Guidehouse

ONTARIO ENERGY BOARD

Vulnerability Assessment and System Hardening (VASH)

(EB-2024-0199)

Toolkit Training

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VASH Overview

Guiding Principles

Project Outcome: A VASH Report that will provide a standard framework that prioritizes customer value to allow LDCs to develop and evaluate climate resilience adaptive actions, whether proactive or responsive, and make investment decisions in a consistent manner.

- **Standardized Evaluation Approach**
  Establish a consistent framework for assessing risk and value, enabling LDCs to implement adaptive actions through simple, repeatable calculations. Include clear guidance on benefit and cost streams for use in cost tests.
- **Data-Driven Vulnerability Assessment**
  Provide a standard dataset to define severe weather events, while allowing LDCs to use unique sources and transparently document assumptions made to address gaps in climate, vulnerability, and VOLL data.
- **Integration with Existing Planning**
  Identify opportunities to align resilience investments with other DSP requirements. While full integration in every case is beyond scope, the framework supports strategic alignment with asset renewal and modernization efforts.
- **Guidance for Implementation and Filing**
  Direct LDCs on applying the VASH approach in their DSPs and cost of service applications. Emphasize customer value, consistent resiliency planning, and readiness for 2026 filings (for 2027 rates), with expectations clearly defined for all stakeholders.

Project Components

Six components combine to inform the final ED VASH Report and are supported by a scan of 3-5 leading jurisdictions.

Component	*Definition*
1. Risk-Based Vulnerability Assessment	A risk-based Vulnerability Assessment that includes the probability/impact of events. The frequency and time-period of the Vulnerability Assessment should also be included.
2. Standardized Vulnerability Assessment Data Sources	The sources for any standardized input variables to be used in the Vulnerability Assessment (including, for example, the use of a common forecast or model that estimates how climate change is likely to alter the frequency and severity of adverse weather conditions; a common set of equipment impacted; etc.).
3. Value of Lost Load Methodology	A value of lost load methodology to quantify risk reduction value from the Vulnerability Assessment.
4. Benefit-Cost Analysis	A benefit-cost analysis to evaluate whether an LDC should pursue an investment based on the cost of the investment in comparison to the value of lost load mitigated and other applicable benefit streams.
5. DSP Integration Methodology	Methodology for incorporating System Hardening into an LDC's system planning as an additional investment driver within their integrated system planning process.
6. Filing Requirement Updates	Recommend updates to the Chapter 2 and 5 Filing Requirements for Electricity Distribution Rate Applications or develop policies resulting from Report. The recommendations for the Filing Requirements should be included as part of Report.

Benefit-Cost Analysis (BCA): DST Perspective

The benefit-cost framework developed for VASH is designed to align with inputs and perspectives of the Distribution Service Test (DST).

- VASH BCA aligns with the customer perspective of the DST.
- VASH BCA allows for **quantitative** resiliency benefits estimation.
- VASH BCA may be used alone or in combination with other DST impact streams.

Impact	Mandatory (M) / Permitted (P)	Quantitative	Qualitative[18]
BENEFITS			
Distribution Capacity (Deferral or Avoidance Benefit)	M	X	
Reliability (Net Avoided Interruption Costs)	P		X
Resilience (Critical Load Benefits)	P		X
Innovation & Market Transformation	P		X
Planning Value	P		X

Source: Benefit-Cost Analysis Framework for Addressing Electricity System Needs, May 2024

