PG&E 2020 Risk Assessment and Mitigation Phase Workshop #2

Risk Analysis and MAVF Implementation

January 13th, 2020

Agenda

#	Agenda Item
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	Attributes / Ranges / Natural Units
	Scaling Functions
	Weights
2	**Risk Analysis**
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	Baseline Risk Score Assumption
	Discounting and Incorporation of Long-Term Benefits
	Modeling Mitigations vs. Controls

1. MAVF Implementation

MAVF Overview

1. What is it?

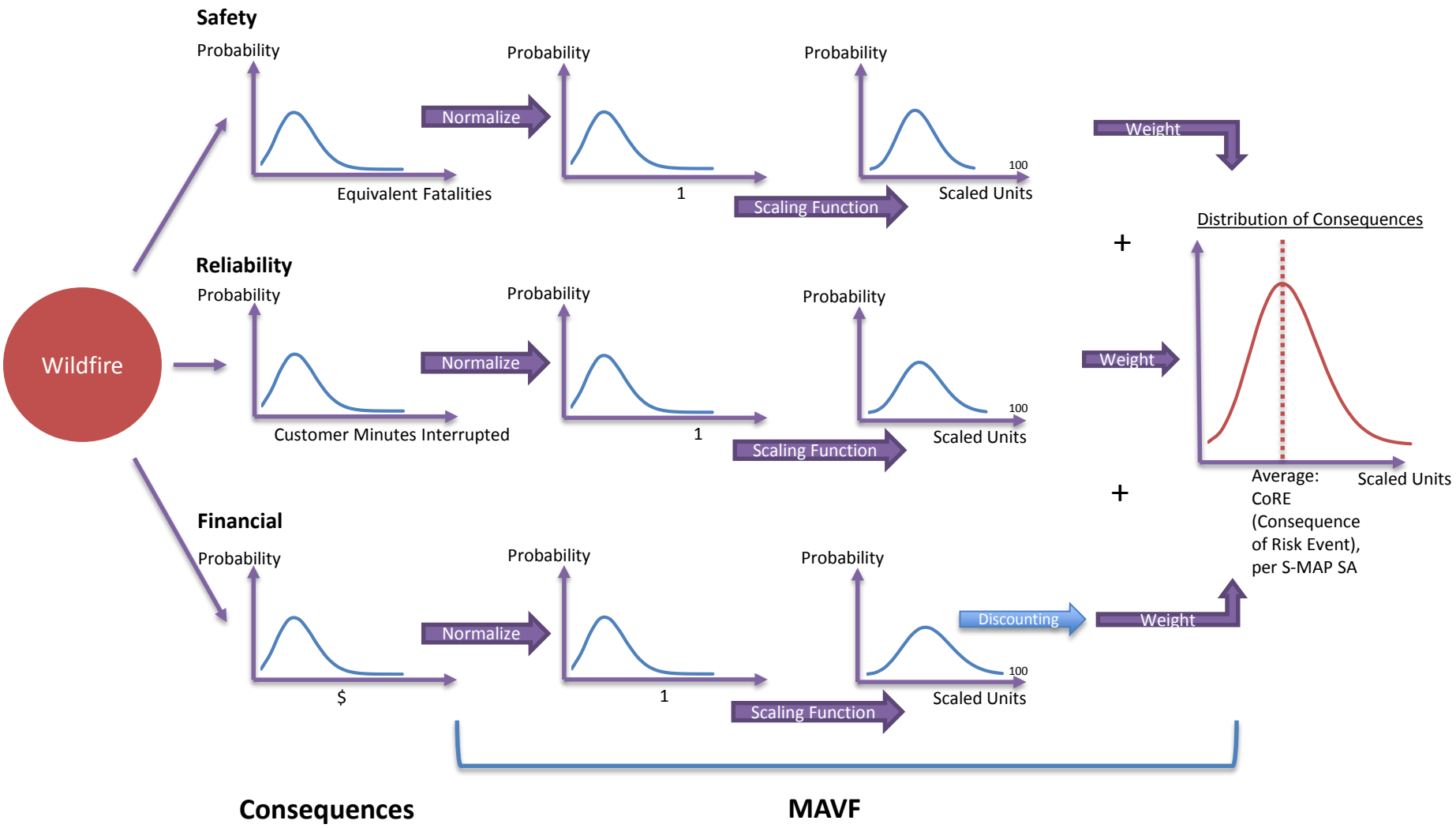
- 2018 S-MAP Revised Lexicon: *A tool for combining all potential consequences of the occurrence of a risk event, and creates a single measurement of value.*

An MAVF consists of the following elements:

- Attributes / Ranges / Natural Units
- Weights
- Scaling Function(s)

MAVF @ PG&E

Illustrative Wildfire Risk Bowtie



MAVF Specification

Attribute	Range	Natural Units	Weight	Scaling Function
Safety	0 - 100	Equivalent Fatalities (EF)/event	50%	Non-Linear
Electric Reliability	0 – 4 Billion	Customer Minutes Interrupted (CMI)/event	20%	Non-Linear
Gas Reliability	0 – 750,000	Customers affected/event	5%	Non-Linear
Financial	0 - $5 Billion[1]	$/event	25%	Non-Linear

Equivalent Fatalities (EF) is defined as the sum of Public, Employee and Contractor Fatalities and Serious Injuries per event occurrence. Serious Injuries are defined as situations that require in-patient hospitalization of an individual. Serious Injuries are converted to EFs using a factor of 0.25 EF/Serious Injury.

[1] Pursuant to D.18-12-014 and D.16-08-018, shareholders' financial interests are excluded.

