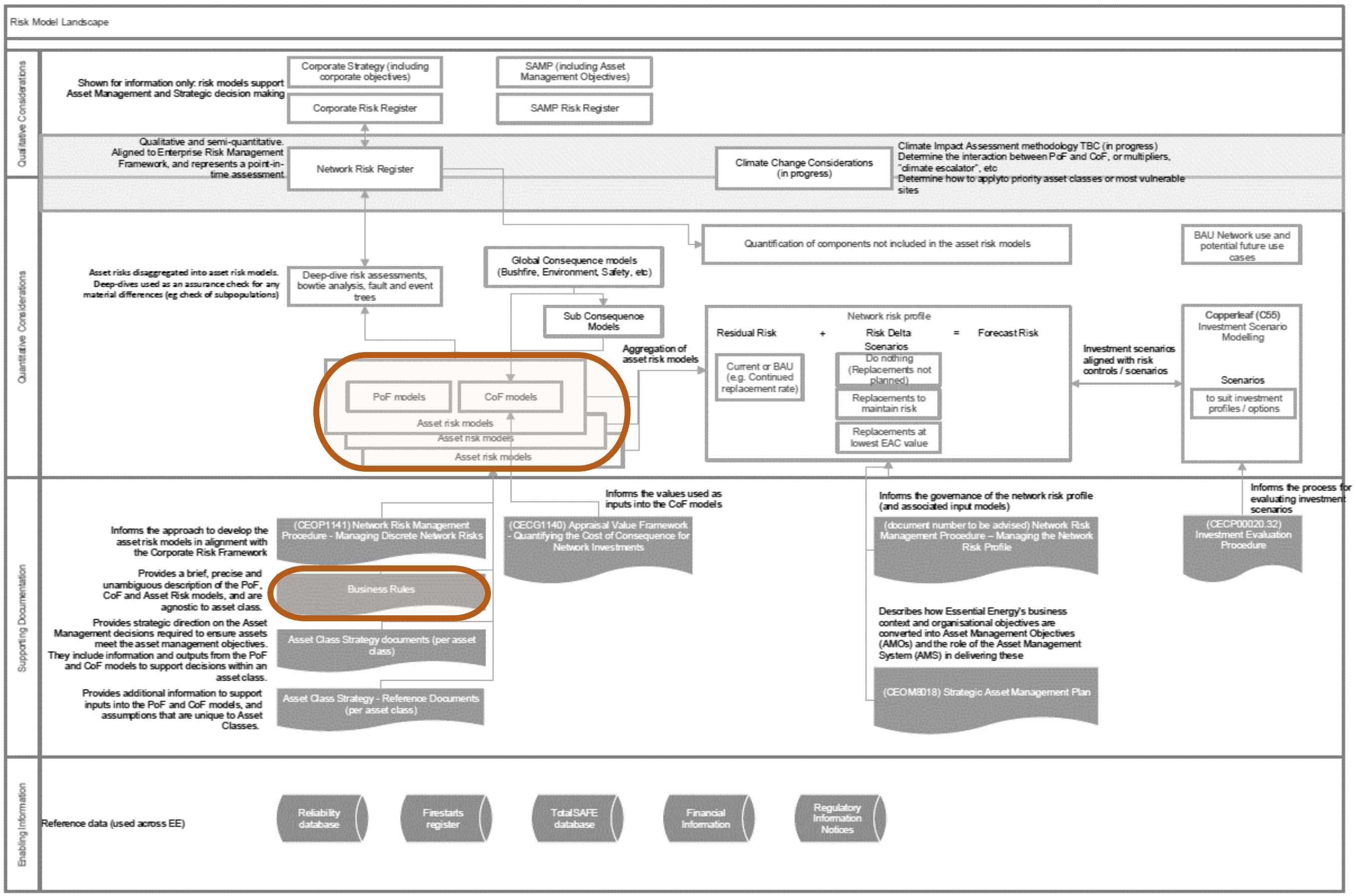
Business Rules

Documented business rules for PoF, CoF and asset risk models

14th February 2022

Context

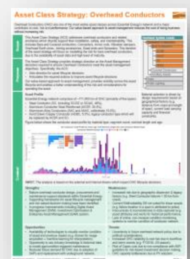
This document captures the business rules for Probability of Failure (PoF), Consequence of Failure (CoF) and asset risk models.



Context

Business Rules are an important tool used to provide clarity and align on a common understanding within an organisation.

Collectively, with the Asset Class Strategy and associated reference documents; this suite of documents is important in quantitative analysis as they identify assumptions, methods and constraints of the underlying models.

Documentation	Business Rules (this document)	Asset Class Strategy	Asset Class Strategy – Reference Document
			
	Author: Senior Engineer Network Compliance & Risk **Purpose:** Business Rules provide a brief, precise and unambiguous description of the PoF, CoF and Asset Risk models, and are agnostic to asset class.	**Author:** Asset Strategy Owners **Purpose:** The Asset Class Strategy documents provide strategic direction on the Asset Management decisions required to ensure assets meet the asset management objectives. They include information and outputs from the PoF and CoF models to support decisions within an asset class.	**Author:** Asset Strategy Owners **Purpose:** Additional information to support inputs into the PoF and CoF models, and assumptions that are unique to Asset Classes.

Further information on the contents of the Asset Class Strategy and Reference Documents is included in Appendix B.

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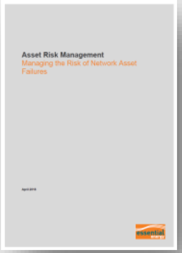
Context

Risk and Value Frameworks are key input documents to allow for a consistent approach for assessing risk.

This document does not contain explanatory material for how to create value calculators or outline the risk assessment process or risk management principles. This information is contained within the documents referenced below:

Documentation

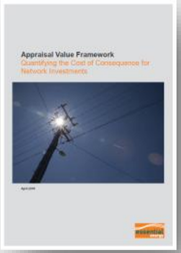
CEOP1141 - Asset Risk Management: Managing the Risk of Network Asset Failures


Asset Risk Management
Managing the Risk of Network Asset Failures

Author: Manager Network Risk & Performance

Purpose:
The how to document, with methods of assessment and common assumptions used for risk analysis, including reference data, methods for calculating probability, and rules of thumb that can be applied in the absence of other methods being applicable.

CECG1140 - Appraisal Value Framework: Quantifying the Cost of Consequence for Network Investments


Appraisal Value Framework
Quantifying the Cost of Consequence for Network Investments

Author: Senior Engineer Network Compliance & Risk

Purpose:
This Appraisal Value Framework sets out the fundamental cost of consequence assumptions that are used to determine the common network risk value. It is designed to be used as a tool to guide risk and value-based decision-making in areas such as network risk management and network investment optimisation.

Further information on the contents of the Asset Class Strategy and Reference Documents is included in Appendix B.

Context

Calibration of asset risk models is an important process step to provide assurance that the model outputs are reflective of reality.

This document does not contain guidance on the approach to calibration of the asset risk models. This information is contained within the document referenced below:

