CutlerMerz Climate Resilience Economic Modelling

Model Methodology

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Document History and Status

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About This Report

The sole purpose of this report, and the associated services provided by CutlerMerz is to provide AusNet with documentation of the Climate Resilience Economic Model developed for AusNet by CutlerMerz to quantify the increasing risks due to climate change, and the risk reduction benefits of corresponding network hardening solutions.

In producing this report, we have relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by AusNet, and from other sources. Except as otherwise stated in the report, we have not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate, and/or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

We derived the analysis in this report from information sourced from data and information available in the public domain, that provided by AusNet and Risk Frontiers, and our understanding and knowledge of AusNet's peers regarding the scope of this assessment. The passage of time, manifestation of latent conditions, and/or impacts of future events may require re-examination, further data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report. We have prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures, and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report has been prepared on behalf of, and for the exclusive use of, AusNet, and is subject to, and issued in accordance with, the provisions of the contract between CutlerMerz and AusNet. CutlerMerz accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by a third party.

Contents

1 Background

The **Climate Resilience Economic Model** has been specifically developed for AusNet to quantify the increasing risks due to climate change, and the risk reduction achieved by corresponding network hardening solutions. This model quantifies the risk due to bushfires and windstorms (climate perils) and compares it against the cost of network hardening solutions and its risk reduction benefits, to develop a program of NPV positive solutions.

Modelling was undertaken across AusNet's HV distribution network. The model aims to assist AusNet in its decision-making process by evaluating the climate risk mitigated by various network hardening solutions and/or the combination of solutions. This evaluation was carried out using a cost-benefit analysis at the individual feeder level.

In additional to the model, CutlerMerz has produced two reports:

- The **Climate Resilience Methodology Report** (this report) outlines the methodology and key assumptions underpinning the Climate Resilience Economic Model.
- The **Climate Resilience Program Report** provides the results of the modelling exercise.

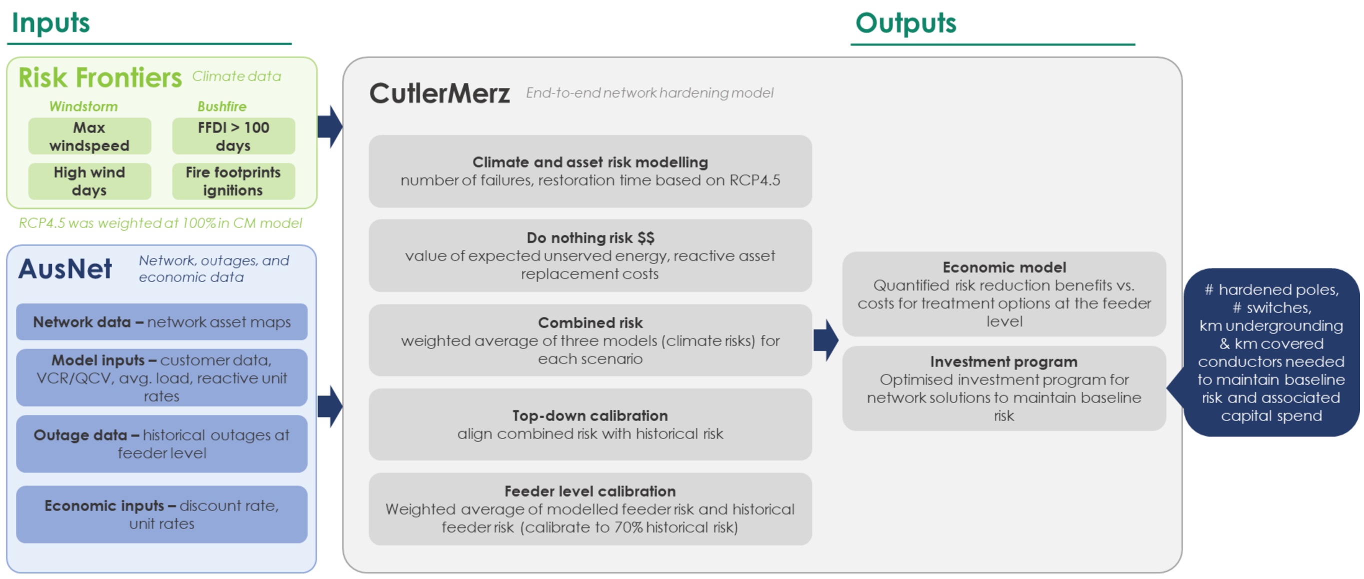
2 Model Methodology

This section provides an overview of the basic principles and process modules applied in the Climate Resilience Economic Model. The primary steps in the process are:

1. Identify and gather the necessary input data required for the modelling.
2. Establish the assumptions.
3. Extract relevant information from input data.
4. Forecast the inherent climate risk (the do-nothing risk) – on a per annum basis – for each climate simulation in the input data.
5. Calculate combined risk as a weighted average of the climate simulations.
6. Perform top-down calibration to ensure alignment with historical risk.
7. Perform bottom-up calibration as a weighted average of modelled risk and historical feeder risk.
8. Analyse the risk reduction benefit of each potential investment solution.
9. Undertake the cost-benefit analysis and economic evaluation of the investment solutions.
10. Identify the most suitable investment solution for each feeder.
11. Select feeders for investment programs across the HV network.

Figure 1 below provides a high-level, graphical overview of the resilience model's process flow.

Figure 1: High-Level Model Process Flow



2.1 Identify the input data

There are two key types of input data: climate data from Risk Frontiers and historical outage data and network information from AusNet.

2.1.1 Climate Data

Risk Frontiers provided the following data – for emission scenarios RCP2.6, RCP4.5 and RCP8.5 – for the period from 2000 to 2099:

- Days with maximum wind speed above 8.7m/s.
- Days with maximum wind speed above 11.3m/s.
- Maximum wind speed on the windiest day of the year.
- Days with a Forest Fire Danger Index (FFDI) above 50.
- Days with FFDI above 100.
- Location.
- Fire Ignition data on AusNet assets based on 30,000 simulation years of bushfires.

For each emissions scenario, simulations developed from an ensemble of three climate models have been provided, making for a combined nine simulations. Data sources used in the development of Risk Frontiers' simulation include the Energy Sector Climate Initiative (ESCI) for most climate variables and the NSW/ACT Regional Climate Model (NARCliM) for wind data.

2.1.2 AusNet Data

The information provided include, but are not limited to:

- All HV distribution feeder segments.
- Feeder.
- Segment length.
- Length of feeder that is downstream from the segment.
- Length of the feeder that is upstream from the segment up until the next recloser.
- The length (meters) that is currently overhead, bare, vegetated, SWER, covered or underground, for the entire feeder, the downstream length, and the length upstream to the next recloser.
- The number of customers and average load on the entire feeder, the downstream length, and the length upstream to the next recloser.
- The number of poles by material on the feeder length downstream of the segment, and the length upstream to the next recloser.
- Historical outage data and value of customer reliability (VCR) for each feeder.

- Historical reactive expenditure resulting from Major Event Day (MED) events for asset repairs or replacements.

2.2 Establish the assumptions

Table 1 below outlines the key assumptions in the Climate Resilience Economic Model.

Table 1 Key assumptions

Assumption	Value	Explanation
Discount rate	5.45% real	Provided by AusNet; average of AusNet's forecast of pre-tax WACC (3.91%) and AEMO's 2023 IASR central case (7.00%)
Calibration window	January 2015 to June 2023	Window selected as up to 10 calendar years prior to the current date (calendar year 2024). 10 years was deemed to be a large enough window to adequately reduce the impact of annual volatility in windstorm climate risk but not too large as to misalign modelled risk in the current year with an earlier baseline that is not representative. Only windstorm risk is used in the calibration as explained in Section 2.3.3.
Baseline risk window	2000 to 2020 (midpoint of 2010)	A 20-year period covers a suitable long historical period, excluding some of the more recent climate change and extreme weather events.
End risk window	2045 to 2054 (midpoint of 2050)	Similarly to how the calibration window was selected, 10 years was deemed to be a large enough window to adequately reduce the impact of annual volatility in climate risk.
RCP weighting	100% weighting to RCP4.5	• RCP 4.5 is considered the most likely based on current emission trends and pledges under the Paris Agreement (it is also the AER's preferred likely scenario) • RCP 2.6 is seen as unlikely due to the significant reductions required. • RCP 8.5 represents a high-risk but possible future.

