.M.9

Distribution Substations program CBA summary

January 2019

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Distribution Substations program CBA summary

Introduction

Ausgrid has reviewed the risks associated with Distribution Substations by undertaking a quantitative risk assessment. Ausgrid has specifically analysed substations of kiosk and outdoor enclosure construction. This document covers the outcomes of cost benefit analysis, and should be reviewed in conjunction with the cost benefit analysis (CBA) modelling methodology report[1].

Scope

This model covers a portion of the forecast mapped to the following RIN categories:

- Transformers - Kiosk Mounted; <=22KV; >60 KVA & <=600 KVA ; Multiple Phase
- Transformers - Kiosk Mounted; <=22KV; >600 KVA ; Multiple Phase
- Transformers - Ground Outdoor/Indoor Chamber Mounted; <22 KV; >60 KVA & <=600 KVA; Multiple Phase
- Transformers - Ground Outdoor/Indoor Chamber Mounted; <22 KV; >600 KVA; Multiple Phase
- Switchgear - <=11KV; Fuse
- Switchgear - <=11KV; Switch
- Switchgear - < = 11 KV; Circuit Breaker

Due to the complex composition of a distribution substation being a combination of different assets that together function as a distribution substation, analysis was completed on the individual components of the substations and then summated together to achieve an overall risk cost that could then be compared to the annual deferral benefit of replacing the entire substation. The 11kV switchgear have been modelled separately and included in other attachments. The distribution transformers, LV equipment and housing were additionally analysed to construct a combined substation model.

The equipment contained within a substation that is supported for replacement under a separate model (11kV switchgear), was excluded from the specific equipment program to realise synergies across multiple replacement drivers.

Analysis Outcome

The analysis was completed using historical data up to and including FY18. The CBA models forecast risk from FY19 onwards. The quantities included in FY19 are reflective of Ausgrid's committed program in this year.

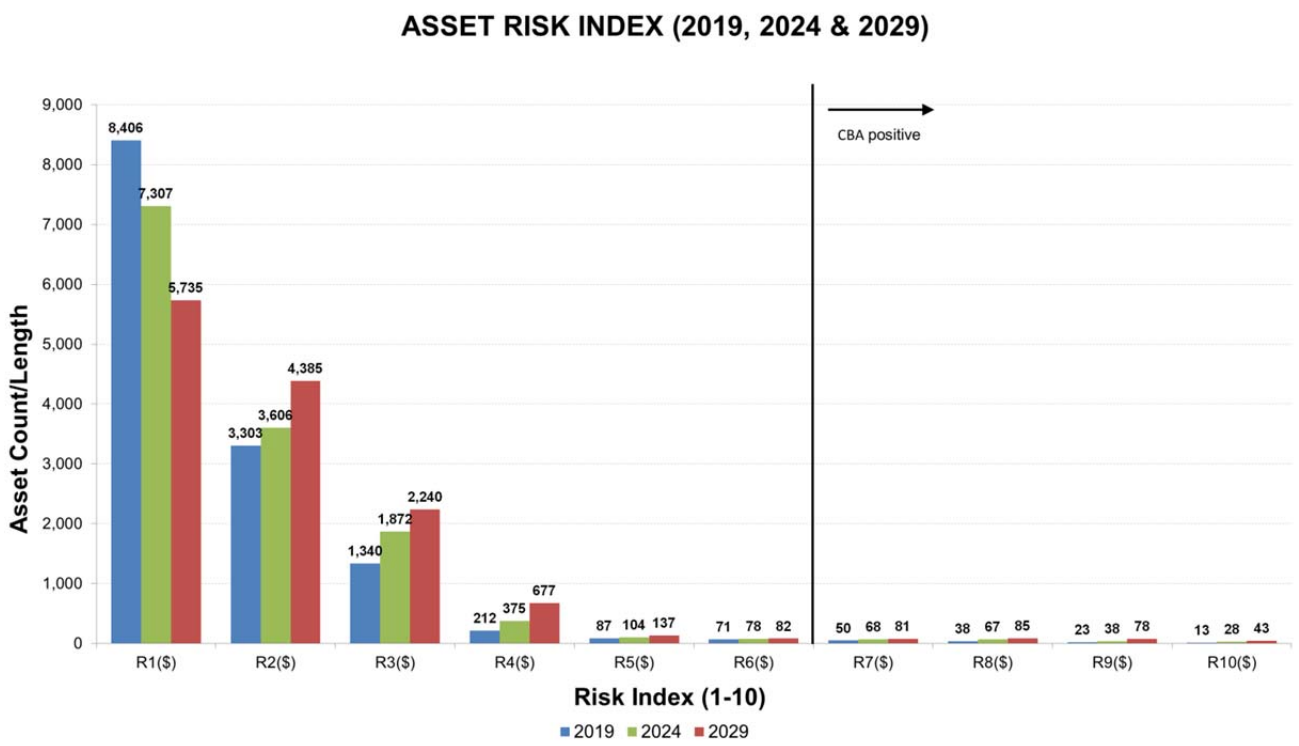
Based on the analysis completed, the model output is supporting the replacement of 201 distribution substations by the end of FY24. This includes a total of 27 distribution substations which have been committed in FY19.