Documentation

Approach for calibration of quantitative asset risk models

Author: Manager Network Risk & Performance

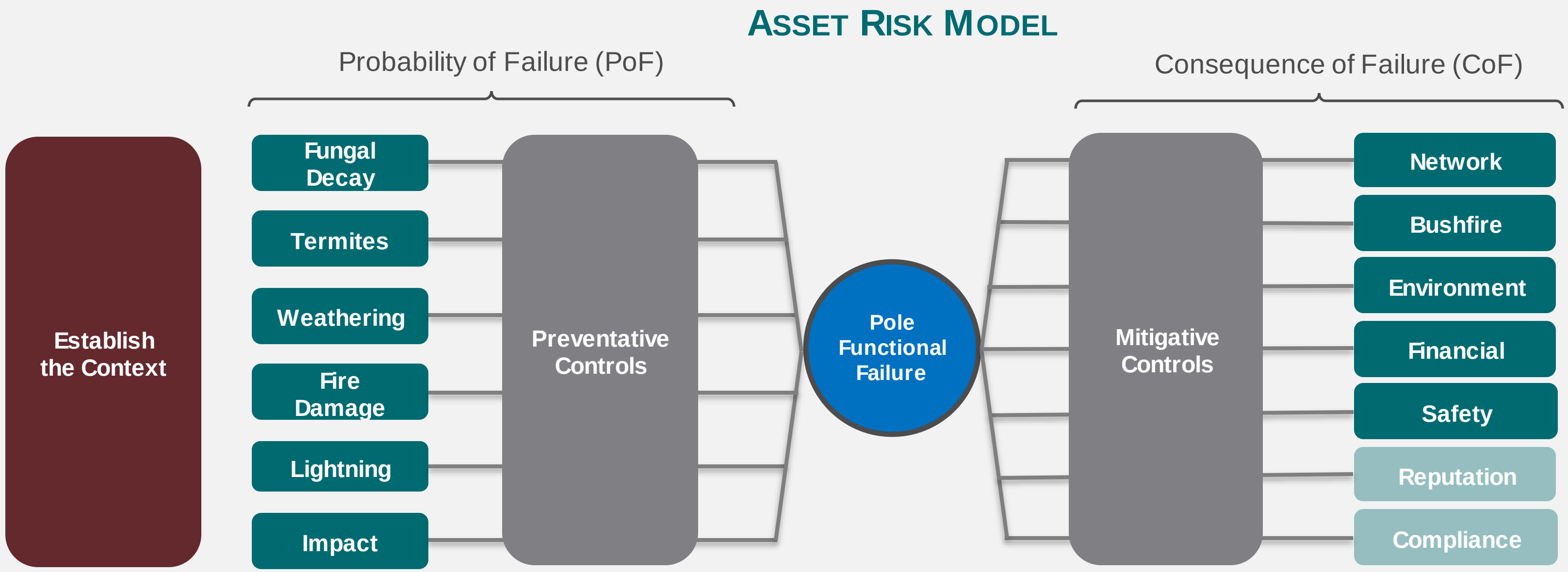
Purpose:
This document captures the calibration of the asset risk models, in order to improve confidence that these aggregate to a credible and realistic representation of the total network risk as a result of unassisted asset failures.

Asset Risk Models

Asset Risk Models – Summary

Summary

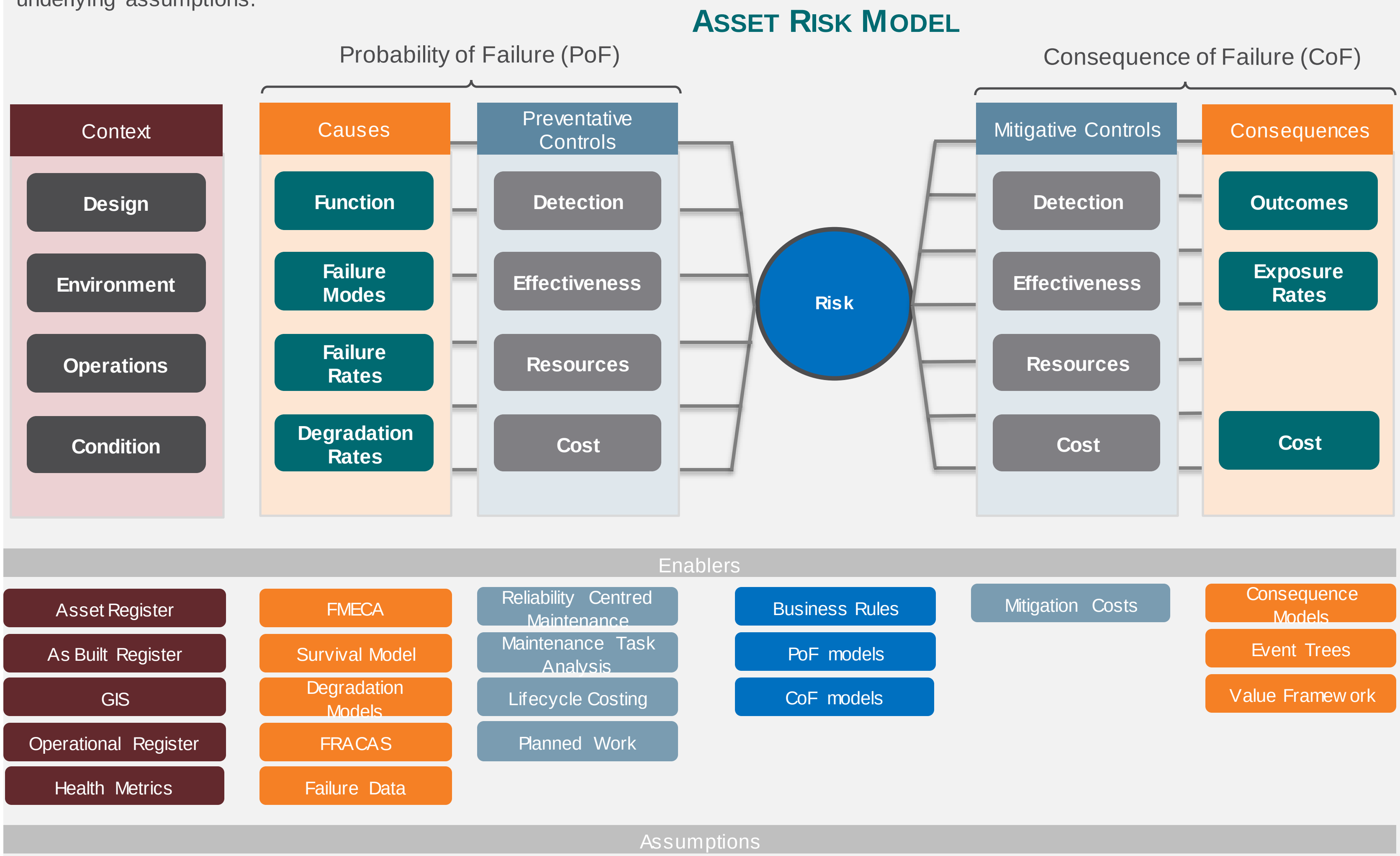
A high-level example to illustrate the scope of the asset risk models is captured below, including consideration of contextual factors:



Asset Risk Models – Summary

Summary

In order to establish an asset risk model, there are a number of items that need to be considered, in conjunction with key enablers and underlying assumptions.



Asset Risk Models – Summary

Purpose	Asset risk is a function of the probability of failure and the consequence of failure. The asset risk models represent the relationship between the drivers of the probability of functional failures and the consequence of failure. They provide a quantitative understanding of expected performance of assets.

Enablers	• Understanding of context:
	    • Asset Register
	    • As Built Register
	    • GIS
	    • Operational Register
	    • Health Metrics
	• Business Rules (this document)
	• PoF models
	• CoF models

Considerations	**Assumptions:** 1. As per the PoF and CoF business rules sections. **Constraints:** 1. Underlying data sources utilised have some limitations, as there is varying degrees of confidence in their accuracy. **Areas for future improvement:** 1. As per the PoF and CoF business rules sections.

Asset Risk Models – Assumptions

Assumptions

Common Assumptions across Asset Risk Models:

1. Operational cost and resource estimates are as per the WASP Estimates table. Summarised consistently across the three system strategies. These estimates were confirmed as valid estimates by the relevant SMEs.
2. Replacement cost and resources were estimated as part of the Asset Class Strategies (ACS) and confirmed in a SME workshop.
3. Actual cost and resource by single asset replacement or task are not readily available and as such a bottom-up calibration was not possible. Estimates have been generated using direct costs with on-costs from task estimates excluding travel and overheads. These have been aggregated into larger groups and were validated with the involved SMEs.
4. Unplanned replacements (i.e. failures) cost are assumed at 1.7x a planned replacement for the distribution network and 1.3 xa planned replacement for zone substations.
5. Unit rate estimates were developed in consultation with SMEs, including through the Unit Rates Working Group. The results are based on a data extract from 3 May 2021 which has been used consistently across the system strategies. These unit rates are based on FY20 data, and not inclusive of travel hours.
6. Growth of the asset base in the underground system is not accounted for in modelling estimates.
7. Defined projects, such as the RM6 type fault replacement & warranty claim are not accounted for in modelling estimates. Suchprojects would be expected to somewhat offset required replacements.