MAVF Attributes

- **Hierarchy:** Each Attribute consists of one lower-level Attribute of the same name (Principle 1) and is Measurable (Principle 2; Measured Observations). Proxies were not used (Principle 3 Comparison).

- **Environmental:** Accounted for financially (i.e., as part of the Financial consequences) because there aren't commonly accepted measures of non-monetary environmental consequences.

- **Levels:** Represented by probability distributions (e.g. $ consequence of a risk event). PG&E uses Monte-Carlo simulations of Attribute Levels based on these probability distributions (Principle 4 Risk Assessment).

MAVF Attribute Ranges and Natural Units

Ranges are defined on a per-event basis. Pursuant to D.18-12-014, S-MAP Settlement Agreement (SA) Revised Lexicon, "… *the largest observable value* (of an Attribute) *is the high end of the range*". PG&E interprets this to be based on historical and/or plausible worst-case scenarios.

- **Safety:** 0 to 100 EF. Based on loss of life due to recent events.
- **Electric Reliability:** 0 to 4 billion CMI. Based on Oct 26-29, 2019 PSPS event consequence of approximately 3.6 billion CMI.
- **Gas Reliability:** 0 to 750k customers affected. Based on scenario of an outage at a critical gas facility.
- **Financial:** 0 to $5 billion. Represents a financial loss commensurate with an Energy Crisis-type event. Per S-MAP SA, utility shareholders' financial interests are excluded and hence estimates from recent wildfires were not used.

MAVF Scaling Function

- PG&E previously used Tail Average (the average of the worst 10 percent of simulated outcomes) to focus on risks with catastrophic consequences but very low likelihood.

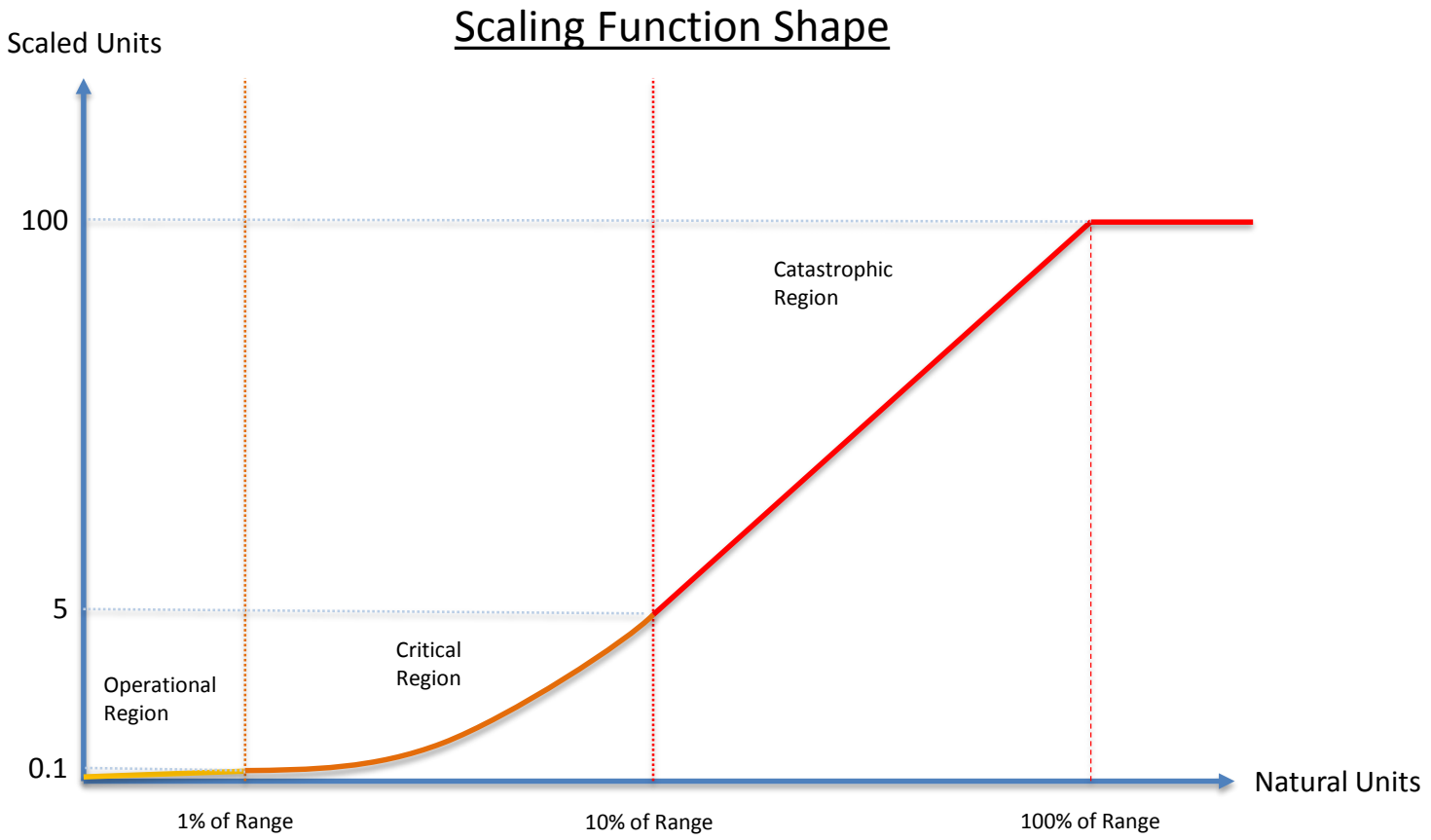
- S-MAP SA directs use of Expected Value (EV) when calculating CoRE, not Tail Average.