In forming this decision Ausgrid considered three options and performed sensitivity analysis as described in this document. Ausgrid is recommending Option 3 – levelled replacement of all assets cost benefit positive by the end of FY24 for this asset category.

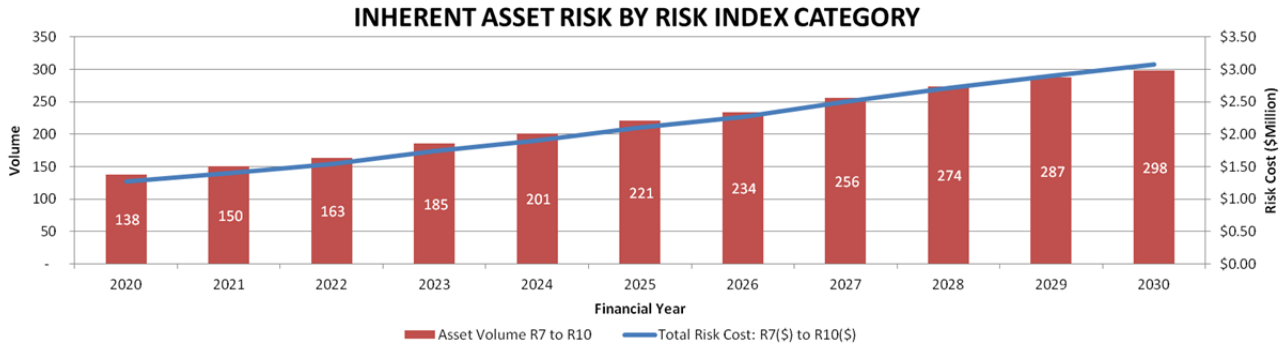
Risk Index

[1] Attachment 5.13.M.0 – Repex program CBA modelling methodology

The normalised risk index below considers the probability of failure, consequence of failure and the annualised replacement cost.



The inherent risk of distribution substations that are cost benefit positive is shown in the figure below.

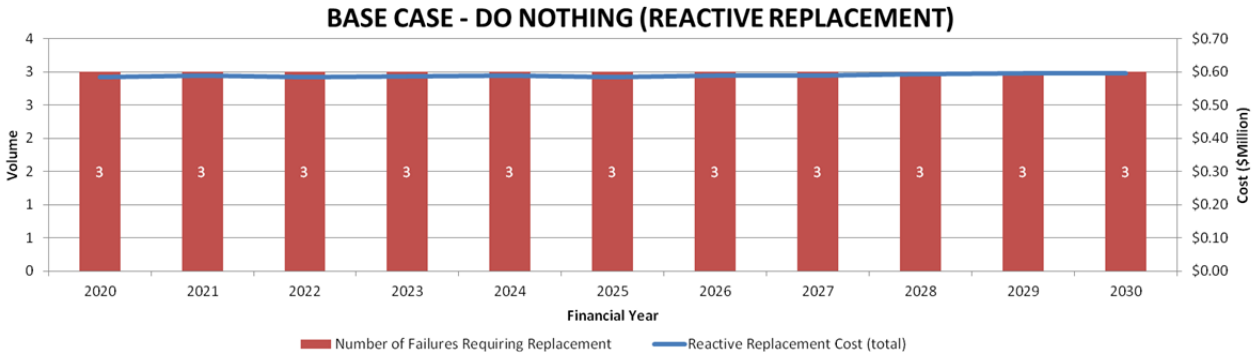


Option One – Base Case (Reactive Replacement)

Given this analysis is a combination of multiple asset failure models, deriving a base case from the failure of an individual asset would over-state the base case requirements as not all failures would lead to the replacement of the entire substation. However, historically Ausgrid has experienced an average of 3 kiosks a year which required full replacement of the substation due to fire. Therefore this data has been used to develop the reactive replacement base case.

