Define and predict the risk of climate change

Climate Resilience Methodology

November 2022

Endeavour Energy

POWER together

Contents

Endorsement and Approval

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Version History

Version	Edited By	Changes
0.1	Samuel Morris	Document Creation
1.0	Samuel Morris	Incorporated customer and stakeholder feedback

1. Introduction

1.1. Purpose

The purpose of this method is to provide context and a framework for the activities required to ensure Endeavour meet the first of three Resilience Strategy Goals defined in the Resilience Plan, specifically Resilience Goal 1, which is to:

Define and predict the risk of climate change on the network and community resilience

To achieve this goal, the process outlined in Figure 1, and further detailed in the following sections of this document, will be implemented.

Understand the Context (Section 2)

- Set a clear purpose and objectives for evaluating climate risk
- Identify relevant stakeholders to contribute and be included in decision making

Identify historical climate risk (Section 3)

- Review historial data to understand the impact of major climate events and system performance
- Define the relevent metrics required to quantify climate change risk in the future

Analyse future climate risk (Section 4)

- Develop emission-scenario-based modelling of future climate.
- Utilising the climate data and modelled emissions scenarios, determine how to assess network and community exposure to these events

Evaluate risks (Section 5)

- Develop models to calculate exposure risk on network assets
- Evaluate increased (or decreased) risk under RCP4.5 and RCP8.5 for each climate hazard utilising developed models.

Treat climate risks (Section 6)

- Identify potential mitigations of the identified risks, either by reducing the likelihood or consequence of a major event.
- Conduct a cost-benefit and sensitivity analysis considering the broader investment landscape in accordance with investment methodologies, and used in case for investment justifications as applicable.
- Put investments into the investment portfolio optimisation process.

Figure 1 – Plan for climate change risks

2. Understanding the context

2.1. Objectives

The objective of this methodology is to set the framework in which Endeavour Energy will assess the current and potential future impact climate events can have on its network and its customers.

An effective climate risk methodology will enable Endeavour Energy to develop and implement investment opportunities to help support its customers.

2.2. Stakeholders

The following table outlines the stakeholders who have interest in the development of climate modelling either due to the direct and indirect impact of climate. This methodology has been developed considering and informed by the engagement with these stakeholders.

Table 1 – Stakeholder of climate modelling

Internal stakeholder	
Stakeholder	**Interest**
Asset Performance	Needs to understand and use escalation factors for major climate risks to determine their impact on optimum asset replacement decisions.
Asset Planning	Needs to know the relative risk of various geographic areas to ensure design takes into account selection of asset location that minimises risk of assets to climate.
Future Grid	Needs to understand the current and future climate as it is crucial to ensure innovation and developing the lowest cost to deliver energy to customers.
System Control	Needs to understand the current and future climate exposure to optimise the post-event response to ensure the lowest possible outage duration for customers.

<table>
<tr><th colspan="2">External Stakeholder</th></tr>
<tr><th>Stakeholder</th><th>Interest</th></tr>
<tr><td>Customers (incl. Major Customers)</td><td rowspan="2">Need to understand the climate risks when engaged to help develop Endeavour Energy’s investment strategies; having informed customers is vital to making efficient decisions.</td></tr>
<tr><td>Community Groups</td></tr>
<tr><td>Regulators (AER/IPART)</td><td>Need to understand climate risks to ensure Endeavour Energy is being prudent and effective with its investments, and to solidify Endeavour Energy’s partnership with its regulators.</td></tr>
<tr><td>Reliant Industry / Utilities</td><td>Need to understand climate risks as these are likely shared and there may be increased reliance on consistent electrical supply for dependent providers, which could lead to co-funding opportunities for resilience investment.</td></tr>
</table>

3. Identify historic climate risk

3.1. Historical climate analysis

Endeavour Energy covers a large geographical area characterised by different vegetation and elevation profiles. This has a large impact on the conditions our network and customers experience. To determine the exposure to various climate events, historical climate data (1986-2005) from the Electricity Sector Climate Information (ESCI), as well as weather station data for wind, is utilised and summarised in Table 1 and Figure 2 to Figure 4.

This data demonstrates how the climate variers across Endeavour Energy's network. The southern areas experience a much cooler, wetter climate, while the northern region is drier with an increased fire danger risk as shown by the increased Forest Fire Danger Index (FFDI).