Global Variables	Description
CoC	Cost of Consequence, should it eventuate
CoF	Consequence of Failure – considers the LoC and the CoC
LoC	Likelihood of Consequence
PoF	Probability of Failure - is the probability that the asset will fail during a specified period

Asset Risk Models – Methodology

Method

Establishing the context

Before any quantitative asset risk model can be developed, an understanding of the context in which the assets operate must be established. This includes consideration of factors such as:

- Asset design life and performance requirements
- Environment of assets, e.g. geographical location
- Asset operations, e.g. duration of operation, maintenance approaches
- Current condition and remaining life of assets

All assets risk models must be created in alignment with the Asset Management Framework.

Defining the Risk Event

The asset risk models have been established to calculate the risk associated with asset failures. To properly define the scope of the model, a definition of an asset failure is required.

For an asset to be considered failed it must no longer provide its primary function. For most network assets the primary function is to transmit, or assist another asset to transmit, electricity.

The definition of failure excludes minor or potential failures where the asset continues to provide its required function. For instance, a conditional failure where a pole is tagged for immediate replacement due to significant degradation is not considered a functional failure as the pole continues to support the conductor (however, the pole would be expected to functionally fail in a short timeframe if it were not replaced).

Asset Risk Models – Methodology

Method

Calculating Risk

The Risk is defined as the monetised value of the consequences that are expected to be realised following the failure of the asset, multiplied by the probability of the asset failure occurring.
Risk is calculated using the following formula:

$$Risk = PoF \times \left[CoF_{safety} + CoF_{financial} + CoF_{reliability} + CoF_{bushfire} \; \ldots + CoF_{legal} \right]$$

The Probability of Failure (PoF) is the probability that the asset will fail during a specified period and is covered in further detail in the PoF Business Rules section.

Likelihood of Consequence (LoC), Cost of Consequence (CoC) and Disproportionate Factors (DFs) are used to inform the Consequence of Failure (CoF) and these terms are covered in further detail in the CoF Business Rules section.

The expected consequence per asset failure is summated across each of the consequence categories, which is then multiplied by the PoF to produce total risk per asset failure.

Asset Risk Models – Governance

Roles & Responsibilities

Responsibility	Role
Accountable (A): Final sign-off on the output	Manager, Network Risk and Performance
Responsible (R): Completes work required	Asset Class Strategy Owner
Supports (S): Assists with work required	Manager Asset Management Framework
Consulted (C): Contributes information / feedback / data	Head of Engineering
	Senior Engineer, Network Risk & Performance
	Consequence SMEs (refer summary table in Appendix)
	Other Asset Class Strategy Owners (refer summary table in Appendix)
Informed (I): Kept up-to-date on progress	Head of Asset Management
	Group Head Asset Engineering Risk and Compliance

Governance

The models have the following review cycle:

Minor:
- Annually

Major:
- 5 years, or;
- When triggered, as per the overarching maintenance and change control approach contained within CECPXXXX - Managing the Quantitative Network Risk Profile

All updates are to be approved by the Accountable Party, with consultation with key parties as deemed appropriate for the context. Key input values should not be changed without going through a formal maintenance and change control process.

PoF Models

PoF Models – Summary

Purpose

The Probability of Failure (PoF) models represent the probability that the asset experiences a failure during a single year. For most assets, the probability of failure increases over time, as the asset degrades. In other cases, the probability of failure is somewhat random, such as lightning strikes and fauna activity. PoF models are used as an input into the overall asset risk models.

PoF models enable asset management decisions across the asset lifecycle of acquisition through to intervention, dependent on their level of development.

Enablers

- Applicable hazards / causes and their likelihood of contributing to the occurrence of a risk event, through various analysis, dependent on the asset class, including:
  - FMECA
  - Survival models
  - Degradation Models
  - FRACAS
  - Failure Data
- Understanding of preventative controls, through Operations & Maintenance information and analysis, including:
  - Reliability Centred Maintenance (RCM)
  - Maintenance Task Analysis
  - Life Cycle Costing (LCC)
  - Planned Work
- Knowledge from Subject Matter Experts (SMEs) captured through expert elicitation
- Understanding of CNAIM / OFGEM methodology for asset classes with limited data

Considerations

Constraints:

1. Underlying data sources utilised have some limitations, as there is varying degrees of confidence in their accuracy.
2. PoF models have been developed to various levels of complexity across asset classes.

Areas for future improvement:

1. Review of the taxonomy of hazards / events for standardisation. Consider how consistency across models can be achieved for common hazard inputs.
2. Asset condition / health has not been considered in the PoF models, and could be incorporated in future revisions.
3. There is potential for increased usage of the engineering digital twin for improved accuracy.

PoF Models – Assumptions

Assumptions

Common Assumptions across PoF Models:

1. Functional Failures have been sourced from the Network Asset Failure Report (NAFR) and the Pole Failure Database.
2. Conditional Failures have been sourced from WASP.
3. New assets have a negligible failure rate in the first 20 years of their life so the probability of failure for replacement assets is ignored in these instances.
4. Assets with missing or inaccurate dates are not included when determining failure rates, but are included when producing forecasts. For forecasting purposes, the age is set to the average age for the population.
5. PoF models used in the system strategy analysis were developed from population-level statistical analysis, which allow for population-level asset management decisions.
6. Given the population-level statistical probability of failure approach used against an asset subpopulation, the OPEX impact can not be related. As such there are no proposed changes to the OPEX tasks or frequency.

System Interactions:

1. Pole replacements are not triggered by other asset classes. Conductor replacements currently trigger pole replacements, and it is noted that this is a conservative assumption regarding the volume of upgraded poles.
2. Pole Top Equipment replacements are triggered by 100% of Pole replacements and 80% of conductor replacements.
3. Conductor replacements are not triggered by other Asset Classes as failures involving conductors are always repaired.
4. Interactions between UG System assets were accounted for at an enclosed substation level. In this first iteration, failures of RMUs were modelled with a 90% chance of elevation to whole-of-substation consequence (replacement), whereas LV Switchboards were modelled with a 10% chance of this same elevation (based on SME elicitation). UG Cable terminations were treated as non-interacting.

PoF Models – Methodology

Method

Cause of a Risk Event

In addition to defining a failure (risk event), consideration must also be given to the cause of the failure and the network's response to the failure.

Failure Cause

There are two main modes through which an asset failure can be caused:

1. **Unassisted failure:** the failure of the asset is caused by its condition. Asset condition degrades over time and may be accelerated by environmental factors, wear and tear and random events, causing the probability of failure to increase over time. The asset condition can be improved by refurbishing or replacing the asset, which will result in a lowering of the probability of an unassisted conditional failure.
2. **Assisted failure:** the failure of the asset is caused by an exogenous factor. This type of failure is independent of the asset condition. If the asset were replaced like-for-like with a new equivalent asset the exogenous factor would still result in the failure of the asset. The only way to prevent this type of failure is to replace the asset with a different asset (such as undergrounding the network in areas where trees are prone to falling on lines). The probability of an assisted failure does not change over time as the condition of the asset changes.

The Australian Energy Regulator (AER) in its Industry Practice Application Note – Asset Replacement Planning [1] (Table 1: Definitions) defines asset failure as:

> *"when an asset can no longer perform its intended function safely and in compliance with jurisdictional regulations, but not as a result of external impacts such as extreme or atypical weather, third party interference (e.g. traffic or vandalism), wildlife or vegetation interference. The asset may still be operating but may not be capable of delivering all of its required functionality. The asset may or may not be repairable."*

The purpose of the practice note is to guide modelling for determining when assets should be replaced. Replacement cannot influence assisted failures so these are excluded from the AER's definition.

The AER definition, which excludes assisted failures, is used for determining the PoF and risk in Essential Energy's asset risk models. Therefore, the **PoF that is calculated for an asset** is only required to estimate the probability that an **unassisted failure** occurs .

[1] https://www.aer.gov.au/system/files/D19-2978%20-%20AER%20-Industry%20practice%20application%20note%20Asset%20replacement%20planning%20-%2025%20January%202019.pdf

PoF Models – Methodology

Method	
	Cause of a Risk Event
	Repairable and Non-Repairable Failures As per the AER definition of an asset failure, the failed asset may be either repairable or non-repairable (requiring replacement). Within the model each asset type is categorised as either repairable or non-repairable. This categorisation is based on standard post-failure practices by Essential Energy. A **repairable failure** is defined as a situation where the failed asset can be returned to service following the replacement of a component/part of the asset, while retaining other components that were not affected by the failure. Following a repair, the asset's **PoF remains at the same value** as it was before the failure. A **non-repairable failure** is defined as a situation where the failed components of the asset are not easily or efficiently replaced without replacement of the entire asset, so the entire asset (or a majority of) is replaced. The key result of a replacement is that the **asset's PoF is reset to that of a brand new asset**.