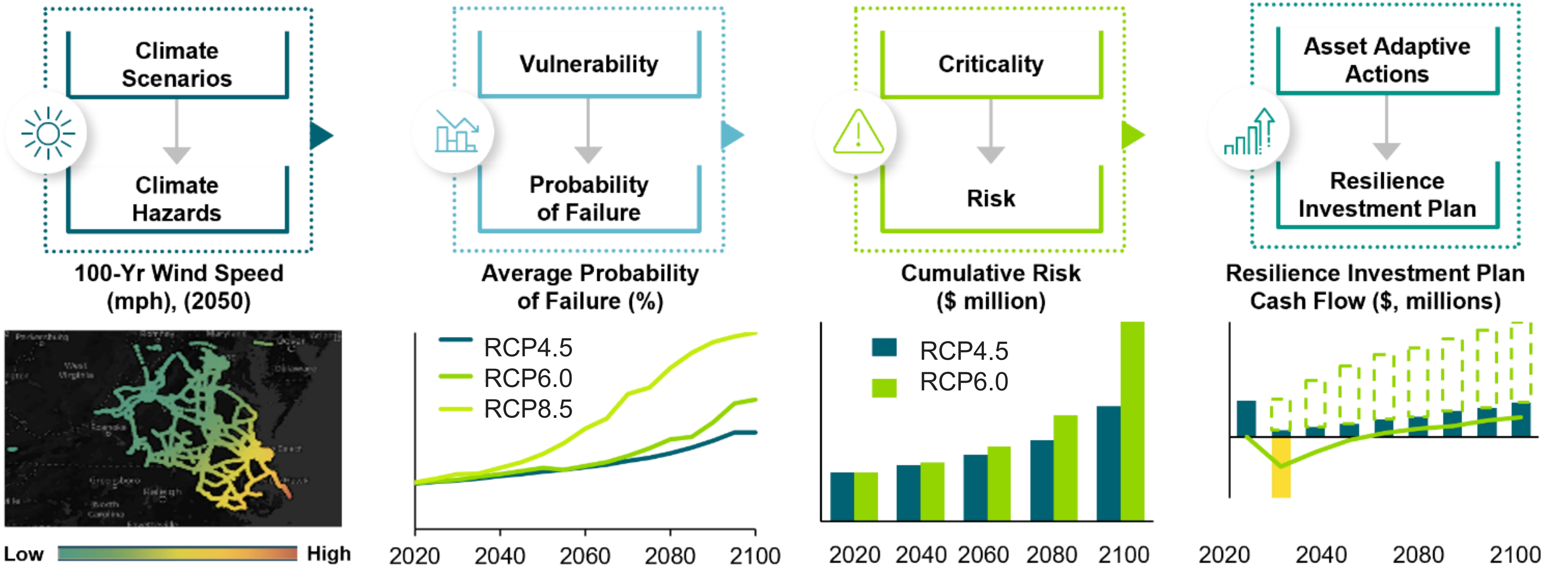
Filing Considerations

- **Applicability**:
  - VASH **complements existing planning** and asset management practices. Projects driven solely by system hardening should be categorized under System Service.
  - **Resilience should be embedded in broader planning decisions**, potentially revisiting previously dismissed projects that could offer resiliency benefits.
- **Requirements:**
  - One of the two **Assessment Approaches** must be used:
    - **Generic Option**: Uses OEB's standardized VASH Toolkit.
    - **Custom Option**: Allows proprietary tools if they meet criteria (e.g., climate data, asset-based analysis).
  - **Pre-Assessment**, to be completed after the VA:
    - Identify significant vulnerabilities and assess feasibility of hardening.
    - Document prioritization, rationale, and data sources.
    - Submit pre-assessment results with DSP.
  - **BCA** :
    - Required for economically feasible hardening projects.
    - Must be project-specific (not system-wide).
    - Generic Option uses BCA Toolkit; Custom Option must meet defined standards identified in the framework.
  - **Timeline**: Distributors must include VASH-related assessments in 2026 rebasing applications for 2027 rates. Filing requirements will be updated to reflect this.

Toolkit Overview

Resiliency Risk Analysis and Investment Development

Objective system asset resiliency risk analysis includes four stages increasingly performed by distributors in the face of observed changes in the frequency and severity of severe weather events.



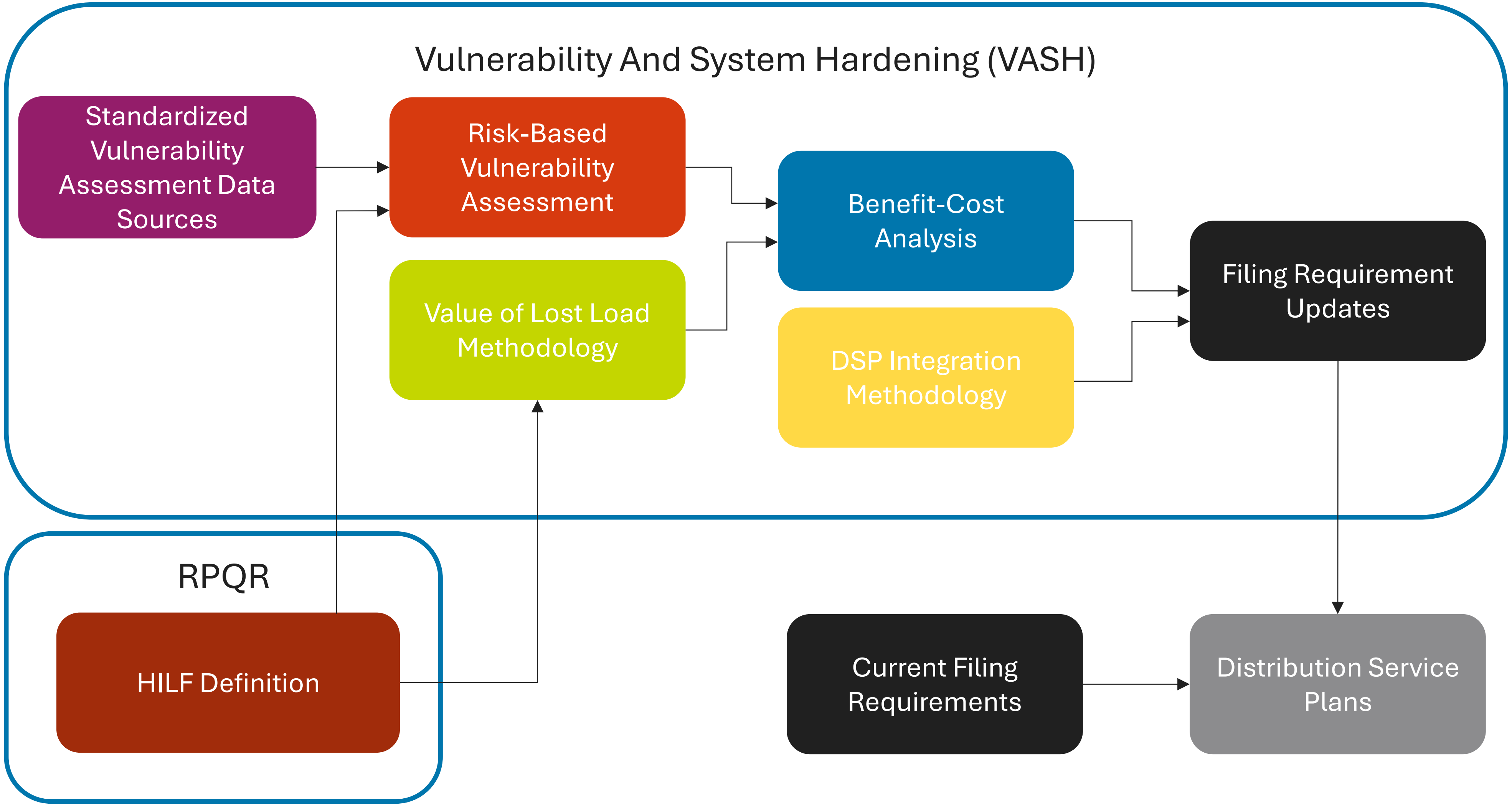
The climate forecast is developed for a broad range of climate hazards and scenarios (RCPs) for screening of assets.