Table 2 - Climate Summary of Endeavour Energy's Area split by Distribution Areas (1986-2005)

Region	Area (km^2)	Number of Customers	Average Maximum Annual Rainfall (mm/day) (1 in 20 year return period)	Average Number of Days > 35ºC per annum	Average number of days with FFDI >25 per annum	Average Max Annual Wind Speed (km/h)
West	848	107,471 *(9%)*	93.7	5	9.6	88.8
East	419	423,598 *(36%)*	124.4	9.5	12	72.8
Central	394	498,463 *(43%)*	136.5	7	10	63.4
South	783	134,287 *(12%)*	148.83	2.5	5	79.5
Entire Area	**2,444**	**1,163,819**	**126.1**	**5.0**	**8.2**	**54.8**

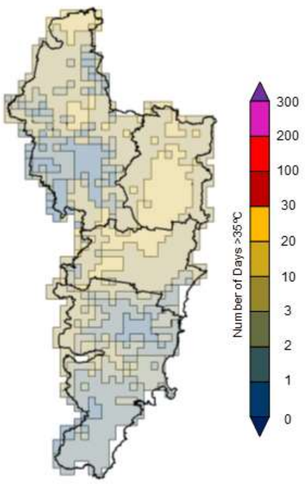


Figure 2 - Number of days > 35ºC

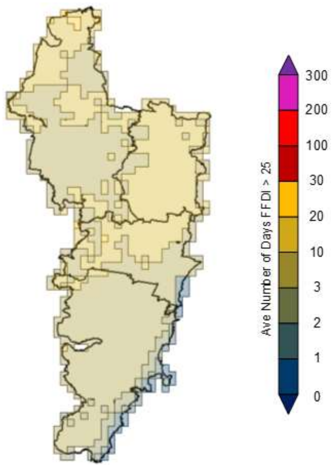


Figure 3 - Average Number of Days FFDI >25

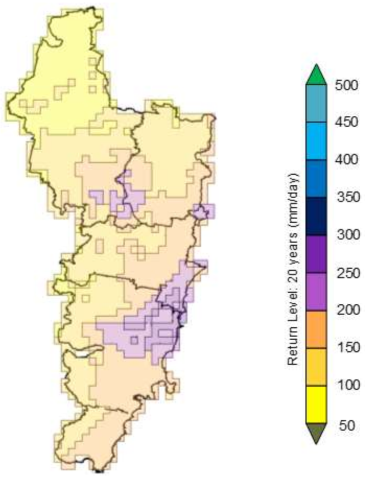


Figure 4 - 1 in 20 year return period for precipitation (mm/day)

3.2. Network impacts from climate events

3.2.1. Frequency and cost of events

To determine the impact of these climate events on Endeavour Energy's network, the reliability impact from events recorded within the Outage Management System (OMS) was extracted and analysed. Figure 5 below shows a summary of network impacts caused by major weather events over the past 10 years. This figure illustrates the variety of major events each year, with storms being dominant. The impact of these events has been quantified in terms of costs and service interruption (reliability), and is summarised in Table 3.

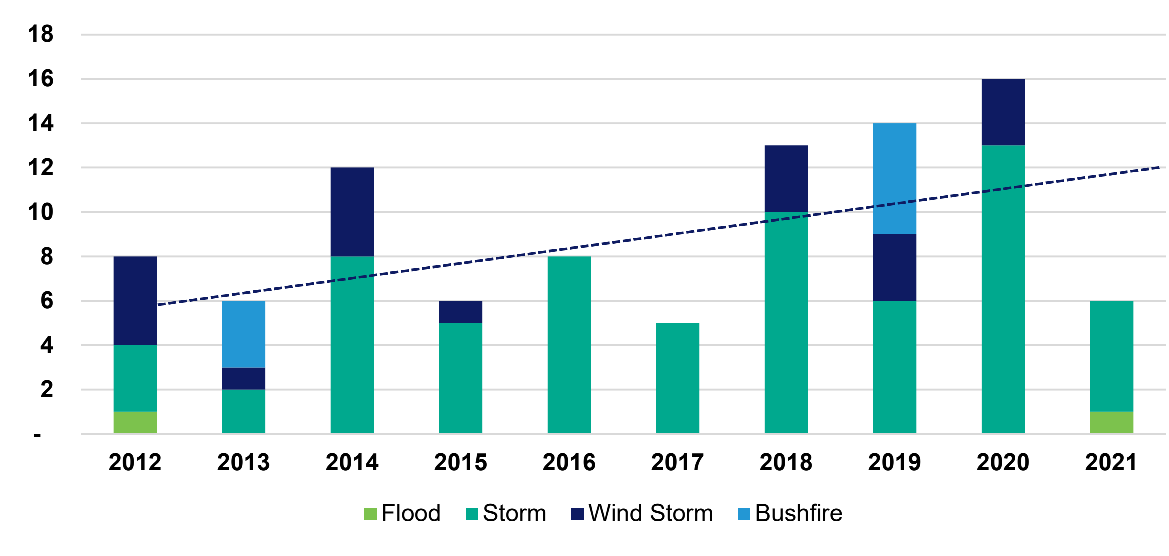


Figure 5 - Major Events experienced by EE (with trendline)

Table 3 - Major Events summary information.

