



PG&E's 2020 RAMP Workshop #3

August 27



Large Uncontrolled Water Release RAMP Presentation Post-Filing Workshop #2

Power Generation
Russ Prentice
August 27, 2020



- PG&E RAMP Risk Summary
- Large Uncontrolled Water Release Risk Overview
- 2017 RAMP Comparison
- Feedback from intervenors at pre-filing workshop #3
- Bowtie model
- Quantitative Risk Assessment and Presentation of the Bowtie
- Cross-cutters impacting risk
- Risk Model Results (2023 Baseline)
- 2017 RAMP Spend Comparison
- 2023-2026 Proposed Mitigation Planned
- Alternatives Considered
- Objectives

Rank	LOB	Safety Risks	2023 RAMP Score	
			Safety Risk Score	Multi-Attribute Risk Score
1	EO	Wildfire	9,856	25,127
2	SHED	Third Party Safety Incident	887	944
3	GO	Loss of Containment on Gas Transmission Pipeline	128	281
4	SHED	Contractor Safety Incident	94	94
5	SHED	Employee Safety Incident	86	90
6	GO	Loss of Containment on Gas Distribution Main or Service ¹	72	99
7	SS	Real Estate and Facilities Failure	69	97
8	PGEN	Large Uncontrolled Water Release (Dam Failure)	41	70
9	EO	Failure of Electric Distribution Overhead Assets	18	525
10	SHED	Motor Vehicle Safety Incident	16	17
11	EO	Failure of Electric Distribution Network Assets	6	7
12	GO	Large Overpressure Event Downstream of Gas M&C Facility	5	13



Large Uncontrolled Water Release Overview

Definition

Given the inherent risk of owning and operating hydro assets, there is potential for a large uncontrolled water release adversely impacting the company, the public, or federal lands

Scope

In scope: High and Significant Hazard Dams per FERC and DSOD classification.
Out of scope: Low Hazard Dams, Canals, Waterways, Powerhouses, other Hydro Assets.

Background

This risk is the only Generation risk with a dedicated chapter in the 2020 RAMP filing. This risk represents a high potential safety impact due to the number of dams and the consequence of failure, but has a low frequency (Aggregated 1 event per 67 years).

Forecast

Long Term Planning forecasts through 2024 were reviewed for mitigating projects on High and Significant Hazard Dams. Major project forecasts and 2025-2026 estimated spend were updated through direct querying of Project Management teams in addition to analyzing prior year spend with expected inflations.

Risk Rank

8

Safety RS = 41
Financial RS = 28
Reliability RS = 0
MAVF RS = 70

Mitigation Forecast Cost
2023-2026

\$330 Million (C)
\$0.4 Million (E)

Overall Risk Reduction (NPV)
2023-2026

47.1

Risk Spend Efficiency
Risk Reduction/\$M
2023-2026

0.43



2017 RAMP

2020 RAMP

Definition

A large PG&E-owned dam failure that is located in PG&E territory with the potential to cause significant safety and environmental damage.

Given the inherent risk of owning and operating hydro assets, there is potential for a large uncontrolled water release adversely impacting the company, the public, or federal lands.

Risk Exposure and Key Risk Drivers

Risk exposure: 20 Highest Consequence Dams
Key risk drivers: Flood, Seismic, Piping (Seepage)

Risk exposure: 61 High and Significant Hazard Dams
Key risk drivers: Flood, Seismic, Internal Erosion
Cross Cutters: Physical Attack, Cybersecurity, IT Asset Failure

Control & Mitigation Plans

<i>Controls</i>	<i>Mitigations (2020-2022)</i>
1. Hydro Operations & Maintenance	1. Seepage Mitigations
2. Facility Safety Inspections	3 Projects
3. FERC & DSOD Inspections	2. Spillway Remediation
4. Part 12D & Follow-up	2 Projects
5. Dam Safety Program	3. Seismic Retrofit
	1 Project
	4. LLO Refurbishments
	0 Projects

<i>Controls</i>	<i>Mitigations (2023-2026)</i>
1. Dam Safety Program	1. Internal Erosion Mitigations
a) Hydro O&M	2 Projects
b) Facility Safety Inspections	2. Spillway Remediations
c) FERC & DSOD Inspections	20 Projects
d) Part 12D & Follow-up	3. Seismic Retrofit
	4 Projects
	4. LLO Refurbishments
	5 Projects

Mitigation Forecasts* (\$000)

	2020	2021	2022	2023	2024	2025	2026
Total Capital	\$30,805	\$44,474	\$76,474	\$120,413	\$116,900	\$47,000	\$45,500
Total Expense	\$6,814	\$7,115	\$2,345	\$350	\$0	\$0	\$0

What Was Presented

Risk ranked #8 with a safety risk score of 41. Tranches presented as each individual high and significant hazard dams. Source data for drivers include Probable Maximum Flood studies and site-specific seismic and internal erosion analyses. Consequence data is derived from limited industry events, Emergency Action Plans, Inundation Maps, FEMA flood studies, and site specific analyses.

Feedback

Consider additional drivers including cross-cutters and misoperation.

How was feedback considered/ decision making process

Physical security has been added as an independent driver. Department of Homeland Security and United States Society of Dams reports were used to determine frequency data as PG&E and other US dam owners do not have actual events. Cybersecurity and IT Asset Failure determined to be sub-drivers as these events would need to occur in conjunction with one of the other drivers to impact the likelihood of a catastrophic dam failure.

Misoperation is planned for 2024 RAMP filing as efforts to quantify the driver are still underway with planned completion EOY 2021.

Current State

Improved Internal Erosion methodology. Dam Safety Program control not quantified. Cross-cutting drivers for Physical Attack, Cybersecurity, and IT Asset Failure have been incorporated.