The vulnerability assessment defines the level at which an asset would fail due to a climate hazard and per climate scenario.

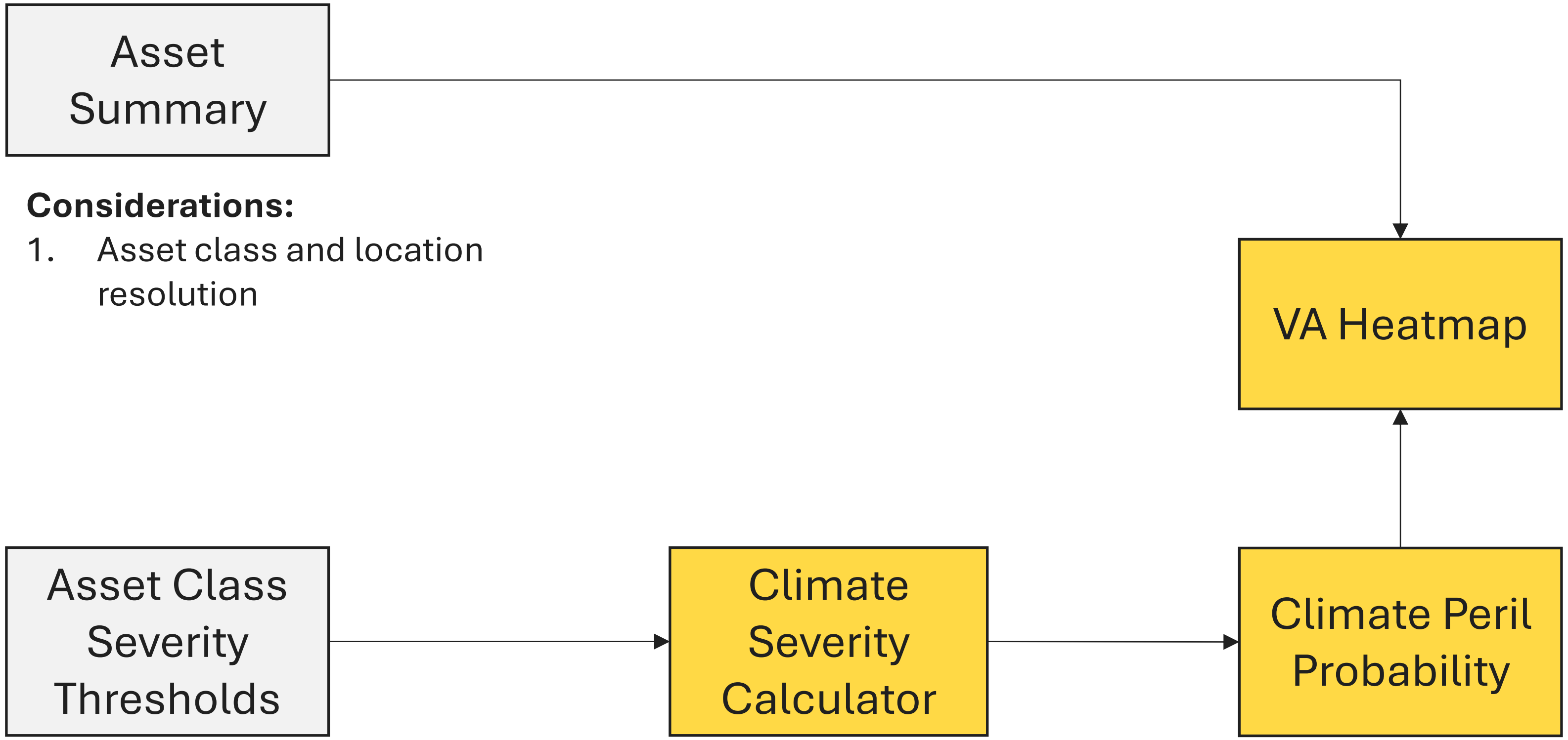
The risk forecast combines the probability of failure with the cost of the asset's failure.

Implement adaptive actions by assessing programmatic investments to mitigate the risk from climate hazards.

VASH Scope and Approach



VASH Toolkit (Generic Option) Flow Diagram – VA



Considerations:

1. Asset class and location resolution

Considerations:

2. Climate peril list
3. Severity thresholds for climate perils

Considerations:

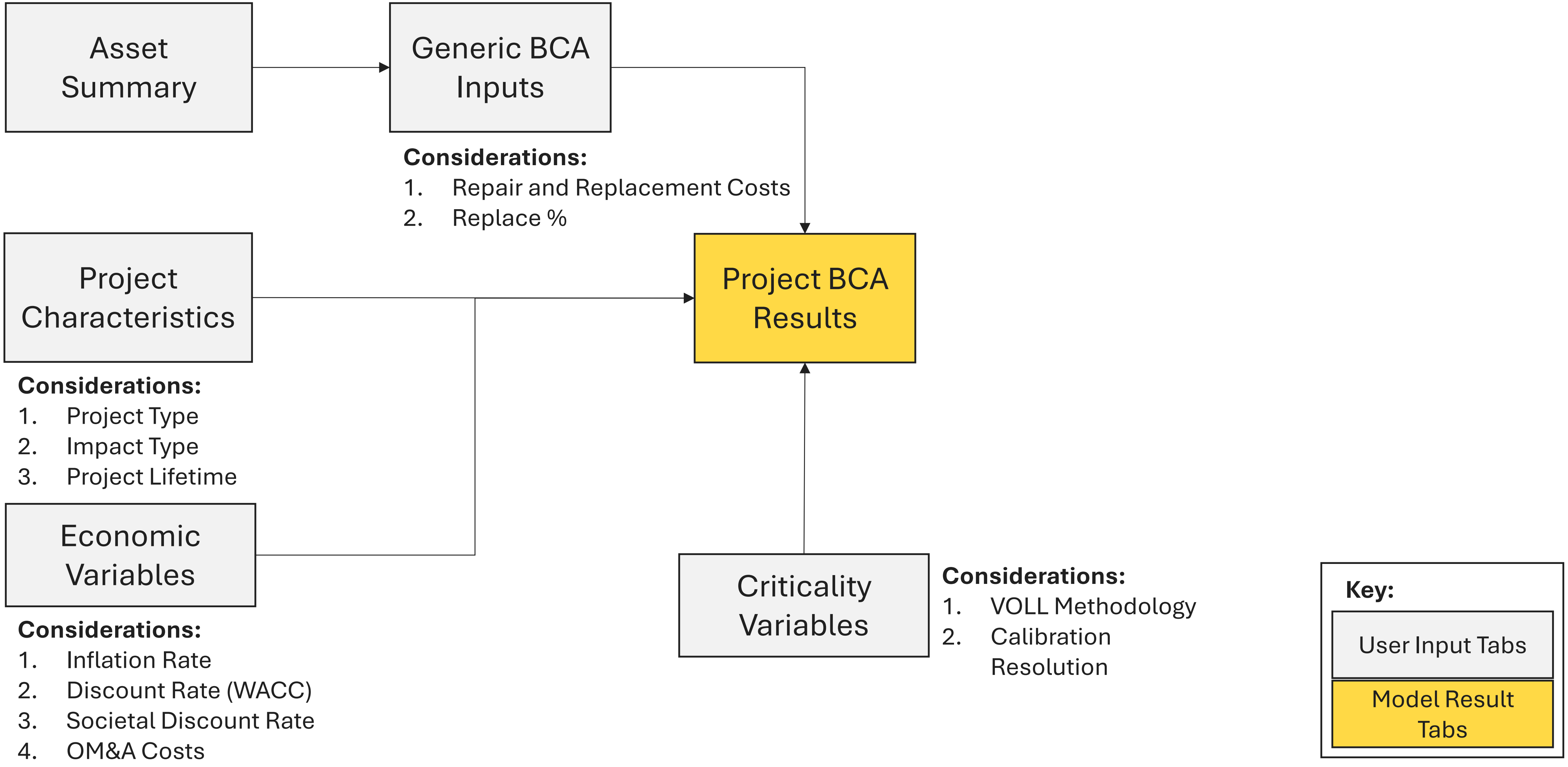
4. Climate event probability forecast data source
5. Climate change scenario choice

Key:

User Input Tabs

Model Result Tabs

VASH Toolkit (Generic Option) Flow Diagram – BCA



Key Vulnerability Assessment Inputs

Vulnerability Assessment (VA) Methodology

A risk-based Vulnerability Assessment includes the probability of a climate peril at severity levels observed in historic extreme weather events, as well as failure thresholds for the most common utility assets in alignment with design standards, resulting in a usable toolkit to support LDC risk analysis.

Climate Peril Identification

Identify historical severe weather events

- Determine list of climate perils that have been observed using historic extreme weather events data
- Use discrete climate perils to map risk to evaluated asset classes

Climate Peril Forecast

Determine expected annual probability of climate perils

- Use publicly available or proprietary climate forecast data for each climate peril.
- OEB recommends aligning with CSA/ECCC on climate projection choice. i.e. using RCP 8.5 for assets with <60-year lifespans and RCP 6.0 for >60 years. Distributors may use other scenarios with rationale.
- The OEB has provided in the VA Toolkit, on a one-time basis, climate peril projections for wind and ice accretion at locations across Ontario, derived from CSA and ECCC data.

Asset Class Failure Modes & Thresholds

Identify climate perils that each asset class is vulnerable to and their associated failure threshold

- Develop list of asset classes and failure modes
- Identify expected failure thresholds for asset classes by climate peril
- Treat asset vulnerability identification in a similar manner to asset condition assessments
- OEB provides examples of asset classes and climate perils that can be included in the VA but has not prescribed them.

Vulnerability Assessment Toolkit Data Requirements

The toolkit combines climate data, design standards, and asset location summaries. Inputs may be developed by LDCs using a variety of sources including the LDCs internal data, CSA guidelines, publicly available climate data, and proprietary climate data. The OEB does not specify a data source expectation. LDCs may leverage data commensurate with their planning granularity and needs.

Toolkit Data Requirements:

LDC Asset Summary

Summarizes asset counts by analysis location. Locations with no assets of a specific class will have no vulnerability for that class regardless of climate projections. For locations and class combinations with higher vulnerability, an LDC may review its asset counts to understand the pervasiveness of the resiliency challenge.

Asset Class Failure Thresholds

Characterizes the expected resilience of LDC assets identified in the Asset Summary to specific climate perils. Sub classes may be included to better estimate failure thresholds across a variety of perils. The total annual probability of failure is the summation across climate perils. LDCs may leverage design standards to quickly review vulnerability or refine failure thresholds with additional condition data of field equipment.