PoF Models – Methodology

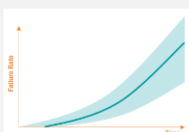
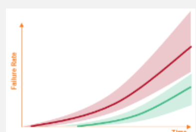
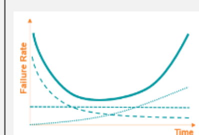
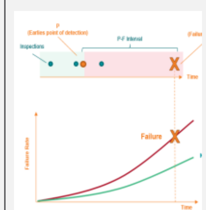
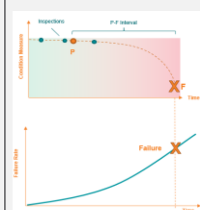
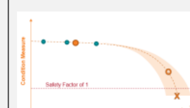
Method

Likelihood of a Risk Event

Failure Modes

Depending on the quality of data, a PoF model can be developed at the asset level (including sub-populations) or failure mode level. The asset management decisions that can be addressed increase in complexity with the 7 levels as shown in the diagram below. Appendix D captures the current state of the PoF modelling per asset class.

Increasing Complexity → Step change → Increasing Complexity

Asset Level		Failure Mode Level				
PoF 1	**PoF 2**	**PoF 3**	**PoF 4**	**PoF 5**	**PoF 6**	**PoF 7**
Statistical Life	Condition Curve	Asset Failure Mode PoF	PoF | defect	PoF | condition (t)	PoF | condition (t) with uncertainties	PoF | Treatment Scenarios
						
We know how many assets failed last year…	*We know this type of asset is worse…*	*We know this asset fails from both corrosion and installation issues…*	*This asset seems to be leaking oil (exhibiting a defect) …*	*We know that 10% of our poles have <100mm of wall thickness...*	*We know that we can't have more than 10 failures or we breach our licence conditions…*	*We think we can refurbish cross arms with a new contractor…*
how many assets do we think will fail this year?	*how many assets do we think will fail this year?*	*how many assets do we think will fail this year?*	*how many assets do we think will fail this year*	*how many assets do we think will fail this year?*	*what is the chance we exceed that?*	*how many asset do we think will fail this year?*

PoF Models – Application

● (orange)	Previous PoF model level
● (grey-green)	Current PoF model level (after ACS completion)

Application

Asset Management Decisions

PoF models enable asset management decisions across the asset lifecycle of acquisition through to intervention.

Asset Strategy Levers		Asset Level		Failure Mode Level				
		PoF 1	PoF 2	PoF 3	PoF 4	PoF 5	PoF 6	PoF 7
		Statistical Life	Condition Curve	Asset Failure Mode PoF	PoF | defect	PoF | condition (t)	PoF | condition (t) with uncertainties	PoF | Treatment Scenarios
Acquisition	Replacement Demand	●	●	●	●	●	●	●
	Design Life	●	●	●	●	●	●	●
	Procurement Specification	●	●	●	●	●	●	●
	Acceptance Criteria			●	●	●	●	●
Operations & Maintenance	Operational Profile		●			●	●	●
	Duty Cycle		●			●	●	●
	Inspection / PM Techniques				●	●	●	●
	Rectification Time						●	●
	Corrective Maintenance							●
	Inspection / PM Frequency					●	●	●
	Condition Definitions		●			●	●	●
Intervention	Thresholds		●			●	●	●
	Coincident Replacements							
	Repair Cost Limits		●		●	●	●	●
	Upgrade	● (previous)		●	●	●	●	●
	Modifications	● (previous)		●	●	●	●	●
	Replacements	●	●	●	●	●	●	●
	Augmentation Demand	●	●	●	●	●	●	●
	Intervention Option							●
Asset Support System	Parts Management			●	●	●	●	●
	Parts Holding Policy			●	●	●	●	●
	Specialist Tools	● (previous)	● (previous)	●	●	●	●	●
	FTE Requirement	● (previous)	● (previous)	●	●	●	●	●

PoF Models – Governance

Roles & Responsibilities

Responsibility	Role
Accountable (A): Final sign-off on the output	Head of Engineering
Responsible (R): Completes work required	PoF Model SMEs (refer summary table in Appendix)
Supports (S): Assists with work required	Manager Engineering Management System
Consulted (C): Contributes information / feedback / data	Manager Asset Management Framework
	Manager, Network Risk and Performance
	Asset Class Strategy Owners
Informed (I): Kept up-to-date on progress	Head of Asset Management
	Group Head Asset Engineering Risk and Compliance

Governance

The models have the following review cycle:

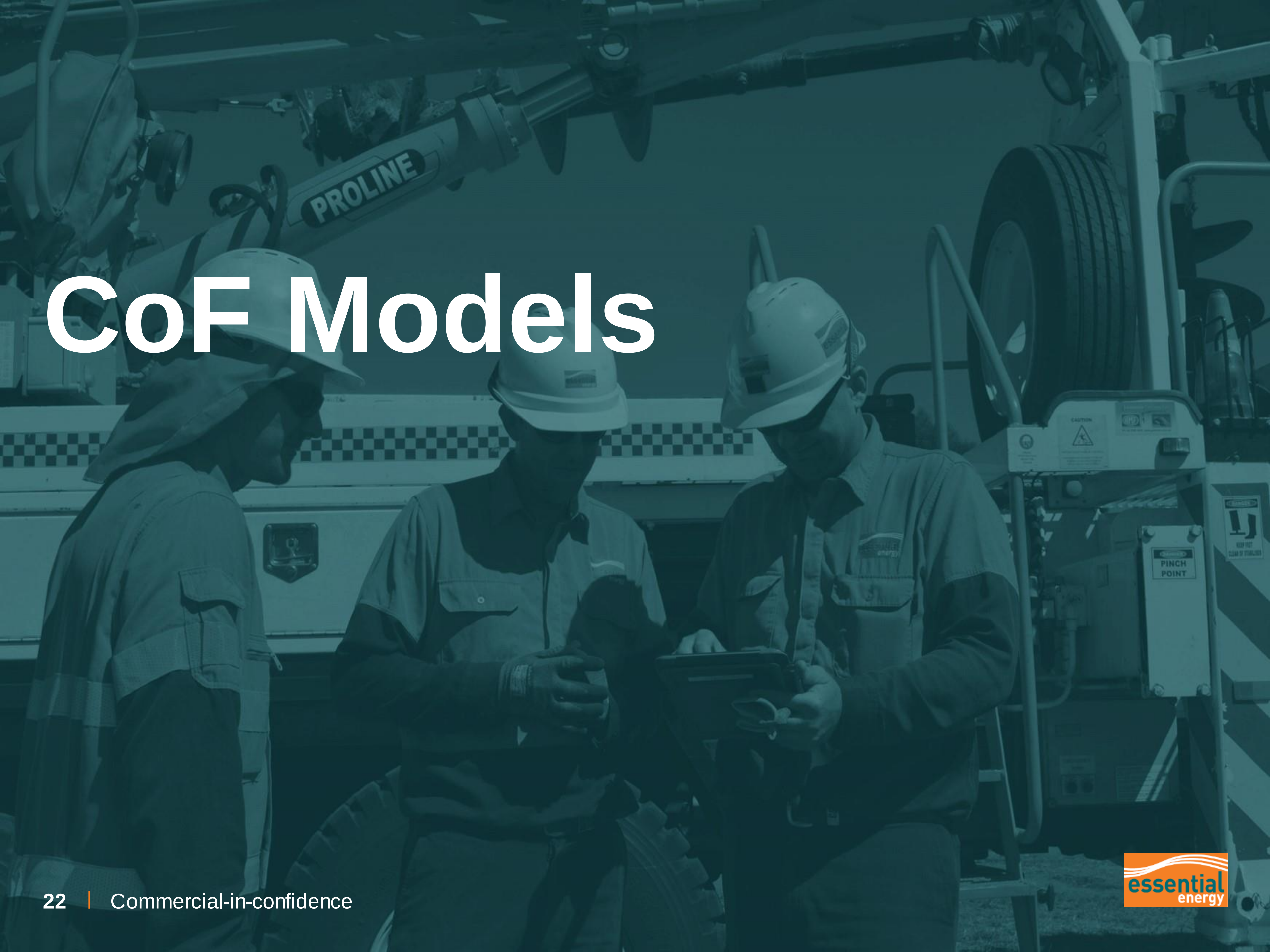
Minor:

- Annually

Major:

- 5 years, or;
- When triggered, as per the overarching maintenance and change control approach contained within CECPXXXX - Managing the Quantitative Network Risk Profile

All updates are to be approved by the Accountable Party, with consultation with key parties as deemed appropriate for the context. Key input values should not be changed without going through a formal maintenance and change control process.



