PG&E 2024 Risk Assessment and Mitigation Phase Workshop #2: Cost-Benefit Approach Demonstration

April 11, 2024

Safety and Security Orientation

Assign safety roles if in person

Psychological Safety

- Practice transparency and vulnerability
- Avoid blame; learn from mistakes
- Show care and appreciation
- Invite new ideas from all
- Disagree respectfully and with curiosity
- Prioritize mental health by encouraging self-care

Fire

- Exits, escape routes, evacuation
- Fire ext.

Earthquake

- Drop, cover, hold

Medical Emergency

- First aid/CPR
- 911/share location
- AED

Security

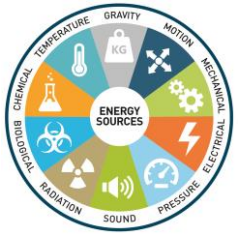
- Active shooter—get out, hide out, take out, call out
- Maintain situational awareness to mitigate hazards

Ergonomics

- Proper ergo
- 30/30: move for 30 secs every 30 min

Don't report to work if testing positive for COVID-19

Energy-Based Hazard Wheel



On the road, off the phone

Park in a safe location

Agenda

Topic	Presenter(s)	Time (min)	Time Slot
SPD Opening Remarks	Safety Policy Division	5	10:00-10:15
PG&E Opening Remarks	Paul McGregor	5	
Safety and Introduction	Ken Arnold	5	
Cost-Benefit Approach Implementation Overview Cost-Benefit Approach – Principles 1 – 5	Yumi Oum	55	10:15-11:10
BREAK		**15**	**11:10-11:25**
Cost-Benefit Approach – Principle 6, Risk Scaling Limitations of Risk Modeling	Vincent Loh	50	11:25-12:15
BREAK (LUNCH)		**60**	**12:15-1:15**
Risk Value Calculation Example Cost-Benefit Ratio Calculation Example	Kim Mullins	75	1:15-2:30
BREAK		**15**	**2:30-2:45**
Session Review	Paul McGregor	5	2:45-2:50
Q&A / Discussion	Safety Policy Division	30	2:50-3:20
PG&E Closing Remarks	Paul McGregor	5	3:20-3:30
SPD Closing Remarks	Safety Policy Division	5	

Introductions

Presenter	Title	Sponsoring Area
Paul McGregor	Sr. Director – Enterprise and Operational Risk Management (EORM)	Overall RAMP Report
Yumi Oum	Director – EORM Risk Analytics	Risk Score and Cost-Benefit Ratio Calculations
Vincent Loh	Sr. Manager – EORM Risk Policy and Regulatory Strategy	Cost-Benefit Approach Principles
Kim Mullins	Principal – EORM Risk Analytics	Calculation Examples

PG&E's RAMP Procedural Schedule

Today's workshop fulfills the Commission's requirement for PG&E to demonstrate its Cost-Benefit Approach implementation

Feb 7, 2024
Preliminary RAMP Risk Workshop

RDF (D.22-12-027 Appendix A) Row No. 12: *"… the utility will host a publicly noticed workshop … to gather input from SPD, other interested CPUC staff, and interested parties to inform the determination of the final list of risks …"*

April 11, 2024
Cost-Benefit Approach Demonstration Workshop

D.22-12-027 OP 3: *"Pacific Gas and Electric Company shall conduct a Cost-Benefit Approach Demonstration Workshop … at least 30 days prior to its 2024 (RAMP) filing."*

May 15, 2024
RAMP Filing Due

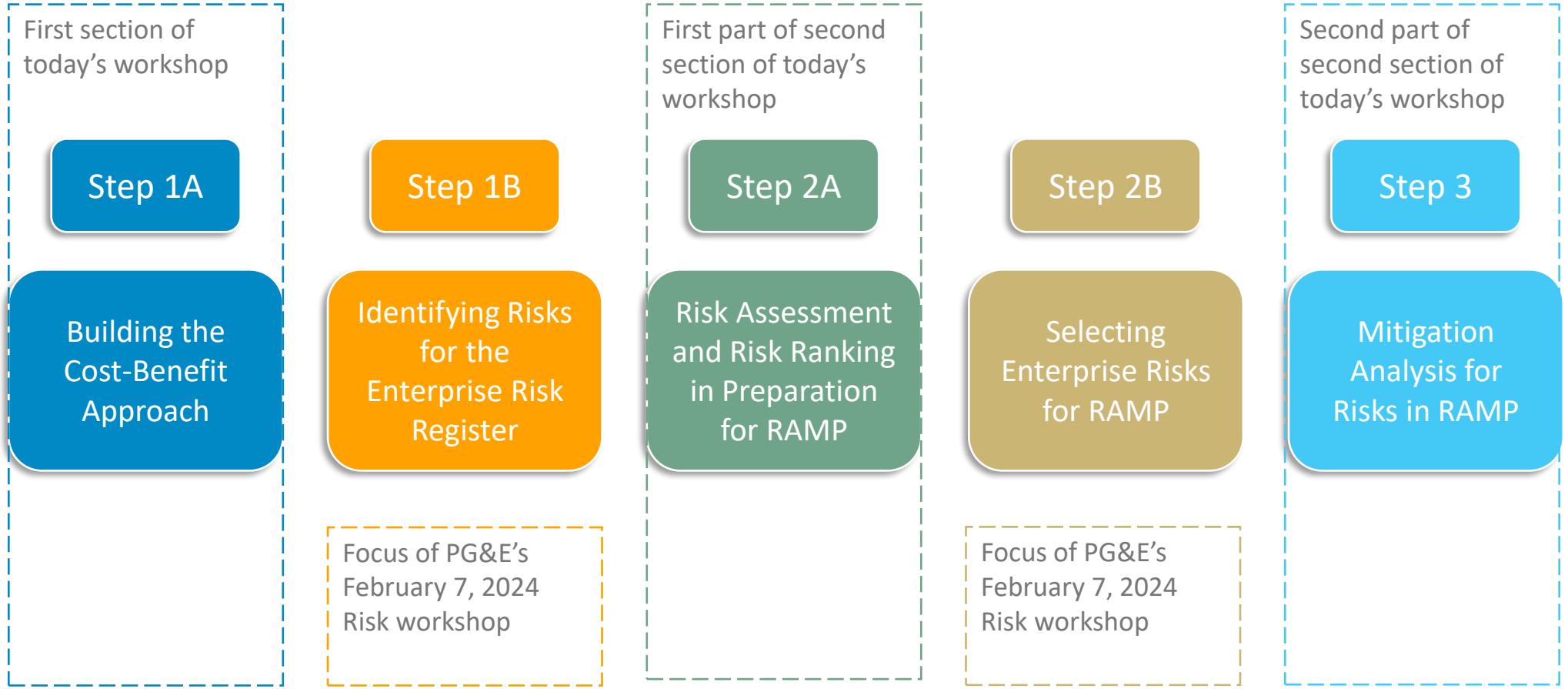
D.20-01-002, Appendix A, Adopted Revised GRC Application Filing Schedule: *"May 15, one year prior to the Utility's GRC filing, Utility files application to initiate its RAMP proceeding."*

June 2024 (Date TBD)
RAMP Post-Filing Workshop

D.14-12-025: *"Within 30 days of the filing... the utility would provide an informational overview of the contents of its RAMP report and any changes to its risk model since the last S-MAP and Commission staff would explain the process it will follow in conducting its technical review."*

PG&E's Cost-Benefit Approach Workshop Series

PG&E implemented the Cost-Benefit Approach adopted in D.22-12-027 for calculating risk



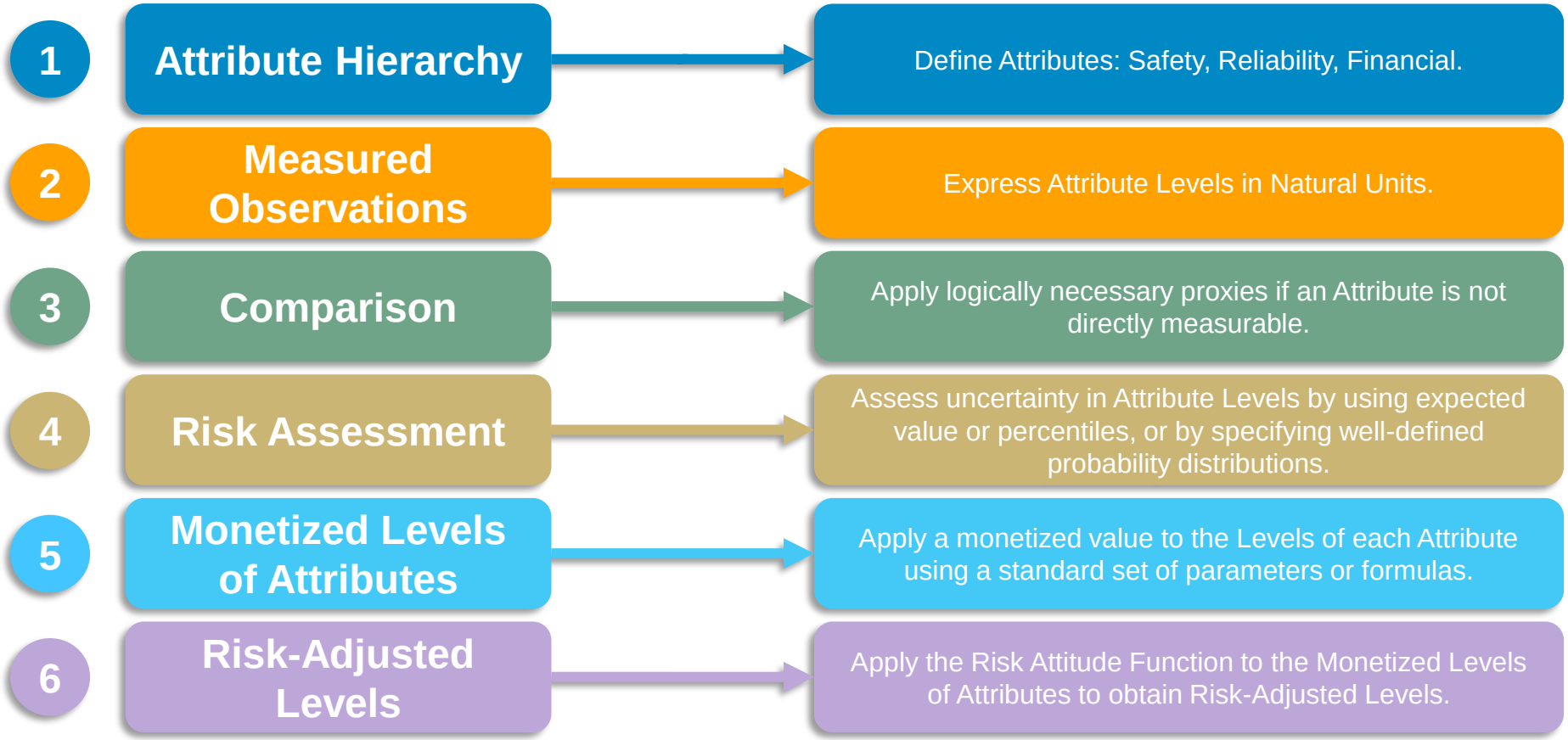
Building the Cost-Benefit Approach

Yumi Oum, Director – EORM Risk Analytics

Step 1A - Principles

PG&E implemented the Cost-Benefit Approach adopted in D.22-12-027 for Calculating Risk

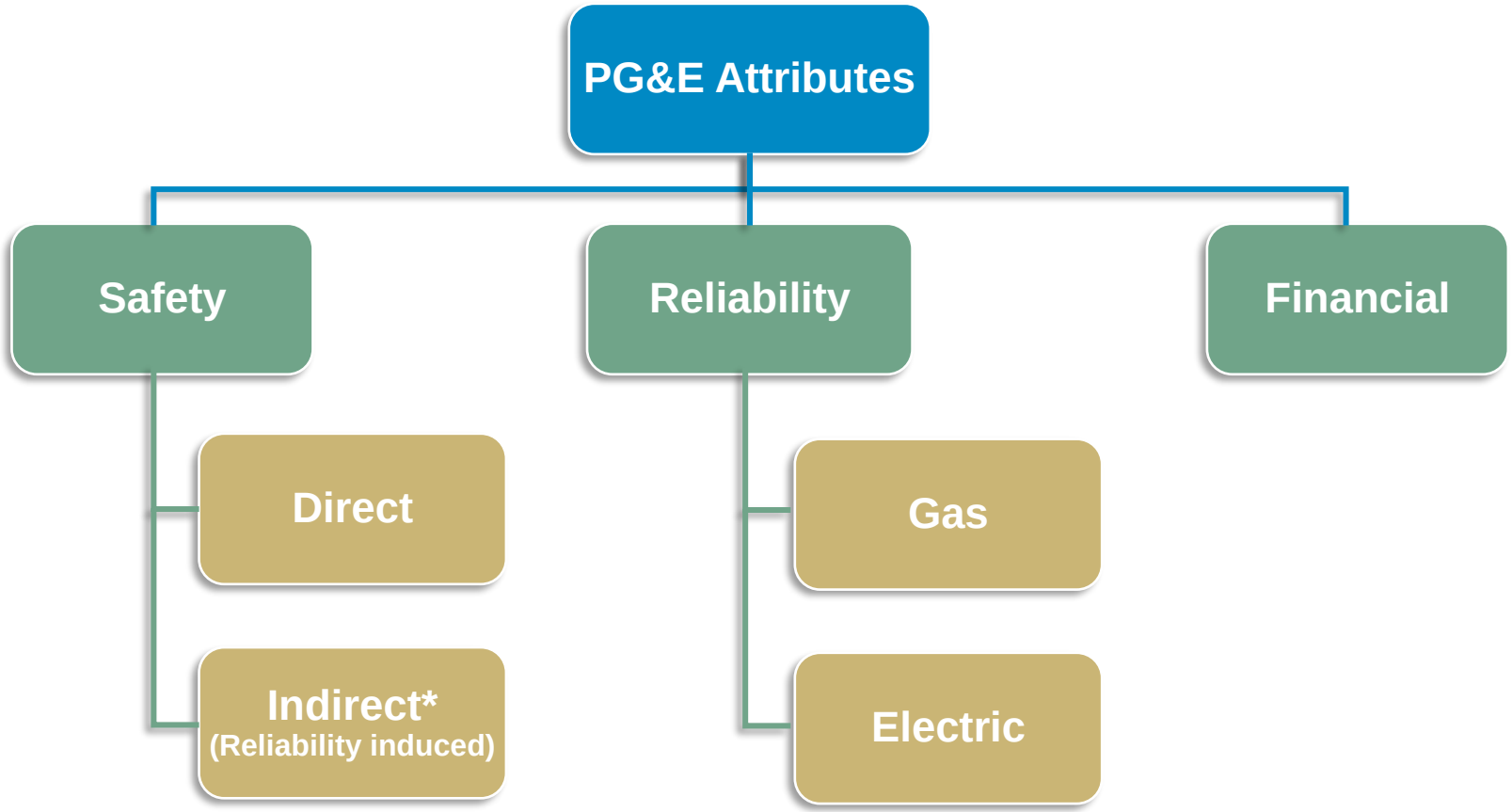
RDF Element No.1: *"A utility's Cost-Benefit Approach should be constructed by following these six principles…"*



Principle 1 - Attribute Hierarchy

Element Description and Requirements

RDF Element No.2: *"Attributes are combined in a hierarchy, such that the primary Attributes are typically labels or categories and the sub-Attributes are observable and measurable."*



* Per D.14-12-025, *"We recognize, however, that reliability-related issues can affect safety. In such situations, those reliability issues should be included in the assessment of safety."*

Integrating Indirect Safety Sub-Attribute

PG&E is Incorporating Reliability-Induced Safety Impacts into its Consequence Modeling

Relevant Regulatory Context

- D.14-12-025: *"We recognize, however, that reliability-related issues can affect safety. In such situations, those reliability issues should be included in the assessment of safety"*
- Joint Motion filed by CalPA, FEITA requested that PG&E analyze the full safety, health and financial consequences of PSPS. In ruling A.20-06-012, CPUC found it is appropriate for PG&E to provide GRC testimony concerning updated risk analysis estimating consequences of calling PSPS events.
- PG&E included safety consequences from reliability events in the PSPS model in its 2023 GRC and WMPs.