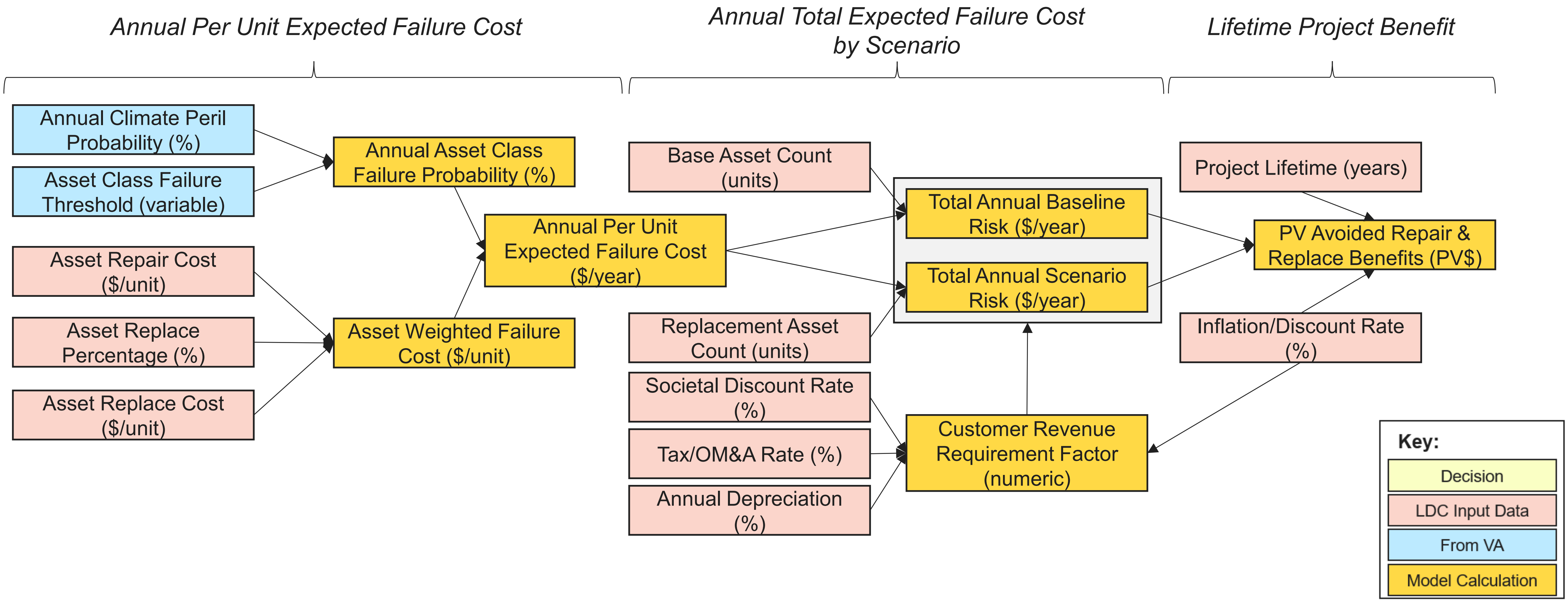
Climate Peril Probability

Projects the annual probability of specific events (relevant to assets in the Asset Summary) occurring at targeted grid locations through time. Climate perils and severity thresholds are linked to specific asset failure modes and thresholds. For example, wind gusts may be evaluated at 80, 100, and 120 kph as these relate to different class pole failures.

Detailed Flow Diagrams

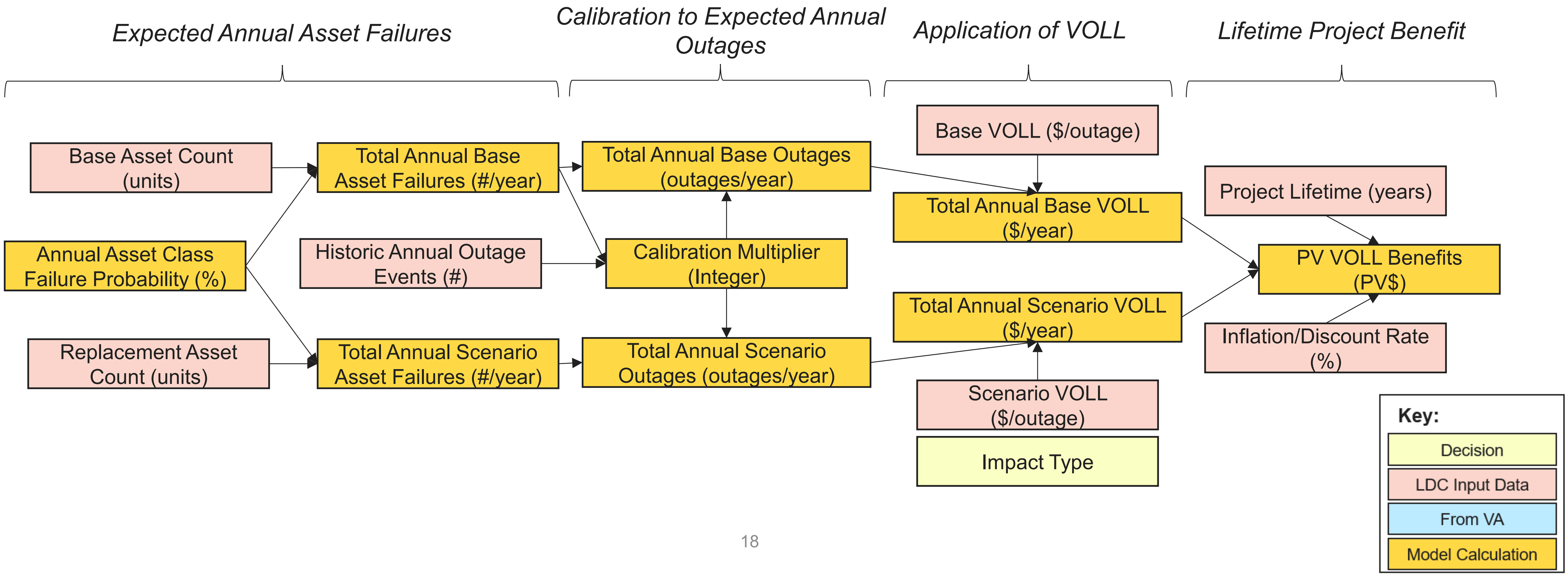
BCA Toolkit – Avoided Repair & Replace Benefits

Avoided repair and replace benefits are the difference between lifetime projected failures from the baseline asset scenario to the hardened asset scenario. The annual probabilities of failure from the VA are multiplied by the weighted cost of failure, scaled to the total project count, adjusted to represent customer value, and present valued over the project's lifetime.



