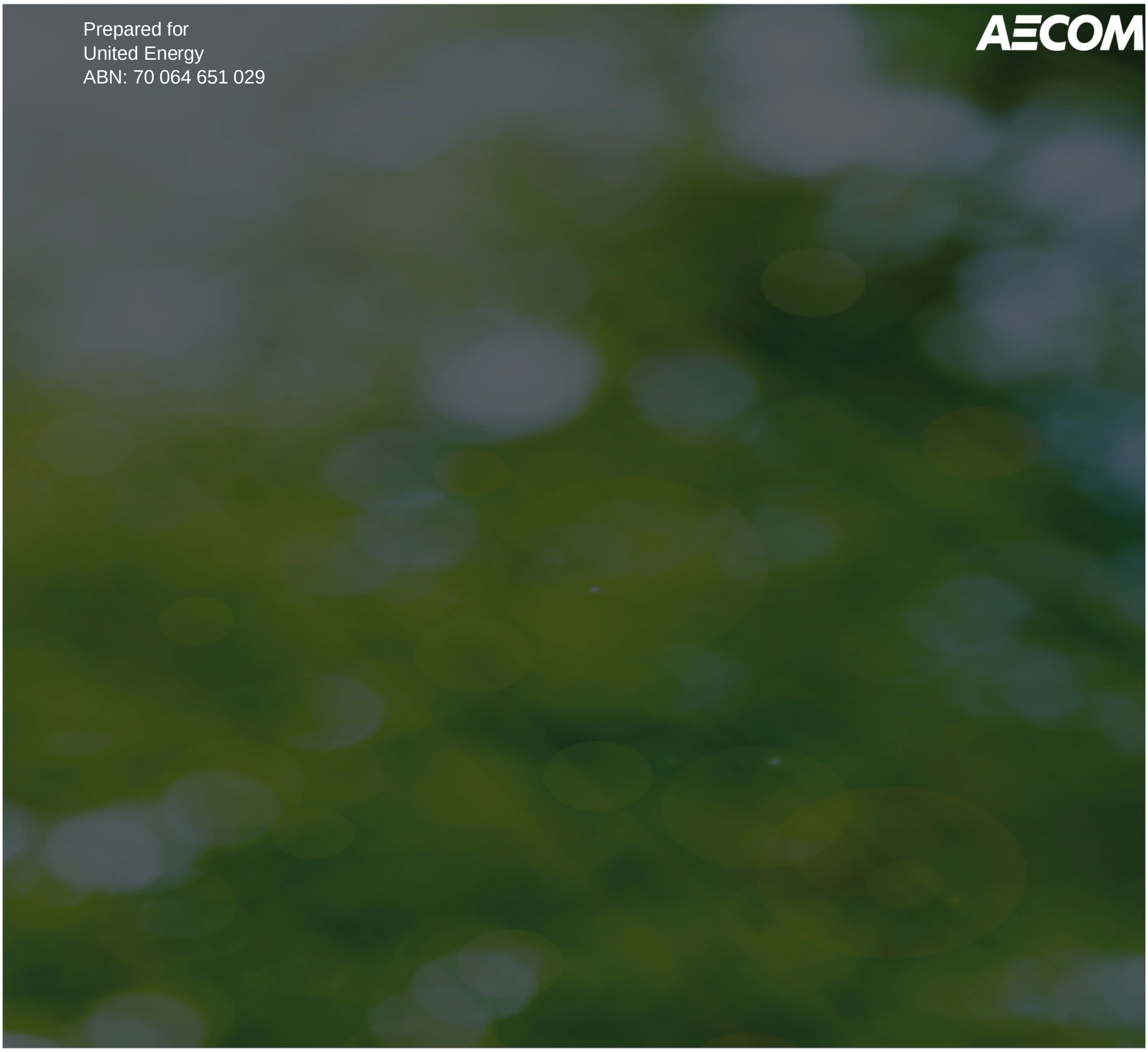

Prepared for
United Energy
ABN: 70 064 651 029

Climate Change Study for Victorian Electricity Distribution Businesses - Phase 2 -

14-May-2024

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Climate Change Study for Victorian Electricity Distribution Businesses - Phase 2 - Methodology

Client: United Energy

ABN: 70 064 651 029

In combination with CitiPower, United Energy, Powercor Australia

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5	14-May-2024	Revised final for issue	Allan Klindworth Associate Director Sustainability and Resilience	

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Glossary

Key term	Definition
Adaptation (to climate change)	In human systems, the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.
Annual Exceedance Probability (AEP)	A term used to describe the probability of an event (i.e., a flood event) occurring in a year.
Annual Recurrence Interval (ARI)	An outdated term used to describe flood events referred to in the Australian Rainfall and Runoff Guidelines 1987.
Climate change	A change in the state of the climate that persists for an extended period, typically decades or longer. Climate change may be due to natural variability or a result of human activity.
Climate projections	Simulated response of the climate system (including variables such as temperature, precipitation, wind, solar radiation, sea level) to a scenario of future emissions or concentrations of greenhouse gases and changes in land use, generally derived using climate models. Climate projections depend on an emission scenario, in turn based on assumptions concerning factors such as future socioeconomic and technological developments that may or may not be realised.
Climate variables	Factors that determine and govern the climate. Main factors include rain, atmospheric pressure, wind, humidity and temperature.
Extreme weather event	An event that is rare at a particular place and time of year. The characteristics of what is called extreme weather may vary from place to place.
Forest Fire Danger Index (FFDI)	A metric used to measure 'bushfire weather', combines a measure of vegetation dryness with air temperature, wind speed and humidity.
Hazard (climate hazard)	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
Representative Concentration Pathways (RCPs)	Scenarios that include time series of emissions and concentrations of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover. The word representative signifies that each RCP provides only one of many possible scenarios. The term pathway emphasises the fact that not only the long-term concentration levels, but also the trajectory taken over time to reach that outcome are of interest.
Resilience	The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure.

1.0 Introduction

1.1 Background

The Australian Energy Regulator's (AER) guidance on resilience investment recommends that Network Service Providers demonstrate:

- The causal relationship between the proposed resilience expenditure and the expected increase in extreme weather events.
- Proposed expenditure is required to maintain service levels and is based on the option that likely achieves the greatest net benefit of the feasible options considered.
- Consumers have been fully informed of different resilience expenditure options, including the implications stemming from these options, and that they are supportive of the proposed expenditure.

To assist in responding to the AER guidance, CitiPower, Powercor and United Energy sought the development of a methodology for assessing adaptation options to address potential future climate impacts. This work builds on the foundational work undertaken in 2023 (i.e., Phase 1 of the project) which identified relevant climate hazards, risks to assets, and an assessment of relative exposure of assets across Victoria's electricity distribution network. This second phase includes consideration of escalating impacts of extreme weather events because of climate change through the quantification of projected change in the frequency of hazards.

1.2 Objective

The objective of developing this methodology is to support the Electricity Distribution Businesses (EDBs) in the preparation of their regulatory submissions, including cost benefit analyses. This work focuses on quantifying the following:

- Changes in the frequency of events (i.e., change in climate projections compared to a baseline).
- The financial and non-financial impacts of an event.
- The capital and expenditure costs of adaptation initiatives.

1.3 Scope

The intention is for the methodology to be applicable to a broad range of climate hazards and assets in support of the assessment of a variety of potential investments to build the resilience of the electricity network.

It is noted that while the methodology aims to guide the assessment of resilience expenditure options, the Australian Energy Regulatory expects businesses to engage with customers to ensure they are fully informed of different resilience expenditure options. This methodology does not include guidance on community or stakeholder engagement.

2.0 Climate variables

To inform the assessment, the study has identified relevant Representative Concentration Pathways (RCPs), timeframes, climate hazards (and variables) and the best available datasets.

2.1 Climate scenarios

The Intergovernmental Panel on Climate Change (IPCC) has outlined four plausible climate scenarios to explore potential future concentrations of greenhouse gases in the atmosphere, referred to as Representative Concentration Pathways (RCPs). These range from high concentrations (RCP 8.5) to intermediate (RCP 6.0 and RCP 4.5) to very low concentrations (RCP 2.6).