Quantitative Risk Assessment and Bowtie

Bowtie Element	Element Type	PG&E	Industry	SME
Exposure	Exposure	61 High and Significant Hazard Dams	FERC Classifications	Confirmed
Flood	Driver	Probable Maximum Flood (PMF)	Potential Failure Mode Analysis (PMFA)	Inspection and trending of dam assets that mitigate driver
Seismic	Driver	Site-specific analyses	FERC 2000-yr design criterion	Inspection and trending of dam assets that mitigate drivers
Internal Erosion	Driver	Site-specific analyses	None	Inspection and trending of dam assets that mitigate driver
Catastrophic Dam Failure	Outcome	No internal data sources	Limited industry events	Assumed exceeding design criteria leads to failure
Financial	Consequence	Dam restoration, value of real estate, infrastructure considerations, loss of generation	None	Identified extent of damage through inundation zones overlaid with satellite imagery
Safety	Consequence	Inundation zone maps	Emergency Action Plan standards set by FERC & FEMA flood studies	Determined number of structures in inundation zones and assumed 1 person per structure
Reliability	Consequence	None – customers impacted would be evacuated	None available	None – customers impacted would be evacuated

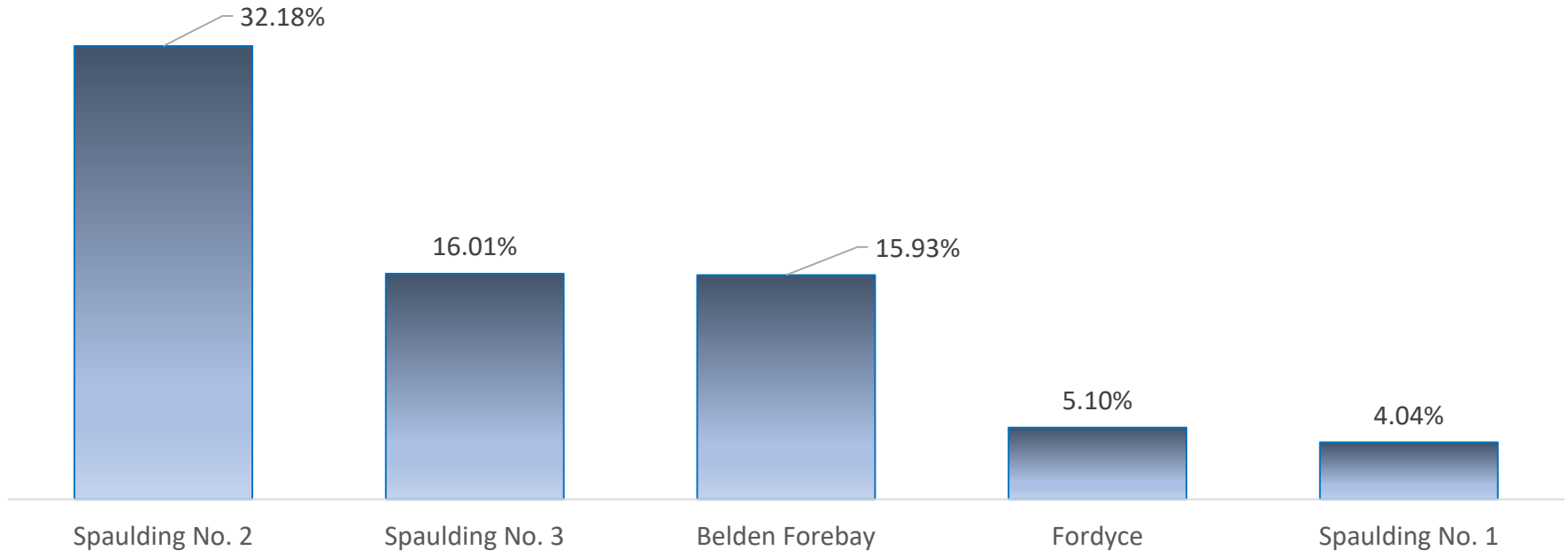
Cross Cutter Factor	Risk Driver/ Sub-Driver	Consequence
Seismic	✓*	
Cyber Attack	✓	
IT Asset Failure	✓	
Skilled and Qualified Workforce		
Enterprise Records Management		✓
Physical Attack	✓	
Emergency Preparedness and Response		✓
Climate Change	✓†	
Contract Management		
Third Party Risk Management		

* Seismic included as inherent driver

† Climate impacts are inherently captured in Probable Maximum Flood studies

Cross Cutter	Frequency Rationale	Impact Rationale
Physical Attack	<p>After assessing the quantification data for frequency, there are no instances of an LUWR driven by Physical Attack in the US. Based on Department of Homeland Security Data (DHS) and a study in the United States Society of Dams Fall 2019 publication and assuming the next dam attacked would result in dam failure gives an event frequency of once per 4.4 million years.</p>	<p>Physical attack may lead to dam failure which would result in the modeled risk event.</p>
Cyber Attack	<p>A Cyber Attack coincident with conditions that cause a risk event (Flood, Seismic, Internal Erosion, Physical Attack) will increase the likelihood that a catastrophic outcome will occur. The frequency of a cyber attack event is estimated to be 1 in 280 years.</p>	<p>The consequences of a Cyber Attack are contained within the current worst case scenario within the model.</p>
IT Asset Failure	<p>An IT Asset Failure coincident with conditions that cause a risk event (Flood, Seismic, Internal Erosion, Physical Attack) will increase the likelihood that a catastrophic outcome will occur. Critical System Availability goals are 99.9% and IT has mapped 39 asset categories to the dam failure risk. This results in an estimated frequency of IT Asset Failure to be 1 in 26 years</p>	<p>The consequences of an IT Asset Failure are contained within the current worst case scenario within the model.</p>
Enterprise Records Management	<p>The risk of not having an effective records and information management program may result in the failure to construct, operate, and maintain a safe system and lead to property damage or loss of life. However, this will be discovered in investigations following the event and is thus not considered to contribute to the frequency of an event.</p>	<p>Financial consequences of records management are included as a multiplier adjusted by Power Generation's records maturity level.</p>