Quantification Approach

- PG&E reviewed widespread US blackout events to estimate the relationship between safety consequences and outage extent. The data sources represent a wide array of events with many varied drivers of injuries and fatalities other than electric power outages.
- PG&E modeled this uncertainty relating mortality to outages using an exponential distribution with mean of 6 EF/1 billion CMI, assembling relevant data from the following blackouts:
  2003 US Northeast Blackout, 2011 Southwest Blackout, 2012 Superstorm Sandy, 2012 Derecho Windstorms, 2017 Hurricane Irma, 2021 Texas
- PG&E delineated the safety consequences from short and long duration outages[1] by assigning indirect safety consequences for 8+ hour duration outages.

(1) Source: Do, V., McBrien, H., Flores, N.M. et al. Spatiotemporal distribution of power outages with climate events and social vulnerability in the USA. *Nat Commun* 14, 2470 (2023). https://doi.org/10.1038/s41467-023-38084-6

Principle 2 (Measured Observations) & Principle 3 (Comparison)

Principle 2: Measured Observations

RDF Element No. 3: *"Each sub-Attribute has Levels expressed in Natural Units that are observable during ordinary operations and as a Consequence of the occurrence of a Risk Event."*

Attribute	Sub-Attribute	Natural Unit
Safety	Direct	Equivalent Fatalities (EF), where Serious Injury = 0.25 EF and Minor Injury = 0.003 EF
	Indirect (Reliability-induced)	EF
Reliability	Gas	Number of Customers Impacted
	Electric	Customer Minutes Interrupted (CMI)
Financial	Cost	$, Real, 2023

Principle 3: Comparison

RDF Element No. 4*: "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."

*PG&E's CBA Implementation does not have proxies

For reference on EF factor for injuries

D.22-12-027, Conclusions of Law #12:
The Commission should require IOUs to apply one of two following methods for the dollar valuation of injury prevention, depending on the availability of data:
(1) A serious injury as 0.25 of a fatality
(2) The injury severity level using DOT estimates for the value of injury prevention:

Injury Severity	Fraction of VSL
Minor	0.003
Moderate	0.047
Serious	0.105
Severe	0.266
Critical	0.593
Unsurvivable	1.000

Source: DOT, Valuation of a Statistical Life Guidance, at 10.

Table 2-3: Relative Disutility Factors by Injury Severity Level for Use with 3% or 7% Discount rates

AIS Code	Description of Injury	Fractional Fatality Values Value of Life	Dollar Value
AIS 1	Minor	0.003	$28,800
AIS 2	Moderate	0.047	$451,200
AIS 3	Serious	0.105	$1,008,000
AIS 4	Severe	0.266	$2,553,600
AIS 5	Critical	0.593	$5,692,800
AIS 6	Fatal	1.000	$9,600,000

Average of AIS 2-5:
(0.047+0.105+0.266+0.593)/4=0.253

Table 2-4: Relative Disutility Factors by Injury Severity Level Based on the NTSB Classification of Injuries for Use with 3% or 7% Discount rates

AIS Code (Description of Injury)	NTSB Classification	Modified Fractional Fatality Values Value of Life	Dollar Value
AIS 1 / Minor	Minor	0.003	$28,800
AIS 2 / Moderate	Serious	0.253	$2,428,800
AIS 3 / Serious			
AIS 4 / Severe			
AIS 5 / Critical			
AIS 6 / Fatal	Fatal	1.000	$9,600,000

Tables source: TREATMENT OF THE VALUES OF LIFE AND INJURY IN ECONOMIC ANALYSIS (faa.gov)

Principle 4 – Risk Assessment

Element Description and Requirements

RDF Element No.5: *"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."

PG&E represents all Consequence Attributes Levels using standard probability distributions for all Risks / Tranches / Outcomes / Attributes. The distribution for each outcome and tranche is chosen based on the properties of the consequences and data available to calibrate.

List of Distributions used for 2024 RAMP Risks
Zero-truncated Poisson x Bernoulli Compound Distribution, adapted for EF*
Normal
Right-truncated Lognormal x Bernoulli Compound Distribution, adapted for EF*
Right-truncated Lognormal
Truncated Pareto I
Lognormal
Deterministic
Truncated Lognormal
Binomial adapted for EF*
Exponential
Truncated Normal
Uniform
Discrete
Zero-truncated Poisson
Truncated Pareto II Distribution

*EF is equivalent fatality, natural unit for Safety Attribute.

Principle 5 – Monetized Levels of Attributes

Element Description and Requirements

RDF Element No. 6: *"Apply a monetized value to the Levels of each of the Attributes using a standard set of parameters or formulas, from other government agencies or industry sources, as determined by the Phase II Decision Adopting Modifications to the Risk-Based Decision-Making Framework Adopted in D.18-12-014 and Directing Environmental and Social Justice Pilots in Rulemaking (R.) 20-07-013.*

A utility may deviate from the agreed upon standard set of parameters or formulas by submitting a detailed explanation as to why the use of a different value would be more appropriate. The use of a different set of parameters or formulas to determine the Monetized Levels of Attributes requires an analysis comparing the results of its "equivalent or better" set of parameters or formulas against the results of the agreed upon standard set of parameters or formulas."

PG&E adopted the following Monetized Attribute values based on the requirements outlined in D.22-12-027.

Safety

Calculated using the Department of Transportation (DOT) guidance for the Value of a Statistical Life (VSL), adjusted for: 1) California price and real wage data, and 2) the base year of the RAMP filing.

2023 CA-Adjusted VSL:
$15.23 million (1,2)

Electric Reliability

Calculated using the Lawrence Berkeley National Laboratory (LBNL) Interruption Cost Estimate (ICE) Calculator, updated with PG&E-specific information.

Expressed in dollars per customer-minute interrupted.

2023 $/CMI
$3.17 (3)

Gas Reliability

For gas reliability, the Risk OIR Phase II Decision directs IOUs to use the implied dollar value from their most recent RAMP MAVF risk score calculations.

The implied gas reliability value expressed in dollars per customer impacted:

2023 $/Customer:
$1,569.75 (4)

Notes to Results:

1. $2023 VSL calculated by adjusting the $2012 DOT VSL using inflation (CPI) and real wage growth data from the Bureau of Labor Statistics (BLS), per DOT guidance.
2. $2023 California-adjusted VSL calculated by applying price and income modifiers derived from CPI and weekly earning data from the BLS and California Department of Industrial Relations
3. PG&E used PG&E-specific data in the ICE Calculator such as customer class composition and annual energy usage, C&I industry percentages, temporal outage distribution and average interruption frequency. ICE Calculator year 2016 results were adjusted to $2023 using BLS CPI data.
4. $2023 Gas Reliability value calculated by adjusting the 2020 MAVF-implied values, which is in 2020 dollars, using BLS CPI data.

Overview of ICE Calculation Used for Reliability Attribute

Note: This shows an initial screen shot of the ICE calculator *prior to* applying PG&E's User Inputs.

ICE Calculator User Inputs (highlighted in yellow)

Reliability Inputs:

SAIFI	2.000
SAIDI	120.0
CAIDI	60.0

❷

Number of Customers:

Non-Residential	1,000
Residential	10,000

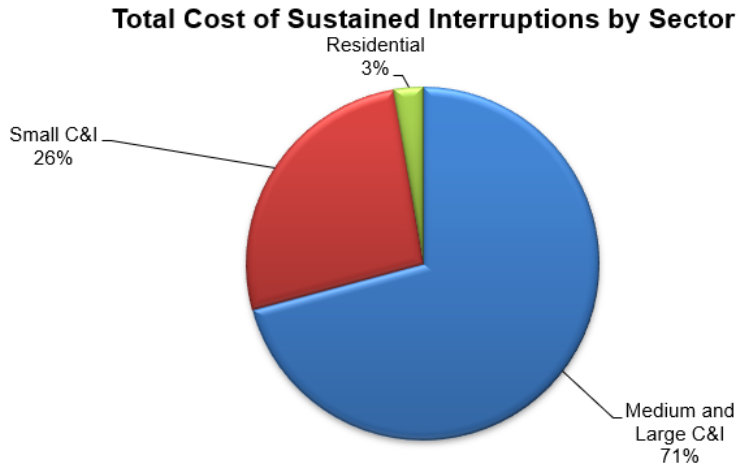
Choose state/states:

State 1	California

❶

Main Output:

Sector	No. of Customers	Cost Per Event (2016$)	Cost Per Average kW (2016$)	Cost Per Unserved kWh (2016$)	Total Cost of Sustained Interruptions (2016$)
Medium and Large C&I	169	$8,444.8	$161.2	$161.2	$2,854,333.0
Small C&I	831	$643.6	$311.5	$311.5	$1,069,733.4
Residential	10,000	$5.3	$6.5	$6.5	$106,819.7
All Customers	11,000	$183.2	$107.3	$107.3	$4,030,886.1



PG&E used the ICE Calculator spreadsheet tool, 2018 update, found on the ICE Calculator documentation page

RDF Requirement regarding ICE Calculator

The RDF Proceeding Phase II Decision requires each IOU to use the most current version of the ICE Calculator to determine a standard dollar valuation of Electric Reliability risk for the Reliability Attribute.

ICE Calculator Overview

The Interruption Cost Estimate (ICE) Calculator is a tool designed for electric reliability planners at utilities, government organizations or other entities that are interested in estimating interruption costs and/or the benefits associated with reliability improvements.

What Interruption Cost Means

Interruption Costs refer to value of electric service reliability estimates developed through either surveys of the economic losses customers experience because of electric service interruptions or customers' willingness-to-pay to avoid/willingness-to-accept compensation for such problems.

PG&E's Electric Reliability Risk Valuation

The natural unit of PG&E's electric reliability attribute is customer minutes interrupted (CMI) per event, however Cost per CMI is not a standard output. Thus, PG&E computes it by dividing ❶[Cost per Event] by ❷[SAIDI] after setting [SAIFI] as 1 and [Number of Customers] as total number of customers.

PG&E Inputs Used in ICE Calculator

PG&E used PG&E-specific data in the ICE Calculator to arrive at $3.17/CMI.

	ICE Calculator Input Variable	User Input Default	PG&E Data	PG&E Data Source
Number of Customers	Non-Residential Residential	1,000 10,000	**633,547** **4,961,426**	2023 recorded accounts data from PG&E's Rate Design and Analytics Department
Number of Accounts by Rate Class	Residential Small C&I Medium and Large C&I	12,971,924 1,567,550 319,434	**4,961,426** **469,588** **163,960**	2023 recorded accounts data from PG&E's Rate Design and Analytics Department
Annual Usage per Customer (MWh)	Residential Small C&I Medium and Large C&I	7.2 18.1 459.0	**5.1** **15.3** **240.6**	2023 recorded usage data from PG&E's Rate Design and Analytics Department
Medium and Large Commercial and Industrial (C&I) Customer Mix	Construction Manufacturing All Other Industries	2.0% 17.1% 80.9%	**2.0%** **9.5%** **88.5%**	2023 recorded accounts data from PG&E's Rate Design and Analytics Department
Small C&I Customer Mix	Small C&I Construction Manufacturing All Other Industries	9.5% 5.0% 85.5%	**9.5%** **7.1%** **83.4%**	2023 recorded accounts data from PG&E's Rate Design and Analytics Department
Reliability Inputs	SAIFI SAIDI CAIDI	2.00 120.00 60.00	**1.00** **120.00** **120.00**	Recorded annual average data from 2013-2022
Outages by Time of Day	Morning (6 am to 12 pm) Afternoon (12 pm to 5 pm) Evening (5 pm to 10 pm) Night (10 pm to 6 am)	25% 21% 21% 33%	**13%** **23%** **28%** **36%**	Electric Operations unplanned outage data from 2016-2023
Outages by Time of Year	Summer (June through September) Non-Summer (October through May)	50% 50%	**29%** **71%**	Electric Operations unplanned outage data from 2016-2023

PG&E's Electric Reliability Attribute Risk Valuation

PG&E Plans to Use the Weighted Average Value of Electric Reliability from ICE for its 2024 RAMP.

- Large disparities in Values between C&I and Residential Customers could lead to significant, unintended consequences.
- PG&E will review the policy of using the Average pending the ICE 2.0 update.
- PG&E expresses the Monetized Electric Reliability Attribute as Cost per Customer Minutes Interrupted ($/CMI), shown below in $2023.

$$\frac{\boldsymbol{Cost}}{\boldsymbol{CMI}} = \frac{Cost\ Per\ Event}{SAIDI} = \frac{Cost\ Per\ Event \times Total\ No.of\ Customers}{Sum\ of\ All\ Customer\ Interruption\ Durations}$$

ICE Model Outputs				
	ICE User Input Default		PG&E Data	
Sector	Cost per CMI (2016$)	**Cost per CMI ($2023)**	Cost per CMI (2016$)	**Cost per CMI ($2023)**
Medium and Large C&I	$70.37	$89.34	$61.35	$77.89
Small C&I	$5.36	$6.81	$7.87	$9.99
Residential	$0.04	$0.06	$0.04	$0.06
All Customers	**$1.53**	**$1.94**	**$2.50**	**$3.17**

- To compute Electric Reliability Attribute Risk Values in its risk models, PG&E is using the $3.17/CMI for all customer classes.
- The resulting Electric Reliability Risk Values are approximately 63% higher with PG&E's User Inputs, compared to $1.94/CMI from the default User Input.

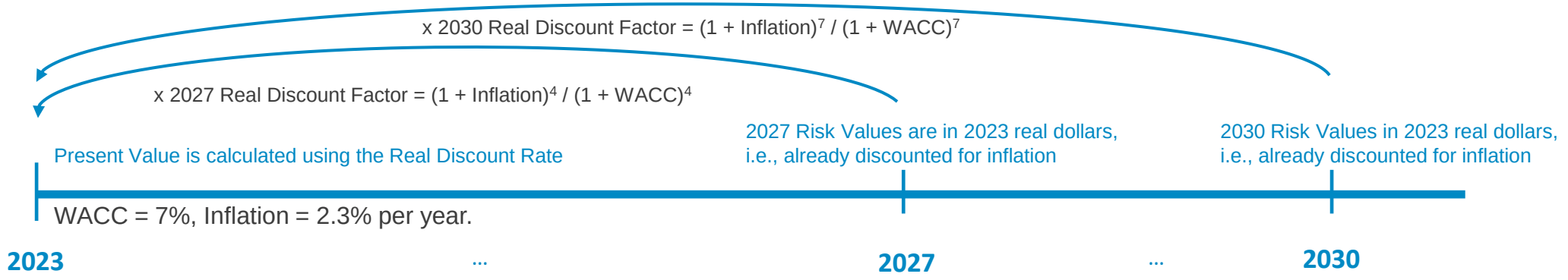
Note: PG&E adjusted ICE Calculator year 2016 results to $2023 using BLS CPI data, available at https://data.bls.gov/timeseries/CUUR0000SA0 .

Monetized Values – Future Years & Discounting

PG&E will represent the monetized risk values for future years without including the effect of inflation, in other words, in real dollars.