- PG&E now uses the scaling function to capture aversion to extreme outcomes:
    - Proposed nonlinear scaling functions' slopes increase up to a factor of 10 for 'critical' outcomes and by a factor of 10 for 'catastrophic' outcomes compared to 'business-as-usual' operational outcomes.

MAVF Scaling Function (continued)

Non-Linear Scaling Function used to convert each Attribute from Natural Units to Scaled Units (0 to 100). It consists of the following segments:

1. 0 to 1% of the Range (operational/moderate events): Linear function from 0 to 0.1 Scaled Units.
2. 1% to 10% of the Range (critical events): Quadratic function from 0.1 to 5 Scaled Units.
3. 10% to 100+% of the Range (catastrophic events): Linear function from 5 to 100 Scaled Units. Capped at 100 Scaled Units. The S-MAP SA defines scaled units as “a value that varies from 0 to 100. (…). The scaled unit is set to 100 for the least desirable level of natural unit in the range of natural units.



MAVF Scaling Function (continued)

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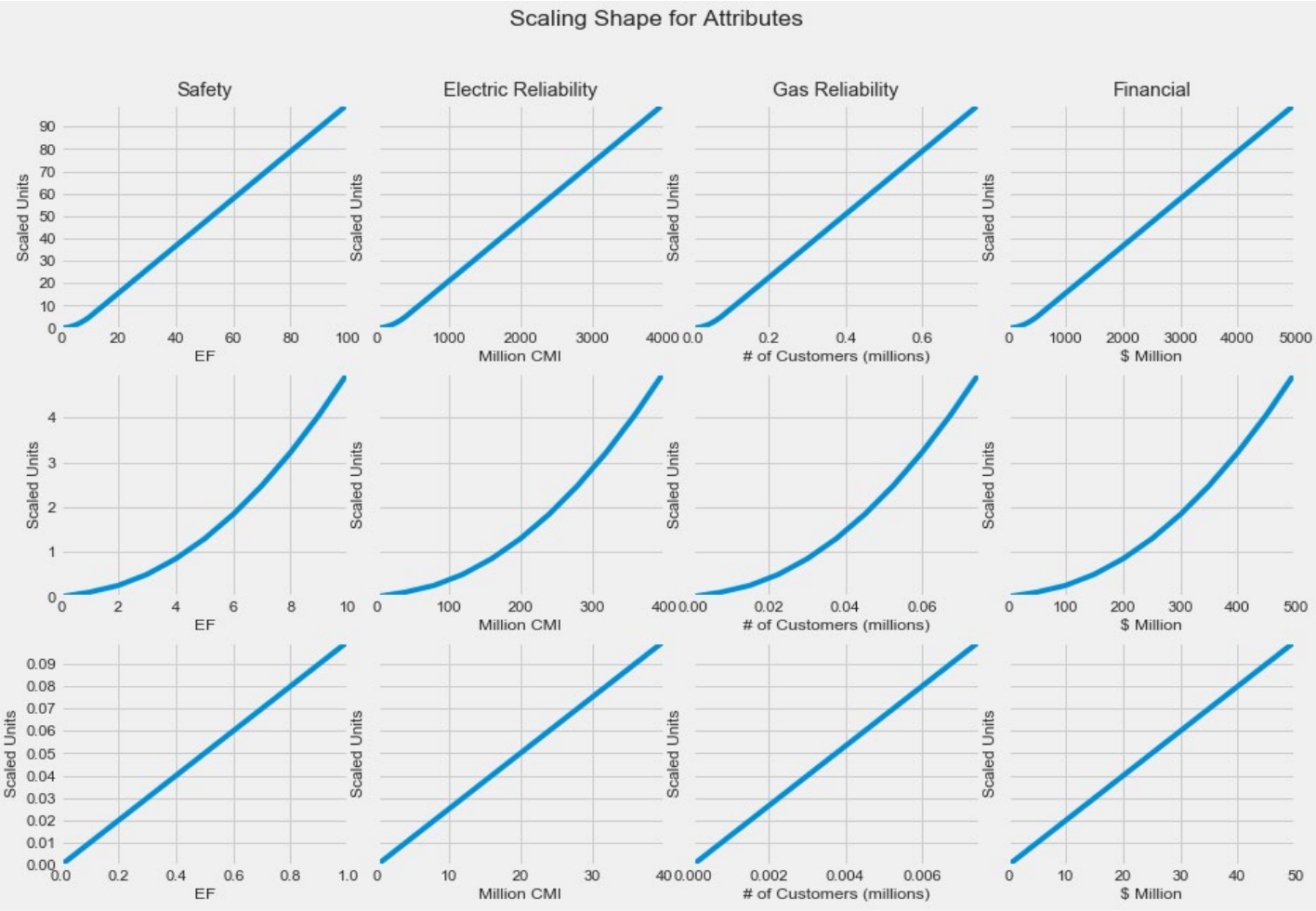
Overall

Critical Region

Operational /Moderate Region



MAVF Weights

- Weights were determined consistent with Principle 6 – Relative Importance.

- In-line with other IOU RAMP weights.