Percent of Total Risk per Top 5 Dams

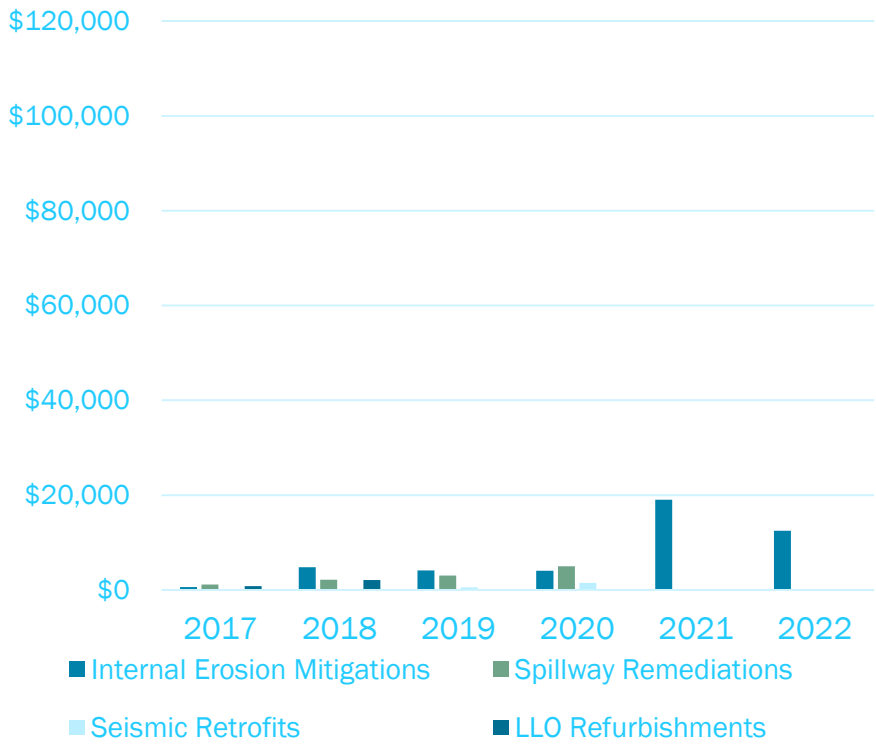


Tranches (Top 5 and Aggregate)	Frequency	Safety	Reliability	Financial	Mitigation	Risk		
	Events per Year	Safety – Equivalent Fatalities	Customers per Year	Millions per Year	Spend (\$k)	Risk Score	%Risk	Risk Reduction (2020-2026)
Spaulding No. 2	6.18E-04	1.66E-02	0	3.81	370	22.48	32.2%	4.0
Spaulding No. 3	3.08E-4	8.27E-03	0	1.90	370	11.19	16.0%	1.7
Belden Forebay	4.10E-03	4.13E-02	0	0.35	17,822	11.12	15.9%	34.7
Fordyce	9.39E-05	2.79E-03	0	0.59	60,943	3.56	5.1%	1.7
Spaulding No. 1	6.66E-05	2.54E-03	0	0.43	800	2.82	4.0%	0.5
Aggregate	1.47E-02	1.29E-01	0	8.02	330,400	69.82	100%	57.8