PG&E is planning to use 7% (WACC[1]) for nominal discount rate and 4.6% for real discount rate.[2]

- For the CBR calculation, real discount rate (i.e., discount rate for real dollars, or inflation-adjusted discount rate) will be used to discount the benefit represented in real dollars.

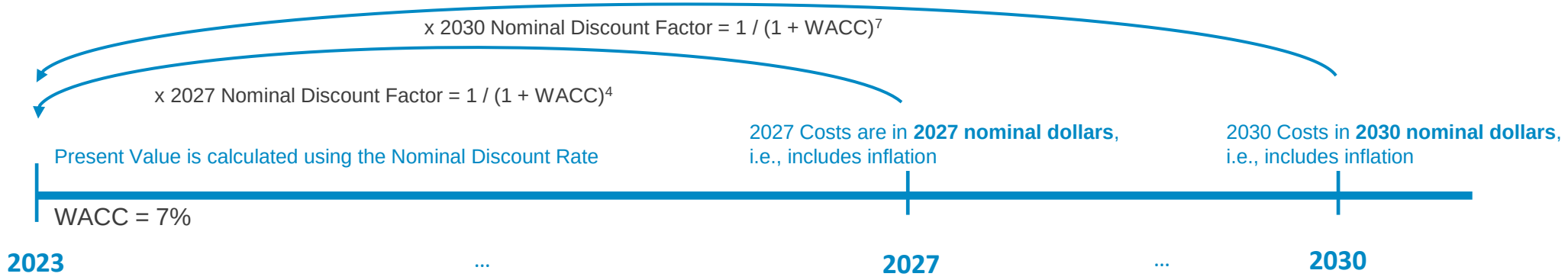


[1] WACC: Weighted-Average Cost of Capital, 7% for PG&E.
[2] Real discount rate 4.6% = (1+7%)/(1+2.3%)-1

Costs – Future Years & Discounting

Unlike Benefits, Cost forecasts include inflation.

- For denominator of the CBR, WACC will be used to discount the program costs represented in nominal dollars (i.e, with inflation) over time as a nominal discount rate.



[1] WACC: Weighted Average Cost of Capital, 7% for PG&E.
[2] Real discount rate 4.6% = (1+7%)/(1+2.3%)-1

Escalation of Monetized Values

PG&E currently assumes that VSL and Value of Reliability will grow at the inflation rate, with no further adjustments for real-income growth, in order to use the same effective discount rate for numerator and denominator of CBR calculation.

- While there is guidance on how to escalate the VSL, but there is no guidance on how to escalate the value of service.
- Using differing escalation methods for different Attributes could have unintended consequences.
- For this reason, PG&E currently does not include real-income growth in either Safety or Reliability Attributes.
- PG&E will continue to seek feedback and investigate this issue for the GRC.

VSL

Per US DOT VSL Guidance, VSL escalation rate depends on the inflation rate and real-income growth rate.

- As shown in Slide 15, PG&E starts from DOT VSL values of 2012 and then escalates to 2023 using actual inflation and actual real-income growth rate between 2012 and 2023.

$VSL_T = VSL_0 \ (P_T/P_0) * (I_T/I_0)^{\varepsilon}$ per US Dept. of Transportation[1]

0 = Original Base Year, T = Current Base Year, P_t = Price Index in Year T
I_t = Real Incomes in Year T, PG&E sets to I_0
ε = Income Elasticity of VSL, set to 1.0 per Fed guidance

Value of Service

The ICE Calculator uses GDP/kwh and Household Income as variables but there is no clear escalation formula that incorporates the impact of inflation.

- As shown in Slide 15, PG&E starts from ICE calculator value output of year 2016 and then escalates to 2023 using actual inflation rate between 2016 and 2023.

1. DOT VSL Guidance – 2021 Update at 7. Available at: https://www.transportation.gov/resources/value-of-a-statistical-life-guidance.

Risk Adjusted Levels

Vincent Loh, Senior Manager – EORM Risk Policy and Regulatory Strategy

Principle 6 – Risk-Adjusted Levels

Element Description and Requirements

RDF Element No. 7: *"Apply a Risk Attitude Function to the Monetized Levels of an Attribute or Attributes (from Row 6) to obtain Risk-Adjusted Levels. The Risk Attitude Function specifies attitude towards different kinds of Outcomes including capturing aversion to extreme Outcomes or indifference over a range of Outcomes.*

The Risk Attitude Function can be linear or non-linear. For example, the Risk Attitude Function is linear to express a risk-neutral attitude if avoiding a given change in the Monetized Attribute Level does not depend on the Attribute Level. Alternatively, the Risk Attitude Function is non-linear to express a risk-averse or risk-seeking attitude if avoiding a given change in the Monetized Attribute Level differs by the Attribute Level."

PG&E Adopts a Risk-Averse Attitude (non-linear, concave function)

- ☑ Accounts for Tail Risks (usually underestimated due to lack of knowledge of extreme outcomes)
- ☑ Ruin/Path Dependence – recognize that extreme outcomes could lead to ruin
- ☑ Abundant evidence that customers have risk-averse preferences
- ☑ Reflects best practice
- ☑ Embraces PG&E's True North Strategy (TNS)

See PG&E's Risk OIR Phase III Workshop #4 Opening Comments

PG&E Risk Scaling Function Guiding Principles

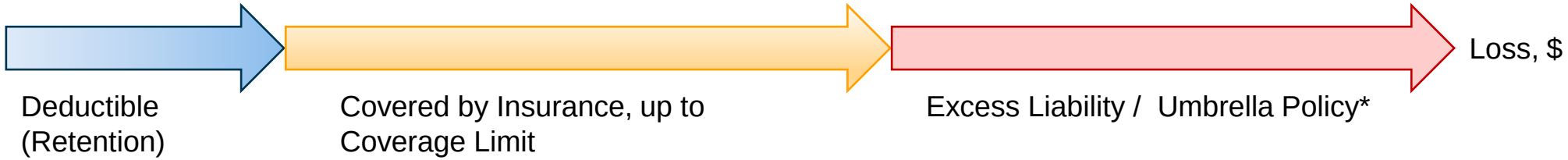
☑ **Objective and Transparent**
- Based on available data, and/or independent assessments.

☑ **Consistency & Alignment**
- Risk scores comparable to other industries. Risk reduction benefits are measured consistently.
- Consistent policies – are other industries (e.g., insurance) adopting a risk-neutral preference?

☑ **Represents Societal Values**

PG&E's Approach to the Risk Scaling Function

Adopt Practices from Insurance and Apply to Operational Risk Management



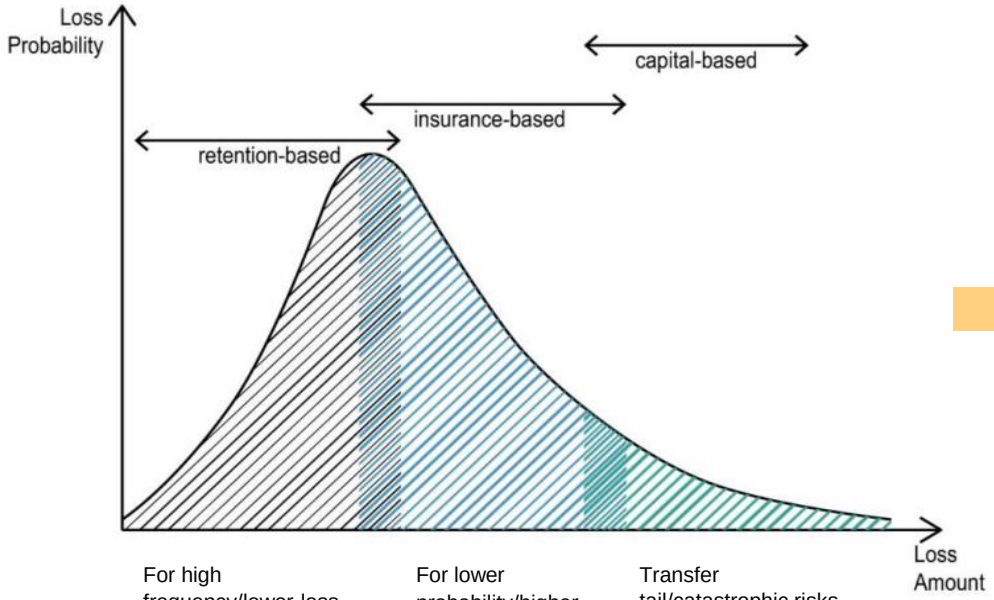
Insurance Premiums (prices) represent the degree of risk aversion for this portion of the potential losses.	Excess Liability/Umbrella Policy Premiums represent the degree of risk aversion for this portion of the potential losses.

These regions represent different scales of losses and are usually priced differently.

*Umbrella insurance works as an additional layer of liability coverage on top of the standard homeowners, auto, and other policies.

PG&E Risk Scaling Function

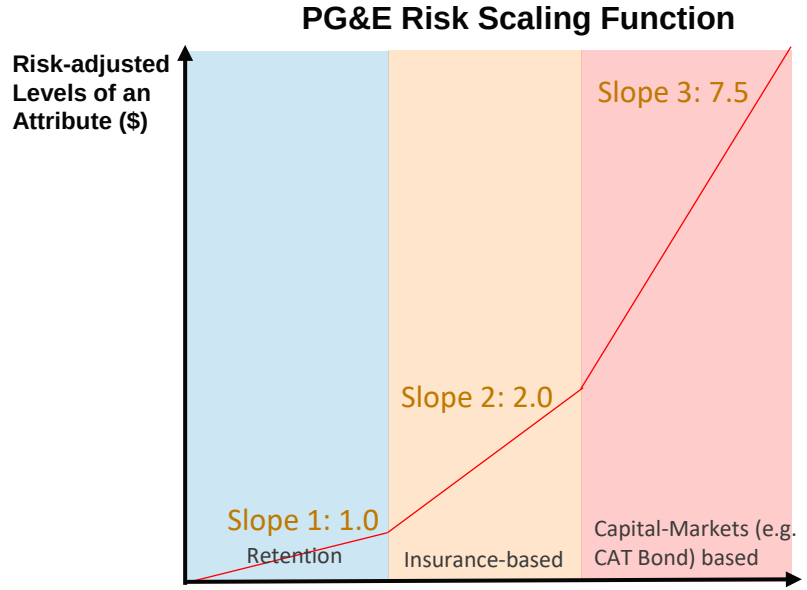
PG&E's Scaling Function Reflects a Common Risk Financing Strategy*



For high frequency/lower-loss risks, firms often assume "deductible" amounts in insurance contracts, i.e., assume losses under a certain amount.

For lower probability/higher magnitude risks, losses are transferred to insurance companies.

Transfer tail/catastrophic risks to capital markets and reinsurers via CAT bonds and other products.



Financial	$0 - $10m	$10m - $1b	$1b+	
Safety	0 – 1 EF $0 - $15.2m	1 – 10 EF $15.2m - $152m	10+ EF $152m+	$15.23m/EF
Electric Reliability	0 - 100m CMI $0 - $317m	100 – 1,000m CMI $317m – $3.17b	1,000m+ CMI $3.17b+	$3.17/CMI
Gas Reliability	0-7.5k cust $0 - $11.5m	7.5k - 75k cust $11.5m – 115m	75k+ cust $115m+	$1,570 / customer

Slope 1 set to reflect preference to "in-house" the risk, slopes 2 and 3 set based on observed multipliers in insurance and Cat-Bond pricing. PG&E continues to review risk attitude function ahead of the 2024 RAMP.

* Carolyn Kousky, Katherine Greig, and Brett Lingle, "Financing Third Party Wildfire Damages: Options for California's Electric Utilities", February 2019, Wharton Risk Management and Decision Processes Center

Rationale for Financial, Safety and Gas Reliability Breakpoints

Breakpoints were driven by the natural units.

Financial Breakpoints are based on the Current Risk Financing Environment Facing PG&E.

Safety and Gas Reliability Breakpoints are based on orders of magnitude of losses.

Region	Financial	Safety	Gas Reliability
Retention	$0 - $10m Based on common deductible amounts for PG&E's policies.	0 – 1 EF / $0 - $15.2m Represents ~1% of largest probable event (100 EF).	0 – 7.5k customers impacted Represents ~1% of largest probable event (750,000 customers impacted).
Insurance	$10m - $1b AB 1054 Wildfire Fund "attaches" at $1b, i.e., assumes that IOUs carry coverage up to $1b.	1 – 10 EF / $15.2 - $152m Between 1% - 10% of largest probable event.	7.5k – 75k customers impacted Between 1% - 10% of largest probable event.
Capital Markets	Over $1b Consistent with AB 1054 in that coverage above this level is difficult to obtain from insurance markets.	Over 10 EF / $152m Over 10% of largest probable event.	Over 75k customers impacted Over 10% of largest probable event.

Rationale for Electric Reliability Breakpoints

Two breakpoints informed by CERP[1] Incident Classification Levels and SOPP[2] model results:

1. **First breakpoint is based on the Elevated level**
2. **Second breakpoint is based on the Catastrophic level**

Capital Markets

Insurance

Retention

Table 3-1: Incident Classification Levels

Level		Response
Catastrophic	5	• Incident includes multiple emergencies, affects many customers, business operations • Significant cost and infrastructure risk/damage • Full mobilization of PG&E, contractor and mutual aid resources • May have heavy media interest and actual reputational risk • EOC and Executive Team are activated
Severe	4	• Incident includes extended multiple incidents and affects many customers • Escalating company impact • Resources, contractors and mutual aid may be shared between region • May have heavy media interest and potential reputational risk
Serious	3	• Incident involves large numbers of customers • Resources may need to move between regions • Potential increased, actual or imminent negative media interest
Elevated	2	• A pending or local incident that requires more than routine operations • Resources may need to move within the region • Increased media interest
Routine	1	• Incident involves a relatively small number of customers • Local resources are sufficient • Little to no media coverage

[1] Company Emergency Response Plan, 2023

SOPP Forecasted of Entire PG&E System	(Estimated) Lower Range of Forecasted CMI of Peak Day for EOC Activation
Category 1	50M
Category 2	**100M**
Category 3	200M
Category 4	350M
Category 5	**1 Billion**

[2] Storm Outage Prediction Program (SOPP) model leverages over 25 years of historical weather and outage data along with high-resolution weather forecasts and real-time weather data to support advance planning and preparation for storm events for electric transmission and distribution asset managers.

Risk Scaling – The Kind of Risk Matters

Risk Neutral only works if the Consequence Distributions are well-behaved – Tail Probabilities Decay Exponentially

Tail Risks are Symptomatic of *Pathological Distributions* that defy common statistical measures like Expected Value.

Adapted from Table 5.1: Ranking Distributions; *Statistical Consequences of Fat Tails, 2nd Ed, Nassim Nicholas Taleb, 2023*

Well-behaved - Estimates of Expected Value accurately reflect risk

Increasingly Pathological – Tails dominate and get more extreme, estimates of Expected Value increasingly underestimates risk.

