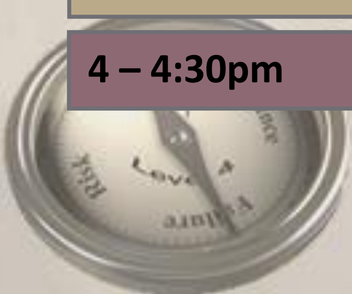
Level 4

Agenda

10 – 10:15am	CPUC & Level 4 Engagement Introduction	CPUC & William
10:15 – 11:15am	General IOU Approach to RSE	Sam
11:15 – 11:20am	Break	
11:20- 12:20am	IOU Approaches to Climate Change	Luis
12:20 – 1pm	Lunch	
1 – 2pm	IOU use of MAVF, PSPS, and other mitigations	Max
2 – 3pm	IOU Approaches to Wildfire RSE	Joe
3 – 3:15pm	Break	
3:15 – 4pm	Risk modeling demo	Sam
4 – 4:30pm	CPUC Meeting close	CPUC

Admin | Demo | Content

The last 10 to 15 minutes of each content session will be for questions, feedback, and commentary



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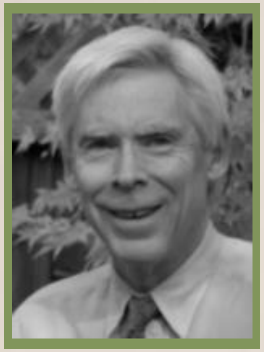
Engagement Team Bios



William Roetzheim, MBA	Sam Savage, PhD	Max Henrion, PhD	Matthew Raphaelson, MBA	Joe H. Scott, MS	Luis Medina, CPA
Engagement Manager	Risk Modeling SME	Risk Modeling SME	Risk Modeling SME	Fire Forecast Modeling SME	Lead Analyst
CEO & Founder Financial Modeler Project Manager Author	Executive Director Statistician Adjunct professor Author	CEO & Founder Decision Analyst Adjunct professor Author	CEO & CFO Financial Modeler	CEO & Founder Fire Ecologist Certified Forester	CPA Financial Modeler

Level 4 | SMEs

IOU Approach to Risk Spend Efficiency.

Sam Savage, Ph.D.

www.level4ventures.com

Goals

- **Improve Consistency.**
- **Improve Transparency.**
- **Simplify Compliance Requirements.**

Accounting for Risk and Uncertainty

1. Costs of Mitigation - Arithmetic.

2. Uncertain Risk Events - Arithmetic of Uncertainty.

3. Stakeholder Preferences - Decision Analysis.

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Accounting for Risk and Uncertainty

1. Costs of Mi…

I'll assume you know this

2. Uncertain Risk Events - Arithmetic of Uncertainty

3. …holder Preferences - Decision Analysis

… will talk about this but …

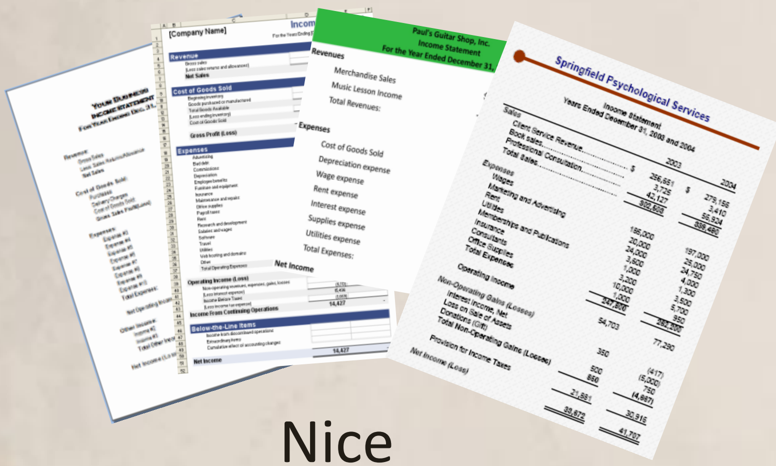
Is there a … stock will go down toda…

Heck no. I've shorted IBM!

RISK IS IN THE EYE OF THE BEHOLDER

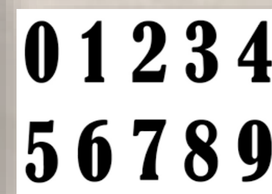
Arithmetic of Uncertainty

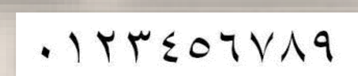
Formats of Financial Statement

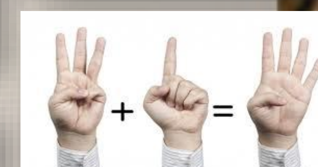


Nice

Representations of Numbers







Foundational

Biggest Shortcoming of Current RSE Approach is the Representation of **Uncertain Numbers.**

Arithmetic of Uncertainty

- Most people are reluctant to learn this due to Post Traumatic Statistics Disorder (**PTSD**)

  but …

- **Stochastic Libraries** as pioneered in **Insurance** and **Finance** make it easy and auditable.
- Recent advances in **Excel** make it universal.

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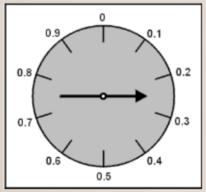
Arithmetic of Uncertainty

- Arithmetic tells us that X+Y=Z.
- The Arithmetic of uncertainty says “What do you want Z to be?”
- Here are your chances.

Arithmetic of Uncertainty

- The Number 1 of Uncertainty



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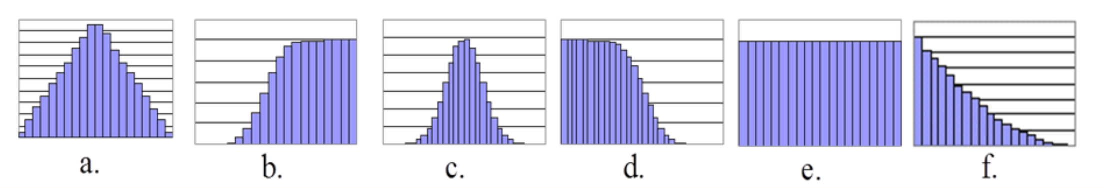
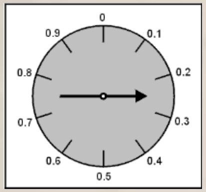


- One Plus One of Uncertainty



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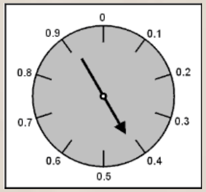

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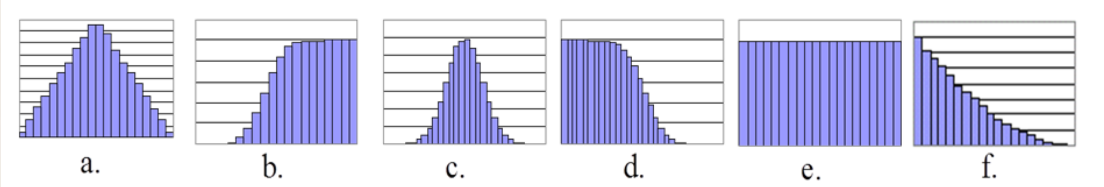

IOU Approach to Risk Spend Efficiency

- Assumptions.
- Bow Tie.
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
- Aggregation across tranches.
- Time dynamics.

IOU Approach to Risk Spend Efficiency

- Assumptions.
- Bow Tie.
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- Horizontal factors.
- Aggregation across tranches.
- Time dynamics.

Assumptions:

- Historical data.
- Expert opinion.

Improve standardization:

- Risk event definition.
- Leverage data of external agencies:
  - PHMSA.
  - EPRI.
  - Many more.

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IOU Approach to Risk Spend Efficiency

- Assumptions.
- **Bow Tie.**
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
- Aggregation across tranches.
- Time dynamics.

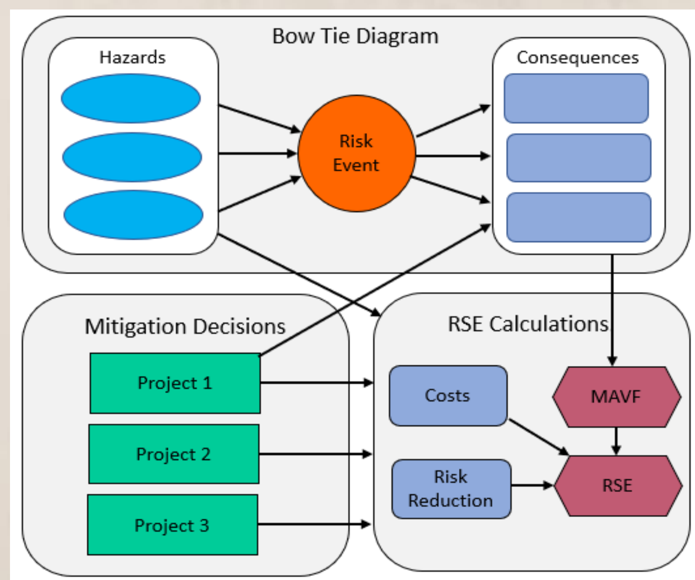
Bow Tie:

Excellent basis for risk management.