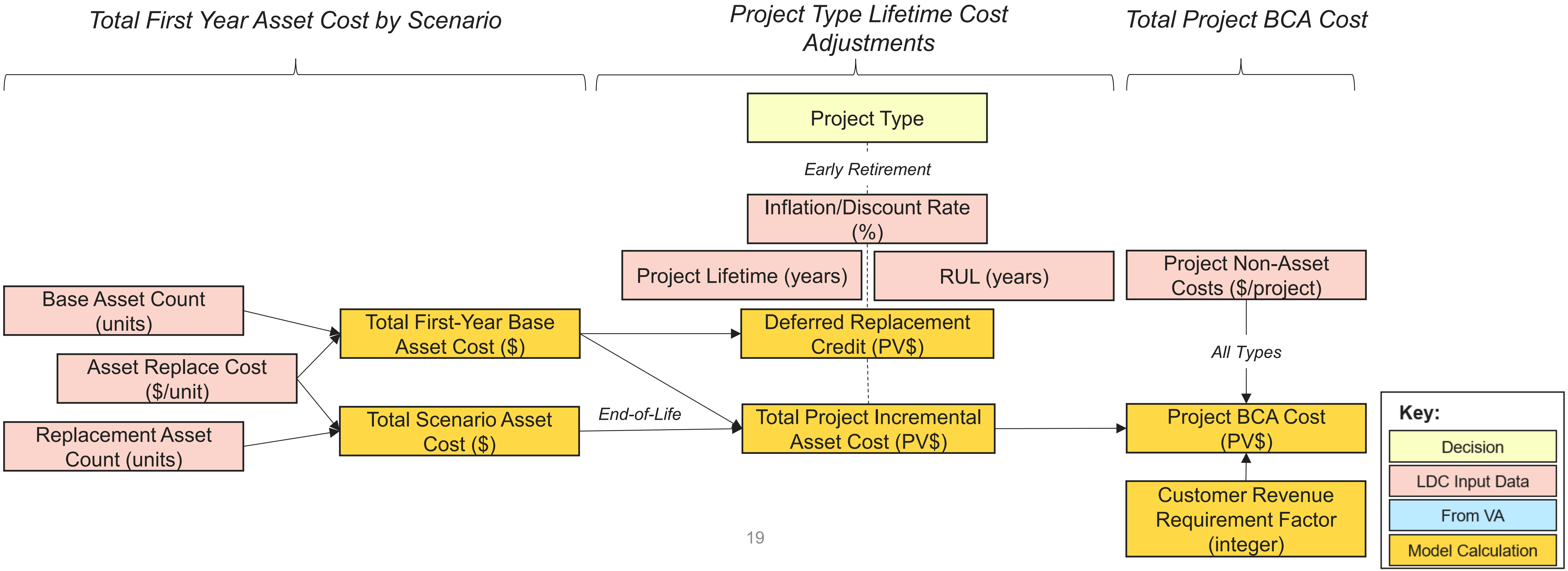
BCA Toolkit – Value of Lost Load (VOLL) Benefits

VOLL benefits are the difference between lifetime projected lost load valuation from the baseline asset scenario to the hardened asset scenario. The annual probabilities of failure from the VA are multiplied by total number of assets, calibrated to reflect system outages, multiplied by the VOLL per outage based on impact type, and present valued over the project's lifetime.



BCA Toolkit – Project BCA Costs

Project BCA costs are the incremental costs of the project above what would have otherwise been spent, converted to the present value of customer revenue requirement. The cost represents the total scenario asset costs minus the total baseline asset costs, plus the project non-asset costs and lifetime changes to O&M. The total incremental asset cost is adjusted for early retirement projects to reflect the remaining useful life (RUL) of existing assets.



Financial Assumptions - VOLL

Value of Lost Load (VOLL) VASH Considerations

Consistent with stakeholder feedback from the vulnerability assessment that the OEB provide clear guidance allowing LDCs to accomplish VASH with minimal increased burden as well as maintain flexibility for those who desire it, the OEB is proposing two VOLL Options.

VOLL Option	Summary	Rationale
Generic Option	LDCs may use the US DOE ICE Calculator[1] with LDC-specific inputs where applicable.	The US DOE ICE calculator provides the ability to customize inputs to LDC specific variables such as outage history and customer characteristics. This resource is free to access and provides an acceptable estimate while significantly reducing research burden on LDCs.
Custom Option	LDCs may propose a VOLL using any industry recognized approach with accompanying methods and justification. VOLL should be proposed at the **customer segment level** and account for **variations in outage duration**.	Certain LDCs have previously conducted VOLL studies targeted at their customers. LDCs may wish to conduct new targeted studies if they feel these will better represent their unique customers.

[1]*https://icecalculator.com/interruption-cost*

Value of Lost Load (VOLL) Outage Methodology Example

The OEB is proposing that the generic option for VOLL analysis uses $/outage for three customer classes based on the US DOE ICE calculator[1]. Additionally, a description of methods and documentation to use external VOLL study values for resiliency events will be included in the report to support the Custom option.

The per outage method captures critical differentiators in VOLL from customer segment variability and outage durations while allowing LDCs to use the ICE Calculator with no additional data manipulation.

Example Calculation of VOLL in $/Outage using the DOE ICE Calculator

Ice Calculator Input[2]	Unit	Baseline Scenario	Reduced Frequency Scenario	Reduced Duration Scenario
Average Outage Duration	Minutes	360	360	180
Estimated Customers Interrupted (Res)	Count	100	100	100
Estimated Customers Interrupted (Small C&I)	Count	10	10	10
Estimated Customers Interrupted (Med/Large C&I)	Count	1	1	1
Value of Lost Load (VOLL) Result	$/Outage	$62,755	$62,755	$32,497
Total Annual Outages	Count	4	2	4
Annual CMI Remaining	Minutes	159,840	79,920	79,920
Annual VOLL Remaining	$	$251,022	$125,511	$118,950
Annual Benefit	$	N/A	$125,511	$132,072

[1]https://icecalculator.com/interruption-cost

[2]Further customization to LDC territory should be completed.