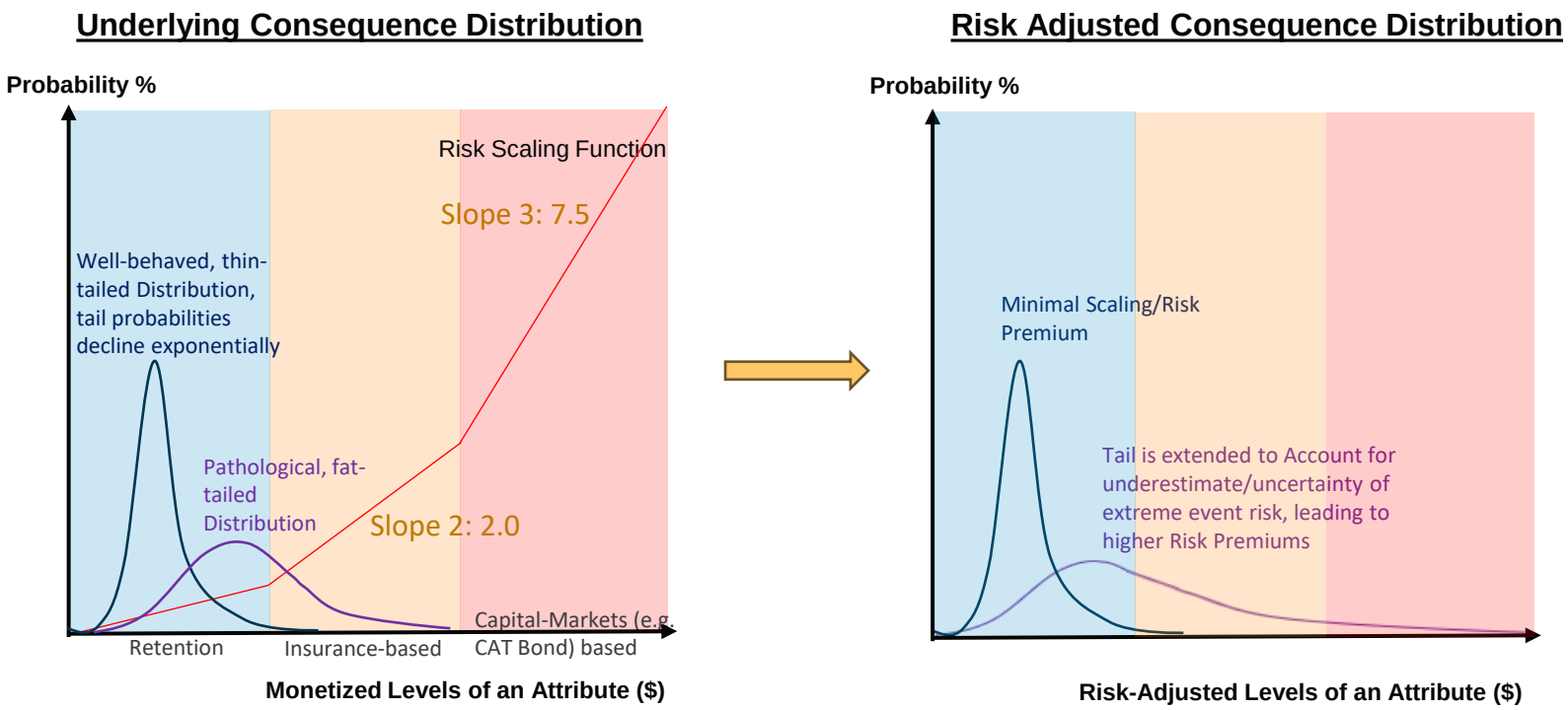
Probability Distribution Class	Description
True Thin Tails	Compact support (e.g., Bernoulli, Binomial)
Thin Tails	Gaussian reached organically through summation/averaging of True Thin Tail samples, by Central Limit Theorem
Conventional Thin tails	Gaussian approximation of a natural phenomenon
Starter Fat Tails	Fatter tail than Gaussian but rapid convergence to Gaussian under summation/averaging
Subexponential	E.g. Lognormal
Infinite Kurtosis (3rd Moment)	E.g. Pareto distribution a < 3
Infinite Variance (2nd Moment)	E.g. Pareto distribution a < 2
Infinite Expected Value (1st Moment)	E.g. Pareto distribution a < 1 (aka Power Law)

PG&E's Risk Scaling Function accounts for different kinds of Consequence Distributions

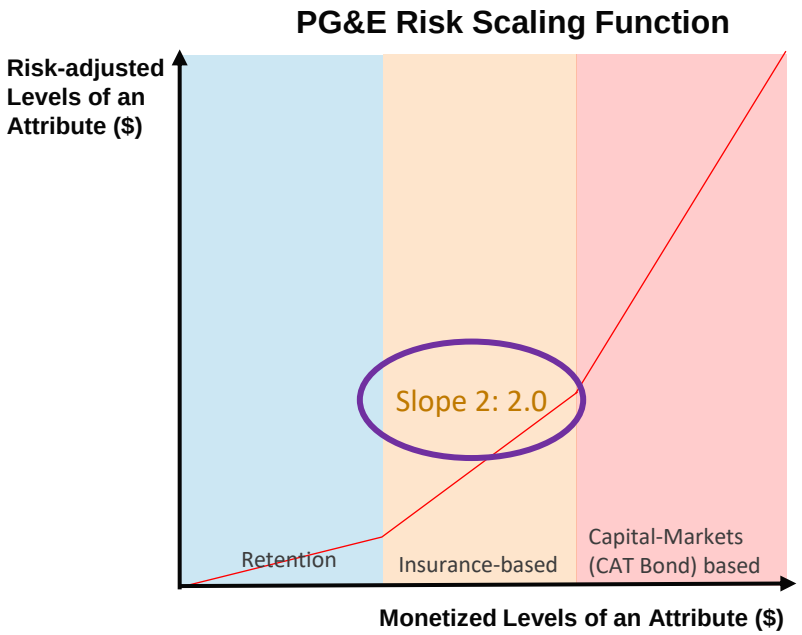
PG&E Risk Scaling Function

PG&E's Risk Scaling Function accounts for different kinds of Consequence Distributions

- For the 2024 RAMP, PG&E will apply the same Risk Scaling Function for all Risks.
- However, the overall Risk Premium for each Risk will be different based on how well-behaved ("thin-tailed") the Underlying Consequence Distributions are.



PG&E Risk Scaling – Insurance-based Region Calibration



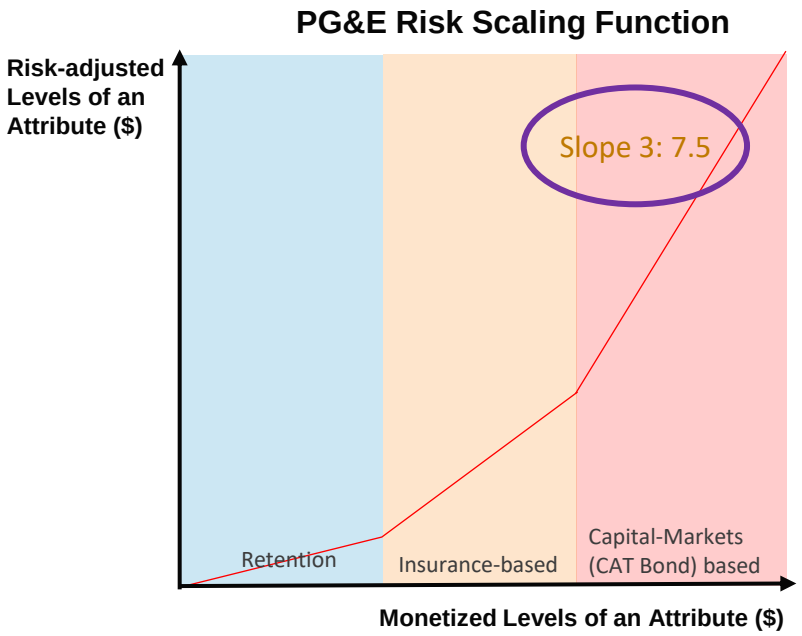
1. Insurance Pure/Direct Loss Ratios (Losses / Premiums) can be used as a proxy for (the inverse of) Slope 2

    - 2014-2023 Loss Ratios for Commercial Multiple Perils policies: 53% - 58%. Implies industry average risk premium (i.e., multiple of expected price) of 1.72x – 1.81x.

Source: National Association of Insurance Commissioners, US Property & Casualty and Titled Insurance Industries, 2023 First Half Results

2. Based on indicative pricing obtained in 2021 from PG&E's insurance broker, a risk premium of ~2.33x is likely for both Wildfire and non-Wildfire Risks

PG&E Risk Scaling – Capital-Markets Region Calibration

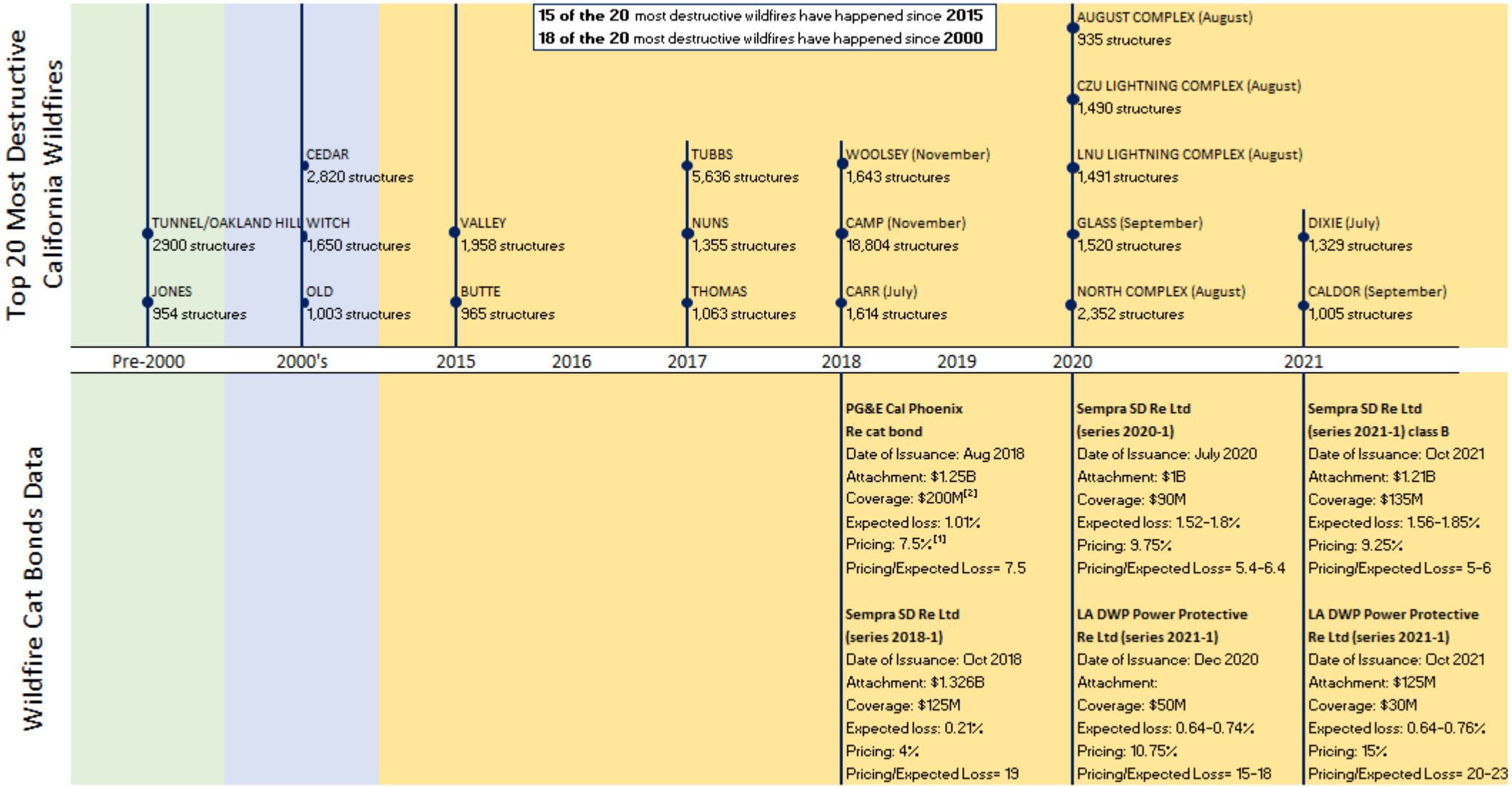


Wildfire Catastrophic (Cat) Bonds

- Wildfire Cat Bonds were used to transfer electric utilities' slice of wildfire risk in excess of $1B (for example) to investors.
- Historically these wildfire Cat Bonds were priced in the range of **5x to 23x** of the expected loss.
- PG&E's wildfire Cat Bonds closed on Aug 2018 (pre-Camp fire) had pricing at **7.5x** of the expected loss.
- Cat bonds price compared to the expected loss provides the cost of transferring catastrophic risks (>$1B), but still can underestimate of the cost of risk transfer due to a limited coverage & transaction cost.

1. National Association of Insurance Commissioners, US Property & Casualty and Titled Insurance Industries, 2023 First Half Results
2. Catastrophe Bond & Insurance-Linked Securities Deal Directory - Artemis.bm (https://www.artemis.bm/deal-directory)

Wildfire Cat Bonds Data



[1] This is coupon pricing. The actual cost was $26.8M, i.e., 13.5%.

[2] couldn't upsize for additional $500M

[Catastrophe Bond & Insurance-Linked Securities Deal Directory - Artemis.bm]

Cyber Cat Bonds Data

Cyber Cat Bonds were issued for the first time in 2023 and have been fast-growing

Pricing/Expected Loss for 2023 cat bonds varied from 5 to 10

PoleStar Re Ltd (Series 2024-1)

Date of Issuance: Dec 2023

Size: $140M

Expected Loss: 1.26%

Pricing: 13%

Pricing/Expected Loss=10.3

East Lan Re VII Ltd (Series 2024-1)

Date of Issuance: Dec 2023

Size: $150M

Expected Loss: 1.387%

Pricing: 9.25%

Pricing/Expected Loss=6.7

Matterhorn Re Ltd (Series 2023-1)

Date of Issuance: Dec 2023

Size: $50M

Expected Loss: 1.721%

Pricing: 12%

Pricing/Expected Loss=7.0

Long Walk Reinsurance Ltd (Series 2024-1)

Date of Issuance: Nov 2023

Size: $75M

Expected Loss: 1.97%

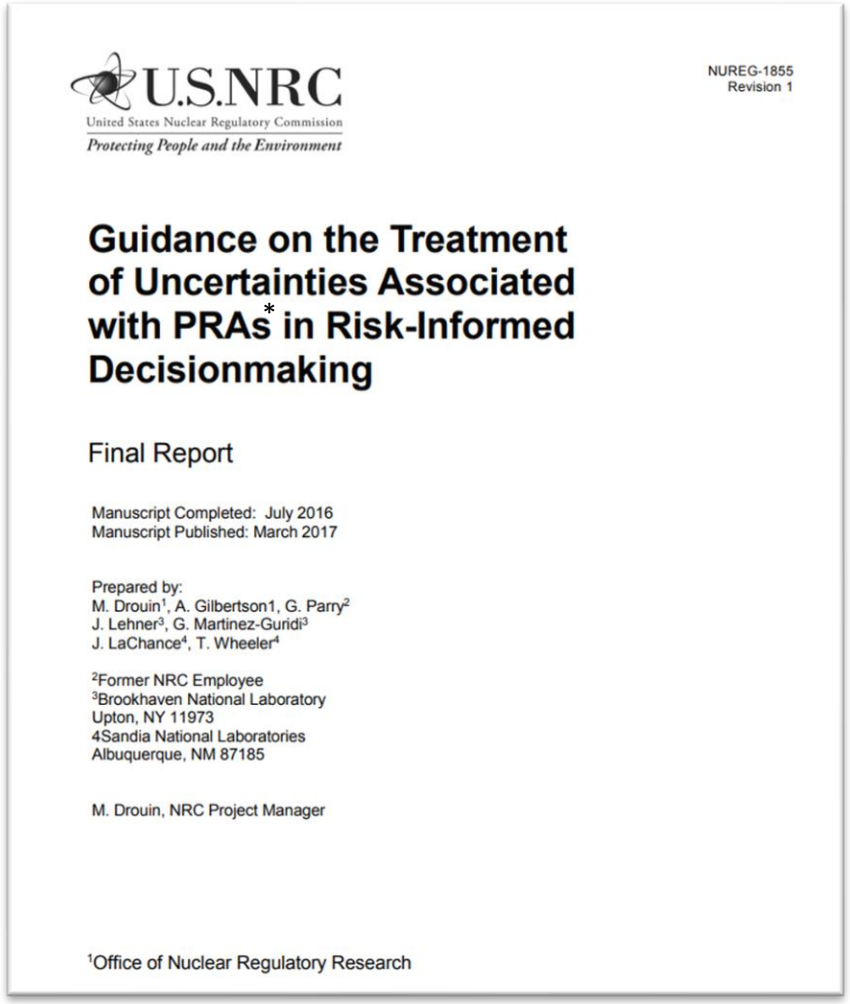
Pricing: 9.75%

Pricing/Expected Loss=5

- Catastrophe Bond & Insurance-Linked Securities Deal Directory - Artemis.bm

Uncertainty and Risk Modeling

There are Different Types of Uncertainty



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-1855
Revision 1

Guidance on the Treatment of Uncertainties Associated with PRAs* in Risk-Informed Decisionmaking