Financial Year	FY20	FY21	FY22	FY23	FY24
Quantity for replacement	3	3	3	3	3

Given this forecast only includes fires which have led to the replacement of the entire substation and does not include any escalation of risk over time, this base case is considered low. This quantity represents the minimum required replacement volume with no proactive strategy adopted.



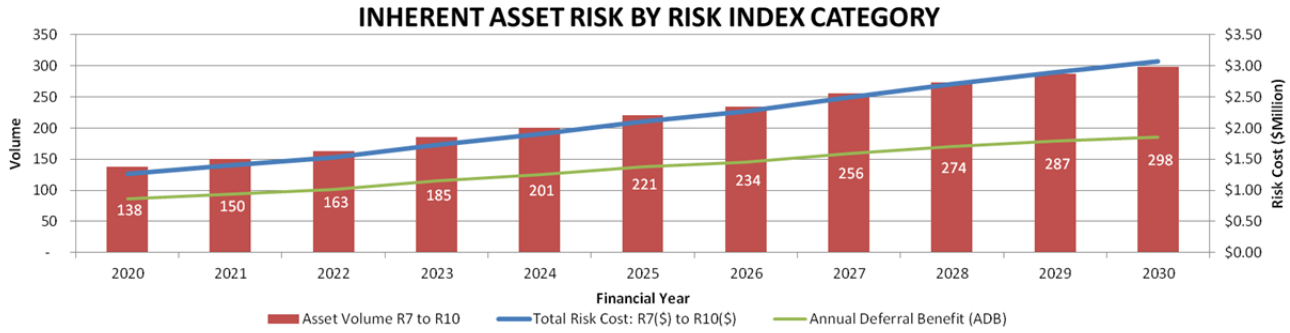
Option Two – Replace where cost benefit positive

Given Ausgrid plans to replace 27 distribution substations in FY19, the recommended replacement quantity for FY20 to FY24 is 174 substations. The table below shows the year in which these assets should be replaced based on when the benefit to customers exceeds the annualised deferral benefit:

Financial Year	FY20	FY21	FY22	FY23	FY24
Quantity for replacement	111	12	13	22	16

The large quantity in FY20 is due to a backlog of distribution substations which are cost benefit positive and using this option would all be replaced in the first year.

Based on this replacement quantity, the annual deferral benefit against the inherent risk for all assets above Risk Index 7 is shown in the figure below. The annual deferral benefit remains lower than the total risk as Ausgrid is not targeting any assets that are not cost benefit positive.



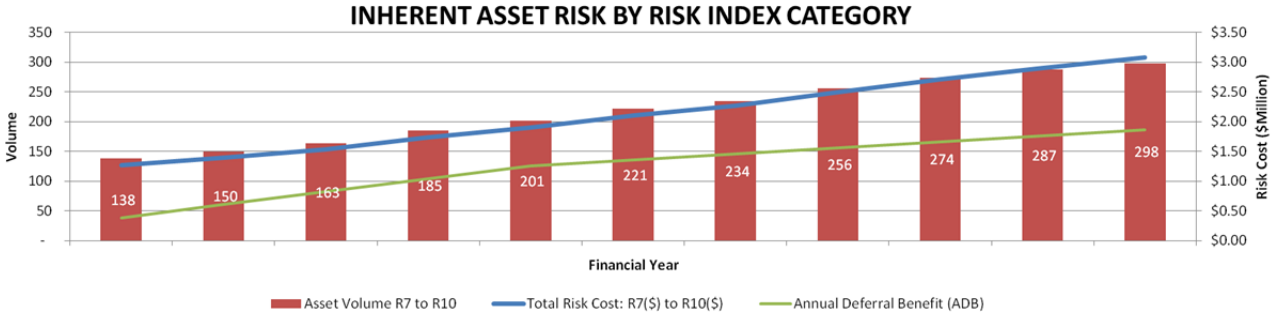
This option provides the maximum benefit to customers as it leads to the avoidance of risk at the point at which the benefits exceed the costs. However, the large delivery requirement in FY20 will not be reasonably achievable due to the constraints on network access, physical access and staff resourcing.