		Bushfire[1]	Flood	Storm (Wind + Precipitation)	High Wind Storm
Freq	Average per year	0.40 *(1 every 2.5 years)*	0.30 *(1 every 3 years)*	6.40 *(once every 2 months)*	1.90 *(Once every 6 months)*
Financial Impact	Average Cost per year ($million)	2.658	0.119	2.046	0.372
	Average Cost per instance ($million)	5.981	0.432	0.295	0.176
Reliability Impact	Average Number of Customers Affected	26,358	17,521	31,725	24,172
	Average CMI (million)	46.5	5.2	4.6	3.91
	Average Yearly CMI (million)	11.1	0.6	32.9	8.4
Assets Lost	Poles Replaced	36	5	1.4	2.2

		Bushfire[1]	Flood	Storm (Wind + Precipitation)	High Wind Storm
	Pole Substations Replaced	1.9	3.0	1.7	0.5
	Length of Bare Conductor Replaced	5.9kms	0.6kms	0.442km	0.569kms
	Length of Covered Conductor Replaced	3.6	1.1	1.8	1.7
	Padmount Substations Replaced	0.1	1.0	0.1	-

1- A fire event is a major large scale bushfire event. Small or asset fires are not included in this figure.

The various major events vary in frequency but on average they are costing Endeavour Energy approximately $4.76 million per year and resulting in 31 million customer minutes interrupted.

Further analysing the cost of each event shows that the main driver is labour accounting for an average of over 50% of total cost for each event, with the cost of physical asset replacement accounting for only 10% of total cost.

3.2.2. High Temperature and Heatwave Events

In June 2022, Endeavour Energy undertook a summary into the impact high temperature days (>35ºC), and heatwaves (3 consecutive days >35ºC), detailed in the report *Network Reliability During Heatwaves*.

From this analysis it was found when comparing to reliability during a heatwave against the average daily reliability within each month, it was found:

- A single day over 35ºC, did not result in deteriorating network performance;
- There was a trend of deteriorating reliability by the end of the third day, with an the outage duration being, on average, 143% higher; and,
- The areas which has the most frequent occurrence of these heatwaves is the Penrith and Kellyville areas.

Figure 6 – Average annual consecutive days >35ºC

3.2.3. Reliability impact

Endeavour Energy's reliability performance from FY12 to FY21 is shown in Figure 7, comparing the un-normalised and normalised System Average Interruption Duration Index (SAIDI). The trendline for normalised SAIDI (dark blue) indicates improved reliability performance of the network. Normalised SAIDI removes major climate events from the reliability metric. The trendline for unnormalised SAIDI (light blue) includes the impact of major climate events, resulting in a negative performance trend. This comparison demonstrates the quantifiable impact of major climate events, and the tangible impact on network performance.

If this trendline is extrapolated through to 2040, the average un-normalised SAIDI target would hit approximately 298 SAIDI minutes, almost double the current average of 158 minutes.