Final Report

Manuscript Completed: July 2016
Manuscript Published: March 2017

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"Generally speaking, there are two main types of uncertainty; aleatory and epistemic. **Aleatory uncertainty** is based on the randomness of the nature of the events or phenomena and cannot be reduced by increasing the analyst's knowledge of the systems being modeled. Therefore, it is also known as random uncertainty or stochastic uncertainty. **Epistemic uncertainty** is the uncertainty related to the lack of knowledge about or confidence in the system or model and is also known as state-of-knowledge uncertainty" p.5

In other words,
"Known" unknowns (aleatory)
vs
"Unknown" unknowns
(epistemic/Lack of Knowledge)

*PRA – Probabilistic Risk Assessment

Uncertainty and the RDF

Step 1A Principle 4 Deals with Known Uncertainty *only*

USNRC NUREG-1855	RDF
Aleatory uncertainty is the uncertainty associated with the random nature of events such as initiating events and component failures. PRA models are constructed as probabilistic models and reflect the random nature of the constituent basic events such as the initiating events and component failures ...	**Principle 4**: 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.
Epistemic uncertainties arise when making statistical inferences from data and, perhaps more significantly, from incompleteness in the collective state of knowledge about how to represent plant behavior in the PRA model. The epistemic uncertainties relate to the degree of belief that the analysts possess regarding the representativeness or validity of the PRA model and in its predictions …	Does not specifically identify this kind of uncertainty, but the elements of the CBA provide the flexibility to account for it.

- Probabilistic models cannot account for the Lack of Knowledge in, or suitability of, the models themselves
- When PG&E refers to addressing Uncertainty with the Risk Scaling Function, it means accounting for the Lack of Knowledge.
- Principle 6 mentions that the Risk Scaling Function can be used to express Risk Aversion, which simply means it can be used to determine risk premiums. Epistemic uncertainty is a valid reason to be risk averse, i.e., to be willing to pay a risk premium because the expected value likely underestimates risk.

Accounting for Uncertainty / Limitations of Risk Modeling

Flexibility in Risk-informed Decision Making is important in accounting for Lack of Knowledge

Type of Epistemic Uncertainty	USNRC NUREG-1855 Approach	PG&E RDF Approach
Parameter Uncertainty (e.g., is the mean being estimated accurately?)	Bayesian analysis, etc.	Sensitivity Analysis / PG&E Transparency Proposal
Model Uncertainty	Various, including using Consensus models	Consensus Distribution – Market Implied / Risk-Adjusted Consequence Distribution using PG&E Risk Scaling Function Sensitivity Analysis / PG&E Transparency Proposal
Completeness Uncertainty ("uncertainty from risk contributors that are not accounted for")	Defense in Depth Safety Margins - "Unknown sources of completeness uncertainty are addressed in risk-informed decision making by other methods, such as safety margins …" p.12 In other words, be more conservative	Use Risk Scaling Function to reflect Risk Aversion, resulting in a risk premium over the expected price*, i.e., be more conservative by being willing to pay a premium over the expected price to avoid unknown, extreme outcomes. **Consider Other Factors**

* Presence of a risk premium (ie, > expected value) implies Risk Aversion and vice versa

Results of CBA for PG&E's top Safety Risks

(1) The results of applying Attribute Monetization is reflected in Risk-Neutral Value
(2) The results of applying PG&E's risk averse Risk Attitude Function are reflected in Risk-Adjusted Value.
(3) Risk Premium is the ratio of (2) to (1), which shows the degree of risk aversion applied for each attribute and each risk.

Risk Values are preliminary and subject to change in the 2024 RAMP report. Not for Any Use other than discussion in the 2024 PG&E RAMP pre-filing workshops.

This Information was requested at the February 7, 2024 Workshop facilitated by the CPUC's Safety Policy Division and served February 9, 2024 on all members on the service lists for CPUC Proceedings A.20-06-012 and R.20-07-013.

	Risk-Neutral Value ($M) [1]					*Risk-Adjusted Value ($M, risk-adjusted)* [2]					*Risk Premium* [3]				
Risk Event	**Safety**	**Electric Reliability**	**Gas Reliability**	**Financial**	**Total**	**Safety**	**Electric Reliability**	**Gas Reliability**	**Financial**	**Total**	**Safety**	**Electric Reliability**	**Gas Reliability**	**Financial**	**Total**
Wildfire with PSPS and EPSS	113	4,242	-	737	5,092	342	5,706	-	3,689	9,737	3.0	1.3	-	5.0	1.9
Loss of Containment on Gas Transmission Pipeline	29	-	15	8	52	140	-	22.4	26	188	4.7	-	1.5	3.2	3.6
Public Contact with Intact Energized Electrical Equipment	58	-	-	-	58	61	-	-	-	61	1.0	-	-	-	1.0
Electric Transmission System-wide Blackout	9	298	-	3	309	59	2,116	-	6	2,181	6.9	7.1	-	2.4	7.1
Failure of Electric Distribution Overhead Assets	50	3,034	-	105	3,188	52	3,118	-	105	3,275	1.0	1.0	-	1.0	1.0
Contractor Safety Incident	36	-	-	-	36	36	-	-	-	36	1.0	-	-	-	1.0
Employee Safety Incident	31	-	-	8	39	31	-	-	8	39	1.0	-	-	1.0	1.0
Cybersecurity Incident	4	155	4	20	183	25	933	24.8	43	1,026	5.6	6.0	6.8	2.2	5.6
Large Uncontrolled Water Release (Dam Failure)	4	-	-	69	73	21	-	-	417	438	5.0	-	-	6.0	6.0
Large Overpressure Event Downstream of Gas Measurement and Control Facility	4	-	0	1	5	20	-	0.3	1	21	4.8	-	1.6	1.1	4.2
Loss of Containment on Gas Distribution Main or Service	15	-	7	81	102	19	-	8.8	81	109	1.3	-	1.3	1.0	1.1
Failure of Electric Distribution Underground Assets	11	708	-	19	739	14	712	-	19	745	1.2	1.0	-	1.0	1.0

[1] Risk-Neutral Values are 2027 TY Baseline Values derived using the methodology described in slides 16-20 of PG&E's February 7, 2024 RAMP pre-filing workshop presentation material ("Presentation") but applying the risk-neutral risk attitude function (linear with slope 1), instead of PG&E's Risk Attitude Function presented in slide 18 of the Presentation.

[2] Risk-Adjusted Values are 2027 TY Baseline Values derived using the methodology described in slides 16-20 of PG&E's February 7, 2024 RAMP pre-filing workshop presentation material.

[3] Risk Premium was obtained by taking the ratio of Total Risk-Adjusted Value to Total Risk-Neutral Value for each Risk.

Additional info provided at this workshop

Risk Assessment in Practice

Kim Mullins, Principal – EORM Risk Analytics

Disclaimer: While the Risk presented below will appear in PG&E's 2024 RAMP, all numbers and results presented are preliminary and solely intended for illustrative purposes.

Risk Assessment (Step 2A) and Mitigation Analysis (Step 3)

This section will walk through the calculation of a Risk Value, with the implementation of key Elements flagged where applicable.

CBR calculations are in the next section.

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 sum of each of the Risk-Adjusted Attribute Values using the utility's full Cost-Benefit Approach.
10	Identification of Potential Consequences of Risk Event	
11	Identification of the Frequency of the Risk Event	
14	Definition of Risk Events and Tranches	
15	Bow Tie	
17	Determination of Pre-Mitigation LoRE by Tranche	
18	Determination of Pre-Mitigation CoRE	
19	Measurement of Pre-Mitigation Risk Score	
24	Use of Expected Value for CoRE	

25.	Cost-Benefit Ratios Calculation	The Cost-Benefit Ratio calculation should be calculated by dividing the dollar value of Mitigation 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 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.

Overview of Quantitative Risk Assessment

In the RDF, “Risk is the potential for the occurrence of an event that would be desirable to avoid, often expressed in terms of a combination of various outcomes of adverse event and their associated probabilities.” Algebraically,

$$Risk = f\,(Likelihood, Consequence)$$

More precisely, RDF Element No. 13 establishes the “Calculation of Risk” to be computed as:

Risk = Likelihood of Risk Event (LoRE) x Consequence of Risk Event (CoRE)

PG&E breaks “LoRE” (left-hand side of the equation) into two components to derive an event **Frequency** value:

1. LoRE: Likelihood of a risk event per unit of exposure per year
2. Exposure: Number of units of exposure

Therefore, risk values are computed as follows:

Frequency of a Risk Event

How frequently the event is expected to occur during some time interval

Frequency = Exposure x Likelihood of Risk Event (LoRE)

x

Consequence of a Risk Event (CoRE)

Encompass relevant adverse impacts *when* the event happens

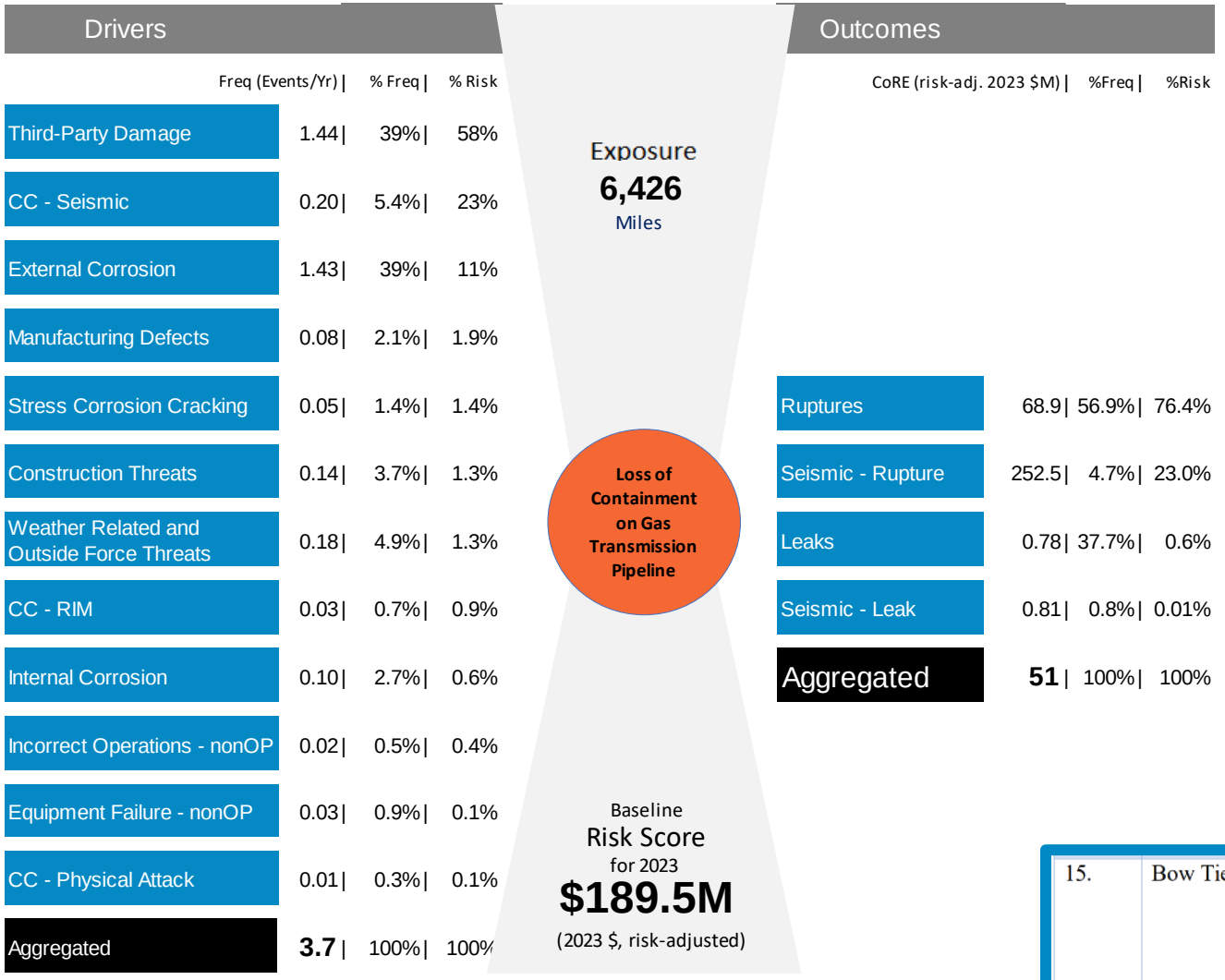
Grouped into **safety**, **reliability**, and **financial** attributes and quantified, and combined into a single metric using PG&E’s Cost-Benefit Approach (CBA)

Expressed in **risk-adjusted dollars** via the application of CBA

Overview of Example Risk Event

RDF No. 10 | RDF No. 11 | RDF No. 15

Loss of Containment on Gas Transmission Pipeline (LOCTM)