Improve standardization and extend:

- Canonical Bow Ties for risk events.
- Extend to include Influence Diagrams of mitigations. and RSE calculations.

Bow Tie extended to include Influence diagram



IOU Approach to Risk Spend Efficiency

MAVF:

- Simplify for ease of calculation.
- Standardize weights.

Max will discuss in detail.

- Assumptions.
- Bow Tie.
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
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- Time dynamics.

IOU Approach to Risk Spend Efficiency

- Assumptions.
- Bow Tie.
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Monte Carlo Simulation:

- All IOUs have capability.
- It generates Stochastic Libraries.
- Native Excel can now process the results.

Trials from a PG&E Monte Carlo simulation

TABLE 3-9
SAMPLE BOW TIE: SIMULATED SEVERE OUTCOMES VALUES IN NATURAL UNITS AND ATTRIBUTE CORE CALCULATIONS[(a)]

Trial	Safety				Reliability				Financial			
	Sim Natural Unit (EF)	Normalized	Scaled	Total CoRE	Sim Natural Unit (1k Cust)	Normalized	Scaled	Total CoRE	Sim Natural Unit ($M)	Normalized	Scaled	Total CoRE
1	5	0.05	1.3	646	84	0.11	6.3	315	871	0.17	12.8	3,207
2	8	0,08	3.2	1,611	86	0.12	6,6	330	871	0.17	12.8	3,209
3	8	0.08	3.2	1,611	91	0.12	7.2	362	982	0.20	15.2	3,791
4	10	0.10	5.0	2,503	96	0.13	8.0	400	987	0.20	15.3	3,819
5	12	0.12	7.1	3,556	97	0.13	8.0	401	1,006	0.20	15.7	3,923
6	12	0.12	7.1	3,556	104	0.13	8.1	406	1,028	0.21	16.2	4,039
7	13	0.13	8.2	4,083	104	0.14	9.1	453	1,031	0.21	16.2	4,053
8	14	0.14	9.2	4,611	108	0.14	9.1	456	1,051	0.21	16.6	4,158
9	14	0.14	9.2	4,611	108	0.14	9.6	481	1,119	0.22	18.1	4,517
10	15	0.15	10.3	5,139	109	0.14	9.7	486	1,134	0.23	18.4	4,594
11	Safety CoRE 3,193				Reliability CoRE 409				Financial CoRE 3,931			
Sum of Attribute Values: 7,533												

(a) The Attribute CoRE is the average of the CoRE per trial for that Attribute.

IOU Approach to Risk Spend Efficiency

Risk Spend Efficiency:

Definition: Risk Reduction/$ Spent.

(Requires the Arithmetic of Uncertainty.)

- Assumptions.
- Bow Tie.
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
- Aggregation across tranches.
- Time dynamics.

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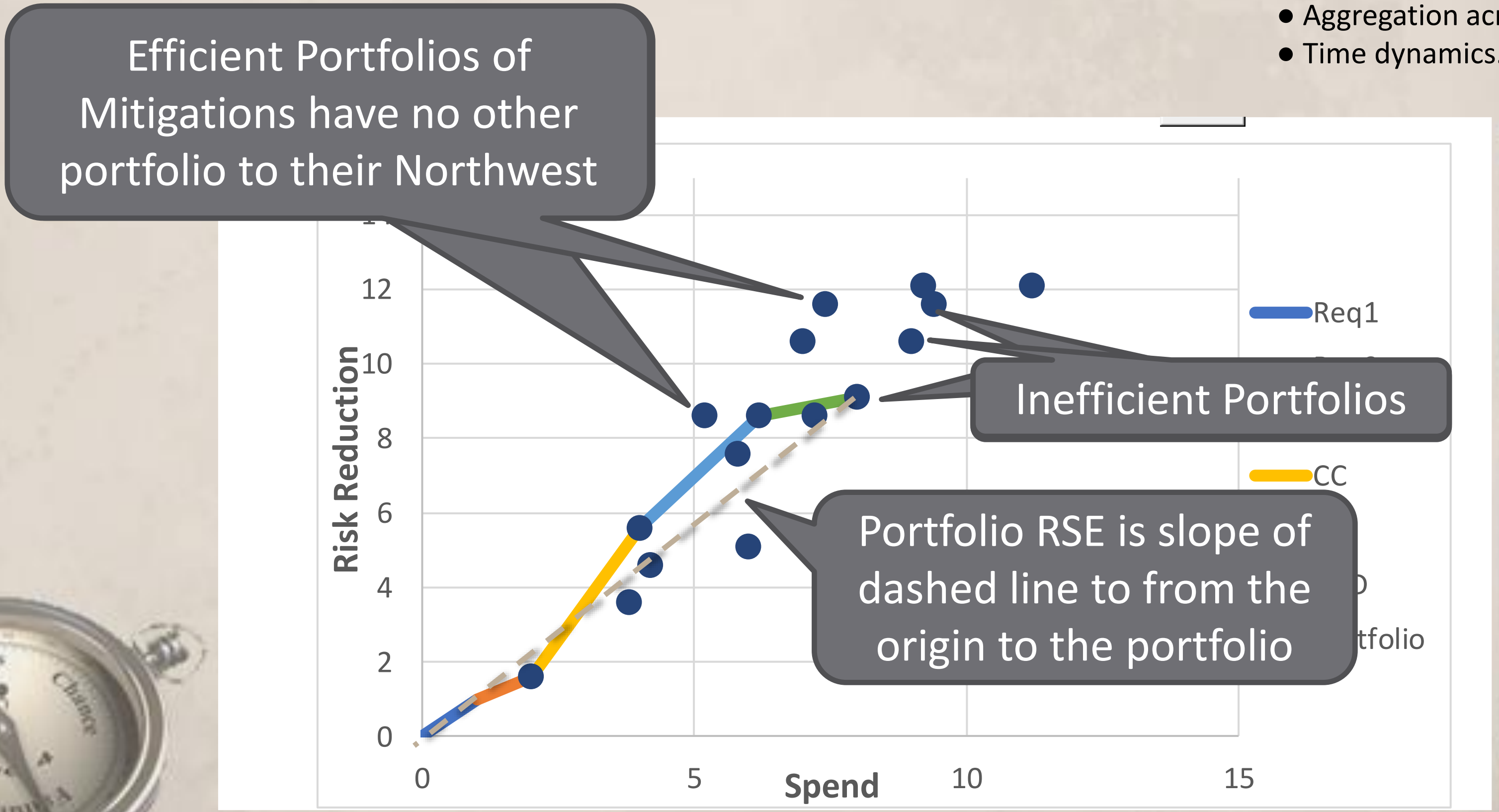
IOU Approach to Risk Spend Efficiency

Risk Spend Efficiency of portfolio:

An efficient portfolio has no other portfolio to their Northwest .

- Assumptions.
- Bow Tie.
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
- Aggregation across tranches.
- Time dynamics.



IOU Approach to Risk Spend Efficiency

RSE of portfolio with interactive or synergistic effects

- Assumptions.
- Bow Tie.
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
- Aggregation across tranches.
- Time dynamics.

Suppose the yellow project, which has a good RSE (as shown in the last slide), is redundant if the grey project is also chosen. Then instead of simple ranking, the well-known technique of Stochastic Optimization must be applied to create efficient portfolios.

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IOU Approach to Risk Spend Efficiency

- Assumptions.
- Bow Tie.
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
- Aggregation across tranches.
- Time dynamics.

Horizontal factors:

These include the effects of extreme demand or climate change that impact many assets at once.

- Currently not adequately handled by any IOU.
- Could be improved with Stochastic Libraries.

Level 4 IOU Approach to Risk Spend Efficiency

- Assumptions.
- Bow Tie.
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
- **Aggregation across tranches.**
- Time dynamics.

Aggregation across tranches:

Can yield invalid results without the Arithmetic of Uncertainty.

May be done correctly with Stochastic Libraries. See Report p. 23

Tranche 1		Tranche 2	
Trial	Sim. Natural Unit (EF)	Trial	Sim. Natural Unit (EF)
1	12	1	10
2	14	2	12
3	8	3	7
4	5	4	6
5	12	5	8
6	8	6	6
7	10	7	12
8	14	8	12
9	13	9	10
10	15	10	5

Figure 7: Monte Carlo trials of consequence.

First these results could be run separately and stored as stochastic libraries of data.