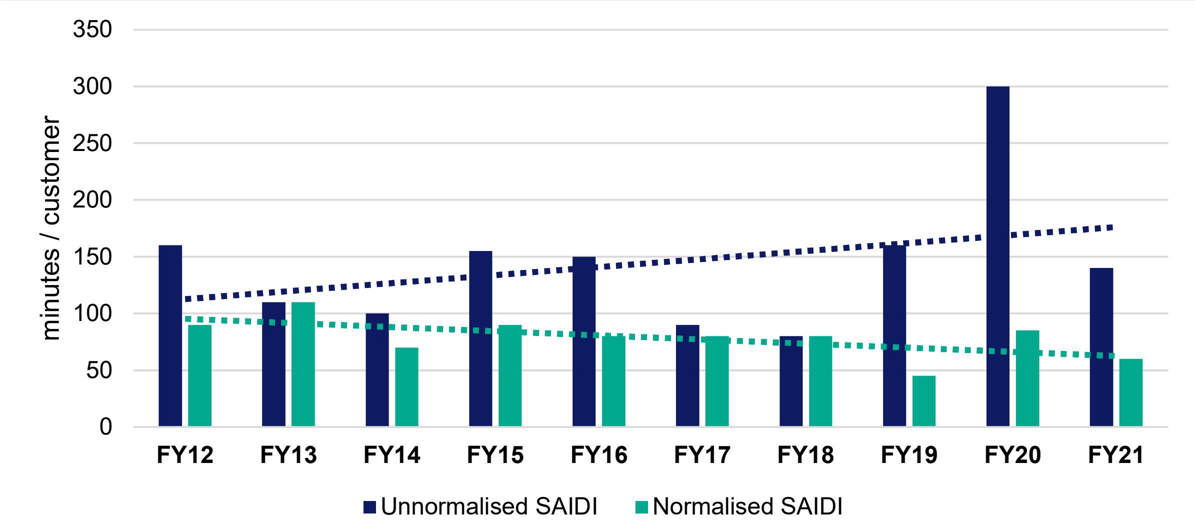


Figure 7 - Endeavour Energy reliability performance

3.3. Metrics for Climate Change

Using the past historical major events, and the subsequent impact on the network and system performance, can highlight the key major event hazards that should be considered as metrics for measuring future climate change. Table 4 outlines the key climate metrics for Endeavour Energy based on historical climate major events and likely future concerns. These metrics will be used when modelling different emissions scenarios (Section 4.1) to determine the future climate risks.

Table 4 - Hazards considered in climate change scenario analysis

Physical Hazard	Climate Metric	Metric Description	Unit
Bushfire	Very High Fire Days	Number of days annually where the Forest Fire Danger Index exceeds 25 (very high rating)	days
Extreme Heat	Extreme Heat	Number of days annually over 35ºC	days
Flood	Extreme Wet Intensity	1-in-20yr wettest day rainfall	mm/day
Extreme Wind Frequency* **	East Coast Low Frequency	Historical and future days per year where an East Coast Low occurs	%

4. Analyse future climate risk

4.1. Develop scenario models

Endeavour Energy's network assets have a service life of up to and beyond 50 years. Prudent asset management investment requires an understanding of what stresses are expected through an assets' lifecycle. This must include an understanding of the impacts of climate change to the environment which assets are exposed to, as well as the usual consideration of standard ageing and deterioration. Ultimately the analysis of the future climate risk needs to assess the change in the service levels of the network it impacts. To understand this impact, first the various scenarios of future climate risks need to be defined, measured, and understood.

The Intergovernmental Panel on Climate Change (IPCC) has developed 'representation concentration pathways' (RCPs) for greenhouse gas emissions. The RCPs scenarios represent future plausible scenarios based on carbon emissions. The two of most relevance are:

- RCP 4.5 – A moderate scenario whereby emissions peak by 2040 and then decline. Global temperature rise will be between 2-3ºC.
- RCP 8.5 – A higher warming scenario where emissions continue to rise through the century. A global temperature risk of approximately 5 degrees is expected.

A 2022 report by Energy Networks Australia, *Electricity Networks: A guide to climate change and its likely effects'*, estimated that for Endeavour Energy's area the impact in 2090 will be:

- **Temperature:** Estimated 1.1-1.9º increase
- **Rainfall:** Seasonal will likely decrease, but heavy rainfall to increase
- **East Coast Lows (ECLs**): to become less frequent but more severe in warmer months
- **Bushfire**: Season to start earlier and last slightly longer

4.2. Future exposure summary

The following table summarises the exposure of the four distribution regions to the various climate hazards, under different emissions scenarios out to 2090.

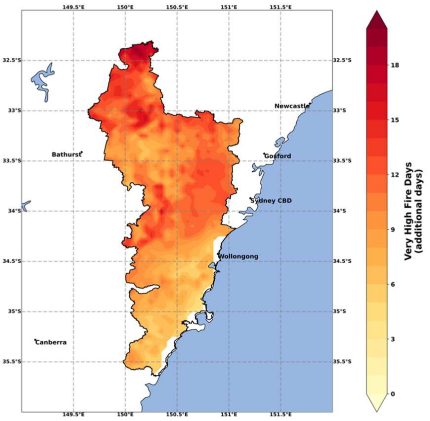
Table 5 – Future exposure and calculation of escalation factors based on location

Bushfire Exposure (average Number of days FFDI > 25)	Region	Historical	RCP4.5		RCP8.5		% increase RCP4.5		% increase RCP8.5	
			2050	2090	2050	2090	2050	2090	2050	2090
	East	16.9	22.5	27.5	23.6	28.7	34%	63%	40%	70%
	Central	13.3	17.8	22.3	19.0	23.9	34%	68%	43%	80%
	West	6.5	10.2	11.8	10.9	16.5	58%	83%	69%	155%
	South	4.9	7.2	9.0	8.2	11.2	46%	82%	67%	128%