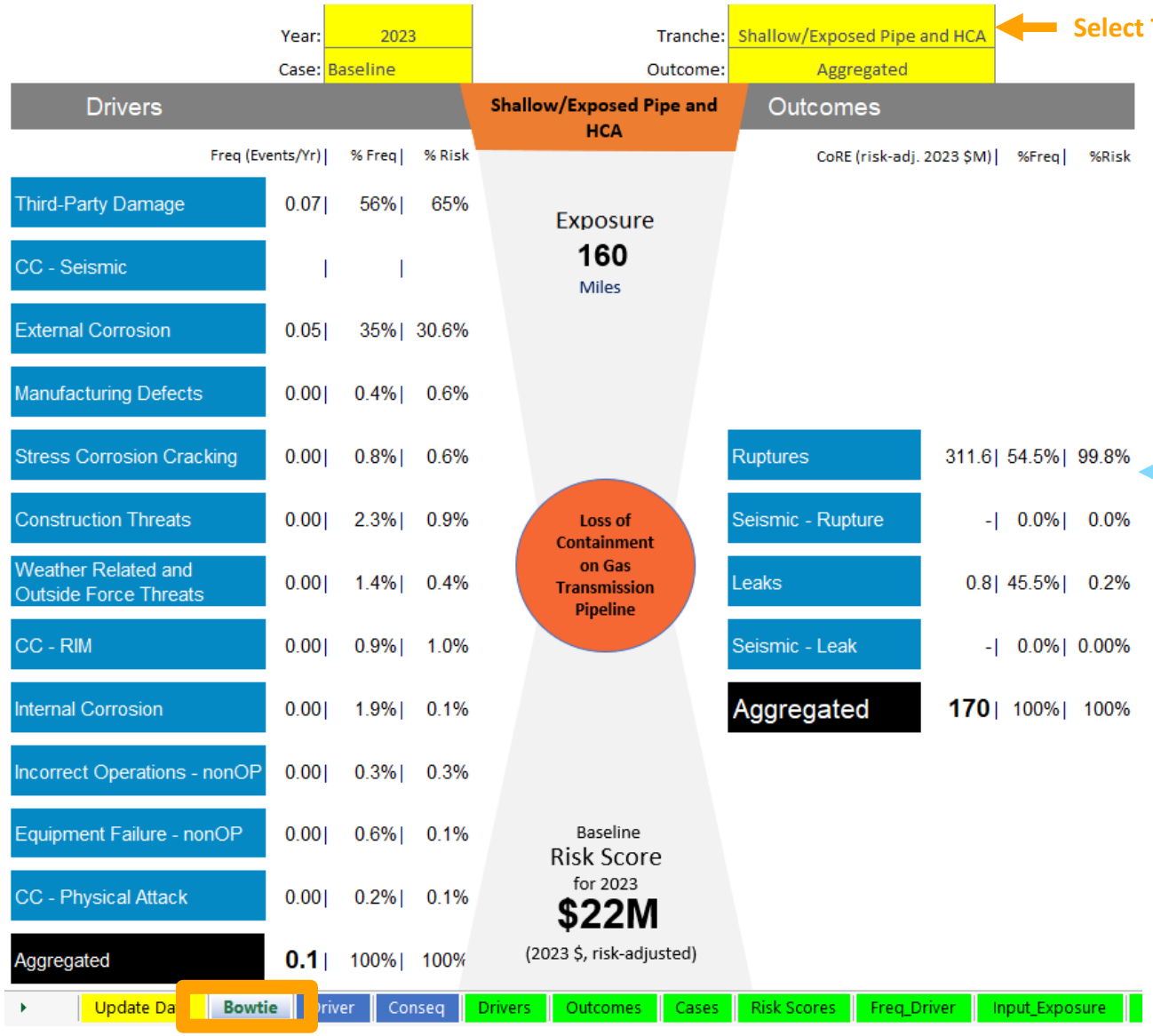
- **Risk Event**: Failure of gas transmission pipe resulting in a loss of containment with or without ignition. Failure can be a significant leak or rupture.
- **Drivers:** 10 driver/sub-drivers + 3 cross-cutting factor drivers
- **Tranches:** 24 based on threat, impact groupings
- **Outcomes:** 4 outcomes
- **Consequence attributes:** 3 attributes (safety, gas reliability, financial)
- **Data usage:** TIMP model, PG&E's Gas Quarterly Incident Report, PHMSA.

2024 RAMP risk safety rank: 2

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.

Walking through an example Tranche: Shallow/Exposed Pipe and HCA

Bowtie Risk Assessment is done at the specific Tranche level



The inputs and results for this Risk are to be included in the following modeling workpaper files in 2024 RAMP:

Name	Description
GO-LOCTM_Risk Workpaper Index.xlsx	Describes all workpaper files
GO-LOCTM-1_Risk Model Input File.xlsm	Risk model input file. Used to specify bow tie elements, frequencies, consequences and programs.
GO-LOCTM-2_Bow Tie File.xlsm	Summary output file including bow tie visualization and test year risk model results.
GO-LOCTM-3_CBR Input File.xlsm	Characterization of each mitigation and control program affecting TY baseline risk and for which CBRs are calculated. Includes summary of CBRs in 'CBR Results' tab.

The convention for workpaper files is "FA_RSKID-#_Purpose"

FA – Functional Area (Gas Ops, Electric Ops, etc.)
RSKID – Risk Name abbreviation (etc. LOCTM, WLDFR, etc.)
- Order of file (1, 2, 3, etc.)
Purpose – Description of what file contains.

Outcomes – Granular Consequences

RDF No. 10

PG&E further differentiates Consequences (and Frequencies) by Outcomes

Tranche: Shallow/Exposed Pipe and HCA

Frequency of Risk Event

Outcomes	Freq
Ruptures	0.07
Leaks	0.06
Aggregated	0.13

X

Consequence of Risk Event (CoRE)

Sampling Probability (Probability of non-zero consequence)		
Safety	Gas Reliability	Financial
18.8%	65.2%	91.1%
1.6%	41.2%	100%
11%	54%	95%

X

Expected Value in Natural Units per Risk Event conditional on non-zero consequences

Natural Units Per Event, Conditional on non-zero consequence		
Safety	Gas Reliability	Financial
EF/event	#cust/event	$M/event
17.0	4,262	14.5
0.4	249	0.5
8.4	2,437	8.2

Expected Risk-Adjusted Consequence of a Risk Event Conditional on non-zero consequence.

Conditional CoRE (risk-adjusted 2023 $M)		
Safety	Gas Reliability	Financial
1,306.3	9.4	66.5
6.3	0.4	0.5
715.0	5.3	36.5

WP ref: GO-LOCTM-2, worksheet 'Conseq', but includes some modifications for presentation

“LoRE” In Practice

Likelihood values are Specified at the Tranche/(sub)Driver/Outcome Level

24 Tranches

Tranche
Shallow/Exposed Pipe and HCA
Shallow/Exposed Pipe and MCA
Shallow/Exposed Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Shallow/Exposed Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Geohazard Pipe and HCA
Geohazard Pipe and MCA
Geohazard Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Geohazard Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Potential SCC/SSWC Pipe and HCA
Potential SCC/SSWC Pipe and MCA
Potential SCC/SSWC Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Potential SCC/SSWC Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Potential IC Pipe and HCA
Potential IC Pipe and MCA
Potential IC Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
…
All Other Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
All Other Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)

X

13 Drivers/Subdrivers

Driver/Sub-Driver
External Corrosion
Internal Corrosion
Stress Corrosion Cracking
Third-Party Damage
Manufacturing Defects
Selective Seam Weld Corrosion
Construction Threats
Weather Related and Outside Force Threats
CC - RIM
CC - Seismic
CC - Physical Attack
Incorrect Operations - nonOP
Equipment Failure - nonOP

X

4 Outcomes

Outcome
Ruptures
Leaks
Seismic - Rupture
Seismic - Leak

= Up to
1,248 Likelihood values to be specified*

*Certain combinations are not encountered/modeled in practice (e.g. Shallow Pipe and HCA Trance/External Corrosion/Seismic – Leak Outcome), and calculations can be turned off. Currently there are 584 active frequencies specified.

"CoRE" In Practice

Consequence Distributions are specified at the Tranche/Outcome/Attribute Level

RDF. No 5, 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."

24 Tranches

Tranche
Shallow/Exposed Pipe and HCA
Shallow/Exposed Pipe and MCA
Shallow/Exposed Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Shallow/Exposed Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Geohazard Pipe and HCA
Geohazard Pipe and MCA
Geohazard Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Geohazard Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Potential SCC/SSWC Pipe and HCA
Potential SCC/SSWC Pipe and MCA
Potential SCC/SSWC Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Potential SCC/SSWC Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Potential IC Pipe and HCA
Potential IC Pipe and MCA
Potential IC Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
…
All Other Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
All Other Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)

X

4 Outcomes

Outcome
Ruptures
Leaks
Seismic - Rupture
Seismic - Leak

X

3 Attributes

Attribute
Safety
Gas Reliability
Financial

= Up to
288 Probability Distributions required*

* Certain combinations are not encountered/modeled in practice (e.g. Shallow Pipe and HCA Trance/Seismic – Leak Outcome), and calculations can be turned off. Currently there are 168 active Consequence Distributions required.

Granularity is not just in tranche definition, but the interaction between tranches, drivers/sub-drivers, outcomes, and attributes

“LoRE x CoRE” In Practice

PG&E’s Risk Model Perform Risk Calculations at the Tranche/(sub)Driver/Outcome/Attribute Level *per year*

24 Tranches

Tranche
Shallow/Exposed Pipe and HCA
Shallow/Exposed Pipe and MCA
Shallow/Exposed Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Shallow/Exposed Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Geohazard Pipe and HCA
Geohazard Pipe and MCA
Geohazard Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Geohazard Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Potential SCC/SSWC Pipe and HCA
Potential SCC/SSWC Pipe and MCA
Potential SCC/SSWC Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
Potential SCC/SSWC Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)
Potential IC Pipe and HCA
Potential IC Pipe and MCA
Potential IC Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
…
All Other Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)
All Other Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)

X

13 Drivers/Subdrivers

Driver/Sub-Driver
External Corrosion
Internal Corrosion
Stress Corrosion Cracking
Third-Party Damage
Manufacturing Defects
Selective Seam Weld Corrosion
Construction Threats
Weather Related and Outside Force Threats
RIM
Seismic
Physical Attack
Incorrect Operations - nonOP
Equipment Failure - nonOP

X

4 Outcomes

Outcome
Ruptures
Leaks
Seismic – Rupture
Seismic – Leak

X

3 Attributes

Attribute
Safety
Gas Reliability
Financial

= *Up to* 3,744 Risk Calculations/ year*

*Certain combinations are not encountered/modeled in practice (e.g. Shallow Pipe and HCA Tranche/Seismic – Leak Outcome), and calculations can be turned off

Computing Frequency

Frequency = Exposure x LoRE

RDF No. 17: "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."

Exposure

Tranche#	Active	Tranche	Year1
1	TRUE	Shallow/Exposed Pipe and HCA	160.402

miles

Workpaper (WP) ref.: GO-LOCTM-1, worksheet '3-Tranche'

✖

This table includes 4 of the 1,248 rows in the LOCTM Frequency table

LoRE

Tranche	Sub-Driver	Outcome	Active Sub-Driver	Active	Driver	Distribution1_param1
Shallow/Exposed Pipe and HCA	External Corrosion	Ruptures	TRUE	TRUE	External Corrosion	0.000134421
Shallow/Exposed Pipe and HCA	External Corrosion	Leaks	TRUE	TRUE	External Corrosion	0.000151415
Shallow/Exposed Pipe and HCA	External Corrosion	Seismic - Rupture	TRUE	FALSE	External Corrosion	0
Shallow/Exposed Pipe and HCA	External Corrosion	Seismic - Leak	TRUE	FALSE	External Corrosion	0

events/mile/yr

WP ref: GO-LOCTM-1, worksheet '4-Freq'

=

Tranche	Sub-Driver	Outcome	Active Sub-Driver	Active	Driver	Frequency
Shallow/Exposed Pipe and HCA	External Corrosion	Ruptures	TRUE	TRUE	External Corrosion	❶ 0.02156
Shallow/Exposed Pipe and HCA	External Corrosion	Leaks	TRUE	TRUE	External Corrosion	0.02429
Shallow/Exposed Pipe and HCA	External Corrosion	Seismic - Rupture	TRUE	FALSE	External Corrosion	0
Shallow/Exposed Pipe and HCA	External Corrosion	Seismic - Leak	TRUE	FALSE	External Corrosion	0

events/yr

❶ Interpretation: PG&E expects 0.02156 Rupture LOC events from External Corrosion among pipe in the Shallow/Exposed Pipe and HCA tranche in 2023.

Computing Attribute CoRE - Input Parameters

RDF No. 5 | RDF No. 18 | RDF No. 24

RDF No. 18: "The pre-mitigation CoRE is the sum of each of the pre-mitigation Risk-Adjusted Attribute Values using the utility's full Cost-Benefit Approach. The CoRE is calculated using the full Cost-Benefit Approach tool constructed consistent with Step 1A"

Attribute CoRE = EV[risk-adjusted attribute level]
= Prob(non-zero attribute level) x EV[risk-adjusted attribute level| non-zero attribute level]

This table includes 12 of the 288 rows in the LOCTM Consequence table

					Sampling Probability	Probability Distribution Parameters					
Tranche	Outcome	Attribute	Active	Distribution1	Distribution1 Prob	Distribution1 param1	Distribution1 param2	Distribution1 param3	Distribution1 param4	Distribution1 param5	
Shallow/Exposed Pipe and HCA	Ruptures	Safety	TRUE	Rtlognorm_bernoulli_ef	❶ 0.188	58.4	95.8	501	0.09		
Shallow/Exposed Pipe and HCA	Ruptures	Gas Reliability	TRUE	Rtlognormal	0.652	5,722.1	23,212.8	70,000			
Shallow/Exposed Pipe and HCA	Ruptures	Financial	TRUE	Truncpareto1	0.911	0.486	15,737.5	15,737.5	1	10,000,000,000	
Shallow/Exposed Pipe and HCA	Leaks	Safety	TRUE	Ztpoisson_bernoulli_ef	0.016	1.00	0.215				
Shallow/Exposed Pipe and HCA	Leaks	Gas Reliability	TRUE	Lognormal	0.412	249.3	1,271.5				
Shallow/Exposed Pipe and HCA	Leaks	Financial	TRUE	Lognormal	1	482,457.6	752,202.3				
Shallow/Exposed Pipe and HCA	Seismic - Rupture	Safety	FALSE	Rtlognorm_bernoulli_ef	0	58.4	95.8	501	0.09		
Shallow/Exposed Pipe and HCA	Seismic - Rupture	Gas Reliability	FALSE	Rtlognormal	0	5,722.1	23,212.8	70,000			
Shallow/Exposed Pipe and HCA	Seismic - Rupture	Financial	FALSE	Truncpareto1	0	0.486	15,737	15,737.5	1	10,000,000,000	
Shallow/Exposed Pipe and HCA	Seismic - Leak	Safety	FALSE	Ztpoisson_bernoulli_ef	0	1.00	0.215				
Shallow/Exposed Pipe and HCA	Seismic - Leak	Gas Reliability	FALSE	Lognormal	0	249.3	1,271.5				
Shallow/Exposed Pipe and HCA	Seismic - Leak	Financial	FALSE	Lognormal	0	482,457.6	752,202.3				

WP ref: GO-LOCTM-1, worksheet '6-Conseq'

6 of the 12 outcome/attribute combinations have non-zero probability of consequence

❶ When there is a Rupture on this tranche, there is a 18.8% probability that there will be Safety consequences.