I7 =C7+F7

	Tranche 1		Tranche 2		Aggregated Risk	
	Trial	Sim. Natural Unit (EF)	Trial	Sim. Natural Unit (EF)	Trial	Sim. Natural Unit (EF)
	1	12	1	10	1	22
	2	14	2	12	2	26
	3	8	3	7	3	15
	4	5	4	6	4	11
	5	12	5	8	5	20
	6	8	6	6	6	14
	7	10	7	12	7	22
	8	14	8	12	8	26
	9	13	9	10	9	23
	10	15	10	5	10	20
Average		11.1		8.8		19.9

Figure 8: The aggregation of risk consequence.

23

IOU Approach to Risk Spend Efficiency

Time dynamics:

Aging of assets acknowledged by IOUs.

- In the future, RSE might be improved with dynamic multi-time-period optimization.

- Assumptions.
- Bow Tie.
- MAVF
- Monte Carlo simulation.
- Risk spend efficiency.
- Horizontal factors.
- Aggregation across tranches.
- Time dynamics.

IOU Approach to Risk Spend Efficiency recommendations, Part 1

1	**Define RAMP risks uniformly across the IOUs.**	This standard taxonomy of risks should incorporate prior work by industry recognized sources such as the Gas Technology Institute, the Canadian Energy Regulator, and the Electric Power Research Institute.
2	**Define a consistent measure of electric reliability**	Define a consistent measure of electric reliability across all IOUs.
3	**Common time horizon**	Use a common time horizon (across all IOUs) for costs and benefits, based on the lifetime of the mitigation and its assets – which may range from one or two years for vegetation management to perhaps 50 years for covered conductors or undergrounding.
4	**Standard discounting method**	Establish a standard method for utilities to discount costs and benefits (risk reduction) over mitigation lifetime using the same discount rate for both, perhaps using the average combined cost of capital for each utility.
5	**Increase use of pooled statistic data**	Maximize the use of public or pooled sources of risk statistics, for example, PHMSA Pipeline and Hazardous Materials Safety Administration, or EPRI for electricity. Where such sources are not available, standardize on risk statistics across the California IOUs where possible.

IOU Approach to Risk Spend Efficiency recommendations, Part 2

#	Recommendation	Description
6	Risk Interrelationships	Interrelationships between risks must be modeled to correctly aggregate risk across tranches as specified in the Settlement Agreement. See Appendix C and Appendix D.
7	Identification of synergistic or antagonistic effects	RDF analysis should identify interactions where mitigations have synergistic or antagonistic effects on each other. Where there are significant interactions, results should be presented for a group or portfolios of mitigations. The contributions of individual mitigations may be reported in terms of the marginal effect to MRR and RSE of adding each mitigation to (or subtracting it from) a portfolio. This will make use of stochastic optimization.
8	Consistent risk characteristics per tranche	Risks should be aggregated at a level of granularity such that the risk characteristics of each risk tranche are consistent.
9	Systematic sensitivity analysis inclusion	Analysis of all risk mitigations should include a systematic sensitivity analysis to identify which uncertain assumptions could have large effects on RSE and to clarify the robustness of its use to prioritize mitigation projects.
10	Portfolio RSE approach	To follow Element 14 of the Settlement Agreement and apply RDF and calculate RSE at "as deep a level of granularity as reasonably possible," when there are interdependencies between projects, the utilities should start with potential portfolios of projects, then measure the change in Portfolio RSE as individual projects are added or removed. This approach is further discussed in Appendix G.

IOU Approach to Risk Spend Efficiency recommendations, Part 3

#	Recommendation	Description
11	Finance and insurance scenario approach	The representation of uncertainty should be made repeatable and auditable by adopting the scenario approach pioneered in finance and insurance. This not only enables the arithmetic of uncertainty, but allows averages, percentiles, chance of exceedance or graphs to be generated from the results as needed.
12	Stochastic libraries standardization	Stochastic Libraries of uncertainties should be standardized and used within the context of Monte Carlo simulation for risk modeling by all of the IOUs. This would allow the proper aggregation of risk while increasing transparency and trust in the results.
13	Direct use of RDF Framework for selected circuits	To guide future decisions on where to choose enhanced powerline safety settings (EPSS), covered conductors (CC), undergrounding (UG) or something else, it would be helpful to ask the utilities to address these questions more directly using the RDF framework for selected circuits in various situations – e.g., by tier 3 vs tier 2 fire safety regions, vegetation, and terrain type – and to do so with a framework that allows direct comparison of their results to identify the sources of the differences.
14	Consistent readability factor	Adopt a consistent readability factor for all utilities, e.g., 1000. For RSE, we recommend dividing MRR*1000 by the mitigation cost in millions of dollars so that most RSEs are greater than one.
15	Templates for inputs and results	Standard templates should be established to present input assumptions, intermediate results, including MAVF attribute values, risk reduction, mitigation costs, and final values for RSE.

IOU Approach to Risk Spend Efficiency recommendations, Part 4

16	**Extension of bow ties**	The Bow Tie, a special case of the broader concept of the Influence Diagram, has already been adopted as a standard for representing the causes and consequences of risk events. Extending Bow Ties to full Influence Diagrams will further increase the domain of transparent representation of risk.
17	**Canonical standardized bow ties**	Canonical, standardized Bow Ties and influence diagrams should be developed where possible for risk events and mitigations both for ease of use and better comparisons between IOUs.

IOU Approaches to Climate Change

Luis Medina, CPA

Climate change approach comparison

Summarize the extent to which the four IOUs incorporate climate change related risks associated with wildfires and rising sea levels into their RAMP, WMP, and GRC filings.

Southern California Edison Company's
Risk Assessment and Mitigation Phase

Climate Change
Chapter 12

Risk Assessment and Mitigation Phase
Cross-Functional Factor

(SDG&E-CFF -2)

Climate Change Adaptation, Energy System Resilience, and Greenhouse Gas Emission Reductions

PACIFIC GAS AND ELECTRIC COMPANY
CHAPTER 20
ATTACHMENT A
CROSS-CUTTING FACTORS

A. Climate Change

1. Overview

Climate change presents ongoing and future risks to Pacific Gas and

Risk Assessment and Mitigation Phase
Cross-Functional Factor

(SCG-CFF-2)

Energy System Resilience

Comparison Methodology

Level 4 reviewed the IOU RAMP filings to identify and compare the following climate change approach areas of interest

1. Approach and time-horizon stated or implied, for climate change mitigation and impact management endeavors.
2. Proposed and/or implemented risk mitigations.
3. Mitigation inclusivity: do IOUs account for less-visible but present third-parties who may be greatly impacted from climate change threats and not usually well represented in mitigation strategies?
4. Utilization of external data to strengthen climate change impact assessment and mitigations?
5. Asset hardening and Sea-Level Rise preparedness?
6. Utilization of external impact indices.

From information we collected, we arrived at nine elements of climate change approach to compare

Climate change selected elements

Climate change approach elements and definitions	
CC Risk Management Element	**Definition**
Time-Horizon	Length of time over which climate change strategies are reviewed
Decentralization	Is the overall approach to addressing climate change one of adaption or one of resilience
Asset Planning and Load Forecasting	Climate change impact on IOU planning for deployment of energy assets and demand forecasts
Weather and hazard Monitoring	Technologies applied to monitoring weather and hazard patterns; specifically, as they apply to addressing climate change impact
Mitigations; internal and	Inclusion of cc mitigation strategies for IOU assets and externalities; costs by borne by a
Application of External Risk Models	Utilization of external risk models to guide how IOU will apply its adaption and/or resilience endeavors
Sources of Data	Data sources used to address climate change risks; input for internal models used
Asset Hardening and SLR preparedness	Modification of generation, transmission, and distribution assets due to expect impact from CC
External Impact Indices	Tools or standards developed by external authorities to define, measure, and/or identify impact of climate change in specific instances

The Level 4 team was especially concerned with climate change models utilized; explanation of how models are integrated and limitations

Climate Change IOU Approach comparison results

Comparison Results

CC Risk Management Element	All four utilities
Time-Horizon	Mostly comparable
Decentralization	Comparable
Asset Planning and Load Forecasting	Comparable
Weather and hazard Monitoring	Comparable
Mitigations; internal and external costs	Mostly comparable
Application of External Risk Models	Comparable
Sources of Data	Comparable
Asset Hardening and SLR preparedness	Mostly comparable
External Impact Indices	Comparable