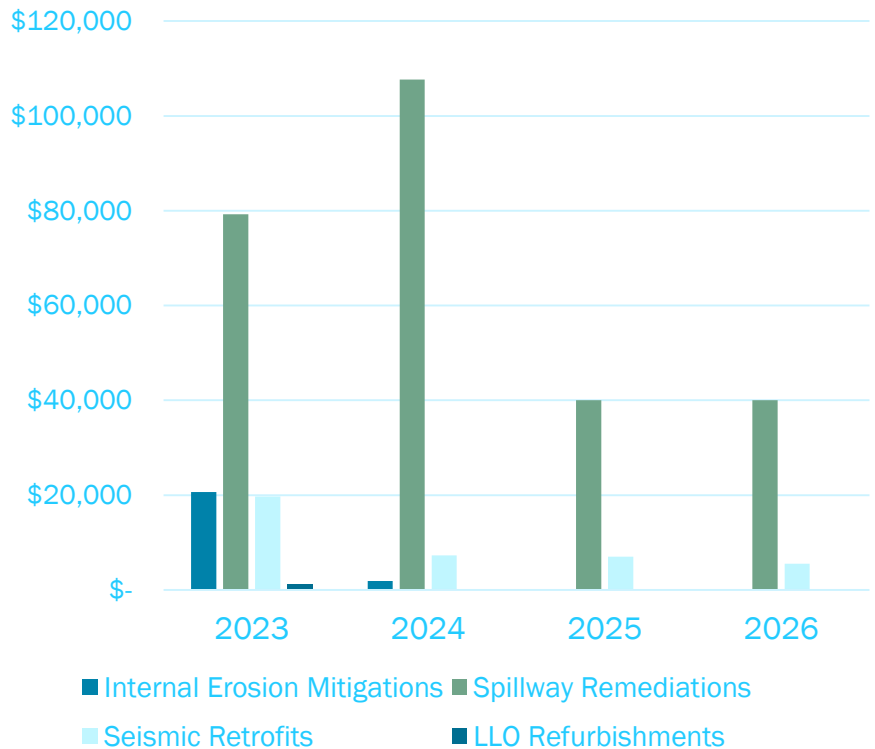


2017 RAMP Spend Comparison

2017 RAMP



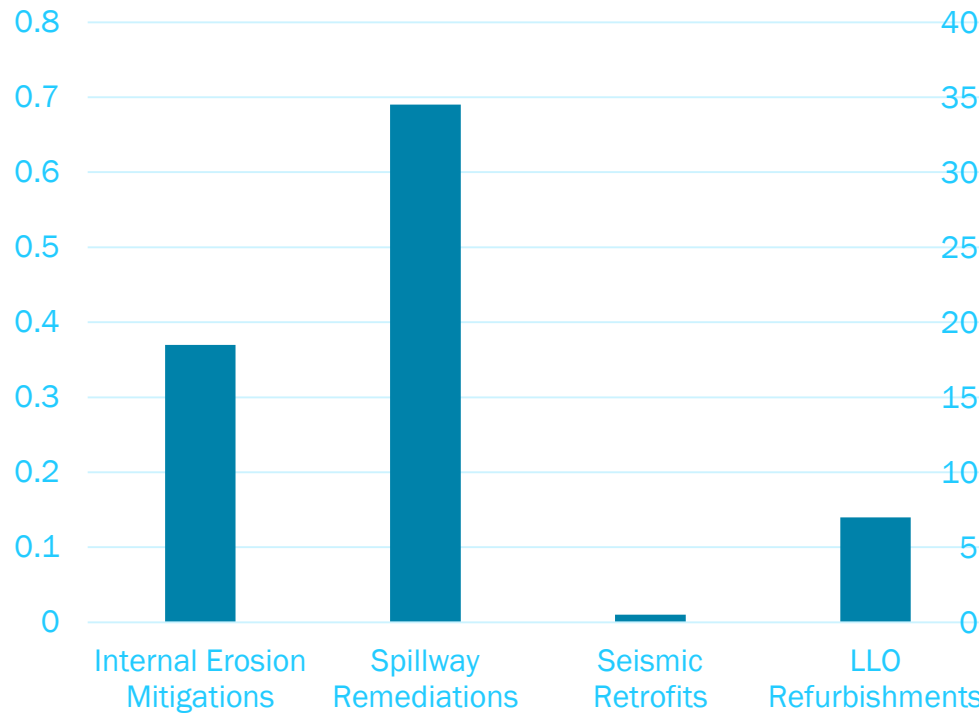
2020 RAMP



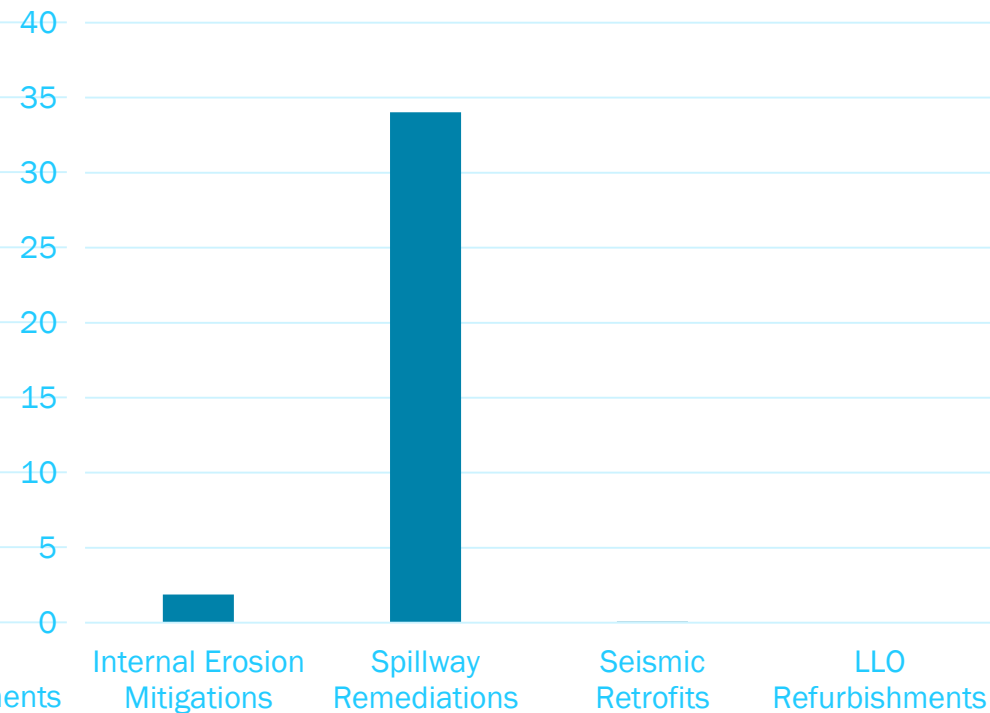
(Dollars in 000's)

Program	2017 RAMP Forecast						2020 RAMP Forecast			
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Internal Erosion Mitigations	\$609	\$4,750	\$4,100	\$4,051	\$19,000	\$12,451	\$20,662	\$1,900	\$0	\$0
Spillway Remediations	\$1,122	\$2,170	\$2,994	\$5,000	\$0	\$100	\$79,200	\$107,700	\$40,000	\$40,000
Seismic Retrofits	\$0	\$0	\$500	\$1,500	\$0	\$0	\$19,700	\$7,300	\$7,000	\$5,500
LLO Refurbishments	\$767	\$2,083	\$100	\$0	\$0	\$0	\$1,202	\$0	\$0	\$0

RSE (Risk Reduction/\$M)



Risk Reduction (Net Present Value)



(Dollars in 000's)

Program	2023	2024	2025	2026	RSE Score	Risk Reduction	Risk Drivers
Internal Erosion Mitigations	\$20,662	\$1,900	\$0	\$0	0.37	1.89	Internal Erosion
Spillway Remediations	\$79,200	\$107,700	\$40,000	\$40,000	0.69	34.03	Flood
Seismic Retrofits	\$19,700	\$7,300	\$7,000	\$5,500	0.01	7.48E-02	Seismic
LLO Refurbishments	\$1,202	\$0	\$0	\$0	0.14	3.17E-02	Internal Erosion, Seismic
Total	\$120,763	\$116,900	\$47,000	\$45,500			



Mitigation Alternatives Considered

Mitigation Alternative 1: Geomembrane Liners

Risk Reduction
1.36
RSE
6.1E-02

Installing geomembrane liners on all high and significant hazard dams that currently have projects planned to reduce internal erosion but do not currently have plans to install a geomembrane liner

Performed in lieu of current proposed internal erosion mitigation plan

Program	2023	2024	2025	2026
Proposed Internal Erosion Mitigations	\$20,661	\$1,900	\$0	\$0
Alternative Internal Erosion Mitigations	\$50,962	\$32,201	\$30,701	\$30,701

Mitigation Alternative 2: Geosciences Engineering & Risk Research Plan

Risk Reduction
0
RSE
0

Implement Geosciences proposal to better quantify the seismic hazards and risk to PG&E Hydro assets through applied research. The program consists of three subject areas: Seismic Source Characterizations, Ground Motion Characterization, and Engineering and Risk.

Alternative would be performed in addition to proposed mitigations

Program	2023	2024	2025	2026
Proposed Plan Total	\$120,413	\$116,900	\$47,000	\$45,500
Alternative 2 Cost	\$200	\$200	\$200	\$200

Mitigation Alternative 3: Probable Maximum Precipitation Studies

Risk Reduction
0
RSE
0

Perform site-specific Probable Maximum Precipitation studies. 21 studies would be necessary to cover all PG&E-owned high and significant hazard dams.

Alternative would be performed in addition to proposed mitigations

Program	2023	2024	2025	2026
Proposed Plan Total	\$120,413	\$116,900	\$47,000	\$45,500
Alternative 3 Cost	\$2,200	\$2,200	\$2,100	\$0

Alternative mitigation plans are a requirement of the RAMP report and do not obligate PG&E to implement.

- PG&E continues to improve accuracy of the Large Uncontrolled Water Release risk model
- PG&E is integrating risk insights into Dam Safety
- PG&E endeavors to develop a state of the art Dam Safety Program integrating risk, compliance, and industry initiatives

Failure of Electric Distribution Network (DUGN) Assets 2020 RAMP Post-Filing Workshop

Electric Operations
Jeff Borders
August 27, 2020



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Objective

Provide overview of PG&E's Failure of Electric Distribution Network Assets Risk Assessment and Mitigation Program Portfolio going into 2023 General Rate Case

- I. Introduction
 - a. *Definition & RAMP Risk Scores*
- II. Risk Assessment
 - a. *Risk Bowtie Overview*
 - b. *Detailed Breakdown of Equipment Failure Sub-Drivers*
 - c. *Tranches Overview*
 - d. *Cross-Cutting Factors*
- III. Controls & Mitigations
- IV. Appendix

Definition

Failure of electric distribution network assets or lack of remote operation functionality may result in public or employee safety issues, property damage, environmental damage or inability to deliver energy.