Computing Attribute CoRE, Illustrated

RDF No. 18

RDF No. 24

Steps to compute Safety Attribute CoRE for Rupture outcome, Shallow/Exposed pipe and HCA tranche:

1. Simulate attribute consequence levels in Natural Units (EF for Safety) trials by sampling from the specified probability distribution (Monte Carlo)
2. Apply monetization factor to Natural Units to compute Monetized Levels for each trial
3. Apply Risk Attitude Function to compute Risk-Adjusted Levels Dollars for each trial
4. Compute expected value (average) over all trials
5. Multiply expected value by sampling probability

RDF No. 24: "The utility will use expected value for the Cost-Benefit Approach-based measurements and calculations of CoRE in Rows 13, 18, 19, 21, 22, and 23. …"

Performed in Python

Trial	Simulated Attribute Levels in Natural Units [EF]	Risk Attitude Function Region	Monetized Attribute Levels [$2023]	Risk Attitude Factor	Risk Adj. Attribute Levels [$2023]	Conditional CoRE [$2023 risk adj.]
1	5.68	2	$86,532,350	1.82	$157,834,699	$158
2	9.21	2	$140,193,527	1.89	$265,157,054	$265
3	1.14	2	$17,361,211	1.12	$19,492,421	$19
4	14.54	3	$221,449,963	3.65	$807,994,725	$808
5	3.93	2	$59,881,361	1.75	$104,532,722	$105
6	3.87	2	$58,943,259	1.74	$102,656,519	$103
7	10.38	3	$158,044,498	2.10	$332,453,736	$332
8	6.96	2	$105,936,853	1.86	$196,643,706	$197
9	22.43	3	$341,558,054	5.00	$1,708,805,403	$1,709
…	…	…	…	…	…	…
10,000	9.01	2	$137,195,053	1.89	$259,160,106	$259
				5.05		

$1,306M Average Value

Prob(non-zero attribute level) x Avg[risk-adj attribute level| non-zero attribute level] = Attribute CoRE

18.8% **x** **$1,306M** **= $244.9M**

Computing Attribute CoRE, alternative visualization

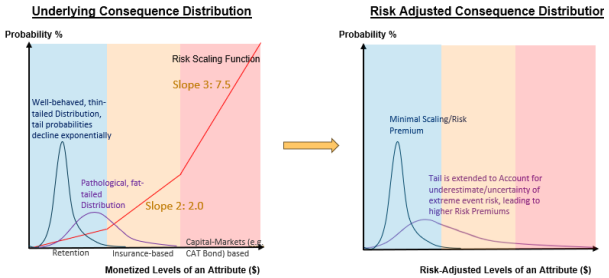
RDF No. 18

RDF No. 24

The Risk Scaling Function is Applied to Each Tranche/Outcome/Attribute Consequence Level

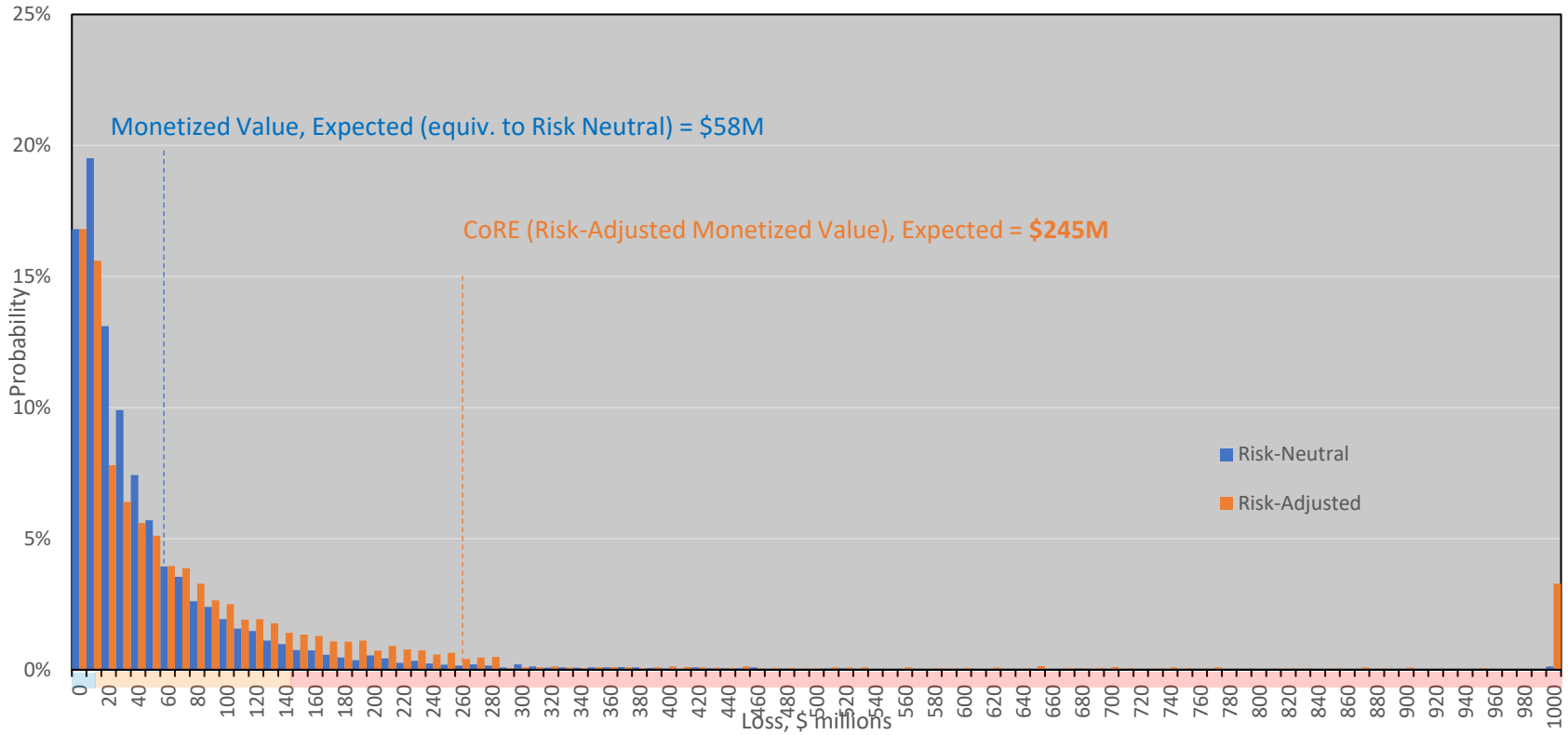
Tranche	Outcome	Sub-Attribute	Distribution1	Distribution1_Prob	Distribution1_param1	Distribution1_param2	Distribution1_param3	Distribution1_param4
				Sampling Prob	Mean (SIFs)	Standard Deviation of SIFs	Right Truncation Point of SIFs	Probability of Fatality given SIF
Shallow/Exposed Pipe and HCA	Ruptures	Safety	Rtlognorm_bernoulli_ef	19%	58.36	95.85	501	0.090

Recall



Estimated (Risk-Neutral) vs Risk-Adjusted Loss Distribution

Illustrative



Aggregating Monetized, Risk Adjusted trial values:

Risk Value Calculation

RDF No. 13

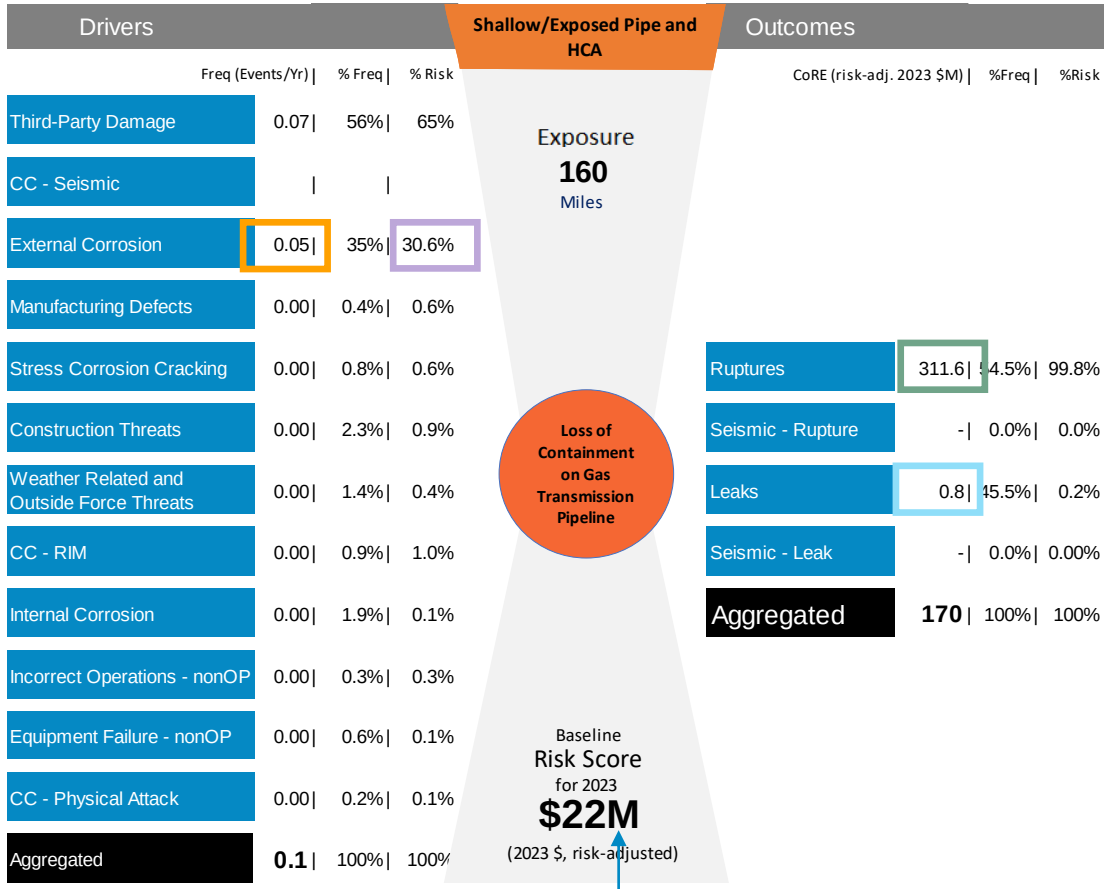
RDF No. 19

PG&E's Risk Model Perform Risk Calculations at the Tranche/(sub)Driver/Outcome/Attribute Level per year

Year 2023, Baseline
Tranche Shallow/Exposed Pipe and HCA
Driver External Corrosion

Attribute	Outcome	Frequency (events/yr)		CoRE ($M risk adj./event)		Risk Value ($M risk adj.)
Safety	Ruptures	0.0216	X	244.9	=	5.3
	Leaks	0.0243		0.1		0.002
	All					5.3
Gas Reliability	Ruptures	0.0216		6.1		0.1
	Leaks	0.0243		0.2		0.004
	All					0.1
Financial	Ruptures	0.0216		60.6		1.3
	Leaks	0.0243		0.5		0.01
	All					1.3
Aggregated	Ruptures	0.0216	Σ	311.6		6.72
	Leaks	0.0243		0.8		0.02
	All	0.05				**6.74**

6.74 driver risk / 22 tranche risk = 30.6% Risk



RDF No. 13: "…CoRE is the sum of each of the Risk-Adjusted Attribute Values using the utility's full [CBA]."

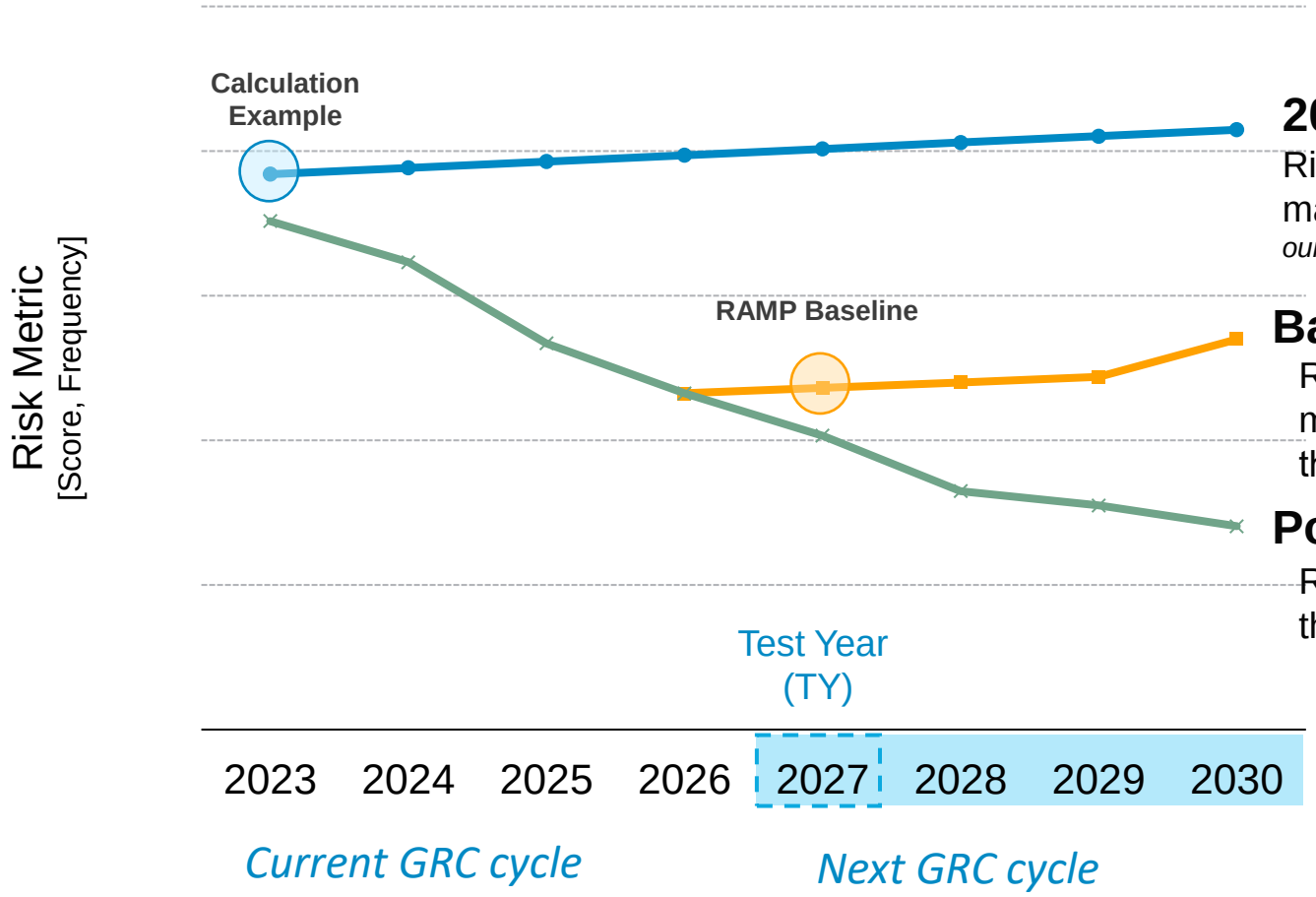
RDF No. 19: "The monetized **pre-mitigation risk value** will be calculated as the product of the pre-mitigation LoRE and the pre-mitigation CoRE for each Tranche subject to the identified Risk Event."

Risk Value varies over time

RDF No. 19

RDF No. 22

Consistent with D.21-11-009, TY 2027 will be the Baseline for RAMP.
PG&E Calculates Annual Risk Values over timeframe necessary for mitigation analysis.



2023 Baseline

Risk trajectory reflecting historic/current PG&E risk management activities, external factors *(what does the past, our current knowledge, tell us about what the future might look like)*

Baseline ("TY Baseline")

Risk trajectory reflecting all risk reduction benefits from all risk mitigation activities projected to have been performed prior to the Test Year (TY) [2027 for PG&E's rate case cycle]

Post-Mitigation

Risk trajectory reflecting proposed mitigation executing through the end of the rate case cycle [2027 to 2030]

Mitigation Analysis and Cost-Benefit Ratios (CBR)

Disclaimer: While the Risk presented below will appear in PG&E's 2024 RAMP, all numbers and results presented are preliminary and solely intended for illustrative purposes.

Risk Assessment (Step 2A) and Mitigation Analysis (Step 3)

This section will walk through the calculation of a Cost Benefit Ratio (CBR), with the implementation of key Elements flagged where applicable, building upon the risk model presented in the previous section

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 sum of each of the Risk-Adjusted Attribute Values using the utility's full Cost-Benefit Approach.