PGE provided great examples of climate change integration disclosures

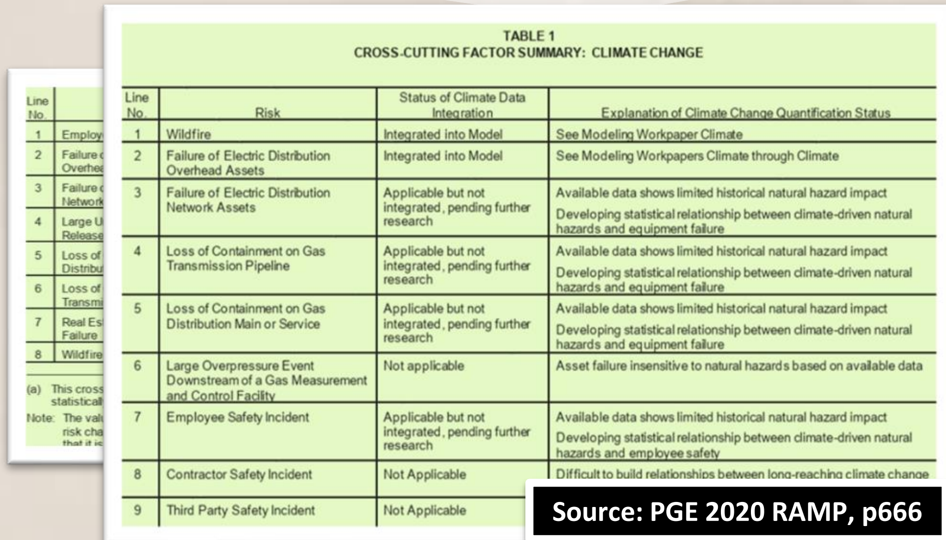

TABLE 1
CROSS-CUTTING FACTOR SUMMARY: CLIMATE CHANGE

Line No.	Risk	Status of Climate Data Integration	Explanation of Climate Change Quantification Status
1	Wildfire	Integrated into Model	See Modeling Workpaper Climate
2	Failure of Electric Distribution Overhead Assets	Integrated into Model	See Modeling Workpapers Climate through Climate
3	Failure of Electric Distribution Network Assets	Applicable but not integrated, pending further research	Available data shows limited historical natural hazard impact Developing statistical relationship between climate-driven natural hazards and equipment failure
4	Loss of Containment on Gas Transmission Pipeline	Applicable but not integrated, pending further research	Available data shows limited historical natural hazard impact Developing statistical relationship between climate-driven natural hazards and equipment failure
5	Loss of Containment on Gas Distribution Main or Service	Applicable but not integrated, pending further research	Available data shows limited historical natural hazard impact Developing statistical relationship between climate-driven natural hazards and equipment failure
6	Large Overpressure Event Downstream of a Gas Measurement and Control Facility	Not applicable	Asset failure insensitive to natural hazards based on available data
7	Employee Safety Incident	Applicable but not integrated, pending further research	Available data shows limited historical natural hazard impact Developing statistical relationship between climate-driven natural hazards and employee safety
8	Contractor Safety Incident	Not Applicable	Difficult to build relationships between long-reaching climate change
9	Third Party Safety Incident	Not Applicable	

Source: PGE 2020 RAMP, p666

Explanation of how external CC models are used was insufficient for all IOUs; not adequate to conclude how models were integrated, their impact

Climate Change Recommendations

#	Recommendation	Description
33	Bowtie inputs adjustments	Climate change related risk Bow Tie inputs should be adjusted to reflect climate change related characteristics.
34	Climate change related correlations	Correlations between climate change related risk Bow Tie inputs should be defined, modeled, and incorporated in the risk models.
35	Consider likely increases in frequency and size of wildfires	Estimates of MRR and hence RSE from mitigations with long-term effects, such as covered conductors or undergrounding, should consider likely increases in the frequency and sizes of wildfires, and hence more frequent use of PSPS, in the absence of such mitigations, based on the best available estimates and ranges of the effects of climate change.
36	Bowtie output adjustments	Risk Bow Tie outputs should be adjusted to incorporate greenhouse gas emissions, associated with risk events, using an accepted cost per added emission ton, such as the EPA recommended social cost of risk event related carbon emissions of $51/tCO2e.
37	Disclose at-risk assets and the extent	IOUs should provide an inventory of assets that will be threatened by rising sea-levels and increased storm surges due to forecast climate change related impacts at ten-year increments over a fifty-year period, along with a plan for mitigating those threats.

Lunch

Forty-minute lunch break.

Level 4

IOU Approaches to PSPS and other high-stakes mitigations

Max Henrion, PhD

Lumina Decision Systems

www.level4ventures.com

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Approaches to PSPS and other high-stakes mitigation activities

Issues	Utility		
	SCE	PG&E	SDG&E
Year of RAMP Report	2018	2020	2021
Plan dates	2018-2023	2020-22 & 2023-26	2022-24
Time horizon	To 2023	Life of the asset	Life of the asset
Discount rate for mitigation costs	No (explored discounts in Appendix 1)	7.1% (ATWACC)	Inflation rate (constant
Discount rate for risk reduction			3%
Readability factor (scaler) for risks	1 (no factor)	1000	100,000
Include outage impacts in PSPS analysis	No	Yes	Yes
Interactions between mitigations	No?	Yes	Yes?
Cost and benefits of PSPS	No	No	No
Covered conductors vs. undergrounding	Yes	Yes	Yes
Sensitivity analysis	Yes for time horizon and discount rate	No	No

PSPS and other high-stakes mitigations recommendations

38 Parametric cost-benefit* analysis	Perform parametric cost-benefit analysis of the "trigger" criteria for PSPS events, such as wind-speed and vegetation dryness, to evaluate the existing protocols and potentially refine the criteria in a way that increases the expected net benefit (or risk score).

*Parametric cost-benefit: Cost-benefit analysis method which uses regression analysis of a database of two or more similar systems to develop cost / benefit relationships which estimate net-benefits based on one or more parameters such as system performance or design characteristics.

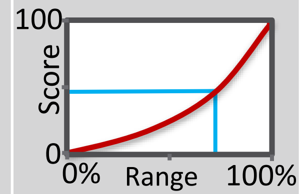
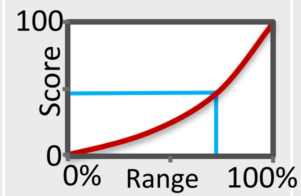
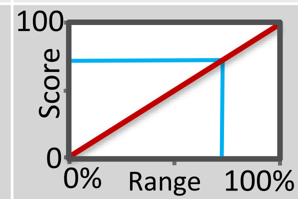
Level 4

IOU Use of MAVF

Max Henrion, PhD

Lumina Decision Systems

The MAVF scheme: An illustration

Attributes	Natural units	Value	Lower bound	Upper bound	% of range	Scaling function	Scaled score	Weights
Safety	Fatalities	20	0	100	20%		12	× 50%
Reliability	CMI Customer-minutes interrupted	500 million	0	2 billion	25%		8	× 25%
Financial	Dollars ($)	$500 million	$0	$5 billion	20%		20	× 25%
						Total weighted risk score	= **12**	

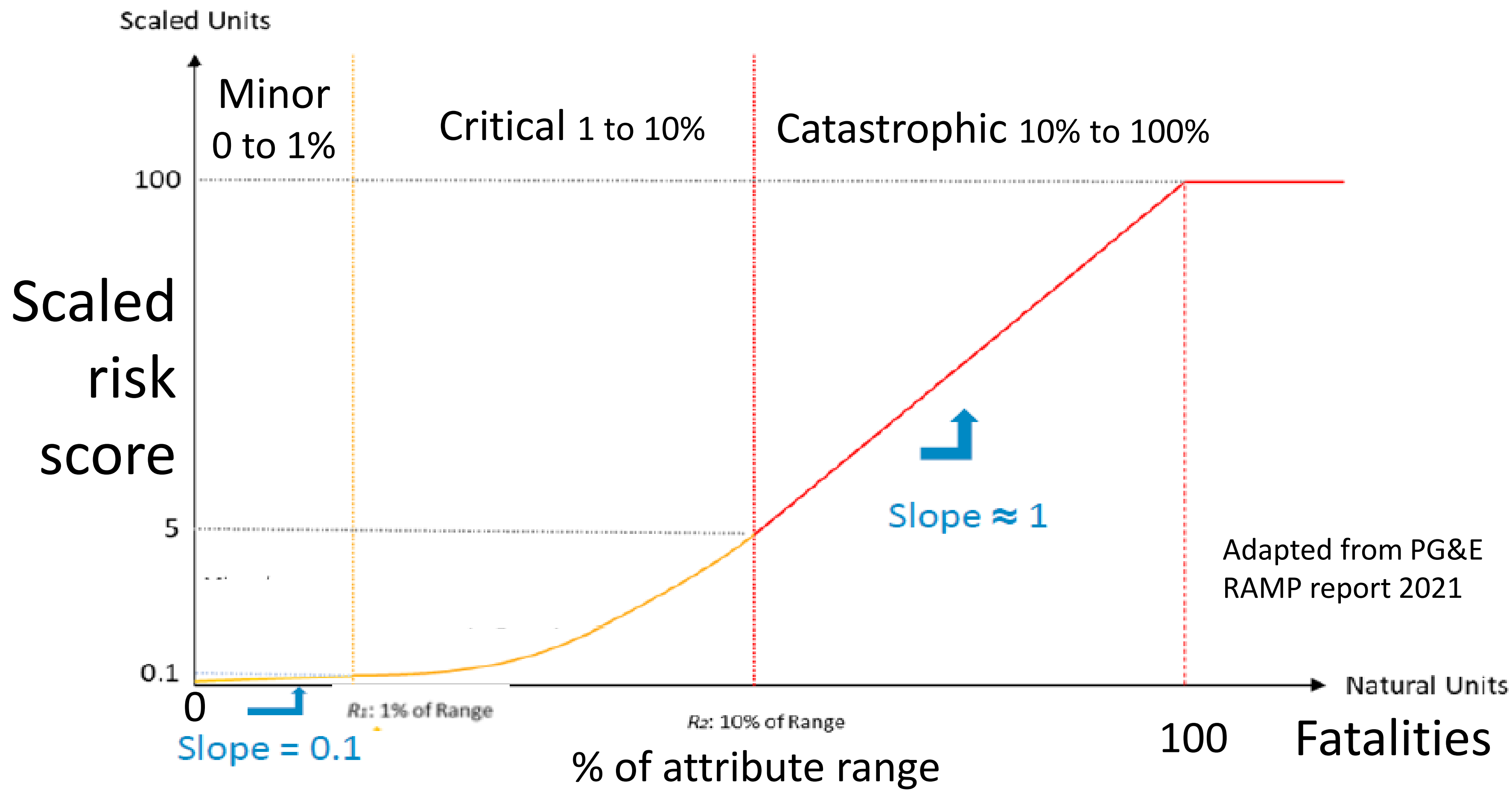
Blue numbers illustrate an application of this MAVF