Scope

- **In Scope:** Failure of assets associated with urban underground electrical distribution networks (downtown SF and Oakland) including network transformers, network cables, and network protectors
- **Out of Scope:** Failure of assets associated with non-network underground and overhead distribution, underground transmission cables

Background

PG&E maintains networked distribution systems in downtown San Francisco and downtown Oakland to provide reliable service to key electric customers. In a networked system, customers can receive power from one of several sources, so that an outage on one of these sources will not result in an outage for the customer. Overall, PG&E's networked distribution systems consist of 188 circuit miles of cable in twelve network groups, nine in San Francisco and three in Oakland. In addition to cable, associated facilities include network transformers, protectors, and relays, monitoring equipment including Supervisory Control and Data Acquisition (SCADA), and the underground vaults where most network equipment is located.

Because PG&E's networked distribution facilities are located in dense urban areas, the consequences of asset failure may be different than for other aspects of the distribution system. Because of this, and because of the different asset mix relative to other aspects of the distribution system, PG&E considers the risk of failure of underground distribution network assets separately from the failure of other distribution assets.



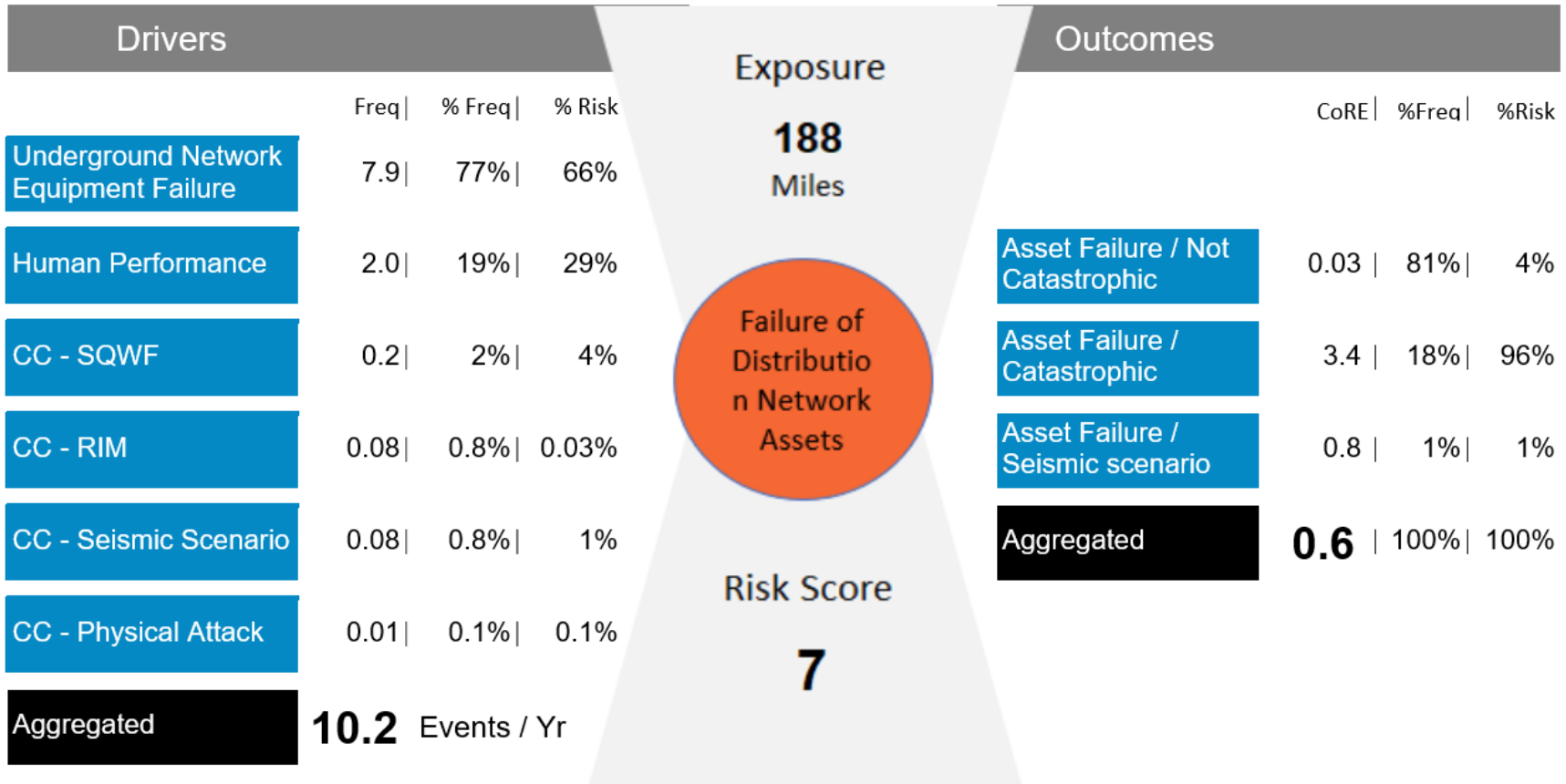
PG&E RAMP Risk Scores

Rank	LOB	Safety Risks	2023 Baseline Score	
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Risk Assessment – Bowtie