Option Three – Replace all cost benefit positive by the end of the period

Given the delivery constraints, under this option Ausgrid have considered the replacement of all distribution substations that are cost benefit positive by the end of FY24. This results in 34 distribution substations being replaced in the first year and 35 per year for the rest of the period.

Financial Year	FY20	FY21	FY22	FY23	FY24
Quantity for replacement	34	35	35	35	35

Based on this replacement quantity, the annual deferral benefit against the inherent risk for all assets above Risk Index 7 is shown in the figure below.



This option balances achieving value for customers by the end of FY24 with consideration of the delivery constraints.

Data input

For all data referring to the circuit breaker[2], fuse switch or RMU[3] asset included within the distribution substation the corresponding model and document should be consulted. Included below is data referring to the distribution transformer asset and the other elements included within the substation such as the LV board and the housing.

		Data Source
Population	13,543 substations	SAP – Asset Register
Object Types	SUB_KIOSK – Kiosk Substation SUB_OE – Outdoor Enclosure Substation	SAP – Asset Register
Conditional & Functional Failures / Time Period	3,815 failures 6 years	SAP – Defect Records
Asset standard life	45.89 years	RAB life
WACC	3.90%	Regulated Rate

Planned Replacement Cost

A weighted average for the period per asset was used in this model.

Cost	Data Source
$166,060	2020-24 Revised Regulatory Proposal (FY19 real direct costs +25% of indirect costs)

Weibull parameters

Developed by applying asset age to failure correlation using Ausgrid historical failure and asset data.

	Outdoor enclosures (excluding Tx & CB/FS)	Kiosks (excluding Tx & CB/FS)	Outdoor enclosure Tx	Kiosk Tx
β_{good}	3.6683	1.7819	3.4541	2.8016
η_{good}	45.8559	38.5320	73.8932	71.1267
$\beta_{average}$	3.7797	1.8023	3.6713	2.8466
$\eta_{average}$	40.9699	36.9728	57.2848	66.4898
β_{poor}	3.8910	1.8227	3.8886	2.8916
η_{poor}	36.8412	35.5094	45.6907	62.2858
b (intercept)	-14.0333	-6.5067	-14.8617	-11.9473

Adjustments factors

Probability of Failure (PoF)	• Actual Failure Data (All) • Substation Type (Outdoor enclosures & kiosks) • Construction Type (Transformers)
Probability of Consequence (PoC)	• Location Type (Transformers)

Model calculated failures

Failures	2020	2021	2022	2023	2024
Outdoor enclosures	72	76	80	84	89
Kiosks	461	477	492	508	523
Outdoor enclosure Tx	26	27	29	31	32
Kiosk Tx	103	109	116	122	129

Sensitivity

Ausgrid tested the sensitivity of the applied grossly disproportionate factor by applying a factor of 3 to transformers and switchgear based on the worker safety risk and 6 to the housing based on public safety risk. The impact of these changes is a 34% reduction to the overall recommended replacement quantities. The model is therefore sensitive to the grossly disproportionate factor selected.

[2] Attachment 5.13.M.7 - Circuit Breakers (excludes switchboards) program CBA summary
[3] Attachment 5.13.M.8 - High Voltage Fuse Switches program CBA summary

Outdoor Enclosures - Modelled inherent incident consequences

In determining the probability of severity, Ausgrid has utilised available information to determine the rate of occurrence of an event by each severity. These values were then tested for sensitivity. The analysis shown below only applies to the equipment that has not been included in other models i.e. substation housing and low voltage switchgear.