2.3 Forecast the inherent climate risk (or do-nothing risk)

The inherent climate risk – risk under do-nothing – is quantified by forecasting the value of expected unserved energy and loss of asset due to the perils.

The value of expected unserved energy (VoEUE) is the monetised value of energy that could not be supplied to a customer due to a fault or failure on the power system. This is the value of the energy that would have been delivered had there been no interruption. Loss of asset refers to the monetised value of the damage to an asset as a result of the climate event, based on historical reactive costs resulting from MED events for both asset repairs and replacements. An example of this is fallen trees damaging cables due to a windstorm. These two values aim to capture the economic cost of climate perils.

Risk Frontiers' Climate Data provides the expected frequency of perils at locations across AusNet's distribution network area; data was provided on a year-on-year basis for each peril. The inherent risk of each feeder is calculated using the estimated number of asset failures on each feeder due to each peril, the average load, the number of customers on the feeder, the value of customer reliability of the feeder, and the expected restoration time.

2.3.1 Windstorm

In the windstorm model, the probability of failure for each asset type is determined using the simulated number of days with a maximum windspeed above 11.3m/s, an extrapolated probability of a 3-second gust[1] of a given windspeed, and a separate asset vulnerability curve for each pole type and for conductors with respect to windspeed. This is calculated by identified asset location. The probability of a 3-second gust of a particular speed is calculated for a given WindMax value using a Gumbel distribution with parameters set out in section 3.2.

- The expected number of pole failures is the product of the probability of failure for poles and the number of poles at each identified location.
- The expected number of vegetation-related conductor failures is the product of the probability of failure for conductors and the proportion of the feeder that is vegetated.

Locations are then mapped to feeders to calculate the total expected pole and conductor failures on the feeder. This is multiplied by the expected restore time and value of customer reliability to calculate the value of expected unserved energy, and by the reactive replacement cost to calculate asset loss risk.

The expected restore time for outages resulting from windstorm asset failures is modelled on an annual basis as a function of the total number of windstorm asset failures that occur in that year. The rationale for this approach is that major event day windstorm events will tend to overwhelm field crews, increasing their response times. This approach is supported by the historical outage data, and uses parameters from historical major event day windstorm outages which can be viewed in the 'Assumptions' worksheet, and the calculations for which can be found in the 'I-Outages' worksheet.

2.3.2 Bushfire

In the bushfire model, the probability of failure is determined using the simulated number of days with an FFDI value above 100, and a probability of a fire start at the asset location given a high FFDI day, and a conditional probability of pole failure given a bushfire at the location and pole material.

The probability of a fire ignition at the asset location given a high FFDI day is calculated using the total number of fire ignitions at the location in the Fire Ignition dataset based on 30,000 simulation years of bushfires, and dividing the number of fire starts by the number of simulation years (30,000).

The conditional probability of pole failure given a bushfire at the location and pole material is a modelling assumption set by the user such that the modelled bushfire risk is calibrated to baseline risk. A further explanation of the calibration can be found in section 2.3.3.

As with the windstorm risk calculations:

- The expected number of pole failures is the product of the probability of failure for poles and the number of poles at each identified location
- The expected number of vegetation-related conductor failures is the product of the probability of failure for conductors and the proportion of feeder that is vegetated.

Locations are then mapped to feeders to calculate the total expected pole and conductor failures on the feeder. This is multiplied by the expected restore time and value of customer reliability to calculate the value of expected unserved energy, and by the reactive replacement cost to calculate asset loss risk.

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[1] A 3-second gust is the highest sustained gust over a 3-second period having a probability of being exceeded per year of 1 in 50.

2.3.3 Calibration

The model employs a two-step calibration process to ensure results align with real-world outcomes. This approach combines top-down and feeder-level adjustments.