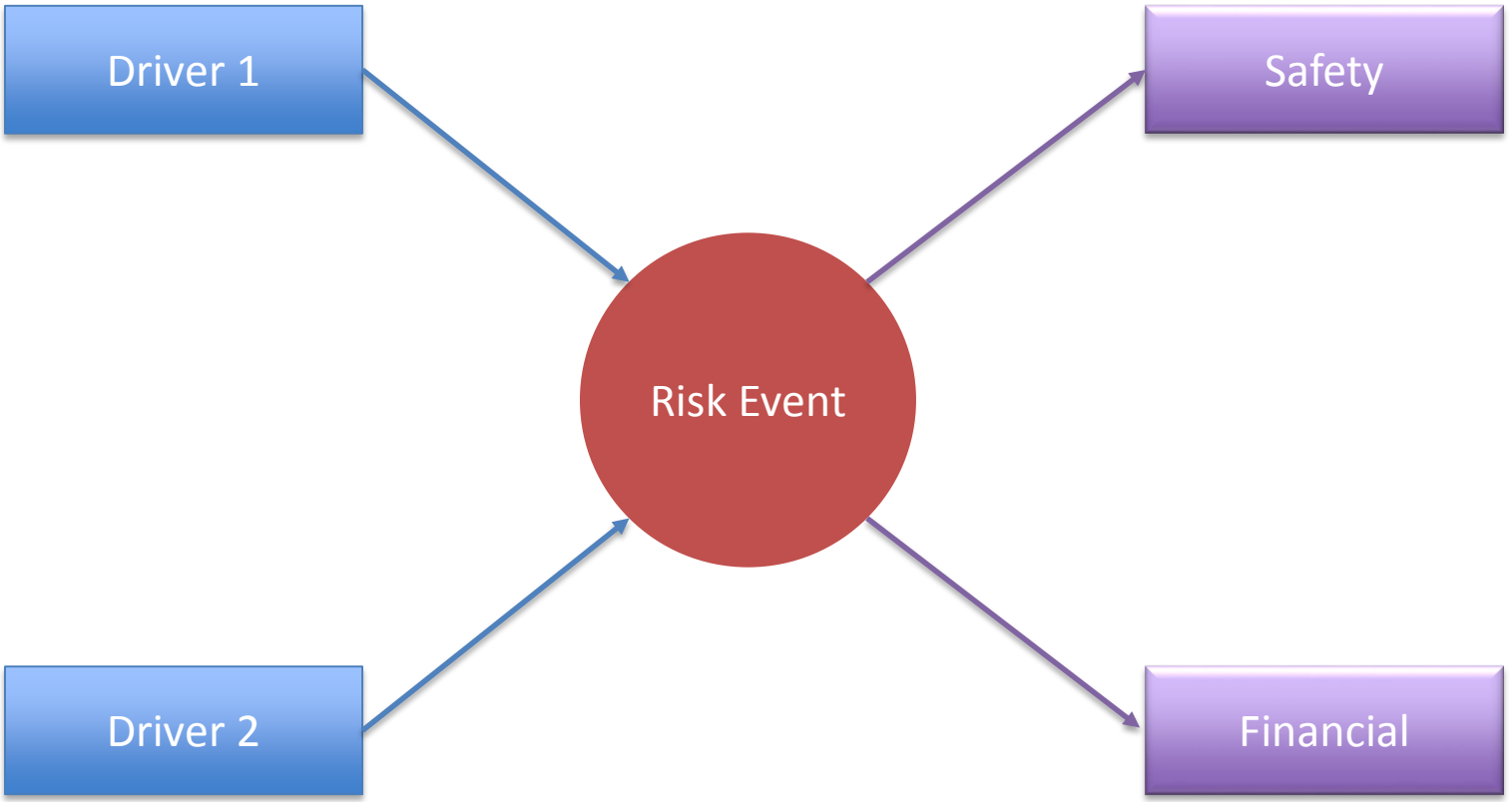
Attribute	PG&E Proposed	SCE	SEMPRA Energy
Safety	Equiv. Fatality: 100 | 50%	Fatality: 100 | 25% Serious Injury: 500 | 25%	Safety Index[1]: 30 | 60 %
Reliability	4B CMI | 20% 750k Customers| 5%	2B CMI | 25%	Reliability Index[2]: 1 | 20%
Financial	$5 billion | 25%	$5 billion | 25%	$1 billion | 20%

[1] Safety Index is equal to 1 for Fatality, and 0.25 for Serious Injury
[2] Reliability Index is 0.25 for 75000 meters for gas meter core outage, 0.25 for 500 MMcf of gas curtailed exceeding 250 MMcfd, 0.25 for 1 SAIFI, 0.25 for 100 SAIDI.