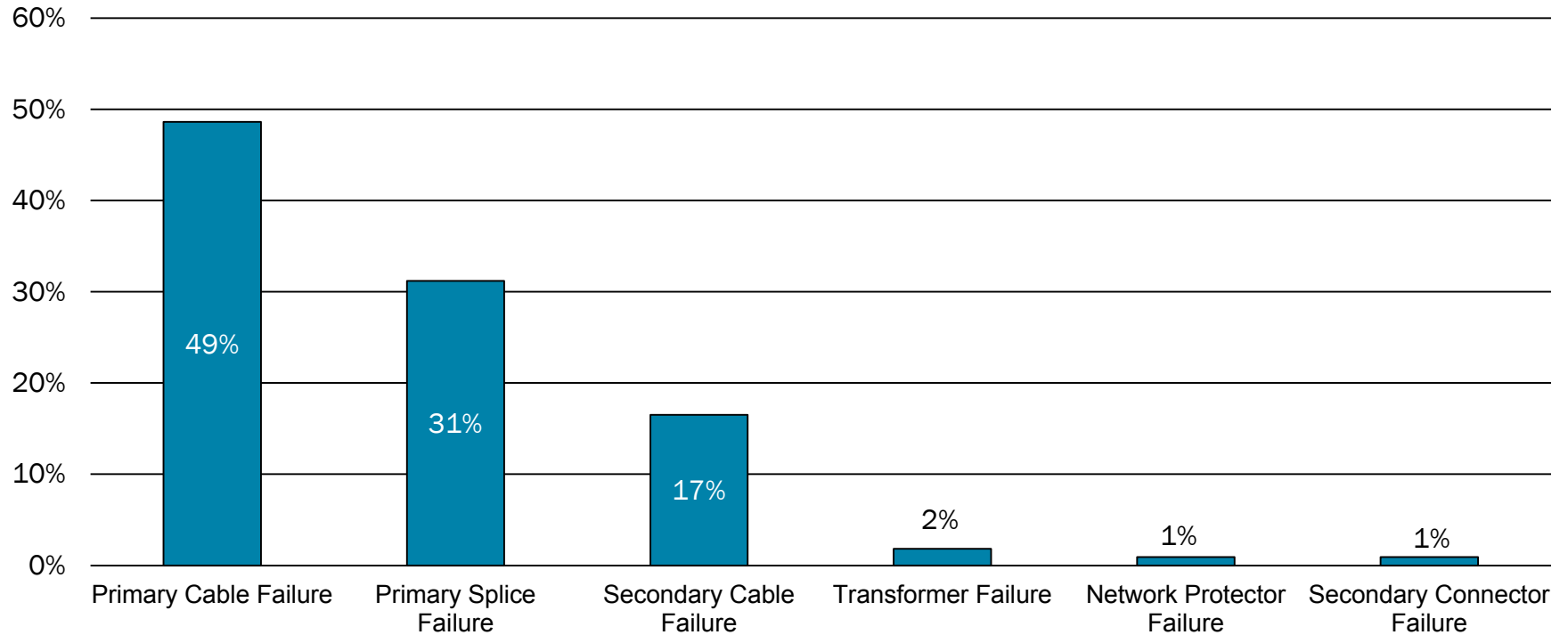
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(1) Bowtie reflects July 15 errata

(2) Risk score represents Test Year Baseline Risk Score for 2023 (i.e. pre-mitigation risk score for 2023, post 2020-2022 mitigations, post all controls)

Equipment Failure Sub-drivers



Note:

- Primary cable and splice failures are the major sub-drivers of Equipment failure incidents in the Electric Distribution Underground Network system

Tranche Development & Categorization

DUGN exposure was divided into 3 tranches, based on PG&E's current primary network cable replacement strategies. This tranching approach also reflects the relative risk scores of different sections of the network.

DUGN Tranche Categories	Description	Total Exposure (Miles)	% of Exposure	% of Risk
Already addressed by Program Replacement	Nine circuits with old vintage cabled replaced by YE 2019 (Y-1117, Y-1116, L-1114, C-1101, X-1153, C-1103, Y-1101, C-1106, X-1162)	33	17.50%	1.90%
Not a Current Replacement Priority	Nine circuits with newer ethylene propylene rubber (EPR) vintage cable type (all the Z-34-1 and Z-34-2 feeders)	23	12.20%	5.50%
Current Replacement Priority	Remaining fifty one circuits prioritized for replacement based on failures and cable testing	132	70.20%	92.50%
Total		188	100%	100%

When quantifying the DUGN bowtie, the impact of the 8 crosscutting risks were incorporated as follows:

Crosscutter	Quantitative Treatment in Bowtie?	Rationale / Assumption / Notes
Climate Resiliency	No	<ul style="list-style-type: none"> Climate risk impact has not been quantified in the DUGN bowtie due to limitations in current modelling approach. Based on SME discussions, climate factors impacting DUGN are primarily associated with sea-level rise. This has the potential of flooding network manholes and resulting in SCADA failures. This risk has not been quantified, however mitigation strategies are being scoped out.
Seismic	Yes	<p>Siesmic risk was modelled in the bowtie as impacting both drivers and consequences:</p> <ul style="list-style-type: none"> On the drivers section of the bowtie, a failure frequency associated with siesmic events was quantified as the expected # of underground repairs estimated in the different earthquake scenarios per PG&E's SERA model. On the consequence section of the bowtie, Safety, Reliability and Financial consequences were isolated seperately for siesmic-related events (details in appendix).
IT Asset Failure	No	<ul style="list-style-type: none"> Based on SME judgement, an IT Asset failure cannot create the risk because loss of monitoring isn't a driver to the risk. The business is able to leverage manual process for checking condition of distribution network assets. The business acknowledges that an IT Asset Failure is consequence multiplier to a DUGN risk event. However, given the time constraints for finalizing RAMP efforts, the bowtie and quantification analysis will not be updated at this time. IT Asset Failure as consequence multipliers to a DUGN risk event will be revisited during the upcoming GRC.
Physical Threat	Yes	<ul style="list-style-type: none"> Physical threat was quantified as a 1 in 100 year event on the driver side of the DUGN bowtie. No additional consequences were identified resulting from Physical threat.
Cyber Threat	No	<ul style="list-style-type: none"> Based on SME judgement, a Cyber Attack cannot create the risk because loss of monitoring isn't a driver to the risk. The business is able to leverage manual process for checking condition of distribution network assets. The business acknowledges that a Cyber threat is consequence multiplier to a DUGN risk event. However, given the time constraints for finalizing RAMP efforts, the bowtie and quantification analysis will not be updated at this time. Cyber Attack as consequence multipliers to a DUGN will be revisited during the upcoming GRC.
Skilled & Qualified Workforce	Yes	<ul style="list-style-type: none"> Based on SME judgement a fraction of Human Performance incidents were remapped to the Skilled and Qualified Workforce (SQWF) crosscutting driver in the DUGN bowtie.
Records & Information Management	Yes	<ul style="list-style-type: none"> Incidents associated with Crossed Wires, Mis-coordination, Incorrect Diagrams, Mapping Errors, Incorrect Tags and Incorrect Switch Logs incidents in the failure dataset were remapped to the Records and Information Management crosscutting risk driver in the DUGN bowtie. RIM is also modeled to contribute to a fraction of consequences based on SME judgement.
Emergency Preparedness & Response	Yes	<ul style="list-style-type: none"> EP&R is modelled as a crosscutting mitigation that impacts consequences in the DUGN bowtie. Based on SME judgement and EORM input, active EP&R protocols are expected to improve the consequences for severe events by 10% in the DUGN bowtie; if Mutual Assistance was invoked (at a rate of 50% of EOC activations), a further 10% reduction was applied. Severe events were estimated as 10% of manhole explosion incidents (subset of the catastrophic outcomes in the bowtie) for DUGN.