CoF Models

CoF Models – Summary

Purpose	The Consequence of Failure (CoF) models represent the impact of an equipment failure on Essential Energy. CoF models are used as an input into overall asset risk models. They can also be used as a benchmarking tool to compare Likelihood of Consequence with peers externally at an asset class level.
Enablers	• Mitigation Costs • Global Consequence Models (where applicable) • Likelihood of Consequence (distribution) captured in Event Tree Analysis • Cost of Consequence as per the Appraisal Value Framework • Disproportionate Factor (DF) for each consequence category as per the Appraisal Value Framework • Subpopulation classifications
Considerations	**Constraints:** 1. Underlying data sources utilised have some limitations, as there is varying degrees of confidence in their accuracy. **Areas for future improvement:** 1. Nil identified.

CoF Models – Assumptions

Assumptions

Common Assumptions across CoF Models:

1. Confidence intervals have been applied to likelihood of consequence and utilise a mean and a standard deviation input.
2. For corrupted data sources, default values have been adopted.
3. Duplicative data has been excluded.
4. Calculations are based on the most exposed reasonably behaved person for a generalised scenario.

Clarifications for Consequence Categories:

1. Generally, the CoF models utilise the formula captured in the methodology (within this document), and based on the assessment of Likelihood of Consequence (LoC), the Cost of Consequence (CoC) and the Disproportionate Factor (DF)
2. **Safety** calculations utilise the Safety Exposure Method, captured in *Global Consequence Model Documentation_Safety Exposure*
3. **Bushfire** calculations utilise information from the Bushfire global consequence model.
4. **Reputation:** this consequence only occurs in addition to network, safety, bushfire and environmental as reputational consequence is already incorporated in each of these other consequence categories. The reputation category captures reputation impact to the organisation from industry, community, government, media or other stakeholders in circumstances other than those captured in the previous consequence categories. The likelihood of reputation impact should be estimated as a proportion of events which are likely to receive attention from stakeholders.
5. **Compliance:** this consequence category captures the need for completing programs to comply with a legislated requirement, for example a breach of the National Electricity Rules or failing to comply with an IPART directive. The consequences of non-compliance are determined on a case-by-case basis through discussion with the appropriate regulatory body (AER or IPART).
6. **Financial:** this captures both financial consequences that incurred to Essential Energy and the community. For instance in the case of high voltage on a line causing a community member's fridge to prematurely fail, this cost is rarely covered by EE, however this cost implication is still considered within the financial consequence category.
7. **Network:** there are two components to the network, namely the VCR calculation and the additional costs to EE, which are quantified via the network table contained within the Value Framework.

CoF Models – Assumptions

Assumptions

Global Variables		Description
Bushfire Priority Level	[P1-P4]	Bushfire priority level refers to the likelihood that a fire start will spread into a bushfire.
CAIDI	N/A	Customer Average Interruption Duration Index [SAIDI / SAIFI]
DF	[0-10]	Disproportion factor as described in CECG1140.
Phoenix Bushfire Value	Number	The expected number of properties lost if a fire were to start in that location. See CEOP8067 for more detail. https://utilnsw.sharepoint.com/sites/PolicyLibrary/Policy%20Documents/CEOP8067.pdf#search=bushfire%20priority%20zone
PoF	[0-1]	Probability of Failure
P_{Severe}, P_{Major}, $P_{Moderate}$, P_{Minor} & $P_{Insignificant}$	[0-1]	Probabilities that describe the severity of each consequence event.
C_{Severe}, C_{Major}, $C_{Moderate}$, C_{Minor} & $C_{Insignificant}$	$	Consequence costs assigned in the Appraisal Value Framework - CECG1140
SAIDI	N/A	System Average Interruption Duration Index [Duration of outage in minutes x Number of customers impacted by outage] / 855000
SAIFI	N/A	System Average Interruption Failure Index [Number of Failure outage in minutes x Number of customers impacted by outage] / 855000
VCR	$	Value of Customer Reliability

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CoF Models – Methodology

Method

Subpopulation aggregation

Assets have been allocated to subpopulations within asset classes based on SME input. Where this has occurred, CoF models have a subpopulation input sheet which captures the allocation of assets to the associated subpopulation.

This allows for differentiators in severity across different subpopulations to be captured. For example, a pole failure in a particular environment may have a different impact than that in an alternate environment.

Likelihood of Consequence

The Likelihood of Consequence (LoC) is the percentage probability that given consequence outcome will be observed following a failure.

Each asset class has an LoC parameter for each consequence type. The following types of consequences are incorporated into the CoF models:

- Safety – Public & Worker
- Financial
- Reliability
- Environment (Bushfire)
- Legal / Regulatory Compliance
- Environmental

The LoC incorporates a range of information. This includes:

- The various failure modes that an asset may experience and the frequency with which each failure mode is expected to occur;
- The likelihood of a consequence eventuating as a result of a failure
- The presence and effectiveness of mitigative controls

This information has been developed by Subject Matter Expert (SME) input for each Asset Class.

Where significant differences in the likelihood of a consequence occurring exist within an asset class, the LoC parameters may differ between subpopulations. Documentation of the approaches to calculating LoC parameters for each asset class is covered in the relevant Asset Class Strategies for each asset class.

CoF Models – Inputs & Methodology

Method

Cost of Consequence

Inputs regarding costs of consequence per severity level and Disproportionate Factors (DF) captured in CECG1140 Appraisal Value Framework (VF2.0) are used as static inputs into the CoF models. These are shown below for information as at the time of issue of this document, however the Appraisal Value Framework should be referred to for the costs of consequence and the determination and application of the Disproportionate Factor.

The Cost of Consequence (CoC) is the cost that will result from a given consequence occurring. Each consequence could result in a range of outcomes with varying levels of severity.

	Cost of Consequence					Disproportionate Factor (DF)		
VFT Category	**Insignificant**	**Minor**	**Moderate**	**Major**	**Severe**	**Insignificant / Minor**	**Moderate**	**Major / Severe**
Safety (Societal – VoSL)	$713	$4,990	$24,951	$499,019	$4,990,190	6	6	6
Safety (EE)	$3,725	$65,545	$406,914	$1,821,601	$13,489,184	1	1	1
Network (Societal – VCR)	TBC *	TBC *	TBC *	TBC *	TBC *	1	1	1
Network (EE)	$2,668	$77,165	$81,060	$656,870	$2,415,515	1	1	1
Financial	$132,100	$2,774,100	$51,852,000	$39,630,000	$73,976,000	1	1	1
Environment (bushfire)	$3,697	$122,677	$2,626,905	$18,323,672	$175,389,897	1	3	6
Environment (other)	$3,442	$46,297	$240,016	$1,532,068	$12,524,244	2	2	2
Compliance	$3,442	$46,297	$240,016	$1,532,068	$12,524,244	2	2	2
Reputation	$1,057	$6,986	$85,218	$579,858	$2,238343	2	2	2

* VCR Calculations are underway and being completed by Essential Energy

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CoF Models – Inputs & Methodology

Method

Disproportionate Factor

Demonstrating that risk is As Low As Reasonably Practicable (ALARP) is undertaken through an economic test where risk is reduced to ALARP by

> *"incurring expenditure up to the point at which the expenditure would be 'grossly disproportionate' to the benefit (risk reduction) achieved. That is, if it is not grossly disproportionately uneconomic to do so, then the source of the risk should be eliminated" [1]*

Disproportionate Factors (DFs) are commonly applied to risk considerations across Network Service Providers (NSPs) as a means of demonstrating that ALARP has been met.
Higher DFs indicate a higher level of societal dread associated with the event, e.g. multiple fatalities or outcomes with large social impact, and/ or a higher level of uncertainty in the risk assessment.

