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ONTARIO ENERGY BOARD

OEB Electricity Distribution Vulnerability Assessment and System Hardening

Proposed Component 3 & 4 Methodology

April 11, 2025

Agenda

Introduction & Overview **5 Minutes**	Review each of the six components and timeline for Components 3 & 4.
Component 2 (VA Data Source) **15 Minutes**	Discuss climate event probability forecast data source and climate scenario choice.
Component 3 (VOLL) **75 Minutes**	Overview of the proposed value of lost load (VOLL) methodology and LDC options. Open discussion.
Break **10 Minutes**	
Component 4 (BCA) **75 Minutes**	Overview of the proposed benefit-cost analysis (BCA) framework. Open discussion.

Introduction & Overview

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.

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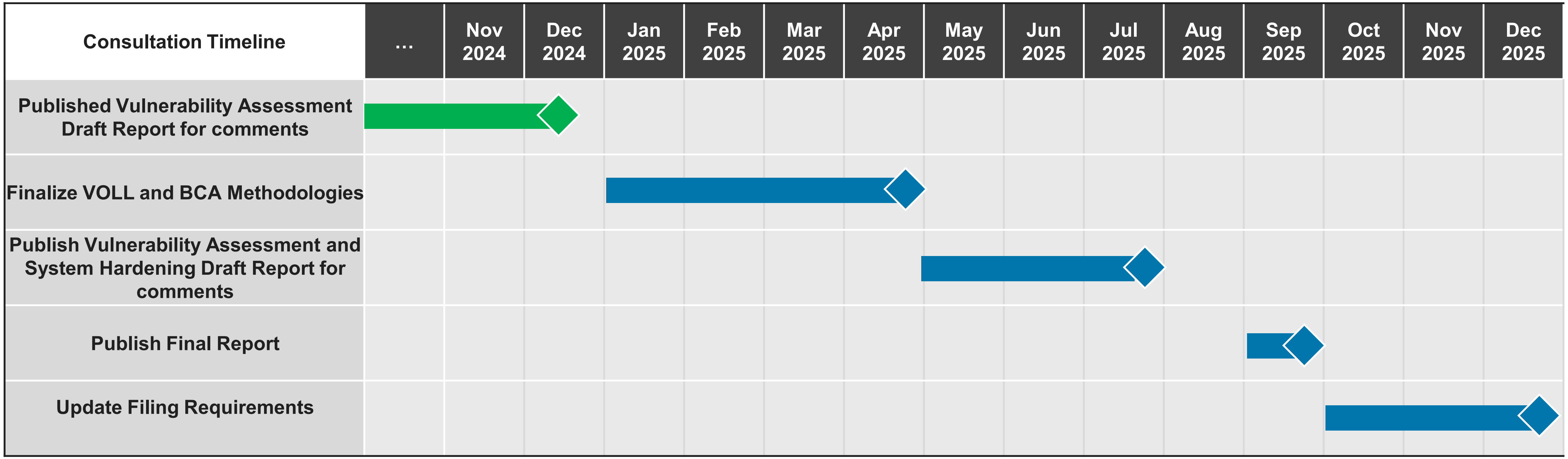
VOLL and BCA Framework Deliverables and Timeline

The draft of the final VASH report, including the Vulnerability Assessment, Value of Lost Load, and Benefit-Cost Analysis components, is planned to be completed by the end of July 2025.