Row	Element Name	Element Description and Requirements
25.	Cost-Benefit Ratios Calculation	The Cost-Benefit Ratio calculation should be calculated by dividing the dollar value of Mitigation 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 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.
16	Expressing Effects of a Mitigation	
20	Determination of Post-Mitigation LoRE	
21	Determination of Post-Mitigation CoRE	
22	Measurement of Post-Mitigation Monetized Risk Value	
23	Measurement of Risk Reduction Provided by a Mitigation	

Cost-Benefit Ratio (CBR)

RDF Element No.25: *"A Cost-Benefit Ratio is calculated by dividing the dollar value of the Mitigation 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 Benefits should reflect the* ***full set of Benefits*** *that are the results of the incurred costs."*

$$CBR = \frac{\text{[NPV of Risk Reduction (in risk−adjusted \$M)]}}{\text{[NPV of Program Costs (in \$M)]}}$$

Mitigation Analysis Overview

Recall: Risk is the potential for the occurrence of an event that would be desirable to avoid, often expressed in terms of a combination of various outcomes of adverse event and their associated probabilities.[1] Algebraically,

Risk = f (Likelihood, Consequence)

PG&E measures as the product of:

Risk = Exposure x LoRE x CoRE

Risk Reduction (Δ Risk) is computed as the product of:

Event frequency reduced → **Reduction in Frequency (Δ Freq)** × **CoRE**

Event consequence reduced → **Freq** × **Reduction in CoRE (Δ CoRE)**

Both event frequency and consequence reduced → **Δ Freq** × **CoRE** + **Freq** × **Δ CoRE** - **Δ Freq** × **Δ CoRE**

Calculating post-mitigation LoRE, CoRE

RDF No. 15

RDF No. 21

RDF Element No. 15: "…For each Mitigation presented in the RAMP, the utility will identify which element(s) of its ass*ociate*d Bow Tie the Mitigation addresses."

Elements in PG&E's Bow Tie

- Tranche(s) (LoRE or CoRE mit.)
- Year(s) mitigation done (LoRE or CoRE mit.)
- Drivers or sub-drivers and Outcomes (LoRE mit.)
- Outcomes and Attributes (CoRE mit.)

RDF Element Nos. 20, 21: "…The post-mitigation LoRE/CoRE calculation will be conducted at the same level of granularity as the pre-mitigation analysis"

Post-Mitigation CoRE Requirements

- Program exposure units by tranche
- % of LoRE reduced (effectiveness) by tranche/driver/outcome
- % of CoRE reduced (effectiveness) by tranche/outcome/attribute
- Duration of risk reduction (benefit length) by tranche/driver/outcome
- Degradation rate of effectiveness over benefit length

Risk Reduction Example – Vintage Pipe Replacement

RDF No. 17

RDF No. 20

Program Exposure

Pre-Mitigation LoRE and CoRE depend on the tranche targeted by the mitigation program and how much of the tranche exposure will be mitigated

Program ID	Type	Program	Tranche	Tranche Exposure	Program Exposure 2027	Program Exposure 2028	Program Exposure 2029	Program Exposure 2030	Unit for Program Exposure
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Shallow/Exposed Pipe and HCA	160.4	0.5175	0.2128	0.2128	0.2128	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Shallow/Exposed Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)	399.8	0.0103	0.0039	0.0039	0.0039	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Geohazard Pipe and HCA	365.555	1.1022	0.3888	0.3888	0.3888	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Geohazard Pipe and MCA	132.388	0.3328	0.1062	0.1062	0.1062	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Geohazard Pipe and (IOC > 0 & rupture mode on Non-HCA/MCA)	28.163	0.0000	0.0005	0.0005	0.0005	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Geohazard Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)	853.609	0.4010	0.1999	0.1999	0.1999	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Potential IC Pipe and HCA	201.799	0.0000	0.0149	0.0149	0.0149	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Potential IC Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)	555.812	0.0352	0.0091	0.0091	0.0091	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	Potential Manufacturing Defect Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)	900.750	0.1281	0.1929	0.1929	0.1929	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	All Other Pipe and HCA	603.057	0.4045	0.1773	0.1773	0.1773	Exposure unit
LOCTM-M001	Mitigation	Vintage Pipe Replacement	All Other Pipe and (IOC = 0 or leak mode on Non-HCA/MCA)	845.128	0.0000	0.0088	0.0088	0.0088	Exposure unit

WP ref: GO-LOCTM-3, worksheet '1-Program Exposure'

Risk Reduction Example – Vintage Pipe Replacement

Effectiveness, Benefit Length, Degradation

Pre-Mitigation LoRE and CoRE depend on the tranche targeted by the mitigation program and how much of the tranche exposure will be mitigated

Vintage Pipe Replacement reduces LoRE, with effectiveness varying over seven targeted drivers

ID	Type	Program	Tranche	Driver	Subdriver	Outcome	Effectiveness - Quantitative	Benefit Length (yrs)	Effectiveness Degradation Rate	Effectiveness Degradation Method
LOCTM-M001	Mitigation	Vintage Pipe Replacement		Construction Threats			90%	100	0.33%	Linear
LOCTM-M001	Mitigation	Vintage Pipe Replacement		External Corrosion			75%	100	0.33%	Linear
LOCTM-M001	Mitigation	Vintage Pipe Replacement		Internal Corrosion			80%	100	0.33%	Linear
LOCTM-M001	Mitigation	Vintage Pipe Replacement		Manufacturing Defects			99%	100	0.33%	Linear
LOCTM-M001	Mitigation	Vintage Pipe Replacement		Stress Corrosion Cracking			80%	100	0.33%	Linear
LOCTM-M001	Mitigation	Vintage Pipe Replacement		Third-Party Damage			80%	100	0.33%	Linear
LOCTM-M001	Mitigation	Vintage Pipe Replacement		Weather Related and Outside Force Threats			56%	100	0.33%	Linear

WP ref: GO-LOCTM-3, worksheet '3-Eff - Freq Programs'

RDF No. 16: "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. …"

Blank entries for Tranche, Subdriver, Outcome indicate the effectiveness, benefit length, degradation rate do not vary by that bow tie element

Computing Risk Reduction

RDF No. 20 | RDF No. 21 | RDF No. 22 | RDF No. 23

Post-Mitigation LoRE, Risk Reduction for 2027

RDF No. 23: "The risk reduction provided by a risk mitigation will be measured as the difference between the values of the monetized pre-mitigation risk value and the monetized post-mitigation risk value."

Year	2027, TY Baseline
Tranche	Shallow/Exposed Pipe and HCA
Driver	External Corrosion
LoRE Effectiveness	75%

Outcome	Case	Exposure (mi)	LoRE (event/mi/yr)	CoRE ($M risk adj./event)	Risk Value ($M risk adj.)	Risk Reduction ($M risk adj.)
Rupture	Pre-Mitigation	0.517	1.31E-04	308.7	0.0209	0.01564
	Post-Mitigation	0.517	3.26E-05	308.7	0.0052	
Leak	Pre-Mitigation	0.517	1.47E-04	0.81	0.00006	0.00005
	Post-Mitigation	0.517	3.68E-05	0.81	0.00002	
Aggregate						**0.01568**

=(1-75%) * 1.31E-04

The following are equivalent calculation methods for Risk Reduction at this granularity:

Pre-Mitigation Risk – Post-Mitigation Risk
= 0.0209 - 0.0052

Exposure * ΔLoRE * CoRE
= 0.517 * (75%*1.31E-04) * 308.7

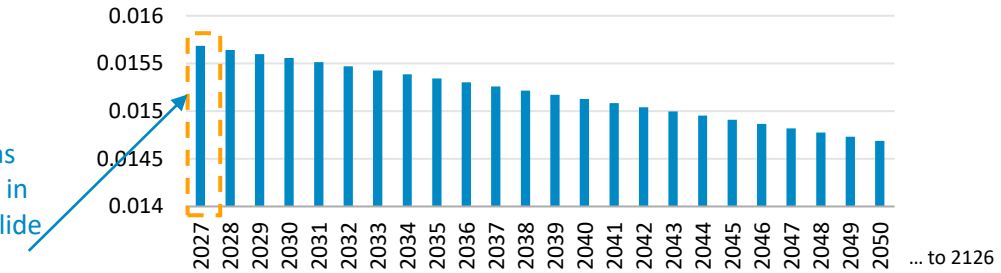
Cost-Benefit Ratio Calculation – Numerator

Reflecting Mitigation Benefits (Risk Reduction) over Time

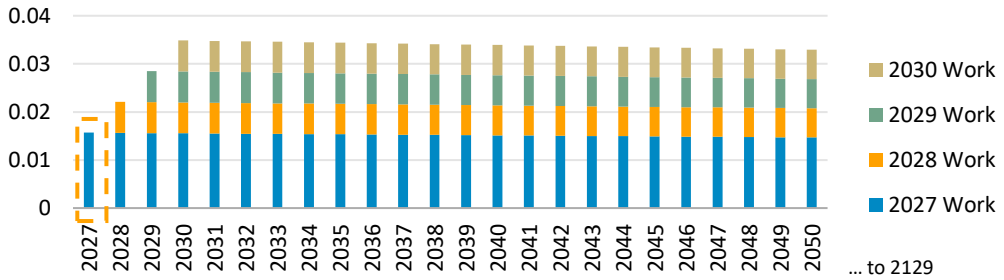
RDF No. 25

Risk Reduction ($M risk adj.) in Shallow/Exposed Pipe and HCA tranche due to External Corrosion mitigation from work in 2027

0.01568, as computed in previous slide



…layering in risk reduction from each year work is executed (2027 to 2030)



…layering in all drivers and applying real discount factor to get NPV Risk Reduction ($2023M risk adj.)

Program	Tranche	2027	2028	2029	2030	2027-2030
Vintage Pipe Replacement	Shallow/Exposed Pipe and HCA	0.95	0.37	0.36	0.34	**2.02**

2.02 is the numerator for the tranche-level CBR presented in RAMP

Finally, aggregating over all tranches to get program-level NPV Risk Reduction ($2023M risk adj.)

Program	Tranche	2027	2028	2029	2030	2027-2030
Vintage Pipe Replacement	Aggregated	2.96	1.10	1.05	1.00	**6.11**

6.11 is the numerator for the program-level CBR

RDF No. 25: "…The values in the numerator and denominator should be present values to ensure the use of comparable measurements of Benefits and Costs."

Cost-Benefit Ratio Calculation - Denominator

RDF No. 25

Cost Estimate

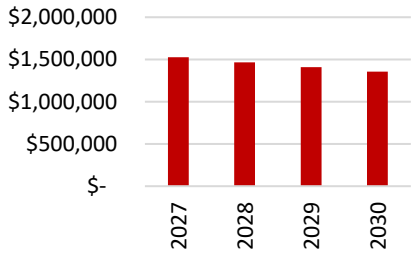
Program ID	Type	Program	CapEx USD 2027	CapEx USD 2028	CapEx USD 2029	CapEx USD 2030	Asset Type	PVRR Multiplier
LOCTM-M001	Mitigation	Vintage Pipe Replacement	$ 2,000,121	$ 2,055,862	$ 2,115,144	$ 2,174,388	Gas transmission & storage	1.37

WP ref: GO-LOCTM-3, worksheet '2-Program Cost'

Computing $2023 dollars for each year of work

Σ NPV of costs = $5,755,193

NPV including PVRR = **$7,876,295**



$$\text{Program CBR} = \frac{\text{[NPV of Risk Reduction (in risk adj \$M)]}}{\text{[NPV of Program Costs (in \$M)]}} = \frac{6.11}{7.876} = \mathbf{0.78}$$

Capital Investments are recovered over the lifetime of the asset and have an associated Rate of Return. Using the direct capital expenditure in our CBR is not accurate. Instead, we compute a **present value of revenue requirement** (PVRR). It is a multiplier to the net present value (NPV) of capital spend, representing the revenue requirement of capital investment over asset lifetime.

Translate Year N $ → cash flow → NPV → PVRR

Where applicable, a multiplier for incremental O&M expenses incurred by capital investments is similarly factored into the cost NPV.

RDF No. 25: "… For capital programs, the costs in the denominator should include incremental expenses made necessary by the capital investment."

Session Review

Paul McGregor, Senior Director EORM

Key Takeaways

PG&E has demonstrated in today's workshop how we will implement the Cost-Benefit Approach as directed by D.22-12-027.

D.22-12-027, p.27, *"… At the workshop providing a demonstration of the Cost-Benefit Approach ("Cost-Benefit Approach Demonstration Workshop"), PG&E should illustrate how a dollar valuation approach impacts its risk assessment and Mitigation proposals using an example from at least one high-priority risk."*

- ✓ Showed how PG&E will implement the Principles that constitute the Cost-Benefit Approach (as given in RDF Step 1A – Building a Cost-Benefit Approach).
- ✓ Demonstrated how the dollar valuation approach impacts risk assessment (i.e., risk values) on a high-priority risk (Loss of Containment on Gas Transmission Pipeline, #2 safety risk).
- ✓ Demonstrated how dollar valuation leads to a Cost-Benefit Ratio (CBR) for a mitigation program (Vintage Pipeline Replacement).

Q&A / Discussion

Appendix

Program Cost Estimates – Present Value Revenue Requirement (PVRR) Example

PVRR Implementation

Capital Investments are recovered over the lifetime of the asset and have an associated Rate of Return. Using the direct capital expenditure in our CBR is not accurate. Instead, we compute a **present value of revenue requirement** (PVRR). It is a multiplier to the net present value (NPV) of capital spend, representing the revenue requirement of capital investment over asset lifetime.

Translate Year N $ → cash flow → NPV → PVRR

Example: For a $100M Capital Investment in Electric Distribution (<69kV), NPV dollar flows over asset lifetime (30 yrs) allow us to calculate Revenue Requirement, PVRR multiplier.

Yr	Return	Depreciatn	Taxes	Insurance	Fixed Charges	M&O	Rev Req	Capital / Rev Req
1	7.3	3.9	3.6	0.6	15.3	0	15.3	7
2	7	3.9	3.1	0.6	14.6	0	14.6	7
…	…	…	…	…	…	…	…	…
29	-0.5	3.9	0.7	0.6	4.7	0	4.7	21
30	-0.7	-12.8	-1	0.6	-13.9	0	-13.9	-7
NPV	***55.4***	***47.1***	***29.5***	***7***	***138.9***	***0***	***138.9***	***9***

138.9 / 100 = 1.39

ICE Calculator Detail

ICE Calculator models interruption as a function of the following variables with their coefficients.

Table 1. Residential Model Coefficients and Average Values

Variable	Probit Model Coefficients	GLM Model Coefficients	Average Value
Interruption Characteristics			
duration	0.002	0.002	167.8
duration²	-6.735E-07	-9.474E-07	82,197.8
summer	0.224	0.237	73.4%
afternoon	-0.255	-0.291	48.8%
evening	-0.083	-0.096	29.1%
Customer Characteristics			
ln(annual MWh)	0.130	0.262	2.4
household income	2.340E-07	1.653E-06	69,243.0
Constant	-0.053	1.299	N/A

Table 2. Small Commercial and Industrial Model Coefficients and Average Values

Variable	Probit Model Coefficients	GLM Model Coefficients	Average Value
Interruption Characteristics			
duration	0.003	0.004	190.8
duration²	-1.783E-06	-2.155E-06	107,424.9
summer	0.215	-0.384	89.3%
morning	0.537	-0.057	45.5%
afternoon	0.664	-0.032	37.6%
Customer Characteristics			
ln(annual MWh)	0.124	0.069	2.6
backupgen or power conditioning	0.082	0.308	27.1%
backupgen and power conditioning	0.272	0.538	3.5%
Industry			
construction	0.261	0.786	4.6%
manufacturing	0.176	0.587	7.8%
Constant	-1.332	7.000	N/A

Table 3. Medium and Large Commercial and Industrial Model Coefficients and Average Values

Variable	Probit Model Coefficients	GLM Model Coefficients	Average Value
Interruption Characteristics			
duration	0.005	0.005	162.4
duration²	-2.689E-06	-2.912E-06	82,724.2
summer	0.380	0.032	86.5%
Customer Characteristics			
ln(annual MWh)	0.118	0.489	6.6
Interactions			
duration x ln(annual MWh)	-3.183E-04	-1.270E-04	1,059.8
duration² x ln(annual MWh)	1.481E-07	1.071E-07	530,871.5
Industry			
manufacturing	0.203	0.818	23.3%
Regional Characteristics			
GDP / kWh (Non-residential)	0.024	0.073	$6.93
Constant	-1.082	4.916	N/A