Each RCP reflects a different concentration of global greenhouse gas emissions, based on assumptions of different combinations of possible future economic, technological, demographic, policy, and institutional trajectories.[1] The Electricity Sector Climate Information (ESCI) Project[2] and the Victorian Climate Projections 2019 (VCP19) guidance recommend that both RCP 8.5 and RCP 4.5 be used to identify the exposure of assets to climate change. The use of RCP 8.5 allows for the identification of hotspots that may be exposed to more significant climate risks. It is also important to consider RCP 8.5, particularly for near-term climate projections as using a lower emissions scenario (e.g., RCP 4.5) assumes a level of mitigation over the last 15 years that did not occur.[3]

While some of the literature suggests that society is tracking more closely to RCP 4.5, emissions would need to peak in 2040 and then decline reasonably rapidly to stay in line with RCP 4.5. RCP 6.0 is plausible, however, downscaled Victorian climate projections are not available for RCP 6.0. RCP 2.6 was not selected as it requires emissions to peak in 2020 and decline through to 2100[4], which is considered to be an unlikely scenario.[5]

Assessments should be undertaken for a high emission scenario (RCP 8.5) and a moderate emission (RCP 4.5) scenario to provide contrasting possible climate futures as shown in Table 1.

Table 1 Features of the Representative Concentration Pathways

RCP	Likely 2080–2100 global average temperature (ºC above pre-industrial levels)	Global greenhouse gas emissions pathway
8.5	3.2 to 5.4	Ongoing high greenhouse gas emissions
4.5	1.7 to 3.2	Emissions peak around 2040

It is acknowledged that the IPCC AR6 has adopted Shared Socioeconomic Pathways (SSPs) which includes updated global and regional climate change projections. While the regional projections are following a similar trend to those developed under the RCP scenarios, these SSP projections are yet to be downscaled to a suitable scale for Victoria, therefore this methodology uses RCP's consistent with existing Victorian climate projections. The exception is for the extreme wind dataset for which downscaled SSP projections for Victoria were sourced from a third party.

It is recommended that the implications of both RCP 4.5 and RCP 8.5 be considered in assessing the costs and benefits of adaptation actions or investment scenarios. This will enable sensitivity testing of scenarios. However, if one scenario is to be selected for a submission to the AER, based on the experience of other network service providers and the conservative approach taken by the regulator, selection of RCP 4.5 would be appropriate.

2.2 Timeframes

Projections for 2050 and 2070 were selected as it is important to assess climate impacts over multiple timeframes to understand how risks may change over time, particularly when assets have a relatively long design life or when planning for and designing new assets.[6] The 2050 timeframe provides context for the medium-term risks that are more immediate. It also aligns with the 20-year timeframe EDBs assess as the appraisal period considered in a business case (i.e., 2026 installation plus 20 years = 2046). The 2070 timeframe was selected as it recognises the longer lifespan of some of the assets and is relevant for future planning.

[1] Department of the Environment. 2013, *Representative Concentration Pathways (RCPs)*. Representative Concentration Pathways (RCPs) (cawcr.gov.au)
[2] The ESCI Project involved scientists from CSIRO and the Bureau of Meteorology, collaborating with the AEMO and electricity sector stakeholders.
[3] Schwalm, C., et al, 2020, *RCP8.5 tracks cumulative CO_2 emissions*, Proceedings of the National Academy of Sciences
[4] IPCC, 2021, Sixth Assessment Report, Climate Change 2021: The Physical Science Basis
[5] The Hamilton Project and the Stanford Institute for Economic Policy Research, 2019, Ten Facts about the Economics of Climate Change and Climate Policy
[6] AS 5334-2013: *Climate Change for Settlements and Infrastructure: A risk based approach.*

2.3 Hazards and variables

The climatic hazards considered in this methodology are extreme rainfall, flooding, bushfires, extreme heat, and extreme wind. Background on the selection of each climate variable is included in Table 2.. The selection of variables will be dependent on the cause of asset failure being considered. Explanation of how to access data specific related to each hazard is included in Appendix A.

Table 2 Climate hazards and variables considered in the analysis.

Hazard	Related climate variable	Commentary on data sources
Bushfires	Number of severe fire danger days	**Historic baseline** • Historic bushfire data including the frequency and duration of bushfire weather risk is assessed using the Forest Fire Danger Index (FFDI) metric, a measure of 'bushfire weather'. This is sourced from the ESCI Climate Change in Australia database[7]. • FFDI includes measures of dryness—based on rainfall and evaporation—wind speed, temperature and humidity but does not include the contribution to bushfire risk from fuel types, ignition, such as lightning, or fuel management practices. **Climate projections** • Climate projections for FFDI are sourced from the ESCI Climate Change in Australia database[8]. • For each climate scenario and timeframe (i.e., RCPs 4.5 and 8.5, 2030 and 2050), the change in frequency of days with severe fire risk (i.e. FFDI > 50) for future periods are compared to the historic baseline. • As no ensemble results from multiple climate models (i.e., Multi Model Mean values) were available for this variable, the climate model used was NorESM1-M1CCAM-QME. This model represents a ‘mid case’ set of projections for Southern Australia (including Victoria) and has projections available for both RCP4.5 and RCP8.5.[9]
Extreme heat	Daily maximum temperature Number of days over 35 degrees Celsius Number of days over 40 degrees Celsius	**Historic baseline and Climate projections** • For each climate scenario and timeframe, projections should be sourced from the Victorian Climate Projections 2019[10]. • The selection of the specific variable will be dependent on the cause of asset failure being considered.

[7] ESCI Climate data: https://www.climatechangeinaustralia.gov.au/en/projects/esci/esci-climate-data/#SearchResults
[8] ESCI Climate data: https://www.climatechangeinaustralia.gov.au/en/projects/esci/esci-climate-data/#SearchResults
[9] ESCI, 2023, https://www.climatechangeinaustralia.gov.au/en/projects/esci/learning-support/esci-key-concepts /
[10] https://vicfutureclimatetool.indraweb.io/

Hazard	Related climate variable	Commentary on data sources
Extreme rainfall and flooding	Increase in rainfall intensity This methodology considered assets in a 1% AEP flood hazard area.	**Historic baseline** • Historic rainfall totals (volumes) associated with 24-hour duration, 1% AEP and 2% AEP rainfall events is sourced from the Bureau of Meteorology (BoM) Design Rainfall Data System (2016) [11] (via the Australian Rainfall and Runoff Data hub.[12]). **Climate projections** • Interim climate change factors representing the percentage increase in the intensity (i.e., volume) of rainfall events for different climate scenarios and timeframes is sourced from the Australian Rainfall and Runoff Data hub.[13] • For each climate scenario and timeframe (i.e., RCPs 4.5 and 8.5, and 2050 and 2070), the interim climate change factors were added to the baseline rainfall totals for the 1% and 2% AEP event obtained from BoM to estimate the adjusted rainfall totals for these events.
Extreme wind	Wind speed, severe convective wind gusts Number of days with max wind gust above 100 km/h	**Historic baseline** • Coarse scale historic spatial data was drawn from the ESCI Project. • In Phase 1 of this project, recognising the importance of wind impacts on assets, and the lack of downscaled projections from Victorian Climate Projections 2019 (VCP19) and ESCI Project, extreme wind data was sourced from CLIMsystems.[14] This data also included baseline. **Climate projections** • Extreme wind data is sourced from CLIMsystems for the 2030 and 2070 timeframes. If required for analysis, data for 2050 will need to be procured from CLIMsystems.

Probability terminology – AEP vs ARI

When describing flood events, the Australian Rainfall and Runoff (ARR) Guidelines refer to the probability of an event of that scale occurring in a given year. This is referred to as the Annual Exceedance Probability (AEP).

Older versions of the ARR Guidelines (i.e., ARR 1987) had used the terminology of Annual Recurrence Intervals (ARI). For example, an event that was previously referred to a 1-in-100 year flood event, is now referred to as a 1% AEP flood event.

This change seeks to overcome the misconception that if a 1-in-100 year event occurs then it will be 100 years before another event of a similar scale will occur, when the reality is that every year there is a 1% probability of an event of that scale occurring.

3.0 Economic appraisal methodology

The objective of a cost-benefit analysis (CBA) is to consider the economic costs and benefits of an initiative (or a set of initiatives). This is done by estimating and comparing the costs and benefits in monetary terms (wherever practicable) to determine if the benefits outweigh the costs.

CBA compares the costs and benefits of an initiative against a 'base case', which represents a real assessment on what would be done in the absence of the initiative/s. The base case includes 'business as usual' works which would typically occur to maintain an asset's existing level of service, including ongoing operating and maintenance costs and planned or foreseeable asset replacements.

[11] Bureau of Meteorology, 2016, Design Rainfall Data System http://www.bom.gov.au/water/designRainfalls/revised-ifd/?multipoint
[12] Australian Rainfall and Runoff Data Hub Home | ARR Data Hub (arr-software.org)
[13] Australian Rainfall and Runoff Data Hub Home | ARR Data Hub (arr-software.org)
[14] CLIMsystems are a global provider of scientifically robust, up to date, and cross validated dynamic downscaled climate projections and data.