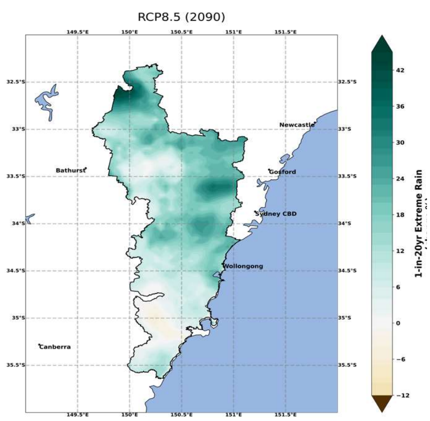
Extreme Heat (Days >35°C)	Region	Historical	RCP4.5		RCP8.5		% increase RCP4.5		% increase RCP8.5	
			2050	2090	2050	2090	2050	2090	2050	2090
	East	10.3	17.7	22.9	20.6	37.5	72%	122%	100%	264%
	Central	6.8	12.4	16.3	14.4	28.1	81%	139%	112%	311%
	West	2.5	6.2	9.0	7.9	18.0	150%	267%	222%	629%
	South	1.6	3.8	5.6	4.6	11.5	141%	253%	193%	629%

Flooding Event (1-in-20yr Extreme Rain level)	Region	Historical	RCP4.5		RCP8.5		% increase RCP4.5		% increase RCP8.5	
			2050	2090	2050	2090	2050	2090	2050	2090
	East	150.8	146.9	159.9	165.5	183.8	-3%	6%	10%	22%
	Central	155.3	161.3	175.4	168.0	186.0	4%	13%	8%	20%
	West	106.6	110.0	108.9	110.4	116.7	3%	2%	4%	9%
	South	165.4	179.9	181.6	186.5	180.9	9%	10%	13%	9%

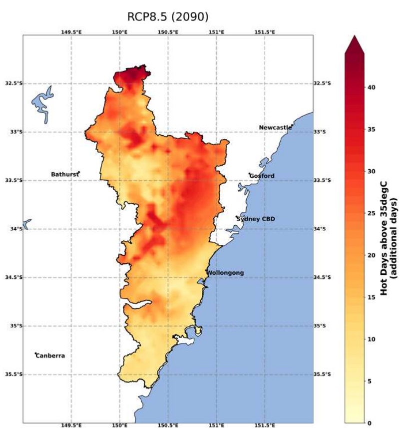
Bushfire Risk Map



Flood Risk Map



Extreme Heat Map



4.3. Note about wind modelling

It has been the advice given to Endeavour Energy from climate scientists, that the data available for wind modelling is not at a maturity level in which confidence in its output can be assured.

From literature assessment and with current data available, it has been assessed that:

- the intensity of wind events is set to vary between -3.0 to 8.5km/h; and,
- the frequency of severe wind events is set to decrease from 38-44 days per year to 18-29 days.

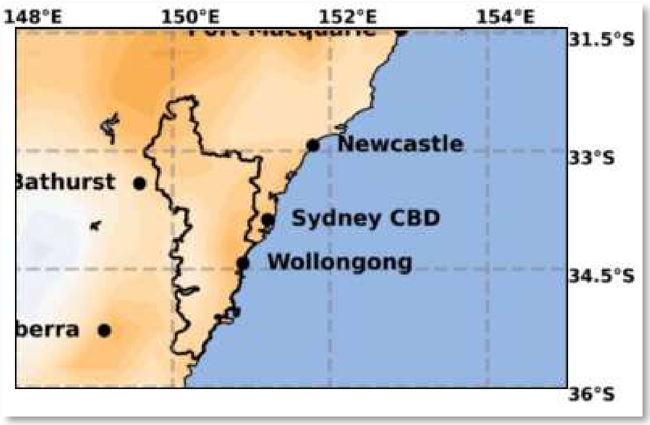


Figure 8 – Projected increase in wind speed by 2090

Utilising local weather station data over the last decade, a more localised exposure map, shown in Figure 9, can be produced for Endeavour Energy's franchise area.

Wind has large impacts to Endeavour Energy's performance, with an estimated 4500 interruptions per year due to vegetation, and a number of conductor clashing incidents.

As such, Endeavour Energy will not be factoring in wind exposure modelling into its climate projections until such time that better data becomes available. Endeavour Energy will however be exploring potential network investments that can be pursued under current exposure levels.