Safety

Worker Safety ICR – 0.11% (Ausgrid recorded ICR)
Physical Impact ICR – 0.36% (Ausgrid recorded ICR)
Public Shock ICR – 0.04% (Ausgrid recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 4,469,292	0.000102	10	0.020	144
Major	$ 446,929	0.000306	8	0.060	48
Moderate	$ 44,693	0.000765	6	0.150	19
Minor	$ 4,469	0.001530	4	0.300	9.6
Insignificant	$ 447	0.002397	2	0.470	6.1

Average **safety** consequence per asset: $5,887 per event.

Ausgrid have proposed that inherently a fatality would occur due to a failure of an outdoor enclosure every 144 years (~150 years) based on recent history and industry experience. Changing the probability of severity to 0.010 (or 1 fatality every 306 years), decreases the financial consequence to $3,608 and decreases the total risk by 17%. Changing this to 0.04 (or 1 fatality every 76 years), increases the financial consequence to $10,446 and increases the total risk by 33%. While the model for the housing and low voltage board is sensitive to these changes, the overall impact on the replacement quantity of distribution substations could not be tested due to the complexity of combining multiple assets into a single model.

Fire

ICR – 0.40% (Ausgrid's recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 66,000,000	0.000000	10	n/a	n/a
Major	$ 6,600,000	0.000060	8	0.015	244
Moderate	$ 660,000	0.000144	6	0.036	102
Minor	$ 66,000	0.000800	4	0.200	18
Insignificant	$ 6,600	0.002996	2	0.749	4.9

Average **fire** consequence per asset: $3,989 per event.

Due to the location of these assets being within a substation, the risk of a severe fire incident was low enough that the probability of consequence was set to zero. Changing the probability of severity to 0.0075 for major fires (or 1 major fire every 489 years), decreases the financial consequence to $2,405 and decreases the total risk by 11%. Changing this to 0.030 (or 1 major fire every 122 years), increases the financial consequence to $7,156 and increases the total risk by 23%. While the model for the housing and low voltage board is sensitive to these changes, the overall impact on the replacement quantity of distribution substations could not be tested due to the complexity of combining multiple assets into a single model.

Environment

ICR – 0.00% (Ausgrid's recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 10,193,119	n/a	1	n/a	n/a
Major	$ 4,558,501	n/a	1	n/a	n/a
Moderate	$ 1,019,312	n/a	1	n/a	n/a
Minor	$ 101,931	n/a	1	n/a	n/a
Insignificant	$ 10,193	n/a	1	n/a	n/a

Average **environment** consequence per asset: $ n/a.

Due to the location of these assets being within a substation and the transformer/HV switchgear being modelled separately, the risk of an environmental incident was low enough that the probability of consequence was set to zero. The model overall is insensitive to changes in the probability of severity for environment risk.

Loss of supply

Ausgrid's failure data has been reviewed to determine the proportion of failures resulting in unserved energy, with consideration of the number of outages recorded using data from Ausgrid's outage management system (OMS).

Outage Type	LV	Data Source
Proportion of failures resulting in unserved energy	3%	OMS - 3 year average
VCR	$40.73/kWh	AEMO / AER
Average interruption duration	7.41 hrs	OMS - 3 year average
Time without supply	0.22 hrs	Calculated

Average **loss of supply** consequence per asset: $1,378 per event.

Finance

		Data Source
Annual deferral benefit of reactive	$2,417	20% increase on planned replacement cost of LV board or housing applied at the WACC
Repair cost	$1,719	FY13-FY18 actuals (Direct '19)
Proportion replaced	4%	SAP – Asset Register
Weighted replacement/repair cost	**$1,747**	Calculated
Maintenance original asset per annum	$848	Based on historical maintenance
Maintenance replacement asset per annum	$43	Based on historical maintenance
Maintenance benefit per asset per annum	**$805**	Calculated

Average **financial** consequence/benefit per asset: $2,552 per event.

AVERAGE TOTAL CONSEQUENCE per asset: $13,806 (including POC x C($))

Kiosks - Modelled inherent incident consequences

In determining the probability of severity, Ausgrid has utilised available information to determine the rate of occurrence of an event by each severity. These values were then tested for sensitivity. The analysis shown below only applies to the equipment that has not been included in other models i.e. substation housing and low voltage switchgear.