Total costs and benefits for base case and options are entered into the CBA. The CBA assesses the incremental difference between the base case and the initiative(s), over the course of a defined appraisal period.

In CBA, costs and benefits that are incurred in future years are converted to a common time dimension by discounting future values using an agreed discount rate. The discount rate represents the time value of money and allows future year cash flows to be considered and compared in like-for-like terms. The result of discounting future year cash flows is the present value, that is, the sum of all future year values which have been discounted using a common discount rate.

The key metrics produced from a CBA are:

- **Net Present Value (NPV) –** the difference between the present value of total benefits and the present value of the total costs (incremental to the base case). A positive NPV indicates that the incremental benefits of a scenario exceed the incremental costs over the evaluation period.
- **Benefit Cost Ratio (BCR) –** the ratio of the present value of total incremental benefits to the present value of total incremental costs. A BCR greater than 1.0 indicates that an initiative's incremental benefits exceed the initiative's incremental costs.

In summary, an initiative is considered more economical than the base case (and thus economically feasible) if it has a positive NPV and a BCR greater than 1.0.

3.1 Key assumptions

The key economic assumptions underpinning a CBA are outlined in Table 3.

Table 3 General economic appraisal parameters and assumptions

Parameter	Assumption	Source
Base year	FY2024	Model assumption
Indexation	CPI (2023-2024): 1.034	Five-year average CPI (Aus), ABS (2023)
Evaluation period	Construction period + 20 years of benefits Sensitivity analysis using appraisal periods to 2050 & 2070 to reflect the climate scenario projections	AER (2023), Cost benefit analysis guidelines
Discount rate (real)	3.63%	Powercor advice

3.2 Principles for selecting critical input data

When determining critical input data, the following principles apply:

- The EDB should use its own data, where practical, and experience, to inform the estimation of the critical input values.
- Any information used from sources external to the EDB should align to the electricity supply industry, and preferably from a comparable Australia region.
- All sources of information should be referenced.
- All assumptions should be documented and adequately justified, including where the EDB has elected to adhere to, or deviate from, the stated sources of information.
- Reference should be made to known industry practice or related research to support estimation of critical input values, where possible.

3.3 Cost analysis

The elements typically considered to evaluate the costs of the adaptation options (and the base case) including the type and scale of the adaptation options, the capital expenditure (CAPEX) and operational expenditure (OPEX) are summarised in Figure 1 and discussed in Table 4.

Figure 1 Summary of elements to consider in cost analysis

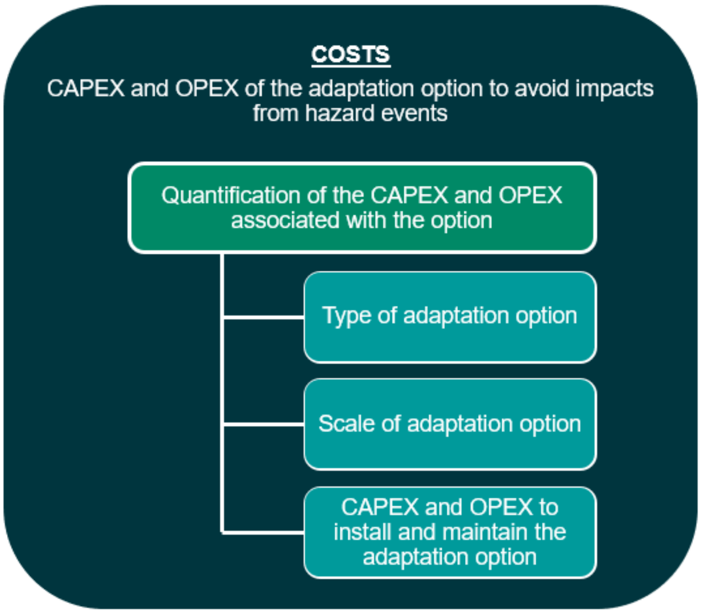


Table 4 Data requirements to consider in cost analysis

Element	Data required
Type of adaptation option	• Information on the type of adaptation option(s) being considered in the assessment. • This may include consideration of options to either replace an existing asset with a new asset or modify an existing asset.
Scale of adaptation option	• Quantification of the number of adaptation option(s) being considered in the assessment. • To quantify the scale and need for adaptation, consideration may need to be given to the condition of the existing assets in the study area. • Specific assessment criteria may include but is not limited to, age of asset, material, condition, height, adjacent pole condition etc. • This scale of implementation may take into consideration design thresholds/trigger events.
Capital and operational expenditure (i.e., CAPEX and OPEX)	• Total CAPEX and OPEX based on the type and scale of the adaptation option(s) (and the base case) to calculate the total expenditure, including: o CAPEX = Cost of replacement (unit rate) x volume of replacements o OPEX = Average annual operational and maintenance costs over the lifetime of the asset. *Note: Base case cost estimates may be derived through assessing patterns or trends in current practices (i.e., asset age-based replacement).*

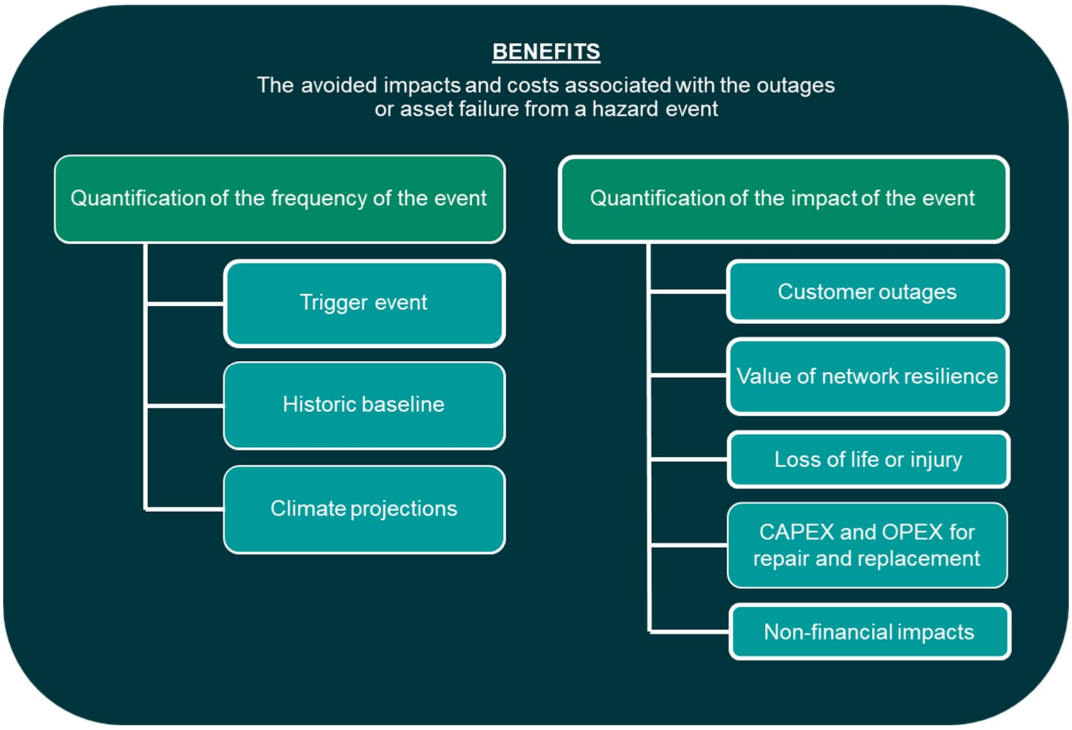
Element	Data required
Scenario assessment	• Multiple scenarios for investment options should be compared to sensitivity test the evaluation of costs and benefits of each adaptation option under consideration. • For example, a baseline scenario representing 'business as usual' activities may be compared to proactive investment scenarios which involve the total replacement of an asset and/or partial replacement of an asset.

Economic costs are provided in FY2024 dollars and are quantified in present value terms, discounted at 3.6 cent per annum over the course of the appraisal period. Where cost or parameter value inputs were provided in terms of financial year dollars other than FY2024, they have been indexed to FY2024 using the Australian CPI (see Table 3).

3.4 Benefit analysis

This section evaluates the avoided impacts and costs associated with outages or asset failure from a hazard event, as summarised in Figure 2. Consideration is also given to the change in the frequency of the hazard event.

Figure 2 Summary of elements to quantify the frequency and impact of the event



3.4.1 Quantification of the frequency of an event

To determine the change in the frequency of the event the following steps should be undertaken:

- Select the climate variable associated with the trigger event (refer to Table 2).
- Collate the baseline value for the variable from the data source listed in Table 2.
- Collate the climate projections for the variable for each climate scenario and timeframe being assessed.
- Compare the projected value to the baseline to determine the change over the assessed time-period.