Consequence of Failure

The overall Consequence of Failure (CoF) is based on the likelihood of the consequence eventuating, the cost of the consequence and the disproportionate factor, as per the Appraisal Value Framework:

$$
\text{Consequence of Failure} = \left[\begin{array}{l}
\text{Likelihood}_{\text{insignificant}} \times \text{Cost of Consequence}_{\text{insignificant}} \times \text{Disproportionate Factor}_{\text{insignificant}} \\
+ \text{Likelihood}_{\text{insignificant}} \times \text{Cost of Consequence}_{\text{minor}} \times \text{Disproportionate Factor}_{\text{minor}} \\
+ \text{Likelihood}_{\text{insignificant}} \times \text{Cost of Consequence}_{\text{moderate}} \times \text{Disproportionate Factor}_{\text{moderate}} \\
+ \text{Likelihood}_{\text{insignificant}} \times \text{Cost of Consequence}_{\text{major}} \times \text{Disproportionate Factor}_{\text{major}} \\
+ \text{Likelihood}_{\text{insignificant}} \times \text{Cost of Consequence}_{\text{severe}} \times \text{Disproportionate Factor}_{\text{severe}}
\end{array} \right]
$$

[1] https://www.aer.gov.au/system/files/D19-2978%20-%20AER%20-Industry%20practice%20application%20note%20Asset%20replacement%20planning%20-%2025%20January%202019.pdf

CoF Models – Governance

Roles & Responsibilities

Responsibility	Role
Accountable (A): Final sign-off on the output	Manager, Network Risk and Performance
Responsible (R): Completes work required	Asset Class Strategy Owner
Supports (S): Assists with work required	Manager Asset Management Framework
Consulted (C): Contributes information / feedback / data	Head of Engineering
	Senior Engineer, Network Risk & Performance
	Consequence SMEs (refer summary table in Appendix)
	Other Asset Class Strategy Owners (refer summary table in Appendix)
Informed (I): Kept up-to-date on progress	Head of Asset Management
	Group Head Asset Engineering Risk and Compliance

Governance

The models have the following review cycle:

Minor:

- Annually

Major:

- 5 years, or;
- When triggered, as per the overarching maintenance and change control approach contained within CECPXXXX - Managing the Quantitative Network Risk Profile

All updates are to be approved by the Accountable Party, with consultation with key parties as deemed appropriate for the context. Key input values should not be changed without going through a formal maintenance and change control process.

Appendix A

Acronyms

Acronyms

Acronym	Definition
ACS	Asset Class Strategies (project)
AER	Australian Energy Regulator
CNAIM	Common Network Asset Indices Methodology
CoF	Consequence of Failure
DF	Disproportionate Factors
FMECA	Failure Mode, Effects and Criticality Analysis
FRACAS	Failure Reporting, Analysis and Corrective Action System
LCC	Life Cycle Costing
MTA	Maintenance Task Analysis
NSP	Network Service Provider
OFGEM	Office of Gas and Electricity Markets
PoF	Probability of Failure
RCM	Reliability Centred Maintenance
SME	Subject Matter Expert
VCR	Value Customer Reliability
VoSL	Value of Societal Life

Appendix B

Asset Class Strategy and Reference Document Overview

Asset Class Strategy Overview

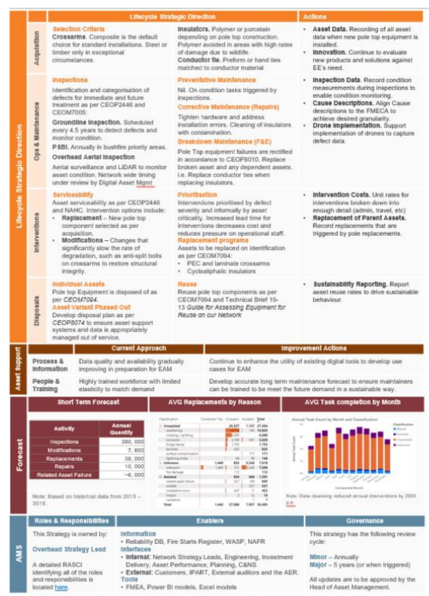
Phase 1 Asset Class Strategies: Load control, Pole top equipment, & HV Ring Main Units

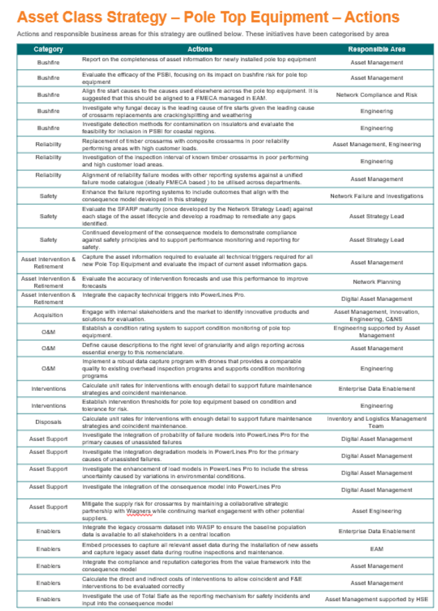
- Context – Purpose and Assets Profile
- Performance and Line of Sight by AM objective: Current and target performance
- Gaps (in AMO performance)

- Lifecyle Strategic Directions and Actions
- Asset Support – Process & Information, People & Training: Current Approach and Improvement Actions
- Forecast: Short term forecast annual quantities, AVG Replacements by Reason, AVG Task completion by month & category
- AMS: Roles & Responsibilities, Enablers, & Governance

- Improvement actions by category (i.e. AM objective) and responsible area


Asset Class Strategy – Pole Top Equipment – Summary



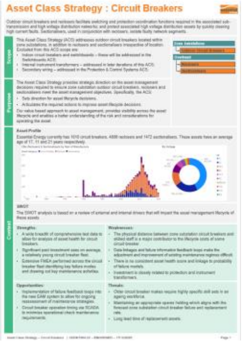

Asset Class Strategy – Pole Top Equipment – Actions

Actions and responsible business areas for this strategy are outlined below. These initiatives have been categorised by area

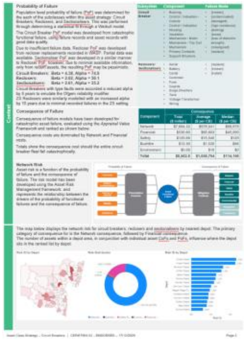
Asset Class Strategy Overview

Phases 2 and 3 All other Asset Class Strategies

- Scope: Assets in scope for this iteration
- Purpose
- Context:
  - Assets Profile
  - SWOT: External and internal drivers that will impact lifecycle asset management



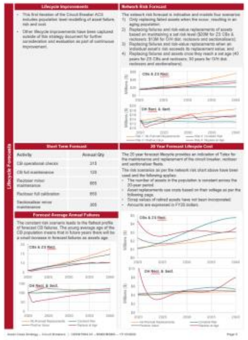
- Context:
  - Probability of Failure Model parameters
  - Consequence of failure values (Appraisal Value Framework)
  - Power BI Map by depot: Consequence of Failure values
  - Asset Risk Model (Bow-tie)



- Line of sight - Linkages to Network Strategies & Corporate Objectives
- Performance by new AM objectives: Historical and target performance

- Strategic Directions by Lifecyle stages and Asset Management System: Current approach and actions for Process & Information, People & Training, & Supply Chain

- Lifecycle Forecasts: Lifecyle improvements, Short term forecasts, 20 year cost and risk forecasts for different scenarios (see next page)



- Strategic Directions: Key Assumptions
- Key Enablers
- Roles & Responsibilities, Information & Interfaces & Governance
- Summary of key changes in this iteration

Asset Class Strategy Overview

Phases 2 and 3 All other Asset Class Strategies

The Reference document (in WORD) contains more technical information and assumptions that support the strategy. It is an informal notepad to drop in details supporting the strategy. An example from ACS Underground Cables is illustrated below.