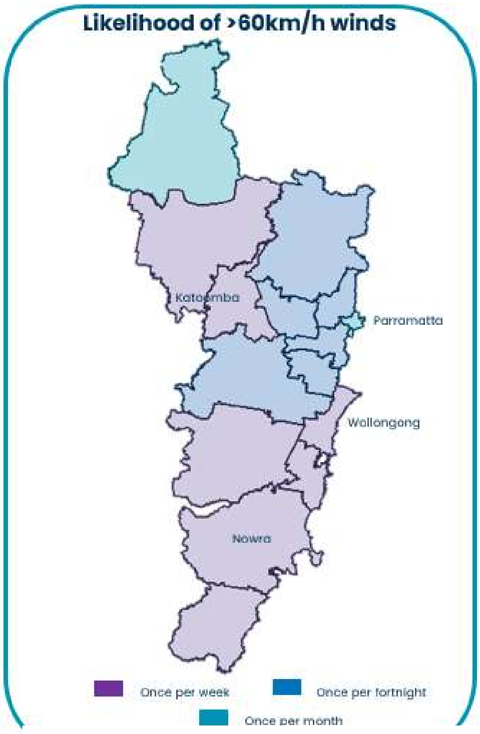


Figure 9 – Exposure to wind gusts >60km/h

5. Evaluate risks

5.1. Development of models to calculate exposure risk

Any investment will be assessed using Endeavour Energy's Customer Value Framework. The framework outlines how an asset risk is evaluated against intervention measures. Ultimately resilience investments are assessed like all other investments, with weighing up risks and opportunity benefits.

Climate escalation factors can be applied in two ways when calculating risks:

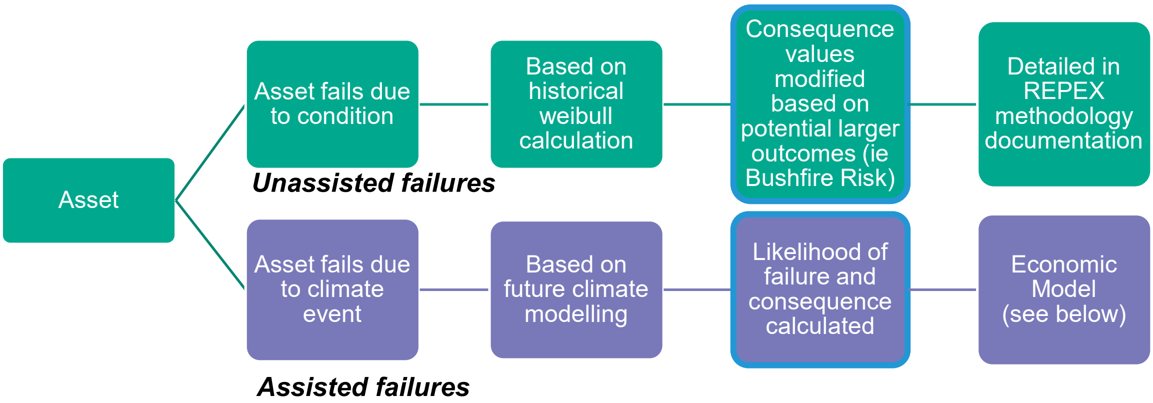


Figure 10 – Justification approaches based on failure type

The sections below detail how the economic model, in the case of assisted failures, is developed.

5.1.1. Methodology for assessing assisted failures

The following graphic details the approach to assessing the impacts of major events to the network.

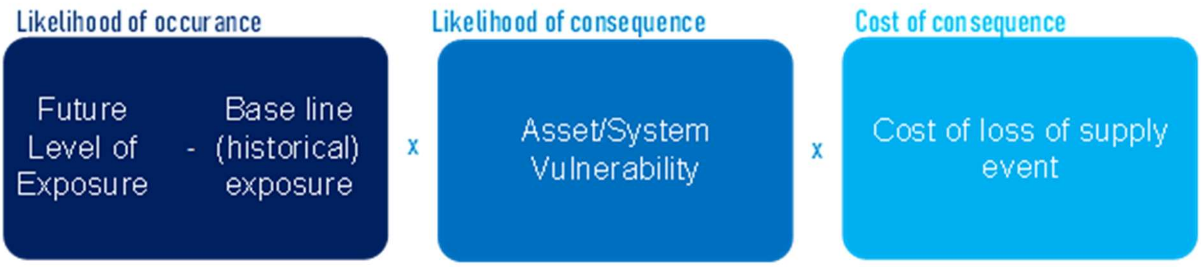


Figure 11 - Climate Assisted Failure Risk Probability

5.1.2. Likelihood of occurrence

The following table summarises how the output of the climate modelling is extrapolated into a probability calculation.

Table 6

Climate Hazard	Annual Likelihood Calculation
Bushfire	Number of days above FFDI 25 / 365
Extreme heat	Number of days above 35ºC / 365
Flood	Average rainfall (mm/day) / 264.9 (mm/day)

5.1.3. Method/model to assess asset/system vulnerability (likelihood of consequence)

To determine as asset's vulnerability to a climate event, a mixture of qualitative and quantitative assessment is undertaken. This involves using a mixture of both failure data and interviews with subject matter experts.