- Where an annual change figure is required for each year included in an assessment, linear extrapolation may be used to estimate annual values between the baseline and the periods for which projections are available. For example, for bushfire related projections, annual values may be determined using a linear extrapolation between the 1995 baseline and the 2030 projection, as well as between the 2030 and 2050 projections. Appendix B provides an example for how the potential change in frequency of a 1% AEP flood event may be estimated.

3.4.2 Quantification of the impacts of an event

To determine the associated benefits from adaptation actions, the avoided impacts are estimated. These impacts include:

Cost of customer outages

- The cost of the outages is estimated by multiplying the energy at risk by the value of customer reliability. This relates to the first 12 hours of an outage.

Cost of outage ($) = *Energy at risk (MWh) (up to 12 hours)* x *Value of Customer Reliability ($/MWh)*

- The energy at risk is the forecasted average demand of customers affected by the outage multiplied by the average duration of the outage event (based on historical events).

Energy at risk (MWh) = *Average demand (MW)* x *Duration (h)*

- The average demand of customers affected by the outage is estimated using the sum of the average annual MW demand forecast of the feeders relevant to the study area.
- The duration of events is based on average historical duration of events in the Powercor area.
- The value of customer reliability is based on a demand weighted approach taking into consideration commercial and residential customer types and historical demands.

Customer value of network resilience

- For outages longer than 12 hours, a recent customer willingness to pay survey conducted by Powercor indicated that customers are willing to pay $8.33 per kWh (FY2024)[15] to reduce outages during major event days (network resilience). This value relates to the length of the outage beyond the initial 12 hours. It is noted that this customer willingness to pay survey is undertaken periodically, and the customer value of network resilience was under review as this methodology was developed and is subject to change.

Value of network resilience ($) = *Energy at risk (MWh) (greater than 12 hours)* x *Customer value of network resilience ($/MWh)*

Damaged asset replacement cost saving benefit

Where an adaptation option improves climate resilience such that an asset becomes partly or wholly safeguarded against climate related events (e.g. flooding or bushfire), a cost saving benefit is realised from avoiding the capital expenditure which would otherwise be required to replace an asset damaged during an event.

This benefit is calculated by considering the annual probability of an event causing damage, the level of climate resilience of an asset (represented by a percentage value), the quantum of affected assets which would require replacement because of an event and asset unit costs. For example, when a wooden pole is proactively replaced with a concrete pole (which is assumed to provide 100 per cent

[15] The customer value of network resilience of $8.33 (FY2024) has been derived by indexing the value given in the FY2022 willingness to pay survey ($8.06) to FY2024.

resilient to bushfires), an annual benefit is accrued based on the avoided risk of having to replace the wooden pole in the event of a bushfire.

Alternatively, where an initiative provides a one-time benefit, a risk cost should be calculated. For example, fire mesh provides pole protection for one bushfire event before the mesh requires replacement. The risk cost may be estimated using the annual probability of a bushfire event occurring combined with the cost of replacing the fire mesh. The risk cost should be treated as a disbenefit within the CBA.

Avoidance of safety risk associated with loss of life or injury

The electricity industry uses the value of statistical life (VSL) and disproportionate factors (DF) in its cost benefit analysis to estimate the value of safety risk reductions. VSL is the value society places on a life and is based on the Australian Government's Office of Impact Analysis assessment. The DF represents the willingness to pay or invest to prevent the loss of a life. The value of the DF used by the electricity industry may vary depending on a few factors, including different values for staff and the public, expected number of lives lost and fire risk of geographical areas.

Key definitions

Value of Statistical Life (VSL) is used to estimate the benefits of reducing the risk of death. The VSL is an estimate of the financial value society places on reducing the average number of deaths by one. As VSL is not based on a particular individual, it does not vary for age, location, occupation, etc. There have been many studies performed globally to estimate VSL. The results of these studies vary greatly by industry and geographic location. The Australian Government regularly releases Guidance Notes on VSL.

Disproportionate Factors (DFs) represent an organisations appetite to spend more than the value of the safety risk avoided to reduce the risk. For example, it may be deemed reasonable to spend $3 for every $1 of risk reduction (a DF multiple of 3). The multiple also reflects the severity of the consequence of the risk. Guidance from the HSE (UK) notionally suggests that a DF between 2 and 10 can be used, where higher values are used for situations where extensive harm, if the risk event were to happen, is not unreasonable or where there in increasing societal concerns. For example, a bushfire has the potential to cause extensive harm, including a great number of fatalities and extensive property damage.

Based on international and Australian research, the Australian Government's Office of Impact Analysis provides a credible estimate of the value of statistical life to be $5.4m in 2023.[16] Powercor's use of the disproportionate factor value of 3 is aligned with electricity industry practices and AER's expectations.

To estimate the annualised benefit, use Powercor's historical incident data if available, otherwise use Ofgem's probability of safety consequence to the public.

The cost of injury / harm associated with an event may be relevant and can be calculated within the CBA. This has not been determined at this stage. The probability of an injury and the financial value associated with an injury would be required to estimate this cost.

Non-quantified benefits

Increasing the resilience of network assets and limiting the disruption to power has additional non-financial benefits for the community. Power disruption to critical infrastructure can have significant consequences.[17] The impacts of power outages on communities include:

- **Health and safety risks** due to interrupted access to water, heating, and cooling services, food spoilage and shortages, generator use in confined spaces and the associated risk of carbon monoxide poisoning and delayed or disrupted healthcare services. The storms in Victoria in June and October 2021 brought attention to some of the lived experiences of customers during power outages.[18]

[16] Value of Statistical Life (2023), Office of Impact Analysis, Department of the Prime Minister and Cabinet, Australian Government
[17] Electricity Distribution Network Resilience Review Expert Panel, 2022.
[18] Electricity Distribution Network Resilience Review Expert Panel, 2022.

- **Vulnerable customers** may include customers on life support and power dependant customers, children, the elderly, and people with disabilities may be exposed to significant risks during power outages.
- **Critical infrastructure** that relies on reliable power supply may include telecommunications infrastructure, water services, healthcare services, aged care facilities and financial systems.

4.0 Other considerations for cost benefit analysis

4.1 Limitations

CBA approach

The CBA approach utilises the conventional discounted cash flow (DCF) method, which assesses the costs and benefits that can be quantified against a defined set of parameters.

As certain impacts of a project do not possess established methods and parameters for measuring economic benefits and costs, it is likely that there would be additional impacts of a project that have not been quantified in this economic appraisal. These non-quantifiable impacts should be considered as part of the economic analysis, in addition to the final calculated BCR and NPV, when evaluating the overall benefits of the program options. Examples may include:

- The relative environmental benefits (e.g., embedded greenhouse gas emissions, end of life recyclability or reuse) of adaptation options.
- Non-quantified benefits of maintaining supply to the community.

Stakeholder engagement

It is noted that while the methodology aims to guide the assessment of resilience expenditure options, the Australian Energy Regulatory expects businesses to engage with customers to ensure they are fully informed of different resilience expenditure options. This methodology does not include guidance on community or stakeholder engagement.

Life cycle analysis

The relative environmental benefit (i.e., embedded greenhouse gas emissions, end of life recyclability or reuse) of the adaptation options have not been considered in this methodology as a life cycle analysis of the materials would be required.

Identification of categories of costs and benefits

The categories of costs and benefits listed in this document are not intended to be exhaustive. Depending on how the methodology is applied and what hazards and solutions are investigated, other costs and benefits, not included in this document, may be relevant.

4.2 Sensitivity analysis

CBA results are dependent upon a range of assumptions, both in terms of financial parameters, such as discount rates and cost estimates. Sensitivity analysis should be carried out for a range of factors within the economic model to test for the degree of change or ‘sensitivity’ of outputs, including:

- Capital cost estimates (higher and lower)
- Discount rates (higher and lower)
- Benefit parameter values (e.g., duration of outages)
- Probability of event parameters (e.g., climate scenarios or projections)
- Asset resilience parameters (e.g. relative effectiveness of solutions).