3.3.3 Asset Profile

In service assets and their age / natural grouping

- David Shepherd:
  - Split into ST (33kV, 66kV, 132kV, 220kV), HV (11kV, 22kV), LV (<11kV)
    - ST: clear runs, lower fault rates
    - HV : shorter runs, more complex
  - NB:
    - Anomalous group exists where we might have HV voltage but currents high enough to be effectively ST near solar generators
    - Some DC cables exist (mostly link between QLD and NSW; very small %)
- John Ward / Joe Barry
    - XLPE has both old and new manufacturing technique.
    - Old batch ~1980s susceptible to water trees, cracks (prior to water tree retardant introduction; steam used in processing, which introduced moisture from the beginning)
- Ross Kempnich
  - Ageing network: XLPE cables from the mid 1980s (without water tree retardant) may be coming up on their end of life, suggesting we could have an uptick in failures on its way
    - Information requested: paper on 40y expected life of this older type of XLPE

3.4.4 Asset Probability of Failure

OFGEM vs. Weibull

- UG cable data quality has the following limitations (amongst others)
  - Tasks are not directly attributable to individual cables because the cables themselves are not represented in WASP
  - High number of cable attribute data fields either missing, invalid, or conflicting
- OFGEM is a useful approach in that
  - It can incorporate what data is available regarding asset health, age, and attributes
  - It produces reasonable results even when data quality is poor
- Weibull in comparison
  - Is more flexible than OFGEM, allowing a closer match to historical failure and local conditions where the data is available, but as a result
  - Is less forgiving than OFGEM where data quality is poor, as fit parameters can vary wildly and be easily misrepresented or misinterpreted to show results which do not reflect reality
- OFGEM was deemed most appropriate for UG Cables PoF.

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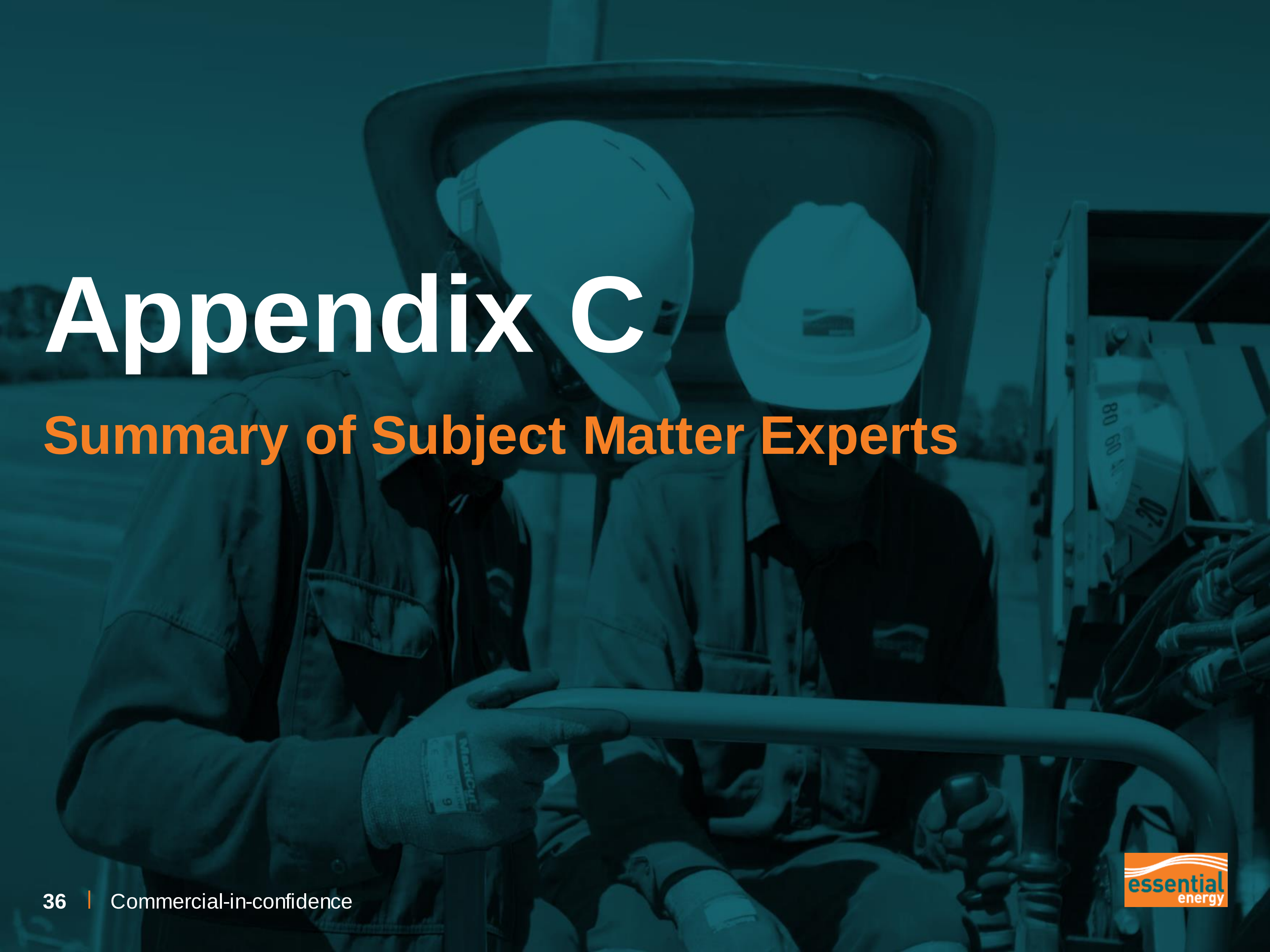