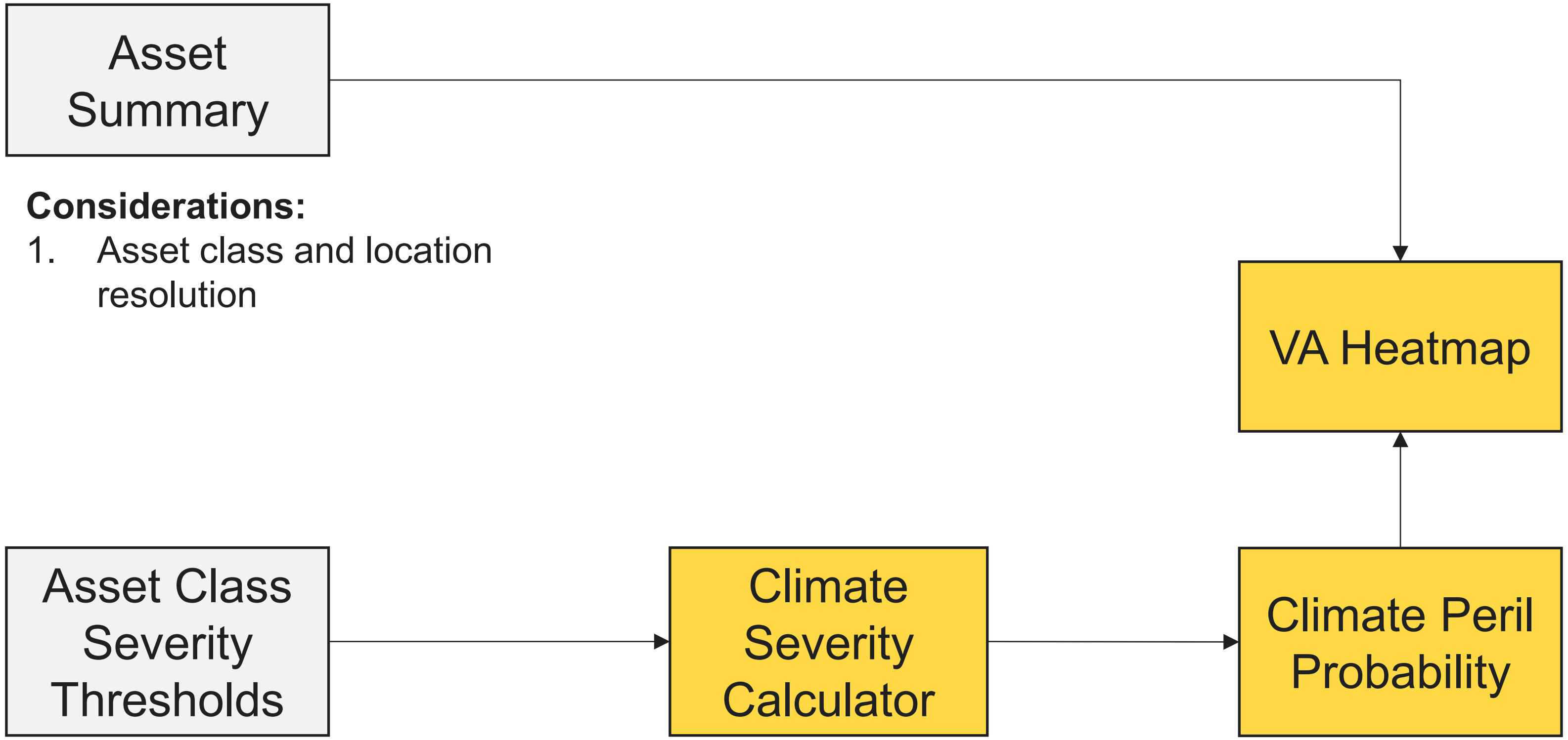
Meetings	Objective
Jan 29, 2025	Solicit feedback on VOLL and BCA initial methodology proposal
Apr 11, 2025	Solicit feedback on VOLL and BCA final proposal
Apr 22, 2025	VASH Toolkit Deep Dive

Completed

Planned

Component 2: Standardized Vulnerability Assessment Data Sources

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

Climate Event Probability Forecast Data

- Baseline data
  - Source: Environment and Climate Change Canada (ECCC) developed dataset for CSA Group (CSA)
  - Based on historical weather station data
  - Working with CSA to determine data acquisition process
- Forecast data:
  - Source: ECCC
  - Exists in form of year-over-year percentage changes from baseline data
  - Forecast data differs for different emissions scenarios: Representative Concentration Pathways (RCP) Scenarios: RCP 8.5, RCP 6.0, and RCP 4.5

Proposal for choosing Emissions Scenario for VASH

The Intergovernmental Panel on Climate Change (IPCC) uses global emissions scenarios to explore future climate outcomes. These scenarios model possible futures with no probability assignments (i.e., each may be as likely as another). ECCC and CSA use RCP scenarios to consider potential futures in alignment with these generally accepted projections.

Proposal: Align with ECCC/CSA approach:

- RCP 8.5 for asset design life less than 60 years and RCP 6.0 for asset design life greater than 60 years *

Rationale:

- Align with the overall approach of leveraging CSA standards for VASH
- Concrete guidance should provide most support to LDCs and aid consistency in decision-making in rate proceedings

* Most assets have TUL of less than 60 years – Asset Depreciation Study for the OEB by Kinectrics

Component 3: Value of Lost Load

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 ICE Calculator[1] with LDC-specific inputs where applicable. *Option 2 (for discussion): The OEB procures a standard value*	The 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*

Proposal for Value of Lost Load

- **Proposal:** Use ICE Calculator with US survey data for the Generic option
- **Rationale:**