Appendix A

Accessing climate data

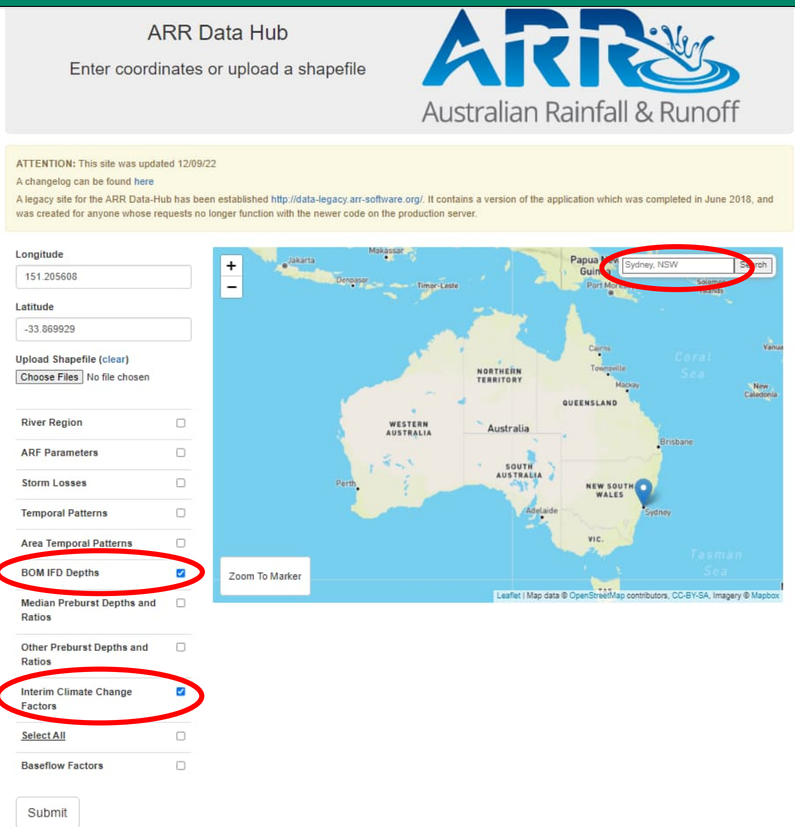
Appendix A Accessing climate data

This appendix provides a guide to accessing climate data related to each of the hazards referenced in Section 2.3 of the main document:

- Extreme rainfall and flooding
- Bushfire weather*
- Extreme heat
- Extreme wind*.

*The guidance below assumes the relevant GIS layers related to climate projections have been downloaded and set up in an accessible manner within the organisation's GIS system. The screenshots for these variables are based on AECOM's ARCGIS mapviewer and may vary from the organisation's viewer.

Extreme rainfall and flooding

Steps	Screenshot examples
• Open the Australian Rainfall & Runoff, ARR Data Hub [Home | ARR Data Hub (arr-software.org)](arr-software.org) • Search for the location of interest • Select 'BOM IFD Depths' • Select Interim Climate Change Factors • Click Submit	

<table>
<tr><th>Steps</th><th>Screenshot examples</th></tr>
<tr><td>

- Note the Interim Climate Factors – percentage values for the selected climate scenarios and timeframes being assessed (i.e., RCP 4,5 and RCP 8.5, 2050)

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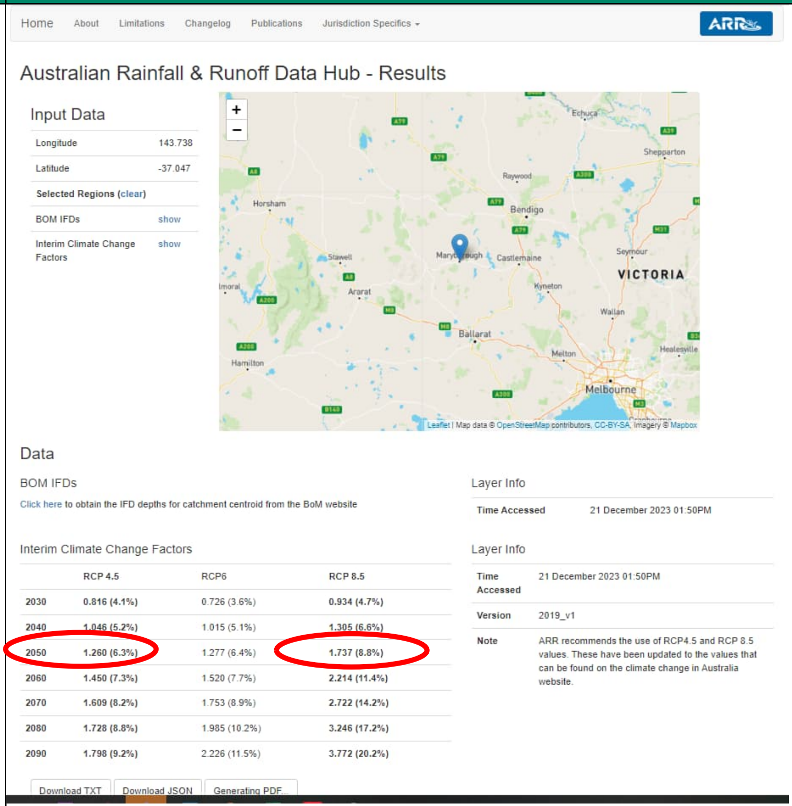

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- Select the hyperlink to the BOM IFDs

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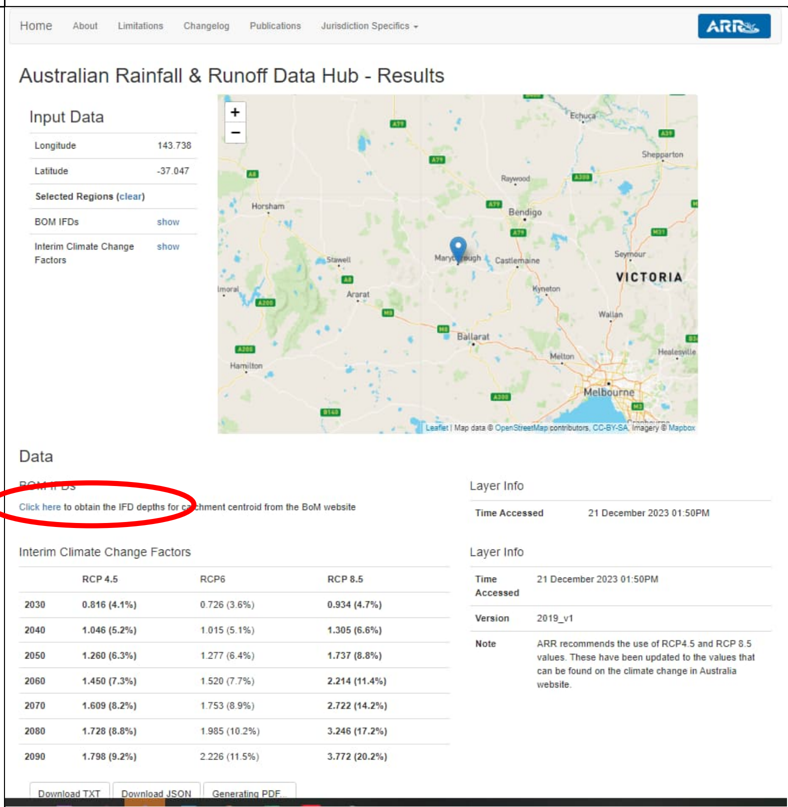