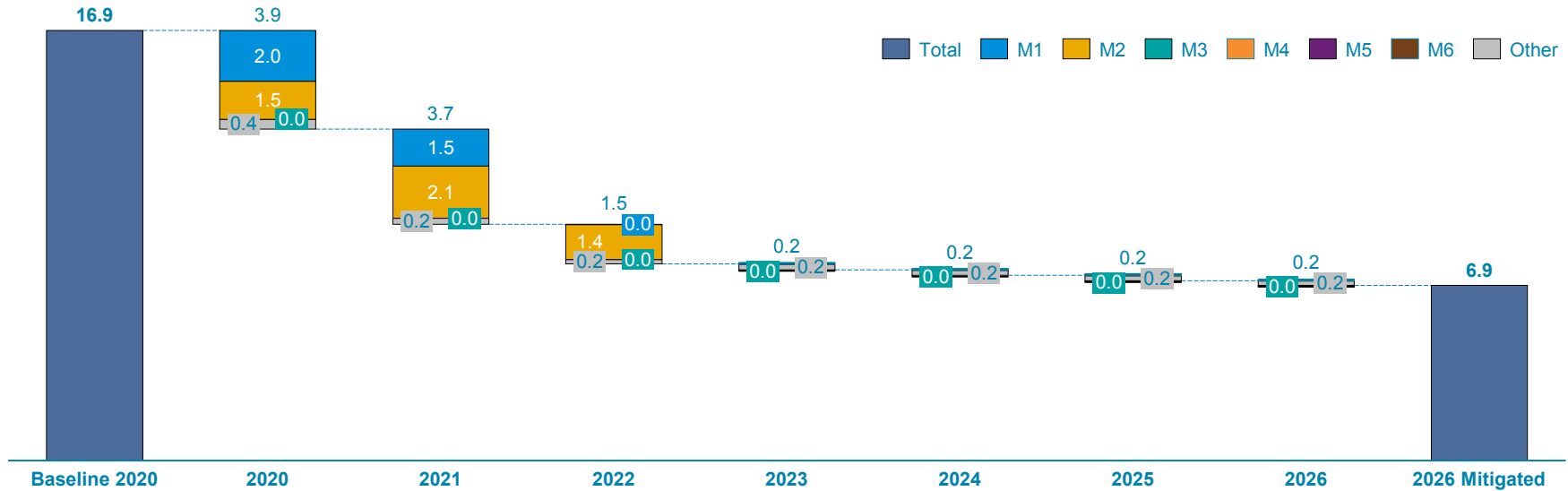
Risk Assessment – Controls & Mitigations



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DUGN has 6 control programs identified for 2020 RAMP

Controls	Description
C1 Network Cable Replacement and Switch Installations	<p>Systematic replacement of network cable assets and installation of switches in downtown San Francisco and Oakland networks. Many of the existing network primary and secondary cables date from the 1920s to the 1960s and are nearing the end of their useful life. The program work includes replacing primary and secondary cables, modifying network transformers to accept the new primary cables, and installing switches.</p>
C2 Network Maintenance and Corrective Work	<p>Maintenance work associated with PG&E's Network Asset Management Plan includes inspection and oil sampling of all major oil-filled network components of transformers, inspection and testing of network protectors, maintenance and routine replacement of the network SCADA system, and electric corrective notification work in network vaults.</p>
C3 Network Component (Transformer, Protector) Replacements - Condition Based	<p>PG&E routinely monitors the condition of its network transformers and network protectors by means of inspection, insulating oil analysis, testing, and on-line sensor monitoring. PG&E replaces network components identified as needing replacement due to their condition with new, safer and more reliable technologies. Replacement transformers are either explosion-resistant or dry-type and use a single-tank design to minimize the risk of catastrophic failure. Network protectors are replaced at the same time as transformers since they have a similar life span.</p>
C4 Asset Information Improvements/Asset Data Comparison and Updates	<p>Various initiatives to validate and improve the quality of data in PG&E's IT systems concerning electric distribution network assets. These initiatives include automating some data entry processes that are currently manual to ensure accuracy and data synchronization, updating IT applications based on construction change sketches, and correcting data based on discrepancy reports for assets and attributes in PG&E databases. PG&E has also initiated an Electric Program Investment Charge project to expand the capabilities of its condition-based maintenance alarm system to use more data sources.</p>
C5 Network Health Report (Units Offline)	<p>Report used to spot check the number of units offline to use as an indicator of the operational health of the network to highlight any prolonged clearances and increased reliability risks.</p>
C6 Standards, Processes, and Training	<p>Workmanship Skills and Training, Standards, Bulletins, Guidelines, Utility Procedures, and Personnel Training & Qualifications.</p>



#	Mitigation Program	Cumulative Risk Reduction						
		2020	2021	2022	2023	2024	2025	2026
M1	Network Component Replacements - Targeted Replacement of Oil-Filled Transformers in High-Rise Buildings	1.997	3.448	3.461	3.438	3.412	3.383	3.354
M2	Venting Manhole Cover Replacements	1.495	3.555	4.923	4.892	4.857	4.817	4.776
M3	Installation of SCADA Equipment for Safety Monitoring ¹	-	-	-	-	-	-	-
M4	Incremental Primary Network Cable Replacements	-	-	-	0.038	0.075	0.108	0.137
M5	Network Component Replacements - Targeted Replacement of Dry-Type Transformers in High-Rise Buildings	-	-	-	< 0.001	< 0.001	< 0.001	< 0.001
M6	Network Component Replacements - Targeted Replacement of CMD-Type Network Protectors	-	-	-	0.046	0.096	0.150	0.207
Other	Crosscutting mitigation programs & Network Cable Replacement Control	0.384	0.621	0.788	1.000	1.190	1.382	1.548
Total		3.9	7.6	9.2	9.4	9.6	9.8	10.0

Note: 1. No risk reduction since this is a foundational mitigation program

Questions?