Top-down Calibration

The level of baseline windstorm modelled value of unserved energy (VoUSE) is calibrated to the actual value of expected unserved energy resulting from major event day windstorm events over the calibration period, which is currently set as January 2015 to June 2023 (inclusive). This is achieved by adjusting model parameters to ensure the modelled VoUSE matches the historical data.

The level of baseline bushfire VoUSE risk, due to a lack of suitable data resulting from a recent lack of major bushfire seasons in Victoria, has been calibrated to an indicative baseline bushfire VoUSE risk calculated using bushfire frequency and severity values from NSW, but using AusNet customer numbers (by customer type).

Feeder-Level Calibration

Following the calibration of total windstorm and bushfire risk discussed above, calibration is also performed at the feeder level such that feeder-level VoUSE is expressed as a weighted average of historical feeder VoUSE and modelled feeder VoUSE. This is only performed for windstorm risk due to a lack of suitable data for bushfires. The weighting is a user-defined assumption, with a default of 70% historical and 30% modelled risk.

The feeder level calibration aligns the relative risk between feeders with historical data. This helps ensure that feeders that have historically been high risk are considered high risk, and vice versa.

If this step is not performed, you may end up with historically high-risk feeders appearing as low risk, and historically low risk feeders appearing as high risk, due to inherent limitations in climate modelling. This may result in investment programs that target the wrong assets.

2.4 Forecast risk reduction benefits

The Climate Resilience Economic Model focuses on the potential of network hardening solutions to address the inherent risk of high-voltage bare overhead cables to climate perils. The difference between climate risk of the feeder after investment and the risk in the absence of investment (or do-nothing) is the risk reduction benefit

In the model, the measure of risk reduction benefit resulting from the implementation of solutions is the reduction in the value of expected unserved energy and asset loss. This metric quantifies the positive impact of the solutions in terms of mitigating the negative consequences of climate risks on energy supply and asset integrity.

The climate risk reduction benefits for each year, over the assessment period, are calculated at the feeder level using the feeder-level risk for each peril and risk metric (e.g., windstorm – loss of supply), a calibration factor to incorporate historical feeder risk, and the percentage of VoEUE mitigated by the solution. To calculate the Net Present Benefit, the benefits are discounted to the 'investment year', and then discounted again to the 'current year'.

$$Net\ Present\ Benefit =$$

$$\frac{\sum_{n=1}^{25}\left[\frac{\text{Feeder Risk}_{\text{year n}}}{(1+WACC)^{n}}\right] \times \text{Calibration Factor} \times \%\ Solution\ Risk\ Reduction}{(1+WACC)^{(Investment\ Year\ -1\ -\ Current\ Year)}}$$

The model also calculates a First Year Risk Benefit, which quantifies the immediate impact of the proposed solution on mitigating the climate risk and enhancing the resilience of the feeder. The First Year Risk is calculated by discounting the benefit that occurs in the 'investment year' to the 'current year'.

$$1st\ Year\ Benefit\ (Loss\ of\ Supply) =$$

$$\frac{\text{Feeder Risk}_{\text{Investment Year}} \times \text{Calibration Factor} \times \%\ Solution\ VoEUE\ Risk\ Reduction}{(1+WACC)^{(Investment\ Year\ -1\ -\ Current\ Year)}}$$

$$1st\ Year\ Benefit\ (Asset\ Loss) =$$

$$\left.\begin{array}{c}\text{Feeder Risk for Investment Year} \times \text{Calibration Factor} \\ \times\ (\%\ of\ Cable\ to\ CCT * Effectiveness\ of\ CCT \\ +\ \%\ of\ Cable\ to\ Underground * Effectiveness\ of\ Underground \\ +\ \%\ of\ Poles\ Hardened * Effectiveness\ of\ Pole\ Hardening \\ +\ \%\ of\ unserved\ energy\ reduced\ through\ Segmentation)\end{array}\middle/ (1+WACC)^{(Investment\ Year\ -1\ -\ Current\ Year)}\right.$$

Table 2 outlines the suite of network hardening solutions assessed for each feeder.