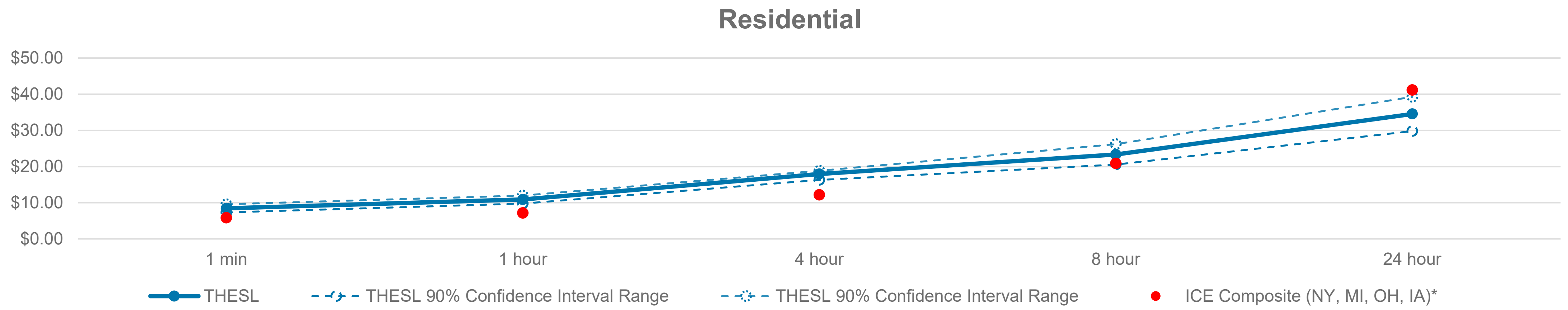
	ICE Calculator with underlying US survey data	ICE Calculator with Ontario specific survey data
Cost	None	Preliminary estimate of $1-2M *
Timeline	Available now	18 months
Results Representative of Ontario Customer Expectations	Reasonably accurate representation **	Most Accurate Representation

* Actual cost would be based on desired level of granularity

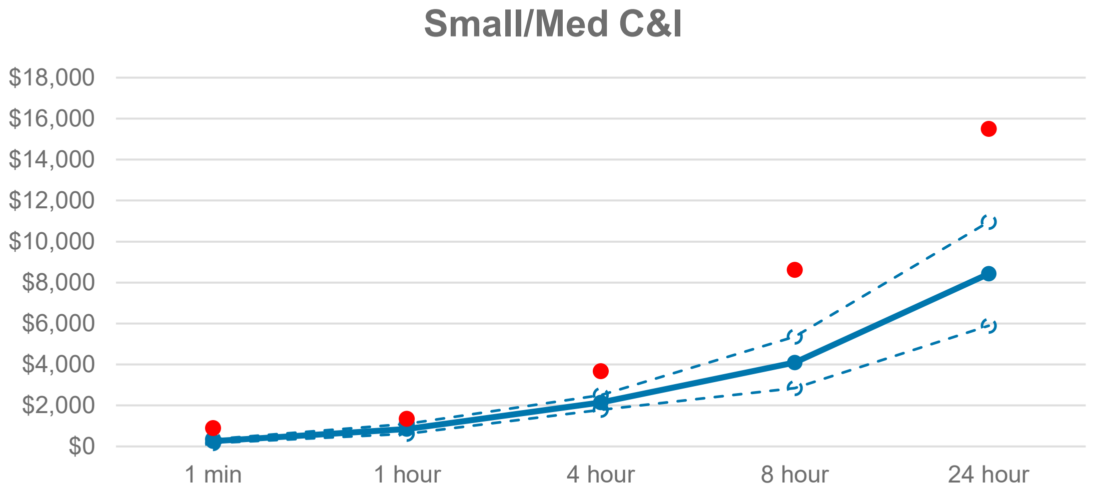
** Based on comparison of outputs from ICE Calculator to Toronto Hydro 2018 VOLL study

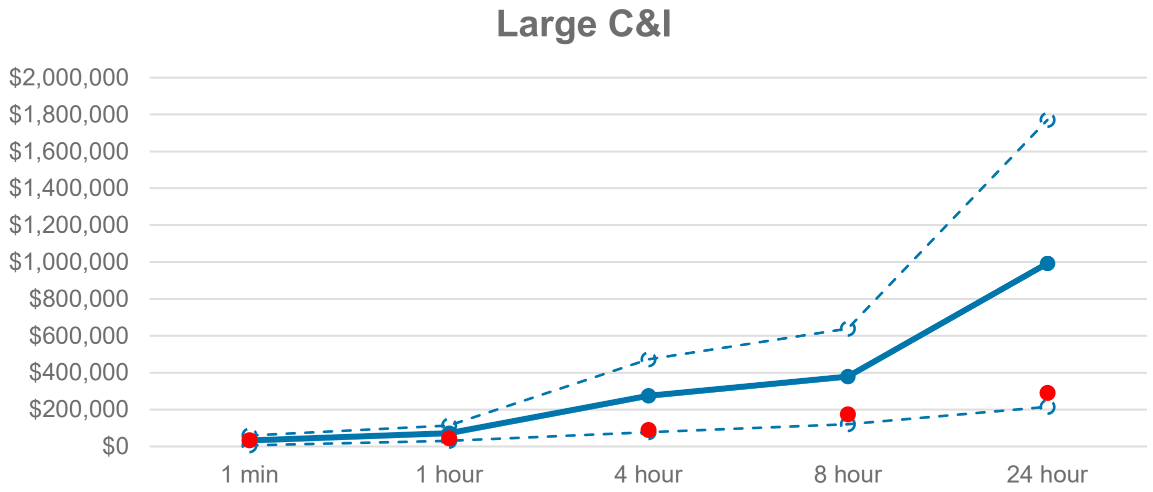
Note: At least two LDCs are currently utilizing the ICE Calculator for investment planning.