Financial Assumptions – BCA

Generic BCA

Expected costs for the replacement and repair of assets should be developed. These values will inform both project costs and avoided repair and replace benefits through hardening investments.

Asset Repair and Replace Costs

Asset Class	Asset Sub-Class	Unit Basis	Unit	Cost Data Year	Repair Cost	Replace Cost	Replace %
Pole	Class 5	pole	$/unit	2025	$500.00	$4,000.00	50.00%
Pole	Class 4	pole	$/unit	2025	$500.00	$4,400.00	50.00%
Pole	Class 3	pole	$/unit	2025	$500.00	$4,840.00	75.00%
Pole	Class 2	pole	$/unit	2025	$1,000.00	$5,324.00	50.00%
Overhead Conductor	Covered	meter	$/meter	2025	$500.00	$250.00	50.00%
Overhead Conductor	Uncovered	meter	$/meter	2025	$500.00	$177.00	50.00%

Unit: Scaling unit of the repair and replace cost inputs.

Cost Data Year: The year of the estimates for repair and replace costs. Costs are inflated in the model to match deployment timing allowing for older vintage costs to be used if that is the best available source.

Repair Cost: Cost to repair an asset given failure if appropriate. Includes all costs attributable to the repair that scale per asset (i.e., material, equipment, labor, etc.).

Replace Cost: Cost to replace an asset given failure to the extent a repair is not appropriate. Includes all costs attributable to the replacement that scale per asset (i.e., material, equipment, labor, etc.).

Replace %: The expected replacement percent should be estimated based on the climate perils and failure thresholds incorporated into the VA. For example, if a specific replacement failure threshold was used to analyze vulnerability, this should be set to 100%. If a threshold based on historic asset class outages was used, an estimate of actual repair versus replace expectations may be appropriate.

Project Characteristics

Identifying key project characteristics is critical for correct application of BCA methods.

Project Characteristics

Project Type Inputs	
Location	Location 1
Project Type	Early Retirement
Impact Type	Both

Location: Predetermined based on the location being viewed in '5. VA Heatmap'. This location should be the area with climate data in which or nearest to where the project being evaluated will be implemented.

Project Type: Three options based on the status of the LDC's existing assets.

- **End-of-Life** should be selected if the project will replace assets that would have been replaced in the absence of resiliency planning due to age or condition.
- **Early Retirement** should be selected if the project will replace assets that would have been expected to remain in service beyond the start date of the project.
- **Retrofit** should be selected if the project will not impact existing assets (e.g., sectionalizing or enhanced emergency response).

Impact Type: Three options based on the mitigation goal of the project.

- **Frequency** should be selected if the project increases the robustness of assets to climate perils (i.e., changes the expected failure threshold) but does not impact the duration or number of customers impacted by remaining outages at that location.
- **Criticality** should be selected if the project reduces the expected outage durations and/or number of customers impacted by an outage but does not reduce the expected frequency of these events.
- **Both** should be selected if the project will reduce the frequency and criticality of outages.

Project Economic Variables

Common economic analysis inputs are necessary to calculate the present value of costs and benefits to customers. These variables act to align the VASH BCA to the DST framework.

Project Economic Variables

Variable	Unit	Value
Inflation	%	2.00%
Nominal Discount Rate	%	7.00%
Social Discount Rate	%	4.00%
Baseline O&M Cost (% of Total Costs)	%	1.50%
Scenario O&M Cost (% of Total Costs)	%	2.50%
Tax Rate	%	26.50%
Project Non-Asset Costs	$	$200,000.00

Inflation: Expected annual inflation rate for the duration of the project lifetime.

Nominal Discount Rate: Discount rate for present value calculations (often the WACC).

Societal Discount Rate: Discount rate used for customer impact present value calculations (given by IESO at 4%).

Baseline O&M Cost (% of Total Costs): The percent of total asset base costs attributable to O&M.

Scenario O&M Cost (% of Total Costs): The percent of total asset scenario costs attributable to O&M.

Tax Rate: Combined federal plus provincial tax rate.

Project Non-Asset Costs: One-time cost that does not scale by number of assets in the project. Examples may include engineering costs, other admin, or fees. For Retrofit projects this field should be used to estimate the entire project cost.

Project Lifetime Variables

Resiliency investments mitigate risk for the lifetime of installed assets and therefore the lifetime benefits of a project should be analyzed.

Project Lifetime Variables

Variable	Unit	Value
Project Start Year	year	2026
Project Expected Lifetime	years	30
Starting Asset's Remaining Useful Lifetime[1]	years	10

[1] RUL only required for the early retirement program type.

Project Start Year: Year in which the project would be implemented.

Project Expected Lifetime: Expected field life of the assets being invested in. If multiple asset classes are included in the project, a weighted average lifetime may be used.

Starting Asset's Remaining Useful Lifetime: A remaining useful life (RUL) for Starting Assets is required for early retirement projects. This should be the expected number of years that these assets would have continued to be in service in the absence of the resiliency project. This field will be blurred for other Project Types.

Criticality Variables

Criticality inputs properly account for VOLL differences by customer segment and duration expectations and simplify ICE Calculator usage.

Criticality Variables

Variable	Unit	Baseline Value	Project Value
Average Outage Duration	minutes	245.3	150
Estimated Customers Interrupted (Res)	count	100	100
Estimated Customers Interrupted (Small C&I)	count	5	0
Estimated Customers Interrupted (Med/Large C&I)	count	3	0
Value of Lost Load (VOLL)	$/Outage Event	$34,425.00	$706.80
Calibration Year	year	2025	N/A
Historic Annual Outage Events[2]	Count	2.2	N/A

[2] *These outages should reflect those caused by the climate perils addressed in this risk analysis. Inclusion of historic outages from other causes will inflate results.*

Average Outage Duration: Expected duration of outages impacted by the project.