Table 2: Resilience Solutions

Solution Name	Description
CCT	Covered conductor (CCT) for bare overhead cable lengths. Covered conductors are more resilient than bare conductors to the effects of wind and reducing the chances of bare wires hitting each other and falling vegetation causing an outage.
Recloser	Recloser placed on feeder to facilitate segmentation. Segmentation can reduce the number of customers impacted by an outage.
Undergrounding	Undergrounding bare overhead cables with no limitation on feeder length. Undergrounding provides additional resilience against both storms and bushfires.
Pole Hardening	Replacement of wooden HV poles with concrete / composite bushfire resilient poles. Pole hardening provides resilience against bushfires.

The effectiveness percentage of each solution at mitigating different climate risks is shown in Section 3.3 as an appendix, and measures the % reduction in different modelled climate risks. If the % effectiveness is less than 100%, some residual risk will remain. These effectiveness percentages are as set out in the 'I-Solutions' worksheet of the model.

2.4.1 Covered conductors

The model assesses multiple covered conductor solution options to economically assess the covering of different lengths of the feeder. These are to cover up to 1,500m, up to 5,000m, up to 10,000m, up to 25,000m, all bare overhead vegetated length, or all bare overhead length. For solution options that do not cover the entire bare or bare vegetated length of the feeder, existing recloser segments are prioritised by the expected percentage reduction in the value of unserved energy achieved by covering that recloser segment and only addresses bare overhead spans.

The expected reduction in the value of unserved energy for each existing recloser segment is calculated by multiplying an assumed fault rate for bare overhead and bare overhead vegetated spans by (1- effectiveness percentage) where the effectiveness percentage is the covered conductor effectiveness percentage for unserved energy shown in Section 3.3. The assumed fault rates and covered conductor fault rates after applying the effectiveness percentages are shown below in Table 3. These fault rates are then multiplied by an assumed fault duration, VCR, and the corresponding length of bare overhead and bare overhead vegetated length for each existing recloser segment, before and after the covering of the recloser segment. Then the after-covering expected value of unserved energy is then divided by the do nothing expected value of unserved energy to determine the expected percentage reduction in the value of unserved energy for that recloser segment.

Table 3: Fault Rates - Covered Conductor

Parameter	Value	Units	Source
Fault rate bare no veg	0.000100	per km	Placeholder
Fault rate bare veg	0.001000	per km	Placeholder
Fault rate covered no veg	0.000050	per km	Placeholder
Fault rate covered veg	0.000500	per km	Placeholder

This value of expected unserved energy is not the value of expected unserved energy used in the final economic model, and is only expressed in percentage terms for the purposes of ranking recloser segments to identify which recloser segments will be covered under each of the different length options for covered conductors and to estimate the final effectiveness percentages for conductor failures in the economic model.

The final effectiveness percentage (to be used in the economic model) for unserved energy risk is calculated as the sum of the combined reduction in expected value of unserved energy for the recloser segments included in each of the different covered conductor length options divided by the do-nothing expected value of unserved energy for the whole feeder. In the case of covered conductors, this effectiveness percentage is only applied to the value of unserved energy resulting from conductor failure, and not from pole failures.

A separate effectiveness percentage is applied to asset loss risk. This effectiveness percentage is multiplied by the reactive asset loss cost (set in the ‘Assumptions’ sheet), the % length of the feeder that is covered, and the do-nothing asset loss risk to calculate the asset loss benefit. In the case of covered conductors, this effectiveness percentage is only applied to asset loss risk resulting from both conductor failures and not pole failures.

2.4.2 Undergrounding

Similar to the approach taken for covered conductors, the model assesses multiple undergrounding solution options to economically assess the undergrounding of different lengths of the feeder. These are to underground up to 1,500m, up to 5,000m, up to 10,000m, up to 25,000m, or all bare overhead length. For solution options that do not underground the entire bare length of the feeder, existing recloser segments are prioritised by the expected percentage reduction in the value of unserved energy achieved by undergrounding that recloser segment, only addressing bare overhead spans.