2. Risk Analysis

Bowtie Elements

Illustrative Risk Bowtie



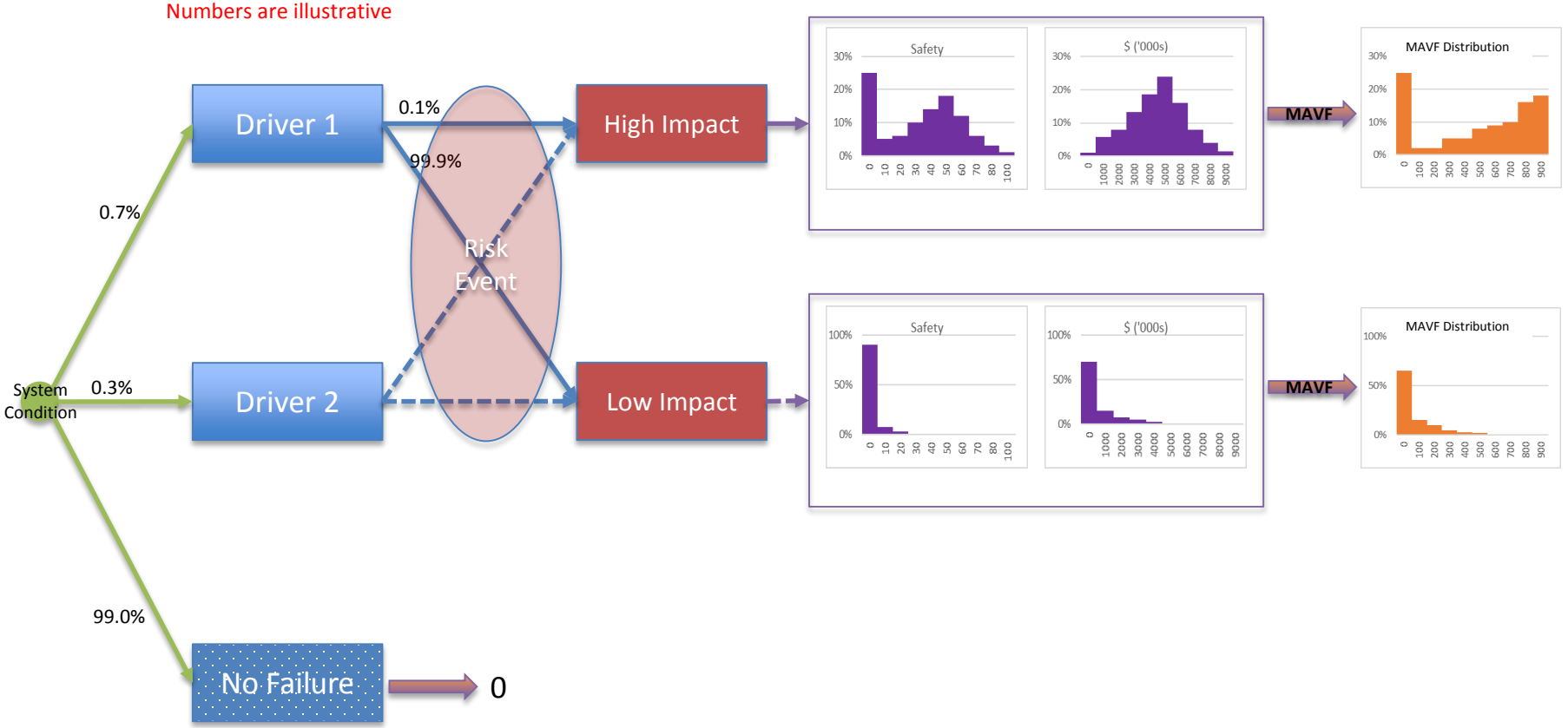
Risk Drivers

Consequences

Bowtie Elements – State Variables

Tranche: Region A

Numbers are illustrative



Risk Driver | Outcome | Consequences

Bowtie Elements - Risk Score Calculation

In PG&E's model, "LoRE x CoRE" is the Expected Risk of operating the system. The year *y* Risk per unit of exposure, $V_{t,y}$, is measured in Scaled Units and determined by the Likelihood, Consequence distributions and MAVF. In the example above,

Let *d* represent the different drivers/failure modes: $d \in \{d_1, d_2, \emptyset(\text{no event})\}$
Let $x_{t,y}$ represent the exposure (e.g. no. of miles in HFTD Tier 3) in the Tranche t

Risk Score$_{t,y}$ = Expected Tranche Risk for year *y* = $E\left[x_{t,y}V_{t,y}\right]$

$$= x_{t,y}\left(E\left[V_{t,y}|d=\emptyset\right].p_{t,y}(d=\emptyset) + E\left[V_{t,y}|\underbrace{d\in\{d_1,d_2\}}_{risk\ \text{event}}\right]\times p_{t,y}(d\in\{d_1,d_2\})\right)$$

$$= 0 + \underbrace{E\left[V_{t,y}|d\in\{d_1,d_2\}\right]\times x_{t,y}}_{\text{CoRE}} \times \underbrace{p_{t,y}(d\in\{d_1,d_2\})}_{\text{LoRE}}$$

PG&E's model is consistent with Rows 13 & 24 of the SA.
Frequencies (i.e., incident counts) are used because they are observable or estimable.

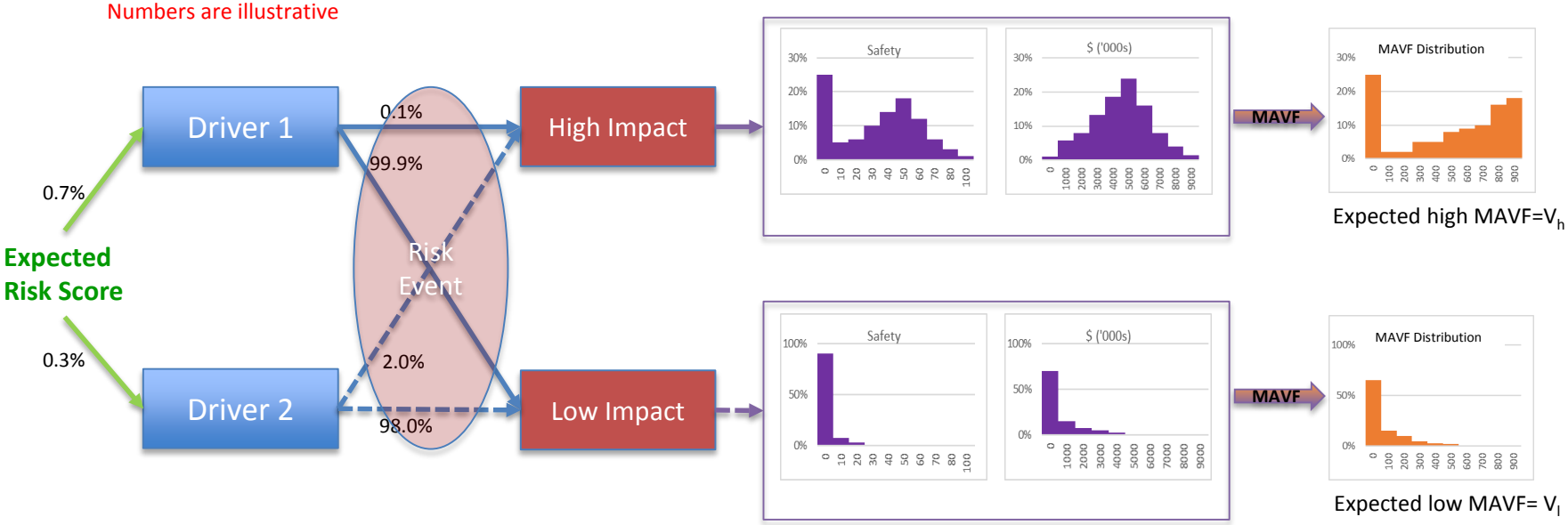
The Bowtie Risk Score for year *y* is the sum of the individual Tranche Risk Scores:

$$Risk\ Score_y = E\left[V_y\right] = \sum_t E\left[x_{t,y}V_{t,y}\right] = \sum_t \text{CoRE}_{t,y} \times \text{Frequency}_{t,y}$$

Risk Score Calculation – Example

Tranche: Region A, 2,000 miles

Numbers are illustrative



$$\text{Expected Tranche Risk Score} = 2000 \times [0.007(0.001V_h + 0.999V_l) + 0.003(0.02V_h + 0.98V_l)]$$

$$= 2000 \times 0.01 \times \left[\frac{0.007}{0.01}(0.001V_h + 0.999V_l) + \frac{0.003}{0.01}(0.02V_h + 0.98V_l)\right]$$

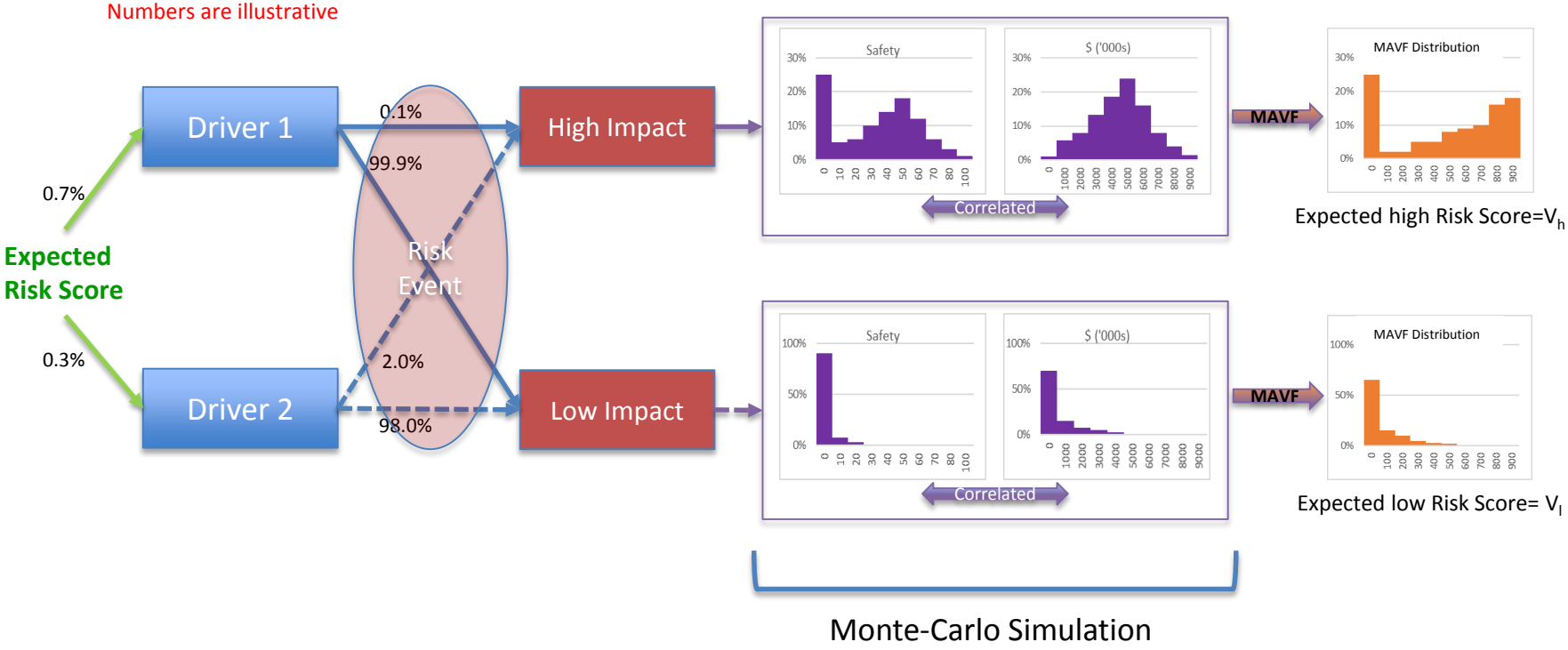
$$= 2000 \times 0.01 \times [p(d = d_1 | d \in \{d_1, d_2\}) \cdot E[V|d = d_1] + p(d = d_2 | d \in \{d_1, d_2\}) \cdot E[V|d = d_2]]$$

$$= \text{Exposure} \times \text{LoRE} \times E[V|d \in \{d_1, d_2\}] = \text{Frequency} \times \text{CoRE}$$