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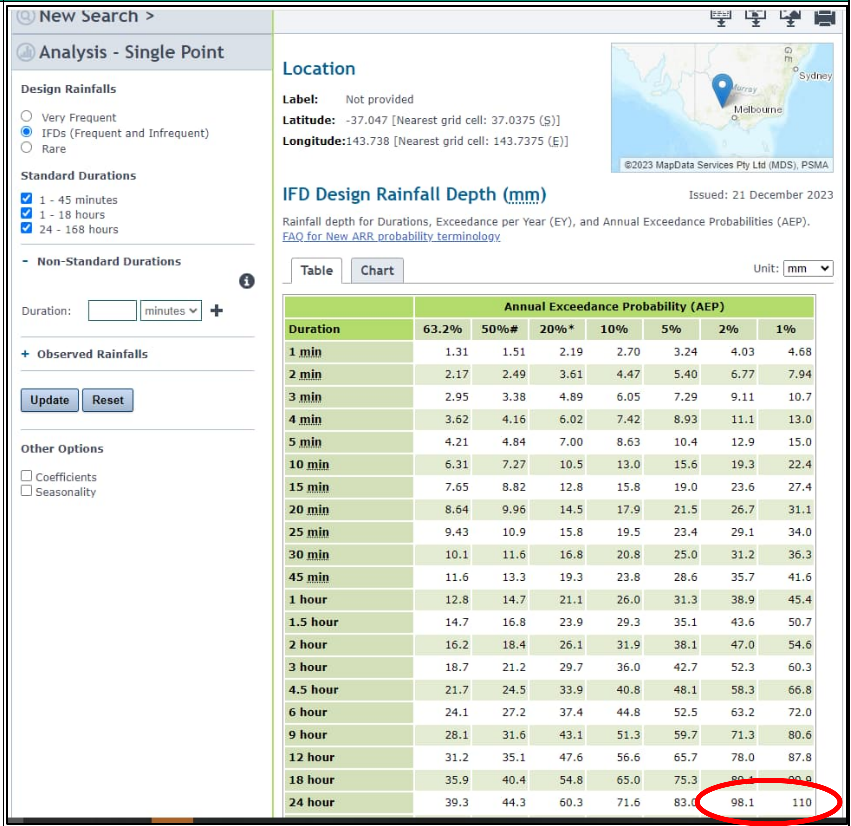
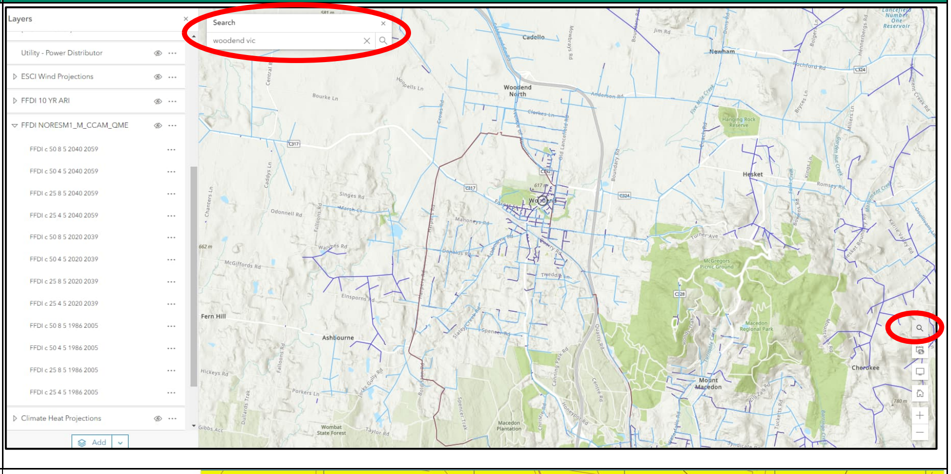
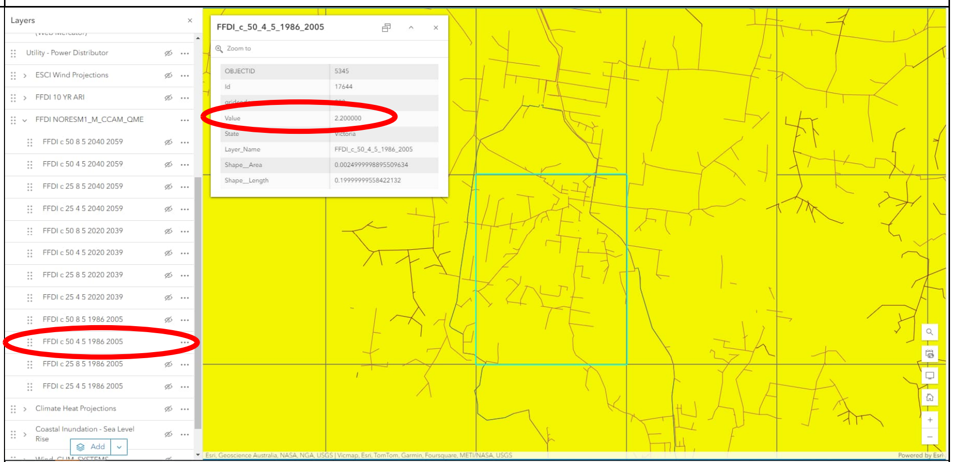
</table>

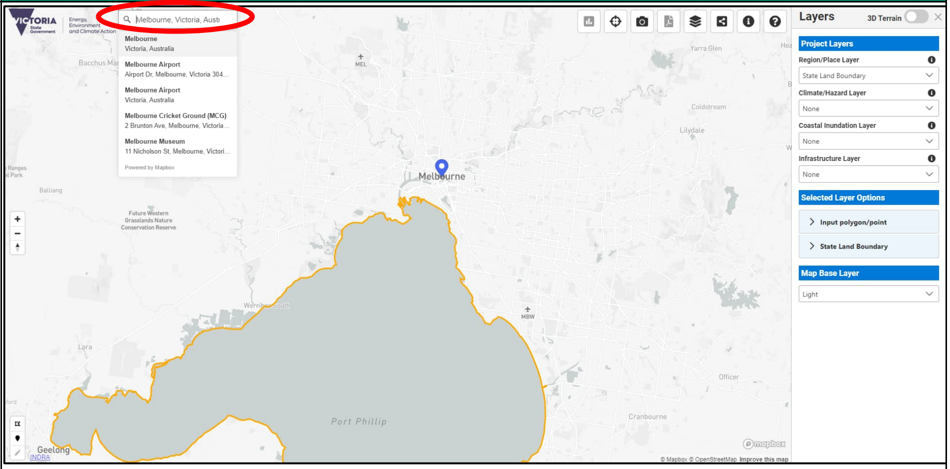
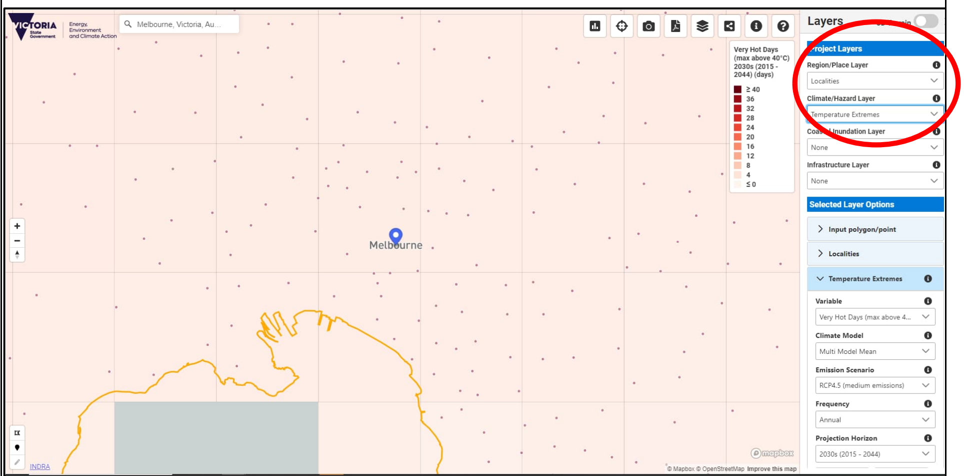
Steps	Screenshot examples
• Note the historic rainfall totals (volumes) associated with 24-hour duration, 1% AEP and 2% AEP rainfall events	

	Annual Exceedance Probability (AEP)						
Duration	63.2%	50%#	20%*	10%	5%	2%	1%
1 min	1.31	1.51	2.19	2.70	3.24	4.03	4.68
2 min	2.17	2.49	3.61	4.47	5.40	6.77	7.94
3 min	2.95	3.38	4.89	6.05	7.29	9.11	10.7
4 min	3.62	4.16	6.02	7.42	8.93	11.1	13.0
5 min	4.21	4.84	7.00	8.63	10.4	12.9	15.0
10 min	6.31	7.27	10.5	13.0	15.6	19.3	22.4
15 min	7.65	8.82	12.8	15.8	19.0	23.6	27.4
20 min	8.64	9.96	14.5	17.9	21.5	26.7	31.1
25 min	9.43	10.9	15.8	19.5	23.4	29.1	34.0
30 min	10.1	11.6	16.8	20.8	25.0	31.2	36.3
45 min	11.6	13.3	19.3	23.8	28.6	35.7	41.6
1 hour	12.8	14.7	21.1	26.0	31.3	38.9	45.4
1.5 hour	14.7	16.8	23.9	29.3	35.1	43.6	50.7
2 hour	16.2	18.4	26.1	31.9	38.1	47.0	54.6
3 hour	18.7	21.2	29.7	36.0	42.7	52.3	60.3
4.5 hour	21.7	24.5	33.9	40.8	48.1	58.3	66.8
6 hour	24.1	27.2	37.4	44.8	52.5	63.2	72.0
9 hour	28.1	31.6	43.1	51.3	59.7	71.3	80.6
12 hour	31.2	35.1	47.6	56.6	65.7	78.0	87.8
18 hour	35.9	40.4	54.8	65.0	75.3	[illegible]	[illegible]
24 hour	39.3	44.3	60.3	71.6	83.0	98.1	110