The expected reduction in the value of unserved energy for each existing recloser segment is calculated by multiplying an assumed fault rate for bare overhead and bare overhead vegetated spans by (1- effectiveness percentage) where the effectiveness percentage is the undergrounding effectiveness percentage for unserved energy shown in Section 3.3. The assumed fault rates and undergrounded fault rates after applying the effectiveness percentages are shown below in Table 4.These fault rates are then multiplied by an assumed fault duration, VCR, and the corresponding length of bare overhead and bare overhead vegetated length for each existing recloser segment, before and after the undergrounding of the recloser segment. Then the after-undergrounding expected value of unserved energy is then divided by the do nothing expected value of unserved energy to determine the expected percentage reduction in the value of unserved energy for that recloser segment.

Table 4: Fault Rates - Undergrounding

Parameter	Value	Units	Source
Fault rate bare no veg	0.000100	per km	Placeholder
Fault rate bare veg	0.001000	per km	Placeholder
Fault rate UG	0.000001	per km	Placeholder

This value of expected unserved energy is not the value of expected unserved energy used in the final economic model, and is only expressed in percentage terms for the purposes of ranking recloser segments to identify which recloser segments will be undergrounded under each of the different length options for undergrounding and to estimate the final effectiveness percentages for conductor failures in the economic model.

The final unserved energy effectiveness percentage (to be used in the economic model) is calculated as the sum of the combined reduction in expected value of unserved energy for the recloser segments included in each of the different undergrounding length options, divided by the do-nothing expected value of unserved energy for the whole feeder. In the case of undergrounding, this effectiveness percentage is applied to both the value of unserved energy resulting from conductor failure and that resulting from pole failures.

A separate effectiveness percentage is applied to asset loss risk. This effectiveness percentage is multiplied by the reactive asset loss cost (set in the ‘Assumptions’ sheet), the % length of the feeder that is undergrounded, and the do-nothing asset loss risk to calculate the asset loss benefit. In the case of undergrounding, this effectiveness percentage is applied to asset loss risk resulting from both conductor and pole failures.

2.4.3 Pole hardening

The model assesses multiple pole hardening solution options to economically assess the hardening of different numbers of poles on a given feeder. These are to harden all poles on the feeder with a bushfire probability of failure over 50%, 100%, 150%, 250%, 500%, or 1,000% above baseline. The baseline bushfire probability of failure is calculated as the average pole bushfire probability of failure over the calibration baseline set in the ‘Assumptions’ sheet. This determines the number of poles hardened under each pole hardening solution option for each feeder.

The risk reduction percentage for both value of unserved energy and asset loss due to bushfires is calculated as the number of poles hardened in the solution option divided by the total number of poles on the feeder. This is then multiplied by the do-nothing risk to calculate the benefit. In the case of pole hardening, the effectiveness percentage is only applied to value of unserved energy and asset loss risk due to bushfires, and not due to windstorms.

2.4.4 Segmentation (Recloser Installation)

A Recloser Benefit Model was developed based on the topology of AusNet’s HV distribution network to quantify the risk reduction benefit of reclosers. The Recloser Benefit Model is embedded within the Climate Resilience Economic Model. This module calculates the optimal location along a feeder for recloser installation based on how it would be able to protect customers upstream from unserved energy due to a fault downstream to the next recloser. Specifically, given a location:

- The probability of a failure downstream to the next recloser is calculated based on the length downstream to the next recloser.

- The percentage reduction in the value of expected unserved energy is calculated as the product of the probability of failure, an assumed outage duration, the value of unserved energy (VCR), and the average load served by the newly created segment.

The optimal location is where recloser installation results in the greatest reduction in the value of expected unserved energy. The optimal location is used in the cost-benefit analysis step for each feeder in determining the preferred solution for each feeder. Only one recloser installation per feeder is modelled.

Similarly to the methodology used for the other solutions, this percentage reduction is multiplied by the do-nothing value of unserved energy to calculate the value of unserved energy benefit in the economic model. Segmentation benefits are only calculated for value of unserved energy due to windstorms, and not asset loss risk or risk due to bushfires.