Risk Score Calculation – Implementation

Tranche: Region A, 2,000 miles

Numbers are illustrative



1. Generate trials from the Consequence Conditional Distributions using Monte-Carlo methods. PG&E assumes 100% rank correlation for Consequences within an outcome. This is a conservative but reasonable assumption.
2. Calculate outcome-based Risk Score for each trial using the MAVF formula
3. Calculate the high impact average ($\overline{V_h}$) and the low impact average ($\overline{V_l}$) Risk Scores
4. Combine $\overline{V_h}$ and $\overline{V_l}$ using the probability weights

Baseline Risk Score Assumption

- For Step 2B of the SA (Selecting Enterprise Risks for RAMP) PG&E will calculate the Risk and Safety Scores using the 2019 Baseline.
- For the Test Year 2023 RAMP Filing, PG&E will use 2022 as the Baseline year to calculate pre- and post-mitigation Risk Scores.

Example

Planning Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Residual Risk Score (incl Controls)	600	600	600	690	690	740	780	830		
2020 Programs Forecast		(50)	(50)	(50)	(40)	(40)	(40)	(40)	(30)	(30)
2021 Programs Forecast			(40)	(40)	(40)	(30)	(30)	(30)	(20)	(20)
2022 Programs Forecast				(30)	(30)	(30)	(20)	(20)	(20)	(20)
2023 Programs Forecast					(60)	(60)	(50)	(50)	(40)	(40)
2024 Programs Forecast						(60)	(60)	(50)	(50)	(50)
2025 Programs Forecast							(60)	(60)	(50)	(50)
2026 Programs Forecast								(50)	(50)	(40)
Forecasted Residual Risk Score	**600**	**550**	**510**	**570**	**520**	**520**	**520**	**530**		

2019 Baseline

RAMP Baseline

Discounting and Long-Term Benefits

Per Row 25 of the SA, the RSE *"should reflect the full set of benefits"* and use present values.

Let DRS_y represent the pre-mitigation discounted Risk Score for year y
Let DRS'_y represent the post-mitigation discounted Risk Score for year y
Let C_y represent the discounted year-y cost of the set of mitigations

$$RSE = \frac{\sum_{y \in \{\text{life of program}\}} DRS_y - DRS'_y}{\sum_{y \in \{\text{life of program}\}} C_y}$$

Item	Discounting
Safety Attribute	None
Electric and Gas Reliability Attribute	None
Financial Attribute	Market-based rate
Program Costs	PG&E Utility Discount Rate

Treatment of Programs

PG&E has 3 different kinds of programs that reduce risk and they will be treated differently for risk reduction purposes.

Program Type	Definition	Treatment	Reason
Mitigation	Measure or activity proposed or in process designed to reduce the impact/consequences and/or likelihood/probability of an event (S-MAP Lexicon).	RSEs will be calculated for each Mitigation.	
Control	Currently established measure that is modifying risk (S-MAP Lexicon).	RSEs calculated on a case-by-case basis	Part of existing operations; difficult to estimate counterfactual Risk Scores. Time permitting, PG&E may select a few Controls to pilot Risk Reduction calculations.
Foundational Program	A program or activity that does not have a stand-alone risk-mitigation effect, but is required to enable other Mitigations.	Does not have an RSE	Foundational programs represent work that must be done to implement more than one Mitigation, hence risk-mitigation effects cannot be directly attributed back to the foundational programs themselves. (e.g. collaborative research on utility ignition data, computing resources, etc). However, the cost of the program will be included in one of the enabled Mitigations' RSE.

Appendix

Appendix A: S-MAP SA: Step 1A – Building a MAVF

No.	Element Name	Element Description and Requirements
1.	MAVF	A utility's MAVF should be constructed by following these six principles (see Rows 2-7, below). The MAVF is required to be built once but the utility may adjust its MAVF over time. Any changes to the MAVF must adhere to the principles of construction set forth in Rows 2 through 7 below.
2.	MAVF Principle 1 – Attribute Hierarchy	Attributes are combined in a hierarchy, such that the top-level Attributes are typically labels or categories and the lower-level Attributes are observable and measurable.
3.	MAVF Principle 2 – Measured Observations	Each lower-level Attribute has its own range (minimum and maximum) expressed in natural units that are observable during ordinary operations and as a consequence of the occurrence of a risk event.
4.	MAVF Principle 3 – Comparison	Use a measurable proxy for an Attribute that is logically necessary but not directly measurable. This principle only applies when a necessary Attribute is not directly measurable. For example, a measure of the number of complaints about service received can be used as a proxy for customer satisfaction.
5.	MAVF Principle 4 – Risk Assessment	When Attribute levels that result from the occurrence of a risk event are uncertain, assess the uncertainty in the Attribute levels by using expected value or percentiles, or by specifying well-defined probability distributions, from which expected values and tail values can be determined. Monte Carlo simulations or other similar simulations (including calibrated subject expertise modeling), among other tools, may be used to satisfy this principle.
6.	MAVF Principle 5 – Scaled Units	Construct a scale that converts the range of natural units (from Row 3) to scaled units to specify the relative value of changes within the range, including capturing aversion to extreme outcomes or indifference over a range of outcomes. The scaling function can be linear or non-linear. For example, the scale is linear if the value of avoiding a given change in Attribute level does not depend on the Attribute level. Alternatively, the scale is non-linear if the value of avoiding a given change in Attribute level differs by the Attribute level.