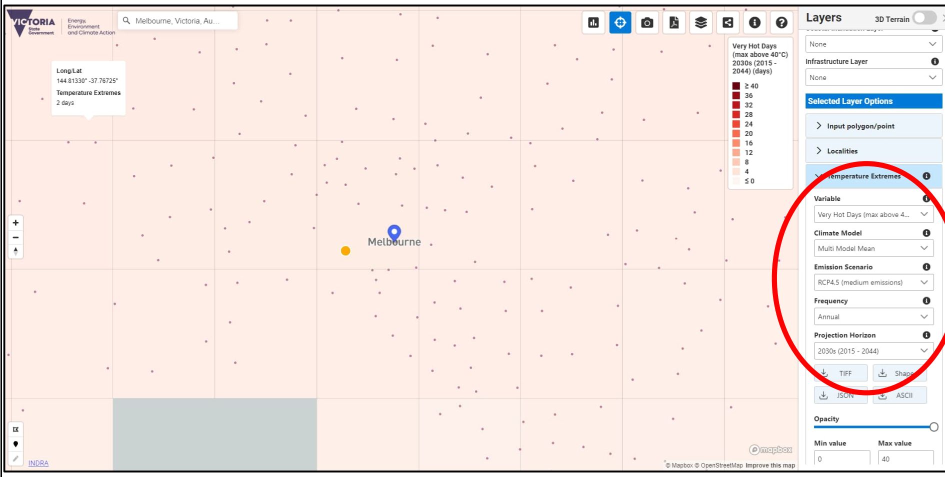
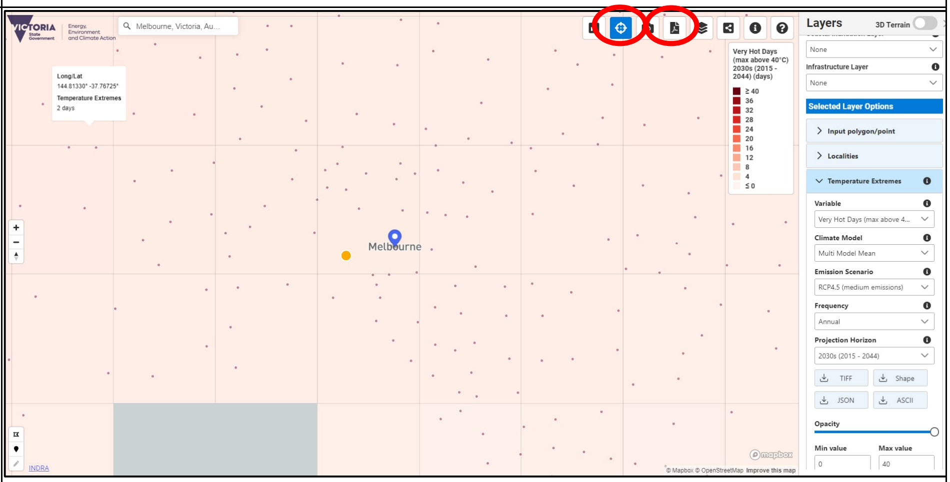
Bushfires

Steps	Screenshot examples
• In the organisation's GIS platform, search for the location of interest (i.e., Woodend, Vic)	
• Select the GIS layer related to bushfire projections for the specific climate scenario and timeframe (i.e., For the baseline: FFDI c 50 4.5 1986-2005) • Select the location of interest and record the 'Value' associated with that grid cell. Repeat this process for each scenario and timeframe (i.e. baseline, 2020-2039 and 2040-2059).	

Extreme heat

Steps	Screenshot examples
Historic baseline and Climate projections • Open the Victoria's Future Climate Tool https://vicfutureclimatetool.indraweb.io/project • Search for the location of interest	
• Make the following selection in the Project Layers window: Region/Place layer: Localities Climate / Hazard Layer: 'Temperature Extremes'	

Extreme heat (continued)

Steps	Screenshot examples
• Make the following selections in the Selected Layer Options window: Variable: Hot Days (max above 35ºC) Climate Model: Multi Model Mean Emission Scenario: RCP 4.5 (medium emissions) Frequency: Annual Project Horizon: 2030's (2015-2044)	
• Select the 'Target' icon • Click on the locality dot that represents the location of interest. • Click on the 'PDF' icon to download a document summarising the relevant projections	

Extreme heat (continued)

<table>
<tr><th>Steps</th><th>Screenshot examples</th></tr>
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- Open the downloaded pdf.
- Tally up the values under the following headings to determine the annual value:
- Past Climate mean: This represents the baseline
- RCP4.5 mean: This represents the average results for the RCP 4.5 climate scenario
- RCP 8.5 mean: This represents the average results for the RCP 8.5 climate scenario

Repeat this process for each scenario and timeframe (i.e. RCP 8.5 and 2050s (2035-2064).

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Month	RCP45 min	RCP45 max	RCP45 mean	RCP85 min	RCP85 max	RCP85 mean	Past Climate mean
January	0.4 days	1.0 days	0.7 days	0.4 days	1.3 days	0.8 days	0.2 days
February	0.1 days	0.9 days	0.4 days	0.1 days	1.2 days	0.6 days	0.0 days
March	0.0 days	0.6 days	0.3 days	0.0 days	0.7 days	0.3 days	0.0 days
April	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days
May	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days
June	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days
July	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days
August	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days
September	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days
October	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days
November	0.0 days	0.2 days	0.0 days	0.0 days	0.1 days	0.0 days	0.0 days
December	0.2 days	0.5 days	0.4 days	0.2 days	0.6 days	0.3 days	0.1 days

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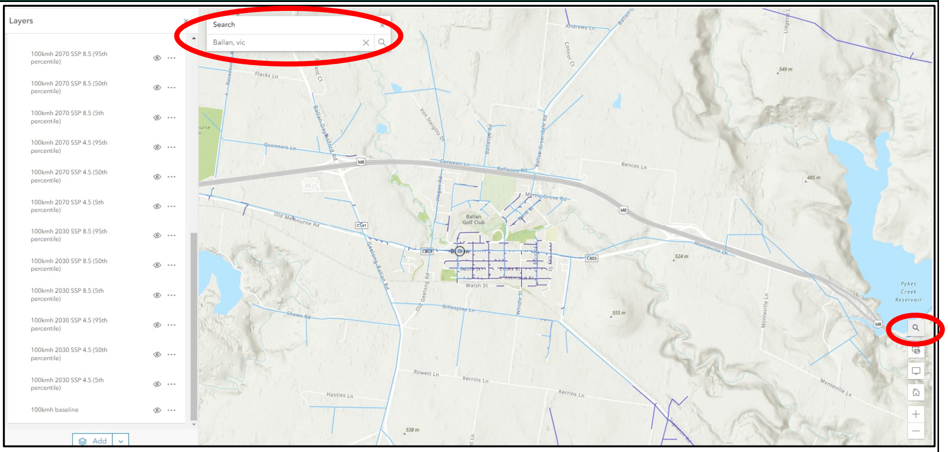
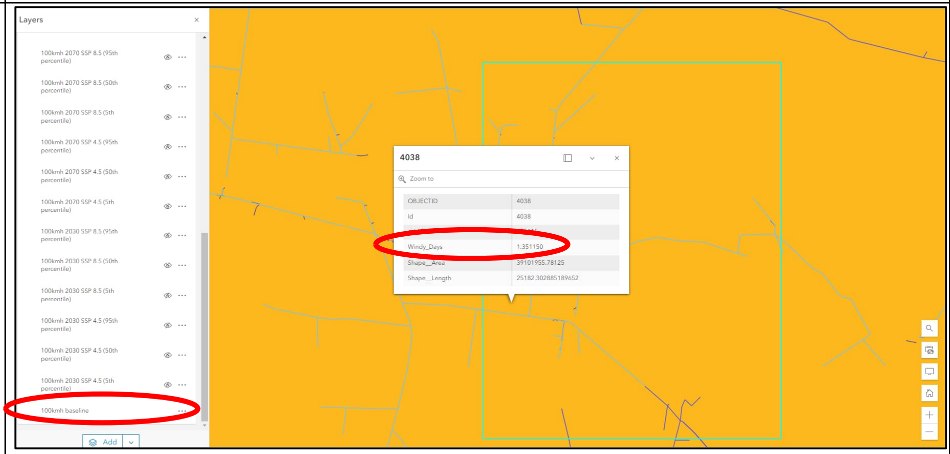
</table>

Extreme wind

Steps	Screenshot examples
• In the organisation’s GIS platform, search for the location of interest (i.e. Maryborough, Vic)	
• Select the GIS layer related to extreme wind projections for the specific climate scenario and timeframe (i.e., For the baseline: 100kmh baseline) • Select the location of interest and record the value listed as ‘Windy_Days’ associated with that grid cell. • Repeat this process for each scenario and timeframe (i.e. baseline, 2030 and 2070).	