MAVF: Multi-Attribute Value Function by IOU

Utility	Primary attributes	Sub attributes	Upper bound	Units	Primary weights	Sub attr factors	Scaling function Risk attitude
PG&E	**Safety**		100	Equivalent fatalities	50%		Averse
		Fatalities		Number		1	
		Serious injuries		Number		0.25	
	Electric reliability		4 billion	Customer minutes interrupted (CMI)	20%		Averse
	Gas reliability		750,000	Customers affected	5%		Averse
	Financial		$5 billion	USD ($)	25%		Averse
S. California Edison	**Fatalities**		100	Number	25%		Tolerant
	Serious injuries		500	Number	25%		Tolerant
	Reliability (CMI)		2 billion	Customer minutes interrupted (CMI)	25%		Neutral
	Financial		$5 billion	USD ($)	25%		Neutral
Sempra	**Safety**		20	Equivalent fatalities	60%		Neutral
		Fatalities		Number		1	
		Serious injuries		Number		0.25	
		Acres burned		acres		0.00005	
	Dollars		$500 million	USD ($)	15%		Neutral
	Stakeholder satisfaction		100	Index	2%		Neutral
	Reliability		1		23%		Neutral
SoCalGas		Gas Meters	100,000	Number of Gas Meters Experiencing Outage		50%	
		Gas Curtailment	666 MMcf	Volume of curtailments exceeding 250 MMcf/day		50%	
SDG&E		Gas Meters	50,000	Number of Gas Meters Experiencing Outage		25%	
		Gas Curtailment	250 MMcf	Volume of curtailments exceeding 250 MMcf/day		25%	
		Electric SAIDI	100 minutes	System Average Interruption Duration Index (SAIDI)		25%	
		Electric SAIFI	1 outage	System Average Interruption Frequency Index (SAIFI)		25%	

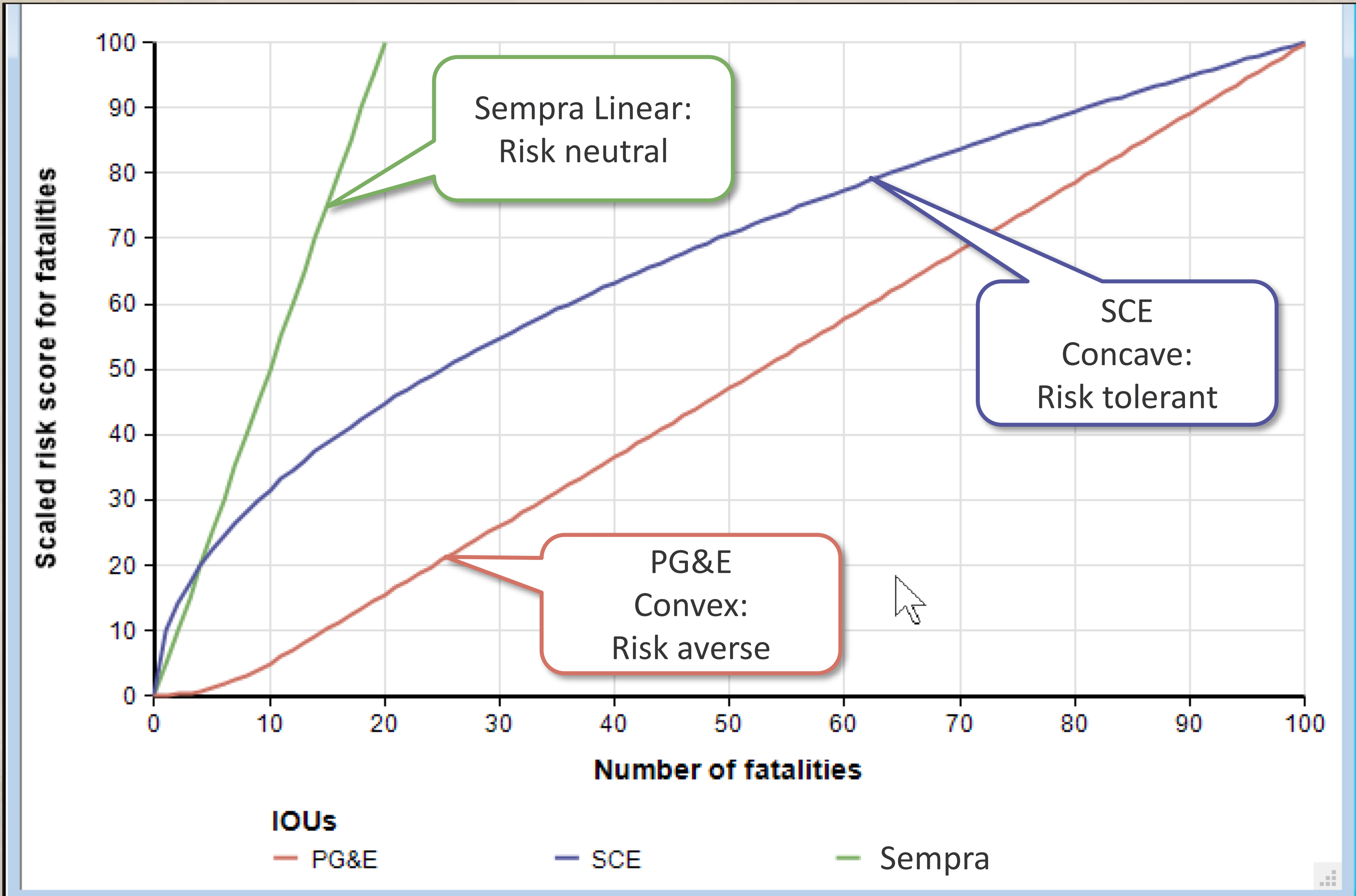
Level 4

PG&E MAVF: Scaling function for each attribute



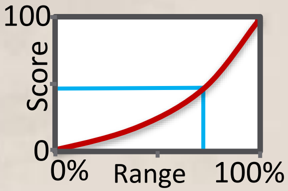
The risk score of the 100th fatality is about 10 times the 1st.
Risk score of the last 10 fatalities is about twice the first 10.
Same scaling function for Reliability and Financial attributes.

Scaled Risk Score for Fatalities by IOU



Use of MAVFs

- MAVFs are all consistent with the S-MAP agreement.
- They vary by IOU:
  - Set of attributes.
  - Weights, and ranges, and hence relative importance of attributes.
  - Scaling functions (risk-averse, neutral, and risk-tolerant.)



- It makes their results hard to compare.
- The upper bounds on attribute values reflect largest past events, not largest conceivable disasters.