Safety

Worker Safety ICR – 0.11% (Ausgrid recorded ICR)
Physical Impact ICR – 0.36% (Ausgrid recorded ICR)
Public Shock ICR – 0.04% (Ausgrid recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 4,469,292	0.000009	10	0.0018	245
Major	$ 446,929	0.000015	8	0.0030	147
Moderate	$ 44,693	0.000102	6	0.0200	22
Minor	$ 4,469	0.000510	4	0.1000	4.4
Insignificant	$ 447	0.004464	2	0.8752	0.5

Average **safety** consequence per asset: $505 per event.

Ausgrid have proposed that inherently a fatality would occur due to a failure of a kiosk every 245 years based on the possibility of such an event. Changing the probability of severity to 0.0009 (or 1 fatality every 489 years), decreases the financial consequence to $300 and decreases the total risk by 6%. Changing this to 0.0036 (or 1 fatality every 122 years), increases the financial consequence to $916 and increases the total risk by 12%. While the model for the housing and low voltage board is sensitive to these changes, the overall impact on the replacement quantity of distribution substations could not be tested due to the complexity of combining multiple assets into a single model.

Fire

ICR – 0.40% (Ausgrid's recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 66,000,000	0.000000	10	n/a	n/a
Major	$ 6,600,000	0.000008	8	0.002	281
Moderate	$ 660,000	0.000040	6	0.010	56
Minor	$ 66,000	0.000400	4	0.100	1.2
Insignificant	$ 6,600	0.003552	2	0.888	0.6

Average **fire** consequence per asset: $733 per event.

Due to the location of these assets being within a substation, the risk of a severe fire incident was low enough that the probability of consequence was set to zero. Changing the probability of severity to 0.001 (or 1 major fire every 562 years), decreases the financial consequence to $522 and decreases the total risk by 6%. Changing this to 0.004 (or 1 major fire every 140 years), increases the financial consequence to $1,156 and increases the total risk by 12%. While the model for the housing and low voltage board is sensitive to these changes, the overall impact on the replacement quantity of distribution substations could not be tested due to the complexity of combining multiple assets into a single model.

Environment

ICR – 0.00% (Ausgrid's recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 10,193,119	n/a	1	n/a	n/a
Major	$ 4,558,501	n/a	1	n/a	n/a
Moderate	$ 1,019,312	n/a	1	n/a	n/a
Minor	$ 101,931	n/a	1	n/a	n/a
Insignificant	$ 10,193	n/a	1	n/a	n/a

Average **environment** consequence per asset: $ n/a.

Due to the location of these assets being within a substation and the transformer/HV switchgear being modelled separately, the risk of an environmental incident was low enough that the probability of consequence was set to zero. The model overall is insensitive to changes in the probability of severity for environment risk.

Loss of supply

Ausgrid's failure data has been reviewed to determine the proportion of failures resulting in unserved energy, with consideration of the number of outages recorded using data from Ausgrid's outage management system (OMS).

Outage Type	LV	Data Source
Proportion of failures resulting in unserved energy	3%	OMS - 3 year average
VCR	$40.73/kWh	AEMO / AER
Average interruption duration	7.41 hrs	OMS - 3 year average
Time without supply	0.22 hrs	Calculated

Average **loss of supply** consequence per asset: $859 per event.

Finance

		Data Source
Annual deferral benefit of reactive	$2,092	20% increase on planned replacement cost applied at the WACC
Repair cost	$1,218	FY13-FY18 actuals (Direct '19)
Proportion replaced	4%	SAP – Asset Register
Weighted replacement/repair cost	**$1,253**	Calculated
Maintenance original asset per annum	$43	Based on historical maintenance
Maintenance replacement asset per annum	$43	Based on historical maintenance
Maintenance benefit per asset per annum	**$0**	Calculated

Average **financial** consequence/benefit per asset: $1,253 per event.

AVERAGE TOTAL CONSEQUENCE per asset: $3,350 (including POC x C($))

Distribution Tx - Modelled inherent incident consequences

In determining the probability of severity, Ausgrid has utilised available information to determine the rate of occurrence of an event by each severity. These ICRs and values include all ground/kiosk mounted distribution transformers. These values were then tested for sensitivity. The analysis shown below only applies to the equipment that has not been included in other models i.e. distribution transformers (excluding CBD distribution transformers)

Safety (specifically worker safety for this asset type)

Worker Safety ICR – 0.10% (Ausgrid recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 4,469,292	0.00002	10	0.020	230
Major	$ 446,929	0.00005	8	0.050	92
Moderate	$ 44,693	0.00010	6	0.100	46
Minor	$ 4,469	0.00020	4	0.200	23
Insignificant	$ 447	0.00063	2	0.630	7.3

Average **safety** consequence per asset: $1,104 per event.