ICE Calculator vs. Toronto Hydro 2018 VOLL study



* ICE calculator configured with Toronto Hydro customer counts, average usage, and estimated median household income. Further customization is possible.





VOLL from ICE Calculator Reasonably Represents Ontario Customer Expectations

- The ICE Calculator's underlying econometric model is based on surveys from various U.S. utilities, providing a proxy for LDC diversity.
- Variation in VOLL from LDC diversity is estimated through customizing the inputs to the ICE Calculator.
  - Configurable utility-specific model input variables:
    - Number of customers and average consumption by rate class
    - Reliability metrics: SAIFI, SAIDI, CAIDI
    - Median household income
    - Outage distribution by time of the day and year
    - Industry composition
    - Penetration of backup generation.
  - Proposed acceptable ICE composite values include input variables from the following states: New York, Michigan, Ohio, and Iowa.
    - Selecting the state(s) does not change the underlying econometric model.
    - The model populates the input variables as a starting point to estimate VOLL.
    - Expectation for LDCs is to modify as many input variables as possible depending on data availability to match their characteristics.

Value of Lost Load (VOLL) Outage Methodology Example

The OEB is proposing $/outage as a weighted average of three customer classes based on ICE Calculator[1].

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 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.

Open Discussion – Component 3 (VOLL)

Stakeholder Feedback:

- TBD
- TBD
- TBD

Component 4: Benefit-Cost Analysis

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).

- The DST takes the **perspective of the customer**:
  - Costs are translated to the present value of revenue requirement changes from investments
  - Societal benefits streams (like VOLL) are permitted
- VASH BCA aligns with this customer perspective in the calculation of both BCA costs and benefits.
- VASH BCA provides an optional framework to quantify resiliency benefits in the DST.

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

Benefit-Cost Analysis (BCA): Baseline Risk

The benefit-cost framework outlines the applicable benefit and cost streams to be evaluated in developing a system hardening BCA ratio. Commonly, benefits of resiliency investments include avoided repair and replacement asset costs and VOLL (reduction in outages) estimates in present value for the expected lifetime of equipment in the form of a risk buy-down.

Illustrative annual risk calculation:

$$\text{Annual Asset Risk} \\ = \big(pRepair * Repair(\$)\big) + \big(pReplace * Replace(\$)\big) + \big(pRepair * \$/Outgage(VOLL)\big) \\ + \big(pReplace * \$/Outage\,(VOLL)\big)$$

Where,

pRepair = Annual probability of an asset requiring repair (*determined by climate peril probability*)
Repair ($) = Cost of asset repair including labor converted to customer revenue requirement
pReplace = Annual probability of an asset requiring replacement (*determined by climate peril probability*)
Replace ($) = Cost of asset replacement including labor converted to customer revenue requirement
$/Outage = Value of lost load per outage accounting for customers interrupted by class and duration

Benefit-Cost Analysis (BCA): Risk Mitigation Modes

Based on this proposed BCA framework, investments in system hardening and other resiliency risk mitigating activities can accrue benefits in three ways:

Reductions in annual asset failure and outage frequency (pRepair or pReplace)

Example: *Infrastructure system hardening may include increasing design standards, undergrounding segments, relocating assets, etc. These investments increase the robustness of vulnerable assets to a measured climate peril.*

Reductions in the number of customers impacted by an outage

Example: *Modernization investments such as improvements to grid situational awareness, IGSDs, sectionalizing, or battery storage. These activities improve the grid's ability to react to outage events in real-time.*

Reductions in the average customer duration of an outage

Example: *Non-infrastructure investments include storm preparedness and response activities as discussed in the RPQR working team activities.*

Benefit-Cost Analysis (BCA): Project-Level Risk Mitigation

Risk is compared between scenarios for the expected lifetime of an asset to determine investment benefits. Costs include incremental asset capital and O&M spend compared to a baseline scenario.

Project benefit calculation:

$$Project\ Benefits\ (\$) = \sum (PV(Asset\ Baseline\ Risk) - PV(Asset\ Mitigated\ Risk))$$

Where,

Asset Baseline Risk = Asset lifetime risk for the baseline
Asset Mitigated Risk = Asset lifetime risk for mitigated scenario