The vulnerability is made up of two components:

1. Whether the asset, when exposed to the hazard will be affected (Annexure A); and
2. If the asset is exposed to the hazard, the probability it will result in a failure (Annexure B).

The outcome of this work is summarised in Annexure A and B, showing the vulnerability of Endeavour Energy's Asset Classes to key climate hazards.

5.1.4. Methods/models for assessing risk costs

The assessment into the risk costs associated with a loss of supply event, is to be undertaken in line with Endeavour Energy's Asset Value Framework. The failure of an asset will be assessed under different risk categories of Safety, Reliability, Environmental and Bushfire. This is performed on a per asset-class basis, with each individual asset having unique approaches.

5.1.5. Assessing indirect impact costs

Endeavour Energy acknowledges loss of supply during major climate events can cause stress and hardship for customers with both financial and non-financial impacts to its customer base. This has also been reflected in conversations with customers (Joint DNSP Engagement March 2022), and through research into major climate events (Resilient Sydney's – 'Insights into community resilience experiences' 2018). Currently, there is no industry accepted method to financially assess these impacts.

The electrical network is critical in facilitating the operation of many sectors in society, with its centrality illustrated in Figure 12. This was also highlighted within the Royal Commission into Natural Disaster

Arrangements which outlined the importance of critical infrastructure (namely energy and telecommunication sectors), and the need for co-ordination and information sharing[1].

There is further work to be done to understand and evaluate the implications of an electrical outage on other industries, including determining the indirect impact costs.

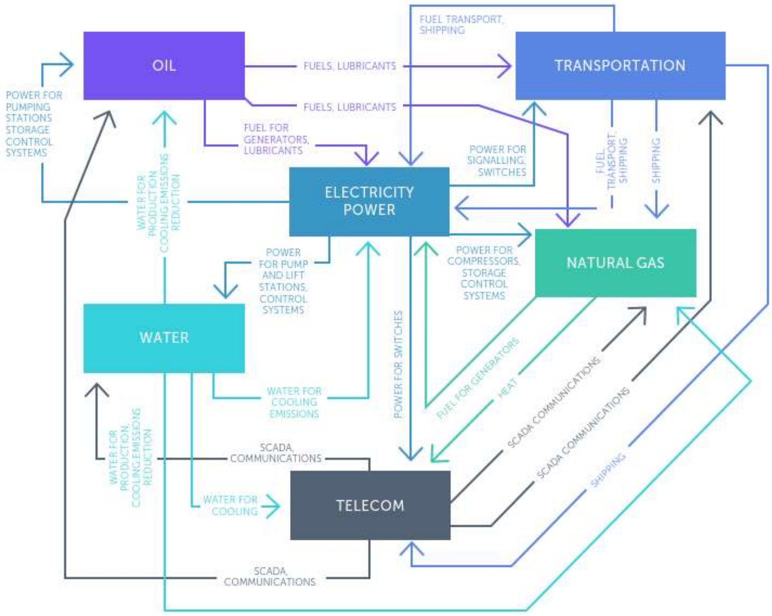


Figure 12- Centrality of a DNSP to industry[2]

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[1] (Pages 241-244, Recommendation 9.5)

[2] (Critical Infrastructure Resilience Strategy — Emergency Management Victoria (2015))

6. Treatment of Climate Risks

Once climate risk has been assessed, evaluated, and prioritised (as per the previous sections of this method) then the risk treatment options can be identified and assessed. The process for the treatment options is outlined in Figure 13 below.

Figure 13 - Climate Risk treatment process to determine investments

Risk treatment options can be categorised into two categories:

- Pre-event investment (network augmentation or network hardening); and/or,
- Post-event investment (customer support, operational responses).

6.1. Identify potential mitigations

Risk treatment options for can be determined several ways, some of which are highlighted in the figure below.