Appendix C

Summary of Subject Matter Experts

Subject Matter Experts - Asset Class

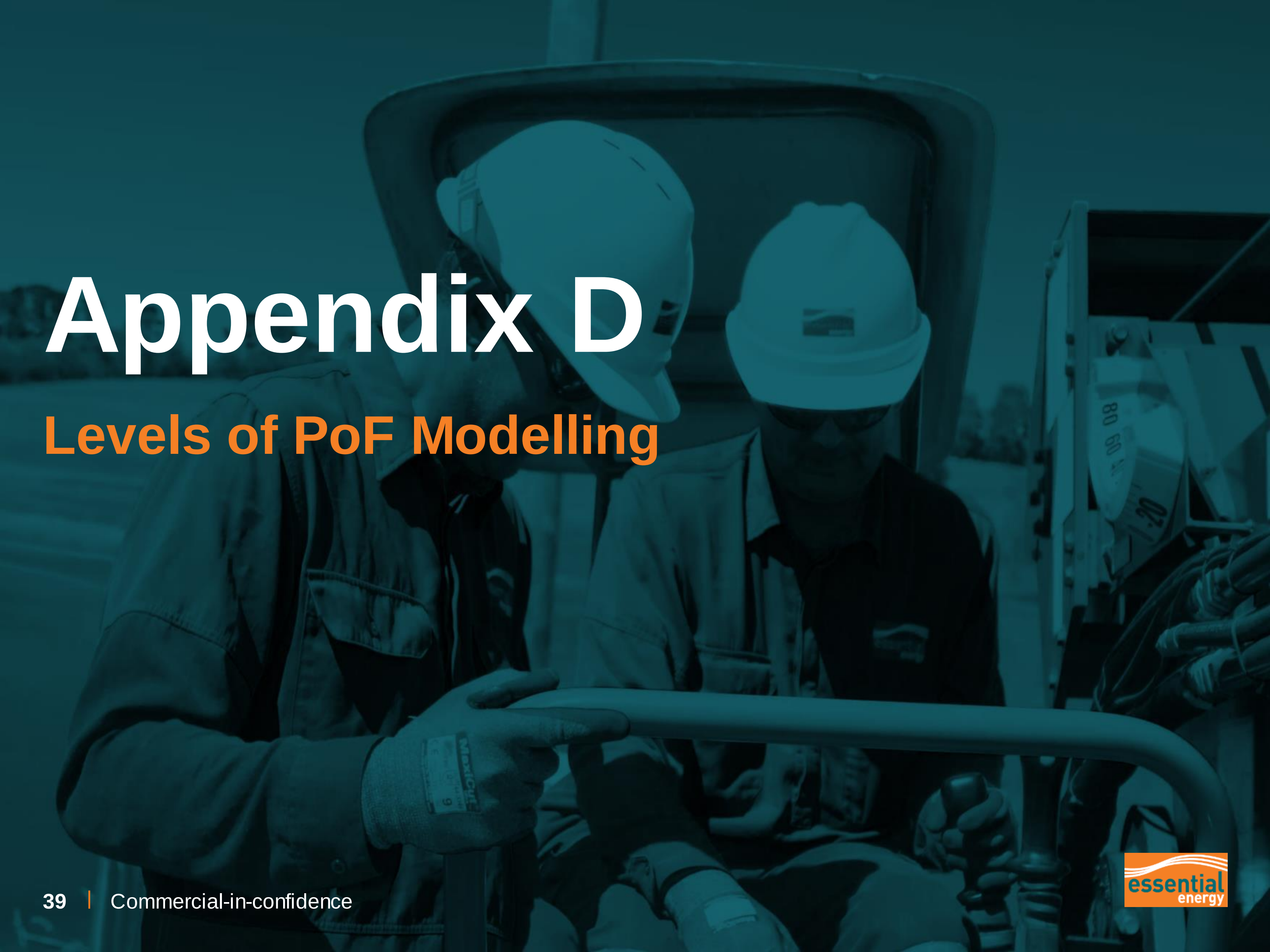
System	Asset Class Strategy	PoF Model Status	CoF Model status	Asset Class Strategy Owners [1]	PoF Model Owners [2]
Overhead	Distribution Power Transformers	Completed	To be updated to VF2	Josh Thomas (Vacant role)	David Shephard
	Overhead Conductors	Completed	To be updated to VF2		James Baker
	Overhead Customer Service Connections	Completed	To be updated to VF2		Not created yet
	Overhead Links, Switches and Fuses	Completed	To be updated to VF2		James Baker
	Pole Top Equipment (PTE)	Completed	To be updated to VF2		James Baker
	Poles	Completed	To be updated to VF2		James Baker
	Voltage Regulators and Voltage Regulating Relays	No PoF model	No CoF model		James Bowman
	Vegetation	Completed	To be updated to VF2	Health Frewin	TBC by EE
Secondary Systems	Auxiliary AC/DC Systems	Completed	To be updated to VF2	Warren McLean	Sam Mulquiney (TBC by EE)
	Electrical Network Telecommunications System	No PoF model	No CoF model		TBC
	Load Control	No PoF model	No CoF model		TBC
	Meters	No PoF model	No CoF model		TBC
	Protection and Control Systems	Completed	To be updated to VF2		Peter Tree (TBC by EE)
Underground	HV Ring Main Units	Completed	To be updated to VF2	David Mason	David Shephard
	Underground Cables	Completed	To be updated to VF2		Graeme Barnewall / Andrew Laing
	Underground Pits, Pillars and Cubicles	Completed	To be updated to VF2		Daniel Kelly / Andrew Laing
Zone Substation	Circuit Breakers	Completed	To be updated to VF2	Samantha Haynes	Aaron Thompson
	Earthing and Lightning Protection	No PoF model	No CoF model		TBC
	Instrument Transformers	Completed	To be updated to VF2		Aaron Thompson
	Reactive Plant	Completed	To be updated to VF2		Majid Tavakoli
	Substation Buildings and Property	No PoF model	No CoF model		TBC
	Surge Arrestors	Completed	To be updated to VF2		Sam Mulquiney
	Switchboards	Completed	To be updated to VF2		Majid Tavakoli
	Zone Substation Outdoor Busbar, Isolators and Disconnectors	Completed	To be updated to VF2		Majid Tavakoli
	Zone Substation Transformers	Completed	To be updated to VF2		Sam Mulquiney

[1] Asset Class Strategy Owner list has been sourced from the System Register

[2] PoF Model Owners have been provided by Head of Engineering and potentially require updating in the System Register

Subject Matter Experts - Consequence

Consequence Category	Consequence SME	Cost of Consequence SME
Safety and Wellbeing	Jason Lindley	Alex Bardon
Network Reliability	Steve Ashton	
Financial (F&E)	John Chilko	
Financial (insurance claims)	David Chinn	
Environment (Bushfire)	Ian Fitzpatrick	
Environment (other)	Brett Hayward and Ian Fitzpatrick	



Appendix D

Levels of PoF Modelling

Levels of PoF Modelling

● (orange)	Previous PoF model level	● (green)	Current PoF model level (after ACS completion)

Endorsed Asset Class Strategy	Level of Modelling: N/A	1	2	3	4	5	6	7	Resulting PoF Model	Key Challenges
Poles 2 Timber poles, Pole cap, Stay assembly		Previous			Current				(1) Weibull PoF model at sub population level → (2) asset condition	Interaction between failure modes
Pole Top Equipment Crossarms (including anti-split bolts), insulators, conductor ties		Previous, Current							(1) Weibull PoF model at sub-population level	Missing condition data
OH Conductors Focus on bare OH conductors due to data availability and high level of maturity		Previous, Current	Current						Weibull parameters from AER submission (for ACSR, SC & HDBC) & OFGEM methodology (for AAAC).	Missing condition data, segments not represented in WASP
OH Customer Service Connections Includes the conductor, electrical connections, and mounting hardware. Low Voltage overhead conductors are in OH Conductors	Previous	Current							Weibull PoF model at population level	Assets not represented in WASP
OH Links, Switches and Fuses Gas switches, Air Break Switches (ABS), LV and HV Links, Expulsion Drop Out Fuses (EDOs), LV Fuses and Fuse Savers. No PoF for LV Fuses and Fuse Savers this iteration.	Previous	Current							Weibull PoF model at population level	Assets only partially represented in WASP
HV Ring Main Units RMUs for the underground power distribution network, including HV switchgear and related ancillaries	Previous	Current							Weibull PoF model at sub-population level and failure modes	Poor failure and condition data (Maintenance recovery program recently started)
UG Pits, Pillars & Cubicles Pits (direct buried, switching and pulling pits), pillars (including service and pot bellied pillars) and cubicles	Previous	Current							Weibull and OFGEM PoF model at population level	Assets only partially represented in WASP, Previous PoF models unavailable
UG Cables UG Cables and their terminations including ST, HV, LV, and Service cables both inside and outside zone substation boundaries	Previous		Current						OFGEM PoF model at population level	Assets not represented in WASP

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Levels of PoF Modelling

Orange dot	Previous PoF model level	Grey-green dot	Current PoF model level (after ACS completion)

Endorsed Asset Class Strategy	Level of Modelling: N/A	1	2	3	4	5	6	7	Resulting PoF Model	Key Challenges
Zone Sub Transformers Power transformers that are located within zone substations, including their key subassemblies of windings, tank, bushings and on load tap changers		Previous Current							Weibull PoF model at sub-population level - Windings, Tap changers, Bushings, All	Significant effort required for prepare data & model the PoF
Switchboards Switchboards located within zone substations, including circuit breakers that are integral to those switchboards		Previous Current	Current						Weibull PoF model at CB population level with OFGEM methodology to differentiate sub-populations	Previous Weibull calculations were unavailable. Significant effort building failure list.
Circuit Breakers Two subpopulations: 1) Outdoor circuit breakers and reclosers located within zone substations; 2) reclosers and sectionalisers located on the OH network.	Previous	Previous Current	Current						Weibull PoF model at subpopulation level with OFGEM methodology to differentiate CB sub-populations	Key challenge was the OH assets as only partially represented in WASP. Previous Weibull calculations were unavailable. Significant effort building failure list.
Earthing & Lightning Protection Earthing equipment on pole top transformers, and specifically HV/LV upgrade tasks*; all other earth sites will be addressed in subsequent iterations									No PoF Model was developed. Focus was to improve the process for end-to-end overhead earthing inspections	*Upgrade tasks are tasks to remediate earth sites with high earth resistance readings
Zone subs outdoor busbars, isolators and disconnectors Air-break switches / isolators / disconnectors, earth switches and links. Fuses, gas switches, capacitor bank isolators and fault throwers have been excluded from this iteration given their relatively low defect rate.	Previous	Current							Weibull PoF model at sub-population level: Air-break switches / isolators / disconnectors, earth switches and links	Task categories in source dataset did not provide a clear indicator of end-of-life / failed assets. Limited availability and consistency of data made it difficult to classify failures as repair or replace.
Load Control Load control plant used in zone substations & some TransGrid bulk supply points (BSP) Load control relays mounted on customer switchboards		Previous Current							Population level PoF (proportion of failures due to causes)	Assets not represented in WASP, condition/maintenance data poor

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