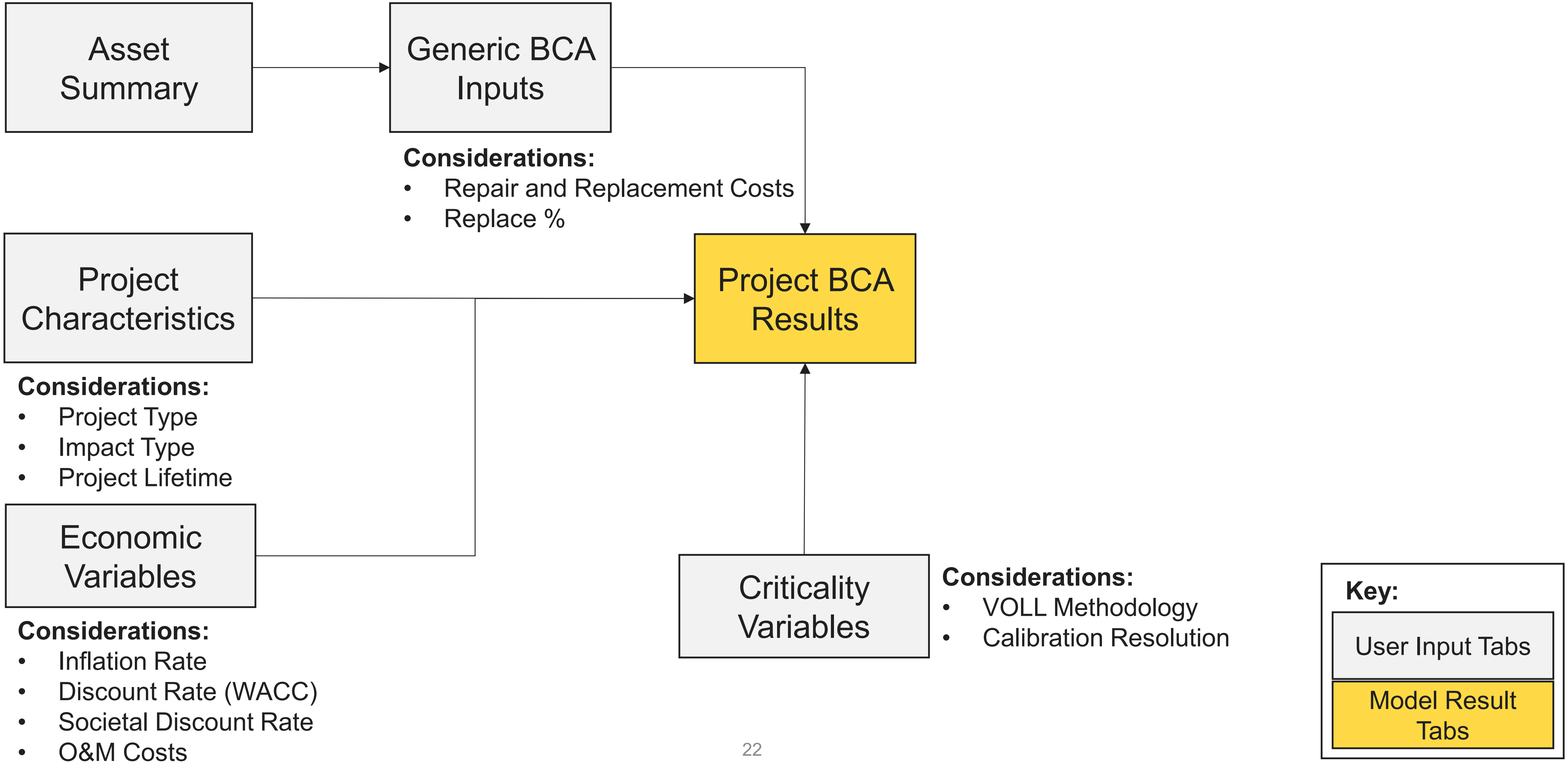
Illustrative project cost calculation:

$$Project\ Cost = \sum (Asset\ Capital\ Cost + Asset\ O\&M\ Cost) + Program\ Parametric\ Cost$$

Where,

Asset Capital Cost = One-time cost at time of purchase above (or below) baseline
Asset O&M Cost = Ongoing annual cost of asset upkeep above (or below) baseline
Program Parametric Cost = Non-asset costs (e.g., admin, replaced asset removal)