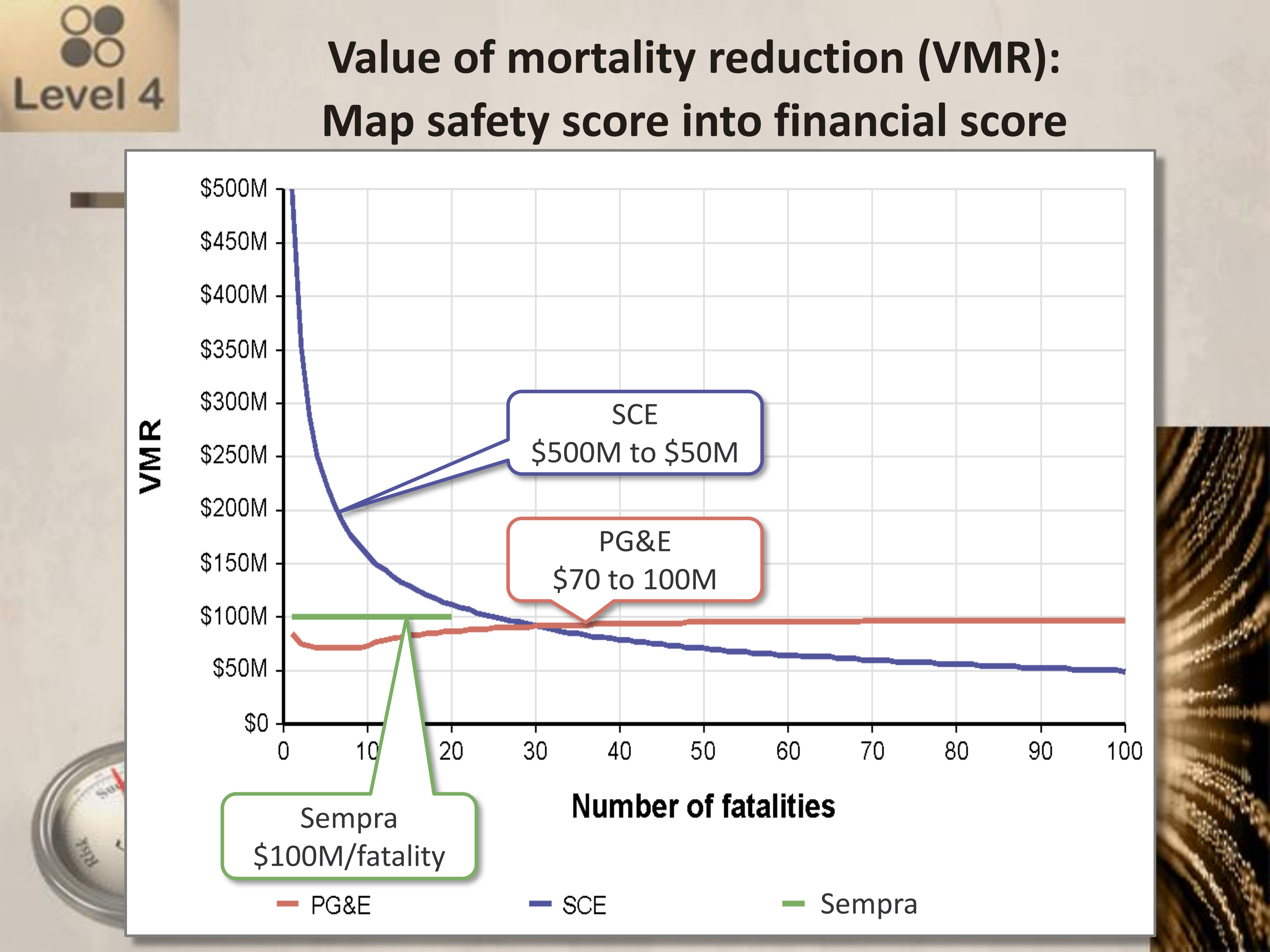
What is the importance of an attribute?

- S-MAP specifies: Weight of safety ≥40%.
- The relative importance of an attribute, say tradeoff between cost ($) and lives depends not just on relative weights, but also ranges, and scaling functions:

$$\frac{\text{Safety}\ /\text{Weight}_{\text{Safety}}}{\text{Ub}_{\text{Cost}}/\text{Weight}_{\text{Cost}}}$$

- Nonlinear scaling functions imply that tradeoff values vary over the ranges.
- The implications of the S-MAP constraint are complicated.

Value of mortality reduction (VMR): Map safety score into financial score



Trade-off values between attributes

- MAVF *seems* to avoid putting a monetary value on human life – *but it's unavoidable*.
- The Value of a Statistical Life (VSL) is widely used by Federal agencies for cost-benefit analysis.
- EPA calls it Value of Mortality Reduction (VMR), and recommends around $10M/fatality avoided.
- Implied reliability trade-off values from PG&E and SCE range from $1 to $2.50/CMI.
- Economic studies estimate the value of reliability for short-term outages – e.g., Value of Loss of Load (VOLL). Need more study of longer outages and gas.

Environmental Impact

- Not currently an attribute.
- Might include:
  - Wildfire effects including ecosystem damage, air quality from smoke, and GHG emissions.
  - GHG emissions from natural gas leaks.

Whose interests do MAVFs represent?

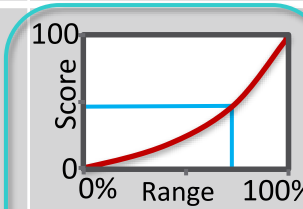
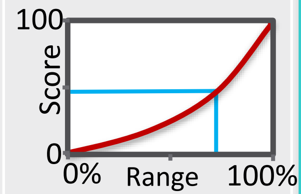
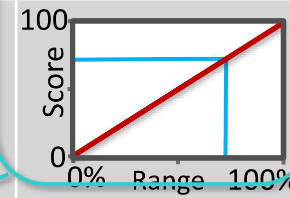
- IOUs, CPUC, ratepayers,
  or the people of California?
- Each IOU develops their own.
- S-MAP specifies that the financial attribute doesn’t represent shareholders.
- Wildfires affect many people – and GHGs are global.
- Should all IOUs use the same MAVF?

MAVF Recommendations

18	A single MAVF	Consider developing a single MAVF to represent ratepayers or the people of California for all IOUs.
19	Simplified MAVF	Consider a simplified MAVF scheme
20	Single risk-attitude	Use a single risk-attitude function to represent attitude to uncertainty to replace the separate nonlinear scaling functions for each attribute.
21	Trade-off values	Use trade-off values (e.g., VMR and CMI) based on Federal agencies and economic studies to estimate of weights and ranges or to replace them. (A constraint on VMR value would avoid the confusion of safety weight ≥40%.)
22	Environmental effects	Add environmental effects as an attribute.
23	Consistent Metrics	Define consistent metrics for electric and gas reliability across IOUs.
24	Upper bounds	Upper bounds of attributes should exceed largest conceivable catastrophes (or avoid them with trade-off values)
25	Monte carlo modeling	Use Monte Carlo to propagate uncertainties about RSEs through MAVFs – and do sensitivity analysis to identify key sources of uncertainty.

Level 4

The current MAVF scheme: An illustration

Attributes	Natural units	Value	Lower bound	Upper bound	% of range	Scaling function	Scaled score	Weights
Safety	Fatalities	20	0	100	20%		12	× 50%
Reliability	CMI Customer-minutes interrupted	500 million	0	2 billion	25%		8	× 25%
Financial	Dollars ($)	$500 million	$0	$5 billion	20%		20	× 25%
						Total weighted risk score		= 12

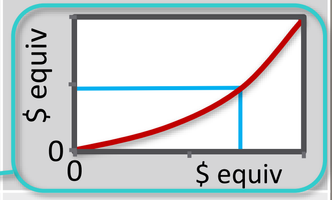
You need *n* upper bounds, *n* scaling functions, and *n* weights (sum to 100%) to specify an MAVF

n is the number of attributes: 3 in this illustration, 4 for current MAVFs

Blue numbers illustrate an application of the MAVF

Level 4

A simplified MAVF scheme using trade-off values instead of ranges and weights

Attributes	Natural units	Example value	Trade-off values	Equivalent cost
Safety	Fatalities	20	$100 million VMR	$2 billion
Reliability	Customer-minutes interrupted (CMI)	500 million	$1/CMI	$500 million
Financial	Dollars ($)	$500 million	1	$500 million
			Total equivalent cost	$3 billion
			Risk-attitude function	
			Risk-adjusted value	$3.5 billion

You need n-1 trade-off values and one risk-attitude function to specify a simplified MAVF

Blue numbers illustrate an application of the MAVF

Advantages of a simplified MAVF scheme

- It needs fewer numbers to assess and only one risk-attitude function vs. multiple scaling functions.
- It avoids the need to estimate the upper bound for conceivable catastrophic events.
- The implications of tradeoff values are clearer than combining range, weights, and scaling functions.
- Tradeoff values (e.g., VMR and VOLL) could be based on Federal agency guidelines and economic studies, adjusted for California.
- It would be even simpler if all IOUs used the same MAVF!