Appendix A (continued)

No.	Element Name	Element Description and Requirements
7.	MAVF Principle 6 – Relative Importance	Each Attribute in the MAVF should be assigned a weight reflecting its relative importance to other Attributes identified in the MAVF. Weights are assigned based on the relative value of moving each Attribute from its least desirable to its most desirable level, considering the entire range of the Attribute. One means of incorporating a weighting process was presented in the February 17, 2017 Report of Joint Intervenor Test Drive Step 1 Results, "Specifying the Multi-Attribute Value Function," by Drs. Feinstein and Lesser. Weights are assigned based on actual Attribute measurement ranges, not a fixed weight arbitrarily assigned to an Attribute. For example, the Attribute weights will reflect the relative importance of moving the safety outcomes from the least to the most desirable levels as compared with moving financial outcomes from the least to the most desirable levels in a risky situation.

Appendix B: S-MAP SA Step 3 – Mitigation Analysis

No.	Element Name	Element Description and Requirements
13.	Calculation of Risk	For purposes of the Step 3 analysis, pre- and post-mitigation risk will be calculated by multiplying the Likelihood of a Risk Event (LoRE) by the Consequences of a Risk Event (CoRE). The CoRE is the weighted sum of the scaled values of the levels of the individual Attributes using the utility's full MAVF.
14.	Definition of Risk Events and Tranches	Detailed pre- and post-mitigation analysis of mitigations will be performed for each risk selected for inclusion in the RAMP. The utility will endeavor to identify all asset groups or systems subject to the risk and each Risk Event associated with the risk. For example, if Steps 2A and 2B identify wildfires associated with utility facilities as a RAMP Risk Event, the utility will identify all drivers that could cause a wildfire and each group of assets or systems that could be associated with the wildfire risk, such as overhead wires and transformers. For each Risk Event, the utility will subdivide the group of assets or the system associated with the risk into Tranches. Risk reductions from mitigations and risk spend efficiencies will be determined at the Tranche level, which gives a more granular view of how mitigations will reduce risk. The determination of Tranches will be based on how the risks and assets are managed by each utility, data availability and model maturity, and strive to achieve as deep a level of granularity as reasonably possible. The rationale for the determination of Tranches, or for a utility's judgment that no Tranches are appropriate for a given Risk Event, will be presented in the utility's RAMP submission. For the purposes of the risk analysis, each element (i.e., asset or system) contained in the identified Tranche would be considered to have homogeneous risk profiles (i.e., considered to have the same LoRE and CoRE).
15.	Bow Tie	For each risk included in the RAMP, the utility will include a Bow Tie illustration. For each mitigation presented in the RAMP, the utility will identify which element(s) of its associated Bow Tie the mitigation addresses.
16.	Expressing Effects of a Mitigation	The effects of a mitigation on a Tranche will be expressed as a change to the Tranche-specific pre-mitigation values for LoRE and/or CoRE. The utility will provide the pre- and post-mitigation values for LoRE and CoRE determined in accordance with this Step 3 for all mitigations subject to this Step 3 analysis.
17.	Determination of Pre-Mitigation LoRE by Tranche	The pre-mitigation LoRE is the probability that a given Risk Event will occur with respect to a single element of a specified Tranche over a specified period of time (typically a year) in the planning period, before a future mitigation is in place.

Appendix B (continued)

No.	Element Name	Element Description and Requirements
17.	Determination of Pre-Mitigation LoRE by Tranche	The pre-mitigation LoRE is the probability that a given Risk Event will occur with respect to a single element of a specified Tranche over a specified period of time (typically a year) in the planning period, before a future mitigation is in place.
18.	Determination of Pre-Mitigation CoRE	The pre-mitigation CoRE is the weighted sum of the scaled values of the pre-mitigation levels of the individual Attributes using the utility's full MAVF. The CoRE is calculated using the full MAVF tool constructed consistent with Step 1A above.
19.	Measurement of Pre-Mitigation Risk Score	The pre-mitigation risk score will be calculated as the product of the pre-mitigation LoRE and the pre-mitigation CoRE for each Tranche subject to the identified Risk Event.
20.	Determination of Post- Mitigation LoRE	The post-mitigation LoRE calculation will be conducted at the same level of granularity as the pre-mitigation risk analysis within Step 3. The calculated value is the probability of occurrence of a Risk Event after the future mitigation is in place.
21.	Determination of Post- Mitigation CoRE	The post-mitigation CoRE calculation will be conducted at the same level of granularity as the pre-mitigation risk analysis. The post-mitigation CoRE is the weighted sum of the scaled values of the post-mitigation levels of the individual Attributes using the utility's full MAVF.
22.	Measurement of Post-Mitigation Risk Score	The post-mitigation risk score will be calculated as the product of the post-mitigation LoRE and post-mitigation CoRE for each Tranche subject to the identified Risk Event.
23.	Measurement of Risk Reduction Provided by a Mitigation	The risk reduction provided by a risk mitigation will be measured as the difference between the values of the pre-mitigation risk score and the post-mitigation risk score.
24.	Use of Expected Value for CoRE; Supplemental Calculations	The utility will use expected value for the MAVF-based measurements and calculations of CoRE in Rows 13, 18, 19, 21, 22, and 23. If a utility chooses to present alternative calculations of pre- and post-mitigation CoRE using a computation in addition to the expected value of the MAVF, such as tail value, it does so without prejudice to the right of parties to the RAMP or GRC to challenge such alternative calculations.
25.	Risk Spend Efficiency (RSE) Calculation	RSE should be calculated by dividing the mitigation risk reduction benefit by the mitigation cost estimate. The values in the numerator and denominator should be present values to ensure the use of comparable measurements of benefits and costs. The risk reduction benefits should reflect the full set of benefits that are the results of the incurred costs. For capital programs, the costs in the denominator should include incremental expenses made necessary by the capital investment.