VASH Toolkit (Generic Option) Flow Diagram – BCA

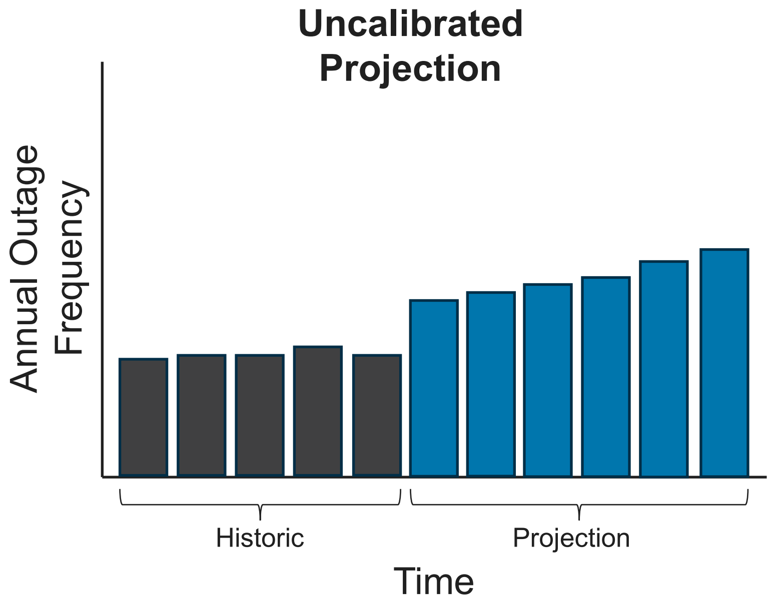


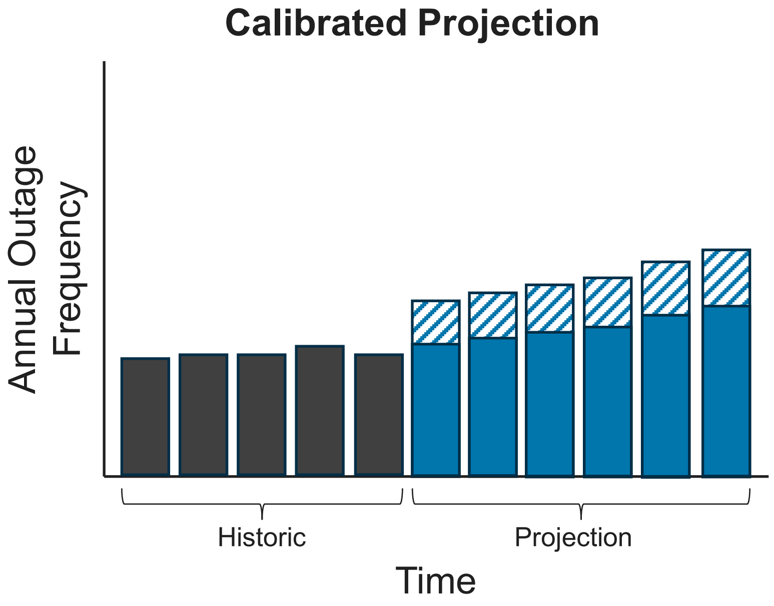
VOLL | The Importance of Model Calibration

- Calibration to historic outage data accounts for the likelihood that two or more assets will fail during the same weather event.

  For example, if a single windstorm damages 10 consecutive poles and their associated conductor, customers impacted by this event will experience a single outage.
- This step aligns asset-specific annual failure frequency estimates from climate projections to a VOLL that is scaled by \$/outage

$$Calibration\ Multiplier = (Average\ Historic\ Annual\ Outages)/(First\ Year\ Modeled\ Outages)$$





VOLL | Average Historic Annual Outages Development

An estimate of the benefits of any enhancement project requires an understanding of the historical outage frequency of existing plant to estimate the relative improvement in reliability to be gained. This variable resembles SAIFI and is often developed from OMS data analysis.

There are three primary considerations for the development of this model input:

- Historic years for average:
  - **Goal:** Reduce variability in observed historic events to reasonably set starting point for projections.
  - **Ideal:** Most recent 5 years
  - **Acceptable:** Most recent 3 years
- Applicable Cause Codes:
  - **Goal:** Match modeled outages from climate perils in toolkit to observed historic outage subset.
  - **Ideal:** Filter OMS to cause codes specifically related to the climate peril(s) targeted for mitigation
  - **Acceptable:** Filter OMS to available resiliency-related cause codes
- Project Locational Granularity:
  - **Goal:** Match modeled outages from assets in project characterization to observed historic outage subset.
  - **Ideal:** Historic outages for the grid location being targeted for mitigation (substation, feeder, section, etc.)
  - **Acceptable:** System wide value

Open Discussion – Component 4 (BCA)

Stakeholder Feedback:

- TBD
- TBD
- TBD

Appendix: VASH Toolkit Details

Generic BCA Inputs

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.

Table 5: 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%

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.

Table 6: Project Characteristics

Project Type Inputs	
Location	Stratford
Project Type	Early Retirement
Impact Type	Frequency

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.

Table 7: Project Economic Variables

Variable	Unit	Value
Inflation	%	2.00%
Nominal Utility Discount Rate (WACC)	%	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%
Incremental Project Non-Asset Costs	$	$30,000.00

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.

Table 8: Project Lifetime Variables

Variable	Unit	Value
Project Start Year	year	2026
Project Expected Lifetime[1]	years	30
Starting Asset's Remaining Useful Lifetime[2]	years	10

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.

Table 9: 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

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.

Calibration Year: The last year historic data is available for calibration. This should be at least 1 year prior to the project start year.

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.

Table 10: Applicable Assets

Existing Assets			Standard 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							

Existing 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

Standard Assets: 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 existing assets. The new standard is to build Class 3 poles instead of Class 4.

Replacement Assets: 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: *Existing 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.