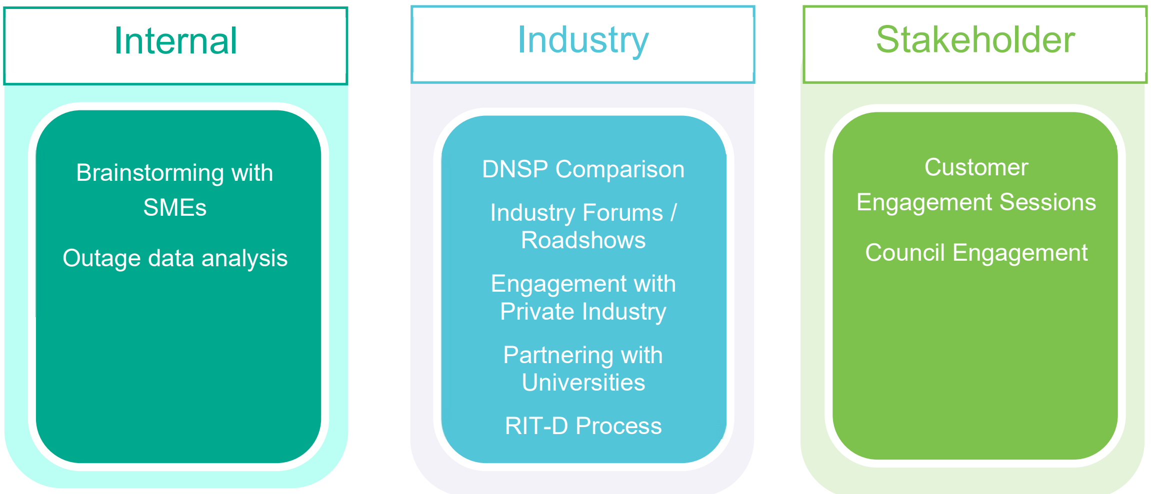

Figure 14

6.2. Credibility/Economic Test

With each generated treatment option, to ensure Endeavour Energy is delivering a safe, reliable and cost-effective solutions, each idea is tested for:

1. Technical and economic feasibility;
2. The effectiveness of the solution and residual risk, and whether this risk level is tolerable;
3. Assessing whether other solutions are more effective and can be implemented in time to meet the need.

These investments follow the process outlined in our Customer Value Framework and result in cases for investment (CFI) to then optimised along with other network investments.

7. Annexure A – Vulnerability Matrices

Table 7- Asset Vulnerability Matrix

Asset Class	Asset Sub-class	Bushfire	Flood	Storm	High Winds	Heat Wave
Pole	Wood Pole	✓		✓	✓	
	Steel Pole	✓		✓		
	Concrete Pole	✓		✓	✓	
	Transmission Poles	✓		✓	✓	
Pillar	-	✓	✓			
Tower	Transmission	✓		✓	✓	
Substation	Pole mounted	✓	✓		✓	
	Padmount	✓	✓			
	Zone Substation	✓	✓		✓	
Conductors	Bare Mains	✓		✓	✓	✓
	Covered Mains	✓		✓		✓
	Comms	✓		✓	✓	
	Services Covered	✓		✓	✓	
Switches	LBS	✓		✓	✓	
	aLBS	✓	✓	✓	✓	
	Reclosers	✓	✓	✓	✓	
	Regulators		✓	✓	✓	

Table 8 - Likelihood of failure

Asset Class	Asset Sub-class	Bushfire	Flood
Pole	Wood Pole	5.0%	0.54%
	Steel Pole		0.54%
	Concrete Pole	0.5%	0.54%
	Transmission Poles	5.0%	0.54%
Pillar	-	75.0%	100%
Tower	Transmission	3.33%	3.33%
Substation	Pole mounted	0.5%	5.0%
	Padmount		50.0%
	Zone Substation	1.0%	2.0%
Conductors	Bare Mains – HV	1.12%	
	Bare Mains – LV	4.67%	
	Bare Mains – TR	4.67%	
Switches	LBS	0.93%	
	Reclosers	0.9%	50.0%
	Regulators		50.0%

Annexure C – Definitions and Abbreviations

Term	Description
Community Resilience	The ability of communities to withstand and recover from the impacts of natural disasters.
CMI	Customer Minutes Interrupted. This is a summation of the durations each customer experiences during a particular outage event.
Major Event	A significant weather event which has the potential to impact the network sufficiently to result in a Major Event Day.
Major Event Day	Interruptions beyond the control of Endeavour Energy, or because they are not representative of a normal day in terms of reasonable network resource availability and goes beyond a pre-defined threshold for organisational SAIDI.
Resilient Network	The ability to anticipate, withstand, quickly recover and learn from disruptive events to the power network.
SAIDI	System Average Interruption Duration Index, the sum of the durations of all the Sustained Interruptions (in minutes), divided by the Customer Base. Momentary Interruptions (of three minutes or less) are excluded from the calculation of unplanned SAIDI.
Normalised SAIDI	SAIDI less approved exclusions, such as impact of major event days.
Unnormalised SAIDI	SAIDI inclusive of all interruptions, including major event days.
FFDI	Forest Fire Danger Index – developed by the CSIRO it indicates the potential fire danger by combining a measure of vegetation dryness with air temperature, wind speed and humidity.

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