Ausgrid have proposed that inherently a fatality would occur due to a failure of a transformer every 230 years based on no recent known fatalities in Ausgrid or industry. Changing the probability of severity to 0.01 (or 1 fatality every 461 years), decreases the financial consequence to $657 and decreases the total risk by 2%. Changing this to 0.04 (or 1 fatality every 115 years), increases the financial consequence to $1,997 and increases the total risk by 4%. While the model for the housing and low voltage board is sensitive to these changes, the overall impact on the replacement quantity of distribution substations could not be tested due to the complexity of combining multiple assets into a single model.

Fire

ICR – 0.67% (Ausgrid's recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 66,000,000	0.00000	10	n/a	n/a
Major	$ 6,600,000	0.00004	8	0.006	115
Moderate	$ 660,000	0.00067	6	0.100	6.9
Minor	$ 66,000	0.00134	4	0.200	3.4
Insignificant	$ 6,600	0.00465	2	0.694	1.0

Average **fire** consequence per asset: $5,191 per event.

Due to the location of these assets being within a substation, the risk of a severe fire incident was low enough that the probability of consequence was set to zero. Changing the probability of severity for a major fire event to 0.003 (or 1 major fire every 229 years), decreases the financial consequence to $4,130 and decreases the total risk by 5%. Changing this to 0.012 (or 1 major fire every 57 years), increases the financial consequence to $7,313 and increases the total risk by 9%. While the model for the housing and low voltage board is sensitive to these changes, the overall impact on the replacement quantity of distribution substations could not be tested due to the complexity of combining multiple assets into a single model.

Environment

ICR – 1.47% (Ausgrid's recorded ICR)

Severity	Cost of Consequence	Probability of Consequence	Grossly DF	Probability of Severity	Years until event
Severe	$ 10,193,119	0.000000	1	n/a	n/a
Major	$ 4,558,501	0.000019	1	0.0013	241
Moderate	$ 1,019,312	0.000074	1	0.005	63
Minor	$ 101,931	0.000735	1	0.050	6.3
Insignificant	$ 10,193	0.013872	1	0.944	0.3

Average **environment** consequence per asset: $378.

Due to the location of these assets being within a substation, the risk of a severe environmental incident was low enough that the probability of consequence was set to zero. Changing the probability of severity to 0.0007 (or 1 major environmental event every 482 years), decreases the financial consequence to $335 and decreases the total risk by <1%. Changing this to 0.0026 (or 1 major environmental event every 121 years), increases the financial consequence to $465 and increases the total risk by <1%. The model overall is insensitive to changes in the probability of severity for environment risk.

Loss of supply

Ausgrid's failure data has been reviewed to determine the proportion of failures resulting in unserved energy, with consideration of the number of outages recorded using data from Ausgrid's outage management system (OMS).

Outage Type	LV	Data Source
Proportion of failures resulting in unserved energy	62%	OMS - 3 year average
VCR	$40.73/kWh	AEMO / AER
Average interruption duration	5.03 hrs	OMS - 3 year average
Time without supply	3.12 hrs	Calculated

Average **loss of supply** consequence per asset: $12,869 per event (for kiosk and outdoor enclosures only).

Finance

		Data Source
Annual deferral benefit of reactive	$5,136	20% increase on planned replacement cost applied at the WACC
Repair cost	$2,894	FY13-FY18 actuals (Direct '19)
Proportion replaced	10%	SAP – Asset Register
Weighted replacement/repair cost	**$3,118**	Calculated
Maintenance original asset per annum	$0	Based on historical maintenance
Maintenance replacement asset per annum	$0	Based on historical maintenance
Maintenance benefit per asset per annum	**$0**	Calculated

Average **financial** consequence/benefit per asset: $3,118 per event.

AVERAGE TOTAL CONSEQUENCE per asset: $22,660 (including POC x C($))