Number of Customers Interrupted: Expected number of customers by class impacted by the project.

Value of Lost Load: ICE Calculator result from specified duration and counts. Other sources may be used, however, must be specified as $/Outage scaled to total number of customers impacted for appropriate use.

Historic Annual Outage Events: A baseline value is necessary for all Project Types. This scenario's inputs should reflect historical values for outage durations and number of customers impacted for the climate perils that the project will address. For Frequency Impact Type projects, the Project Value should equal the Baseline Value as there is no change in the criticality of remaining outages after project implementation. For Criticality and Both Project Types, the resulting duration and customer counts should be input into the ICE Calculator as a separate scenario to determine the post-project implementation VOLL.

Project Asset Map

Projects are defined by the assets currently installed, what would have occurred in the absence of a resiliency project, and the proposed resilient asset alternative.

Applicable Assets

Baseline Assets			Code Assets		Replacement Assets			Project Budget	Cost for BCA
Asset Class	Asset Sub-Class	Unit Basis	Code Asset Class	Code Asset Sub-Class	Replacement Asset Class	Replacement Asset Sub-Class	Project Count	Budget ($)	BCA Cost ($)
Pole	Class 5	pole							
Pole	Class 4	pole	Pole	Class 3	Pole	Class 2	100	$532,400.00	$739,922.49
Pole	Class 3	pole							
Pole	Class 2	pole							

Baseline Assets: The assets currently installed that are being considered for resiliency upgrades. Prepopulated from Asset Summary.

Example: A utility is evaluating a feeder with 100 Class 4 poles

Code: The asset class that would have been installed in the absence of resiliency considerations. This may vary from baseline assets in situations where the baseline assets would not be replaced like-for-like in a normal replacement.

Example: A utility's standards have changed since the installation of the baseline assets. The new standard is to build Class 3 poles instead of Class 4.

Replacement: The resilient asset class that will be installed through the project.

Project Count: The total number of assets for an asset class being considered for the project.

Project Budget: Total up-front asset cost to implement the project (*automatically calculated*).

BCA Cost: Project cost used for BCA may vary by Project Type and reflects customer costs through recovery (*automatically calculated*).

***NOTE:** Baseline Asset Classes not applicable to the project being evaluated may be left blank.*

Project BCA Results

The VASH Toolkit calculates key decision metrics for project evaluation.

Project Summary Metrics

Metric	Unit	Expected Value
Total PV Benefits from Avoided Repairs and Replacements	PV 2026$	$154,603
Total PV Benefits from Frequency Reductions (VOLL)	PV 2026$	$712,289
Total PV Benefits from Criticality Reductions (VOLL)	PV 2026$	$135,595
Total PV Costs	PV 2026$	$939,922
BCR	ratio	1.07
Expected Annual Average CMI Reduction[1]	CMI	35,793
Expected Lifetime CMI Reduction	CMI	1,073,788

[1] *Simple average over project lifetime.*

Total PV Benefits from Avoided Repairs and Replacements: Will be non-zero if existing assets are impacted by the project.

Total PV from Frequency Reductions (VOLL): Will be non-zero if the project hardens assets to climate perils.

Total PV from Criticality Reductions (VOLL): Will be non-zero if the project reduces the number of impacted customers and duration of remaining outages.

Total PV Costs: Includes all asset costs plus one-time parametric cost. Project BCA costs will not equal project budget as the BCA perspective is that of the customer. Incremental cost used for end-of-life and a deferred replacement credit applied for early retirement.

BCR: Project benefit-cost ratio (PV benefits divided by PV costs).

Expected Annual Average CMI Reduction: Modeled annual customer minutes of interruption avoided by system hardening through reductions in frequency, duration, and total customers impacted.

Expected Lifetime CMI Reduction: Expected annual average CMI reduction multiplied by project lifetime.

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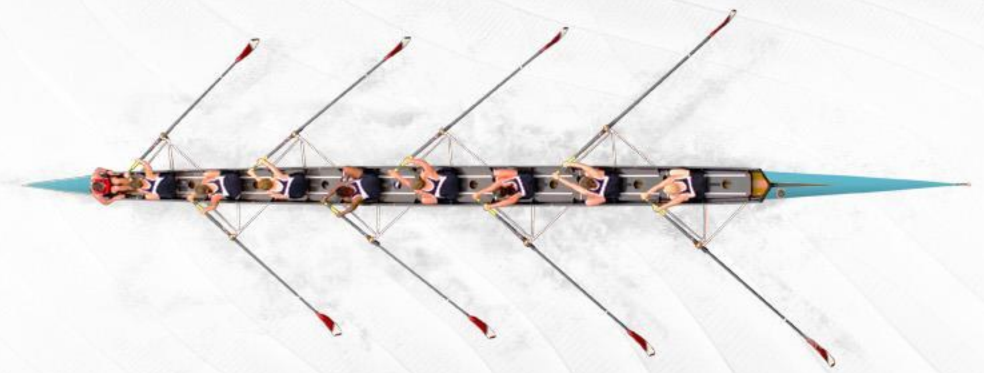

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Appendix

Reliability vs Resiliency

Severe weather events range from low impact, high frequency (LIHF) to high impact, low frequency (HILF). The VASH Report addresses resiliency risk, however, **the severity of event required for VASH consideration has yet to be determined**.

High-impact low-frequency (HILF) event means a severe weather event that meets the following criteria: (i) the daily System Average Interruption Duration Index exceeds the distributor’s Major Event Day threshold as calculated in accordance with IEEE Standard 1366; and (ii) more than 48 hours is required for the distributor to restore service to at least 90% of affected customers. (OEB Distribution System Code)

Source:
Utility Investments in Resilience of Electricity Systems. Future Electric Utility Regulation Report Series, FEUR Report No. 11. Lawrence Berkeley National Laboratory.