Level 4

IOU Approaches to Wildfire RSE

Joe H. Scott, MS

Level 4

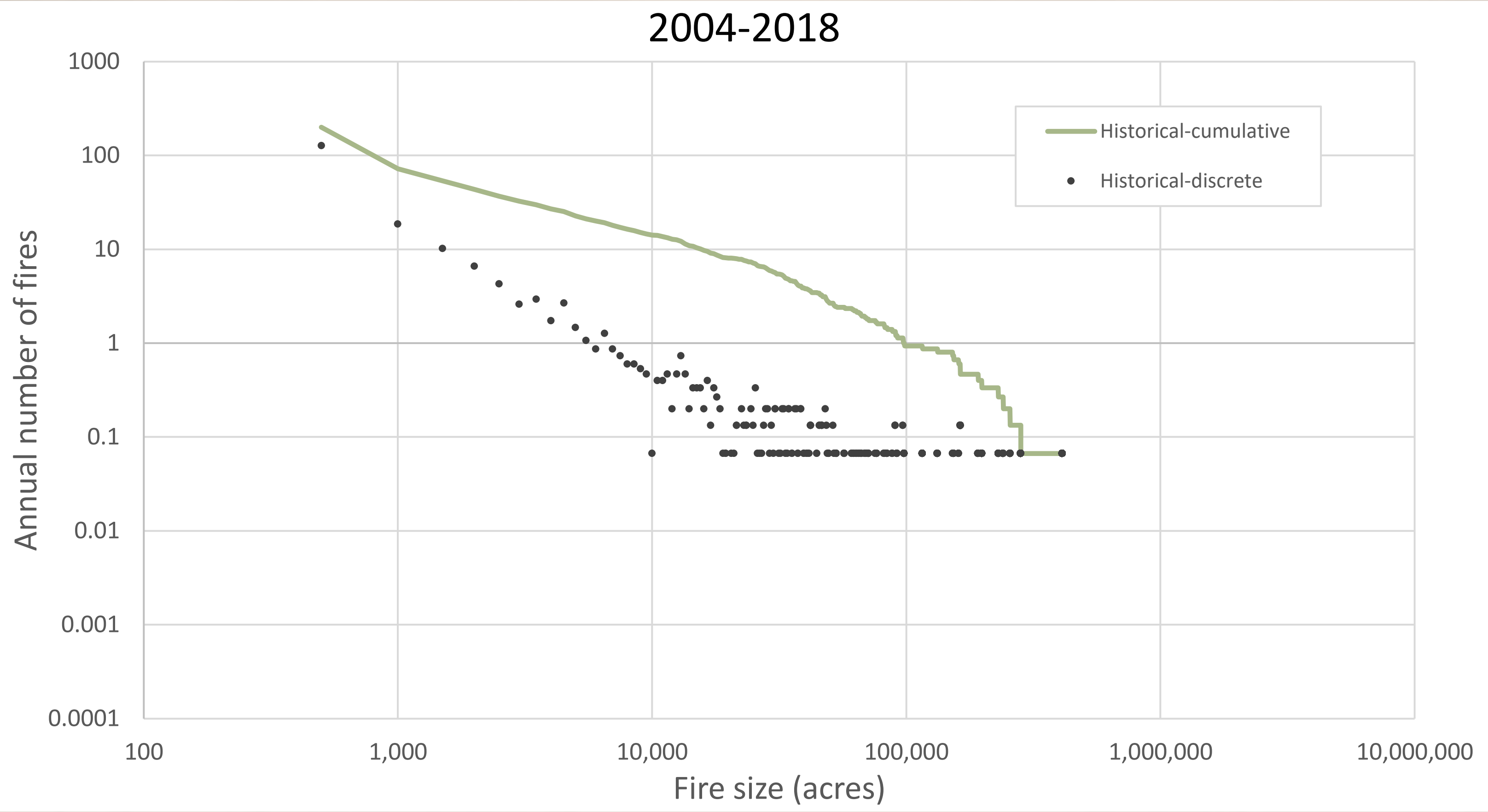
Types of wildfire risk assessment

Example wildfire risk mitigation actions for different risk types and time horizons		
	Near-term (hours to days)	Long-term (years to decades)
Source of wildfire risk (safety)	• Operational restrictions and situational awareness. • Equipment settings (reclosing). • Staging field observers and firefighting resources. • PSPS.	• Install covered conductors or bury conductors underground in high-risk locations. • Sectionalize overhead distribution to minimize required PSPS footprint. • Replace equipment prone to failure. • Increase inspection frequency in high-risk locations.
Receiver of wildfire risk (reliability)	• Situational awareness. • Pretreat wooden poles as fire approaches to minimize fire damage. • Stage equipment to quickly replace fire-damaged equipment.	• Using fire-resistant equipment (poles) in locations with high likelihood of wildfire. • Mitigate fuel immediately surrounding critical but sensitive equipment (e.g., substations).

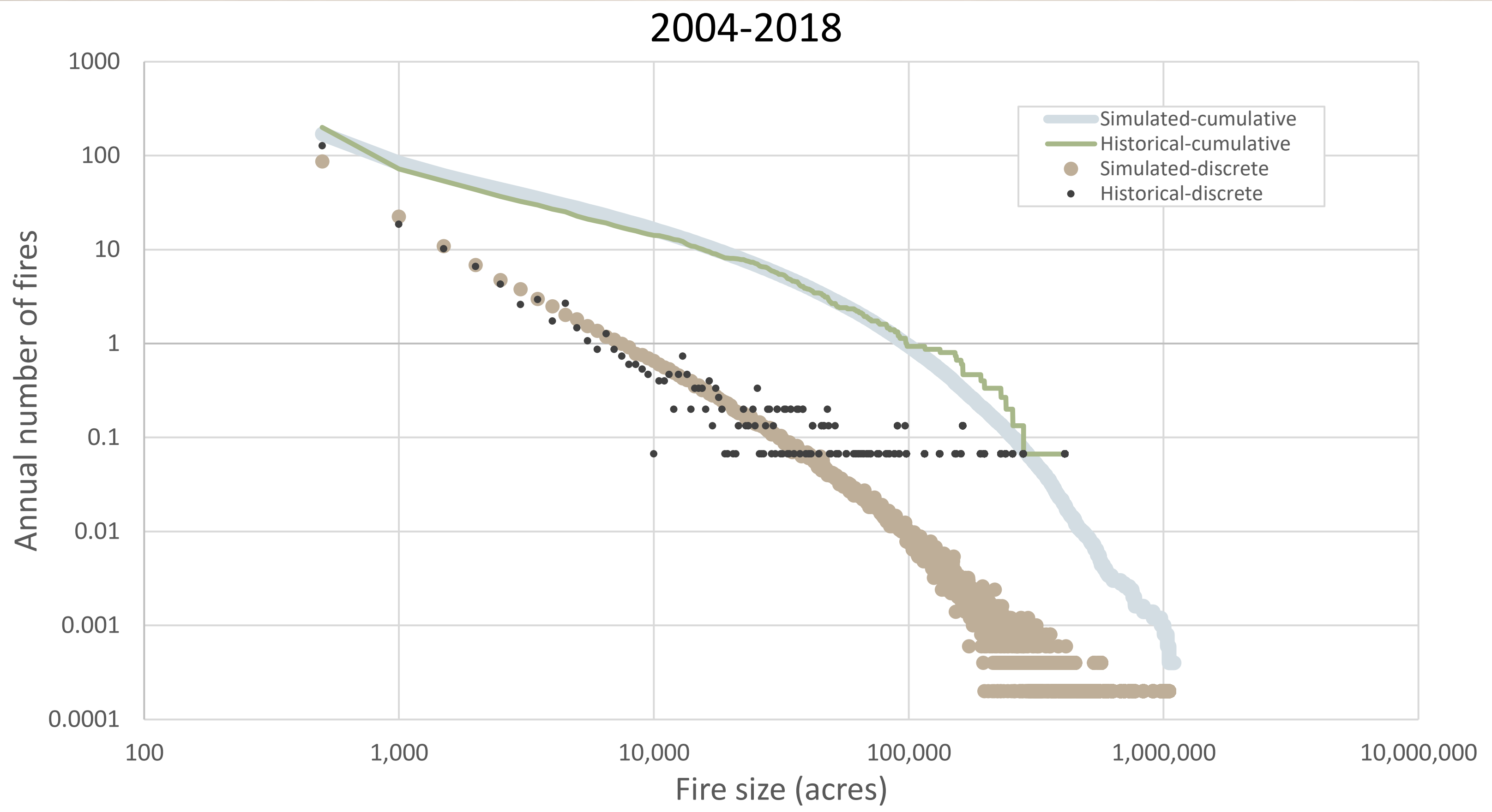
Wildfire risk modeling approaches

- Average-worst:
  - Quantifies the tail of the distribution.
  - CPUC FireMap1.
- Complete enumeration:
  - Simulate all combinations of possible weather scenarios (wind speed/direction, fuel moisture).
- Stochastic simulation:
  - Monte Carlo simulation of ignition and growth under possible weather scenarios.
- Statistical:
  - Power-law distributions.