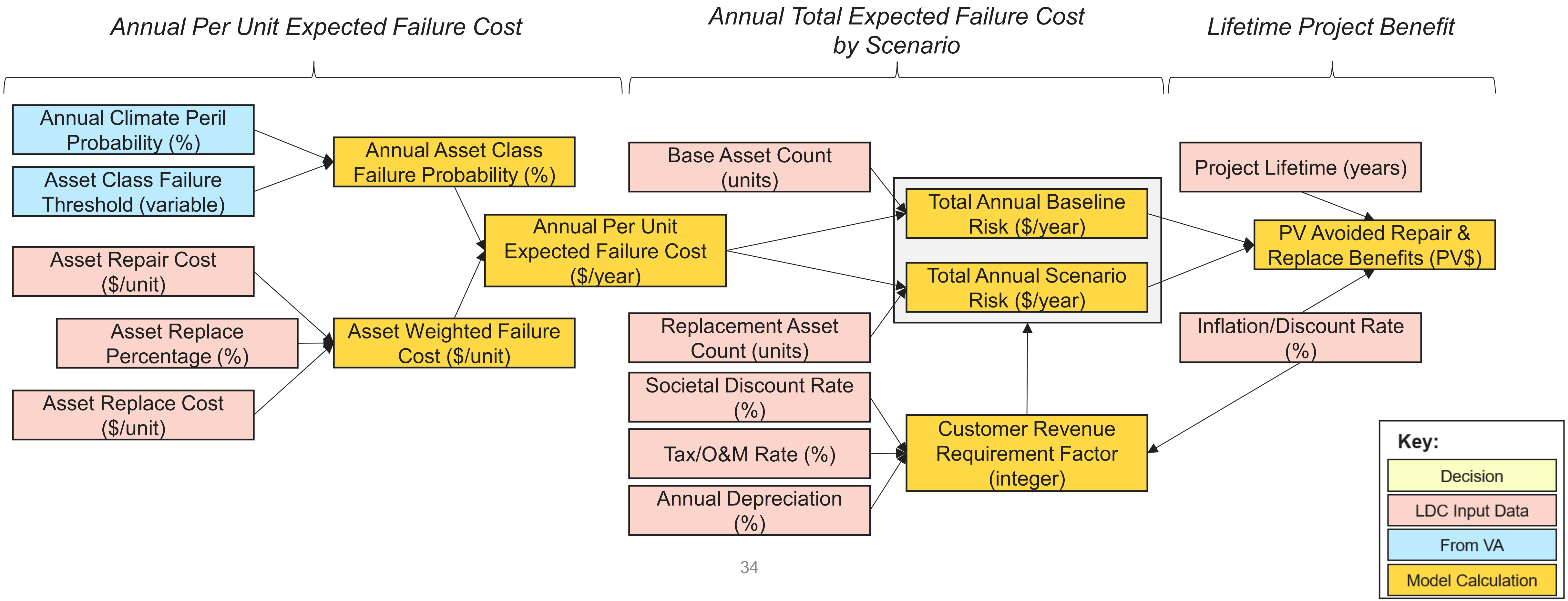
BCR: Project benefit-cost ratio (PV benefits divided by PV costs).

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.

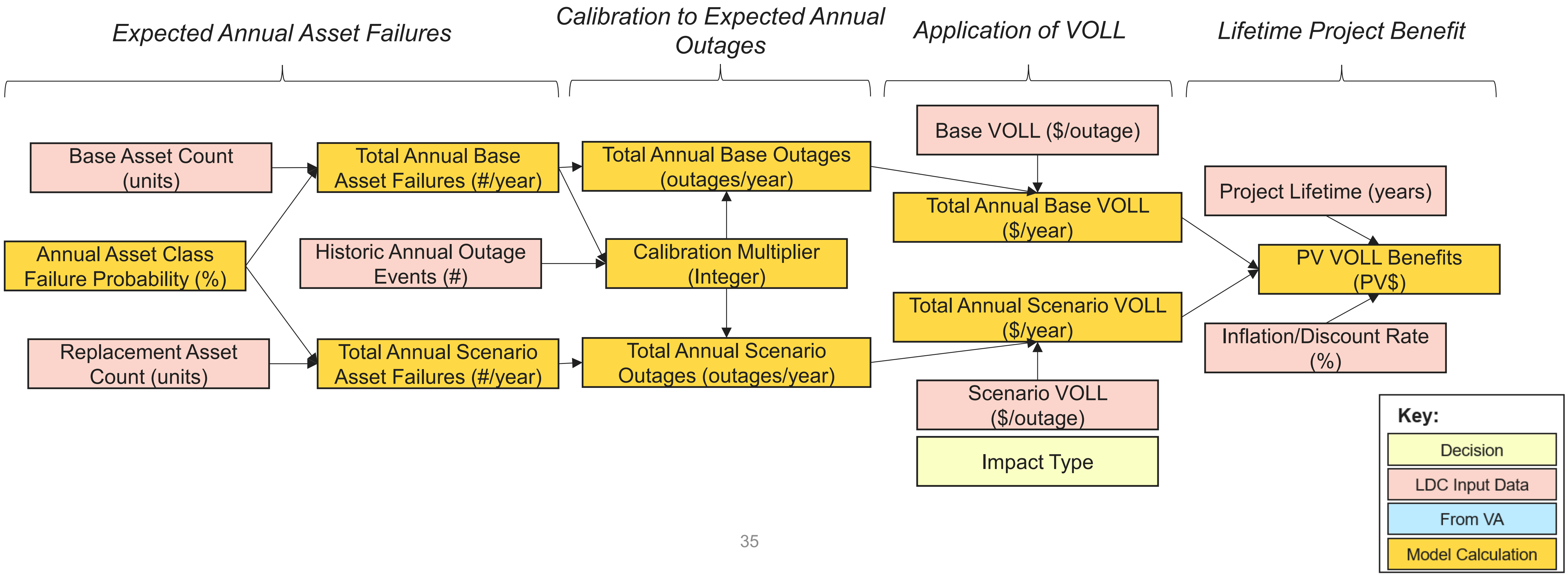
BCA Toolkit – Avoided Repair & Replace Benefits

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.