2.5 Cost-Benefit Analysis

By assessing the risk reduction benefits against the cost of implementing the solutions, the model provides a comprehensive evaluation of the economic feasibility. Specifically, the key outputs include the Net Present Value (NPV) and benefit-to-cost ratio (BCR) for each proposed solution. This approach allows decision-makers to prioritize and allocate resources effectively based on the balance between incurred costs and forecast benefits.

Where the NPV is greater than zero (NPV positive), the present value benefits exceed the present value cost of the solution investment. Therefore, the solution is economically viable and beneficial.

Economic Benefit ($) ÷ Cost ($) = Benefit-Cost Ratio

The model is configured to only assess a single investment solution for each feeder. While combinations of different solutions could potentially be economically viable, the impact on the total level of expenditure or risk reduction of the preferred option is likely minimal. The reason for this is that these would only be expected to be viable for feeders where relatively expensive solutions are preferred, namely undergrounding. There are relatively few feeders for which undergrounding is the preferred option and the highest risk recloser segments along these feeders are already being invested in. Additionally, the interaction effect of the risk reduction between the two is complicated to model.

The evaluation of the present value of the cost for each solution depends on whether the asset type solution is discrete (recloser and pole hardening) or linear (UG and CCT). In cases where a recloser is selected, the unit rate of the recloser is the standard cost of a single recloser installation. For solutions where cable installation is required, the proposed length of the cable is summed on a per km basis for each feeder and multiplied by a unit rate. The Net Present Cost (NPC) assesses this cost in the current year.

$$Net\ Present\ Cost\ = \frac{\text{Cost}}{(1+WACC)^{(Investment\ Year\ -1\ -\ Current\ Year)}}$$

The two investment ratios analysed are Investment ratio and BCR. The investment ratio is the NPV as a percentage of the net present cost of the solution. This allows for the quantification of the initial investment against potential financial benefit of the solution. BCR assesses the economic viability of the solution by taking the net present value of climate risk reduction benefits as a ratio of the net present investment cost.

Net Present Benefit of Investment ($) ÷ First Year Cost of Investment ($) = Investment Ratio

2.5.1 Investment Programs

The results of the cost-benefit analysis to select the preferred solution at the individual feeder level for a range of investment program options. For all options except for Option A – Base case, which includes no investment, and Option H – Maintain Current Risk to 2050, the highest NPV solution is selected for each feeder.

Only one solution is selected for each feeder, before feeders are selected for investment programs based on the cost-benefit analysis results of the selected solution for each feeder. In all cases except for the do-nothing option, the investment is spread over four EDPRs, but each uses a different prioritisation approach.

Details of the investment program options are as follows:

Option A - Base case

Option A is the 'do nothing' option and includes no investment in resilience solutions.

Option B - Upfront investment

Option B is to invest in the highest NPV solution for each feeder, if the NPV is positive in EDPR FY27-31.

Option C - Target high-risk zones before starting in rest of network

Option C includes the same total level of investment over the entire assessment period as Option B but prioritises investment in zones with the highest total quantified risk in the first EDPR. After the first EDPR, Option C invests based on feeder BCR in decreasing order (highest BCR first).

Option D - Do all projects with a BCR >2 in first period

Option D includes the same total level of investment over the entire assessment period as Option B but prioritises investments with a BCR that is greater than 2 in the first EDPR. After the first EDPR, Option D invests based on feeder BCR in decreasing order (highest BCR first).

Option E - Balances affordability - highest BCR projects first

Option D includes the same total level of investment over the entire assessment period as Option B but prioritises investment in feeder-level solutions which have the highest benefit/cost ratio first. The benefit/cost ratio is equal to the present value of quantified benefits divided by present value of costs.

Option F - Option G 35% Frontloaded

Option F is variant of Option G where 35% of the expenditure is targeted for the first EDPR as opposed to an even split (25%).

Option G - Maintain current risk to 2050 if efficient

Option G is to invest in the highest NPV solution for each feeder, if the NPV is positive up to the point where the baseline level of risk (the average risk from 2000-20) is maintained up until 2050 (the average risk from 2050-2054). Option G invests in the feeders with the highest risk growth first.