Power-law distributions



Power-law distributions



5,000 years of simulated fire occurrence with FSim

CPUC High Fire Threat Districts

Mapping Environmental Influences on Utility Fire Threat

A Report to the California Public Utilities Commission Pursuant to R.08 – 11-005 AND R.15-05-006

FINAL REPORT, 2/16/2016

Fire Threat Mapping Independent Expert Team

David Sapsis, Cal Fire (Chair)
Tim Brown, Desert Research Institute
Catherine Low, CAP Low SE
Max Moritz, University of California, Berkeley
David Saah, Spatial Informatics Group, University of San Francisco
Ben Shaby, Penn State University

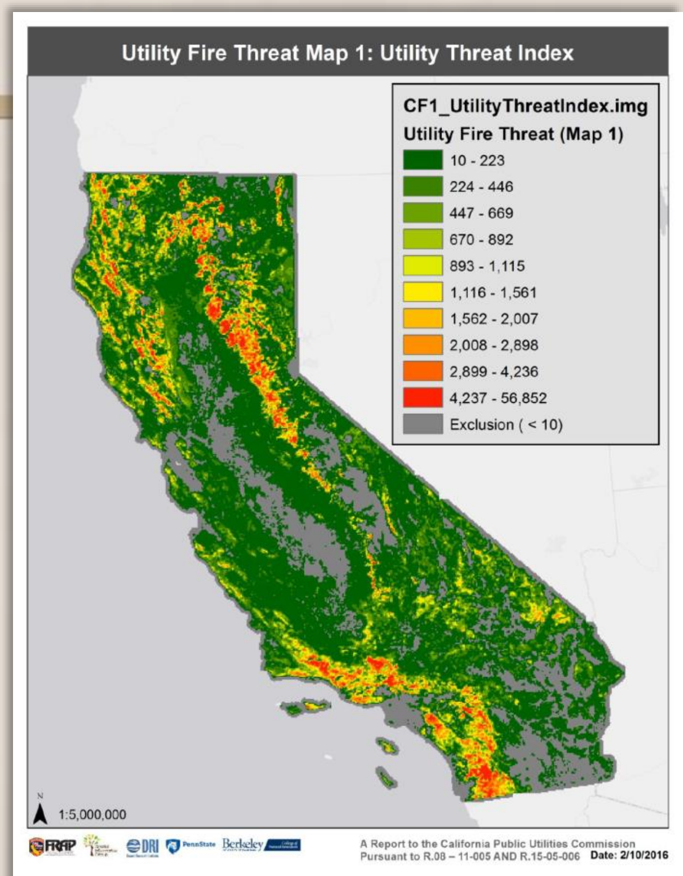
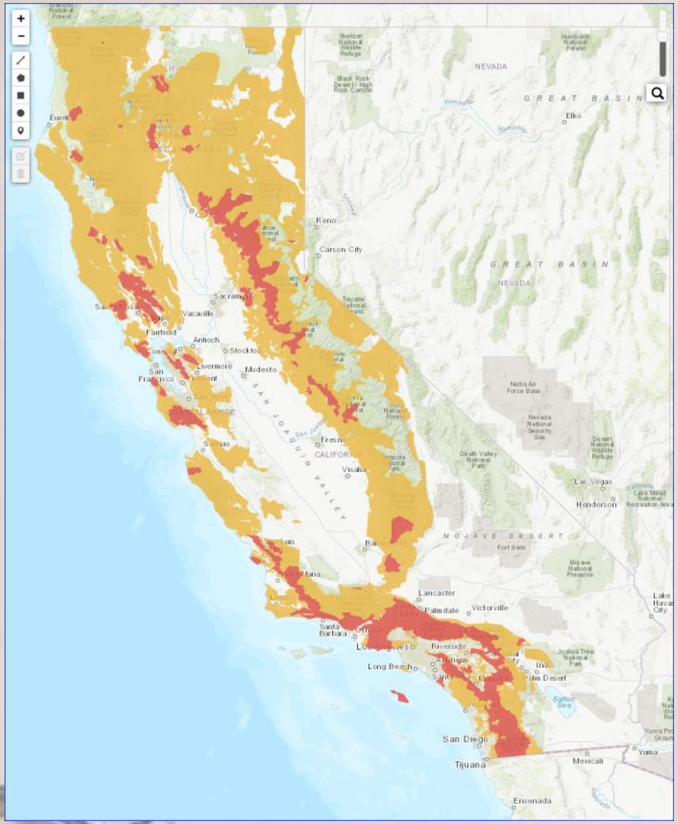
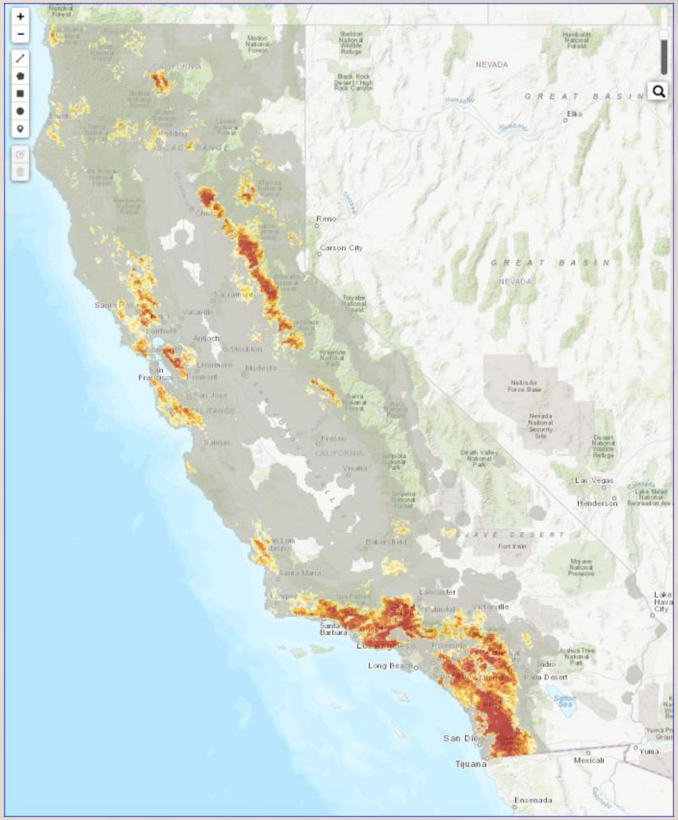


Figure 17: Optional Utility Fire Threat Model 1, with display classes based on equal area deciles subject to a lower limit exclusion.

CPUC High Fire Threat Districts





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Wildfire RSE Recommendations, Part 1

26	**Inclusion of long-duration utility-caused wildfires**	Require the IOUs to extend their wildfire risk assessments to include the consequences of long-duration utility-caused wildfires in addition to their current assessment of short-duration fires (up to eight hours).
27	**Adopt a wildfire risk type classification**	This will enable consistent descriptions of wildfire risk assessment approaches for near-term decisions like PSPS, versus long-term decisions like equipment replacement, undergrounding, etc. It will also highlight the different approaches for assessing IOU equipment as a source of the risk versus the risk to their infrastructure and equipment of wildfire of any cause.
28	**HFTD granularity enhancements**	Update the High Fire Threat District (HFTD) map to 1) increase its granularity, 2) account for fuel changes that have taken place since the map was created, and 3) account for the effects of climate change on wildfire size and consequence. An updated HFTD map should be generated using a single analytical approach across the entire state.

Wildfire RSE Recommendations, Part 2

#	Recommendation	Description
29	**Use RDF at less aggregate level to compare EPSS, covered conductors, and undergrounding**	To guide future decisions on when and where to choose enhanced powerline safety settings (EPSS), covered conductors, or underground, it would be helpful to ask the utilities to address these questions more directly using the RDF framework for selected circuits in various situations – e.g., by tier 3 vs tier 2 fire safety regions, vegetation, and terrain type – and to do so with a framework that allows direct comparison of their results to identify the sources of the differences.
30	**Consequence model enhancement**	Update the consequence model to account for damage to resources like timber, drinking water, wildlife habitat, particulate emissions, carbon emissions, etc.
31	**Standardized out-year fuelscape**	Develop or standardize on a statewide out-year fuelscape supporting a long-term assessment of risk priorities.
32	**Wildfire risk-type classification**	See Recommendation 27.

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Risk Modeling Illustrative Demo

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