Appendix B

Example of estimating the change in frequency of a flood event

Appendix B Example of estimating the change in frequency of a flood event

Literature indicates that there will be a likely doubling and tripling in the frequency of 10% AEP (10-year ARI) and 2% AEP (50- year ARI) events, respectively, compared to the recent past at 4°C of global warming.[19] While there are no specific projections related to the change in frequency of a 1% AEP flood event, it is important to note that the increase in the frequency of heavy precipitation events will be non-linear with more warming, and will be higher for rarer events (high confidence).[17] The following approach provides an example of how the potential change in frequency of a 1% AEP flood event in Maryborough, Victoria, may be estimated:

- Historic rainfall totals (volumes) associated with 24-hour duration, 1% AEP and 2% AEP rainfall events were sourced from the Bureau of Meteorology.
- Climate change factors representing the percentage increase in the intensity (i.e. volume) of rainfall events for different climate scenarios and timeframes were sourced from the Australian Rainfall and Runoff Data hub.
- For each climate scenario and timeframe, the climate change factors were added to the baseline rainfall totals for the 1% and 2% AEP event to estimate the adjusted rainfall totals for these events.
- The adjusted rainfall totals were then compared to the historic 1% AEP rainfall volume, to determine and approximate equivalent annual exceedance probability volume, and therefore an increase in frequency.
- To identify annual change figures for each year included in an assessment, a linear extrapolation may be used for simplicity between the baseline and the end time-period (i.e., a linear increase between 1% AEP in 2023 and 1.5% in 2050 under the RCP4.5 2050 case).

The following figures show the comparison of rainfall volumes under different climate scenarios for the 2050 timeframe. The intent of these figures is to illustrate how the frequency of a 1% AEP event may change over time. This was done by comparing the total volume of rainfall for different frequency events to the volume for the historic, or baseline, 1% AEP event (i.e., 110 mm).

Figure B.1 illustrates the RCP4.5 scenario at 2050. Comparing the volume of the original baseline 1% AEP event (110 mm) with the volumes associated with the climate change 2% AEP (104.3 mm) and climate change 1% AEP (116.9 mm) scenarios, the baseline total is approximately equivalent to half of the difference, plus the total of the 2% AEP volume. This could be inferred as being halfway between the 2% and 1% AEP, or a 1.5% AEP event. It is important to note that the change in volumes between the 2% and 1% AEP events may not be linear. Due to the limited data points available, a linear increase was used.

[19] IPCC, 2021. Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

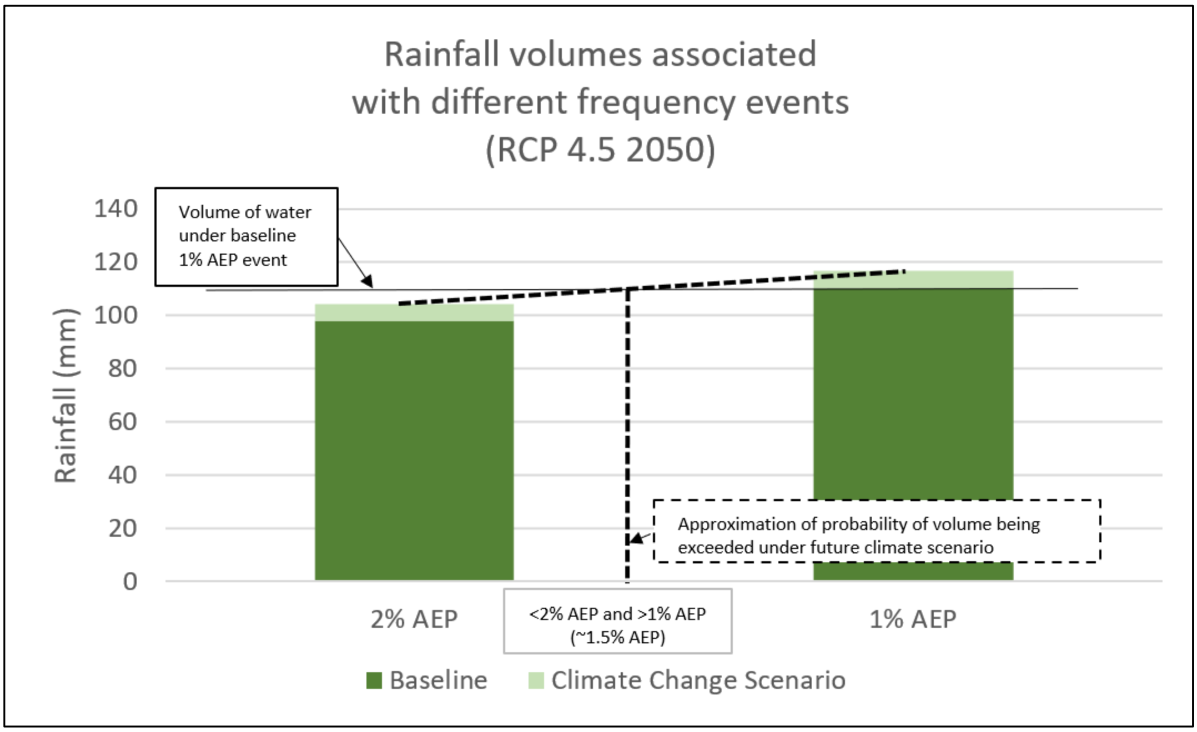


Figure B.1 Change in frequency of the 1% AEP event for 24-hour duration in 2050 under RCP 4.5

The comparison of the RCP8.5 scenario at 2050 has a similar result to the RCP 4.5 2050 scenario. Although the volume of water associated with the 2050 RCP 8.5 2% AEP (106.7 mm) event is larger than the equivalent RCP4.5 2050 event (104.3 mm). This may imply that the frequency could be between a 1.5% AEP event and a 2% AEP event, or approximately 1.75%. Refer to Figure B.2 for a visual comparison of the totals.

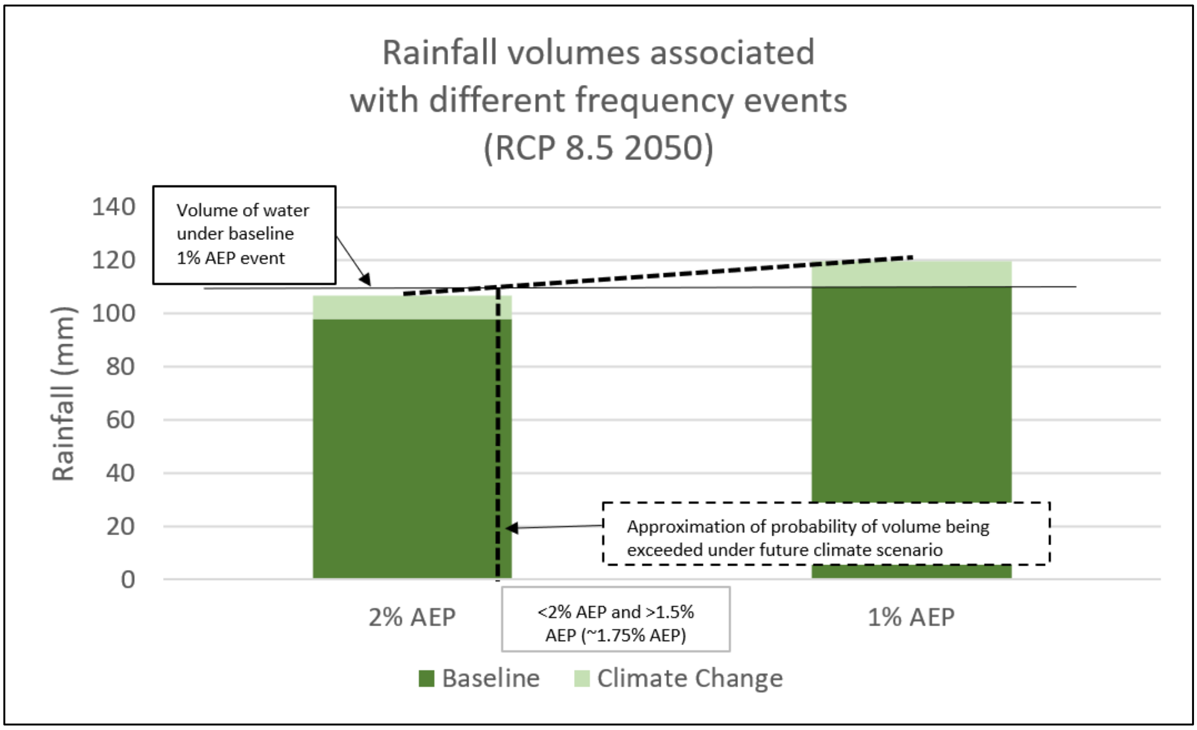


Figure B.2 Change in frequency of the 1% AEP event for 24-hour duration in 2050 under RCP 8.5