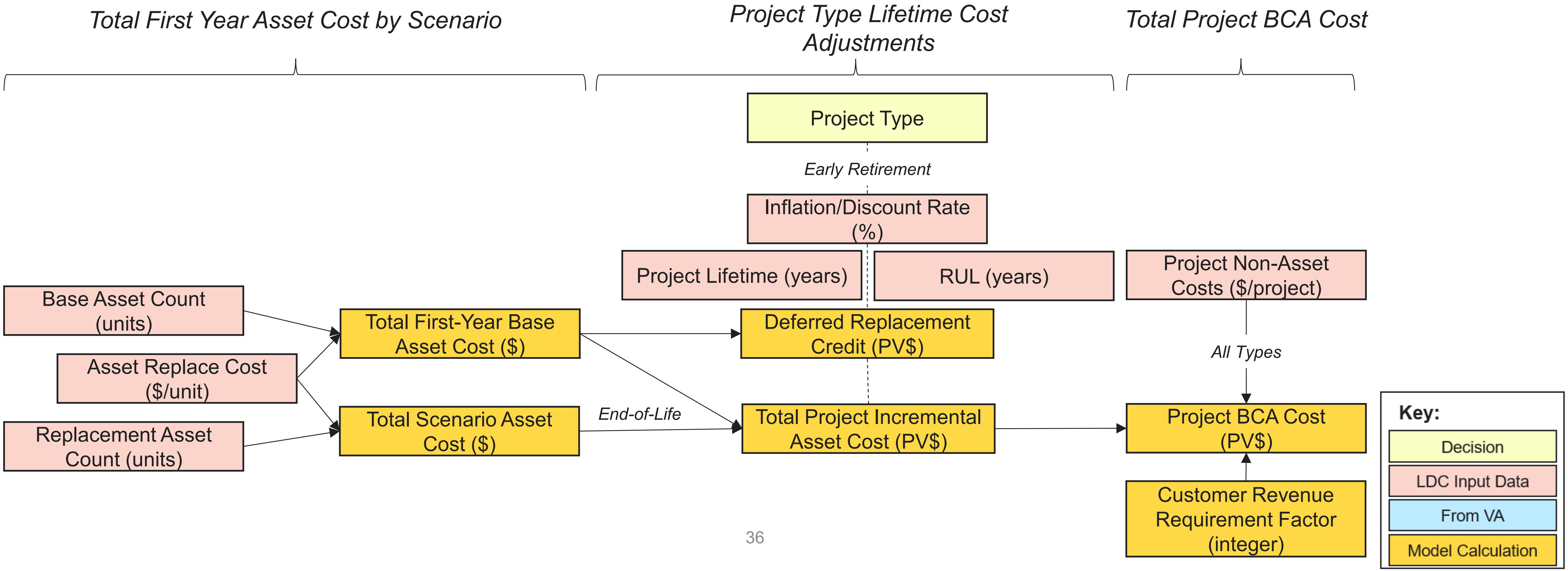
BCA Toolkit – Value of Lost Load (VOLL) Benefits

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.



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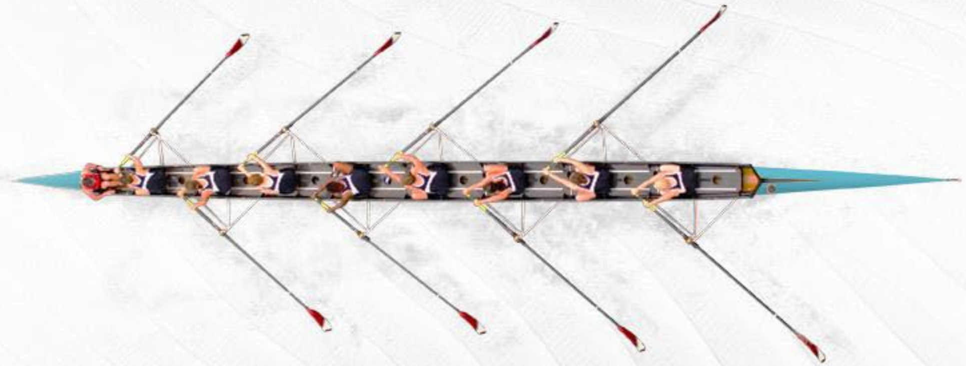

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Outwit *Complexity*