Option H - Maintain current risk levels to 2050

Option G is to invest in all investments required to maintain the baseline level of risk up until 2050 regardless of whether they are the highest NPV solution or if the solution is NPV positive, unlike Option G, but prioritises efficient investments.

2.5.2 Validation

To validate the model, a single feeder was chosen as a representative case. The economic metrics for two solutions on this feeder were manually calculated using the same methodology employed in the model. This manual calculation process ensured consistency and allowed for a direct comparison with the model's output.

The calculated economic metrics, such as total investment cost and total climate risk reduction present value, were then compared to the corresponding results generated by the model. This comparison aimed to confirm the accuracy and reliability of the model's calculations and outputs.

By validating the model in this manner any discrepancies or variations can be identified and addressed. This validation process helps ensure the model's robustness and confirms its ability to accurately assess different solutions for climate resilience.

2.6 Key outputs

In evaluating the results of the Climate Resilience Economic model, various metrics were considered. The methodology resulted in the selection of one solution for each feeder according to the previously described process.

The key outputs of the model are:

- Total investment cost ($).
- The program quantities (e.g., number of hardened poles, number of reclosers, length of undergrounding and length of covered conductors).
- Present value of total climate risk reduction benefits ($).
- Customer metrics: System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI). To assess the impact of the solutions on customers, SAIDI and SAIFI are approximated for the selected baseline window, the 2050 window (2045-2054), and interim periods.
- Mapping outputs: Investment locations, segment risk measured by customer minutes off supply (CMOS) among other outputs are mapped to individual segments and poles to enable the creation of maps in mapping software such as QGIS.

These metrics provided valuable insights into the economic, customer-focused, and engineering aspects of the selected solutions, enabling a comprehensive evaluation of the Climate Resilience Economic model.

2.6.1 Customer metrics

The major event day (MED) components of SAIDI and SAIFI are calculated using the expected number of outages and expected restore time for windstorm and bushfires separately for each of the three climate model simulations for each climate scenario. The values for each climate model simulation are averaged for each of the climate scenarios and the final value is calculated as a weighted average of the result for each climate scenario to calculate the final MED SAIDI and SAIFI values.

To calculate total SAIDI and SAIFI, the non-MED component of SAIDI and SAIFI in the baseline window (set by the in the 'Assumptions' sheet) is added to the modelled MED SAIDI and SAIFI values.

The reduction in SAIDI and SAIFI under each investment program is estimated from the total reduction in VoUSE under each program.

3 Appendices

3.1 Financial Assumptions

Assumptions	Value
WACC	5.45% (real)
Assessment period	Years 2000 to 2054
Benefit Accrual	25 Years
NPV hurdle	0.00

3.2 Climate Risk Assumptions

Assumptions	Value
Wind Gust Conversion Distribution	Gumbel distribution: beta value of 2.3
Climate scenario weightings	2.6: 0%, 4.5: 100%, 8.5: 0%
Historical risk weighting adjustment	AusNet Historical: 70%

3.3 Solution Assumptions

Resilience solution	Effectiveness (Risk Reduction) %				Cost		
	Windstorm Asset Loss[2]	Windstorm Loss of Supply	Bushfire Asset Loss[2]	Bushfire Loss of Supply	Cost ($)	Cost SWER ($)	Cost unit
Replace overhead bare 22kV with UG bored 22kV line	99%	99% Non-Vegetated 99.9% Vegetated	99%	99%	CIC	CIC	per km
Replace overhead bare 22kV line with covered 22kV line	75% Conductor fault 0% Pole failure	50% Conductor fault 0% Pole failure	N/A	N/A	CIC	CIC	per km
Segmentation of HV feeder	N/A	100%[3]	N/A	N/A	CIC		per segmentation
Replace wooden HV pole with Concrete / composite bushfire resilient poles	N/A	N/A	N/A	99% Pole failure 0% Conductor fault	CIC		per pole

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[2] Includes investigation, fault clearing, repair and replacement costs.

[3] 100% risk reduction of entire feeder risk is not attainable, as only customers between the segment of installation and the upstream recloser can benefit. The average risk reduction over an entire feeder is approximately 16%.