APPENDIX



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Model Element	Data Source(s)	Additional Commentary
Exposure	SME Input	
Driver 1: Underground Network Equipment Failure	Distribution Underground Network Failure Dataset	<ul style="list-style-type: none"> ▪ GIS data is GIS PG&E Asset Mapping data ▪ Distribution Underground Network Failure data consist of failure incidents in PG&E distribution underground network system from February 2008 through December 31st 2019 ▪ EIR is the Electric Incident Report Dataset from February 2014 through end of 2019 ▪ In this case, SME judgment estimated 2 injuries and 2 fatalities impacted Safety Consequences ▪ Distribution Underground Outage Restoration Costs range from January 1st through September 2019
Driver 2: Human Performance	Distribution Underground Network Failure Dataset	
CC – Seismic	PG&E SERA Model	
CC – SQWF	Distribution Underground Network Failure Dataset	
CC – RIM	Distribution Underground Network Failure Dataset	
CC – Physical Threat	SME Input	
CC – EP&R	Historical EOC Activation Records from 2014-2019 Outage datasets (for DOH and DUGN)	
Driver 3: Natural Hazard	Distribution Underground Network Failure Dataset	
Driver 4: Sabotage / Terrorism	Distribution Underground Network Failure Dataset	
Outcome 1: Asset Failure / Catastrophic	Distribution Underground Network Failure Dataset	
Outcome 2: Asset Failure / Non-Catastrophic	Distribution Underground Network Failure Dataset	
Financial Consequence	Distribution Underground Restoration Costs Dataset	
Safety Consequence	EIR + SME Judgment	

Mitigation Details



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M1 – Network Component Replacements – Targeted Replacement of Oil-Filled Transformers in High Rise Buildings

Description

Targeted program to replace older, oil-filled transformers located in high-rise buildings with dry type units to improve reliability and minimize fire risk in the event of a transformer failure.

Drivers, Sub-drivers, and Consequences

This mitigation has the potential to reduce the Underground Network Equipment Failure driver.

Tranche Level Analysis

Focused on Current Replacement Priority and Already Addressed by Program Replacement

RSE Analysis

No RSE since program ends before 2023

Mitigation Changes

PG&E replaced nine transformers in 2019 as part of the program and plans to complete the remaining 14 replacements in this program by 2022.

Mitigation Effectiveness

90% Effective on Equipment Failure – Transformer

Description

Ongoing program to replace existing solid and grated manhole covers on vaults with hinged venting manhole covers designed to stay in place in the event of a vault explosion. A venting cover that stays in place during a vault explosion reduces the potential for exposure to hot gasses from the vault, eliminates the risk of a projectile manhole cover, and reduces the force of the explosion.

Drivers, Sub-drivers, and Consequences

This mitigation has the potential to reduce the consequences of a network equipment failure by reducing the likelihood and negative effects of an underground vault explosion.

Tranche Level Analysis

Includes all tranches

RSE Analysis

No RSE since program ends before 2023.

Mitigation Changes

PG&E plans to complete its planned replacement of manhole covers on network vaults by 2022, with an estimated 200 replacements in 2020, 341 replacements in 2021, and 241 replacements in 2022.

Mitigation Effectiveness

> 90% Effective. The venting manhole cover design is expected to prevent the manhole cover from ejecting and becoming a projectile under most manhole explosion scenarios

	Foundational Mitigations	Description
M3	Installation of SCADA Equipment for Safety Monitoring	Targeted program to upgrade PG&E's original 1980s vintage SCADA monitoring equipment on its 12 network groups. The upgraded system provides additional equipment condition information, which allows PG&E to identify equipment conditions that can be addressed before in-service failure occurs. It also allows PG&E to operate some equipment in network vaults remotely, instead of having to send crews to the vault to operate the equipment manually. The new features enhance the safety, reliability, and efficiency of the network systems.

Foundational Mitigation: Because these programs support other mitigations that reduce Failure of Electric Distribution Network Assets risk, but do not reduce the risk themselves, PG&E considers them foundational and does not calculate a risk reduction or RSE.

Description

Since 2011, PG&E has been proactively replacing older Paper Insulated Lead Covered (PILC) cable in its electric distribution network with EPR cable. Newer EPR cables are significantly less likely to fail than older PILC cables and industry studies also suggest that EPR cables have higher tolerance to overload conditions.

Drivers, Sub-drivers, and Consequences

This mitigation has the potential to reduce the Underground Network Equipment Failure driver.

Tranche Level Analysis

All incremental replacements will be in the “Current Replacement Priority” tranche only

RSE Analysis

RSE - 0.073

The risk reduction for this program reflect the net risk reduction attributable to the incremental cable replacements, over and above the regular cable replacement.

Mitigation Changes

Beginning in 2023, PG&E is proposing to increase the number of circuit miles of network cable replaced in this existing program (recorded in Maintenance Activity Type (MAT) 56N and described in the C1 control) by 25 percent, which would result in replacement of approximately three additional miles of network cable per year from 2023-2026.

Mitigation Effectiveness

90% Effective on Equipment Failure – Primary Cable



M5 – Network Component Replacements – Targeted Replacement of Dry-Type Transformers in High-Rise Buildings

Description

PG&E plans to complete its replacement of oil-filled network transformers in high-rise buildings in 2022.

Drivers, Sub-drivers, and Consequences

This mitigation has the potential to reduce the Underground Network Equipment Failure driver.

Tranche Level Analysis

Focused on Current Replacement Priority and Already Addressed by Program Replacement

RSE Analysis

RSE - 4.25E-04
The low RSE for this program has been identified to be a result of not being able to tranche out these assets under the current methodology. The dry-type transformers have a unique risk profile that can be better represented if they are separated into their own tranche.

Mitigation Changes

In 2023-2026 period, PG&E is planning to replace some older dry-type transformers also located in high-rise buildings. PG&E has identified 22 of these older dry-type transformers, mostly installed in the 1980s, located in four high-rise buildings (three in San Francisco and one in Oakland).

Mitigation Effectiveness

90% Effective on Equipment Failure – Transformer



M6 – Network Component Replacements – Targeted Replacement of CMD-Type Network Protectors

Description

PG&E has approximately 1,390 network protectors in its electric distribution network system. There are four different kinds of network protectors in service currently: GE, CM22, CM52, and CMD. Based on service records, PG&E has concluded that CMD network protectors are more difficult to repair and replace as they are of an older style and have obsolete components. This program aims to replace all CMD units in the PG&E network with more reliable network protector models.

Drivers, Sub-drivers, and Consequences

This mitigation has the potential to reduce the Underground Network Equipment Failure driver.

Tranche Level Analysis

Includes all tranches

RSE Analysis

RSE - 0.445

The RSE for this program suggests that, for the same program investment, it is slightly more beneficial to replace primary network cable than to replace CMD network protectors. PG&E chooses to implement this program since there are limits to how much cable replacement can be performed at a time (due to program clearances, etc.)

Mitigation Changes

PG&E estimates there are 229 CMD network protectors on its electric distribution network system. PG&E is proposing an eight-year program to replace these units beginning in 2023 at a rate of approximately 30 units per year.

Mitigation Effectiveness

90% Effective on Equipment Failure – Network Protector

	Mitigation	Drivers Addressed	2020-2022 (\$M)	2023-2026 (\$M)	RSE (2023-2026)
M1	Network Component Replacements - Targeted Replacement of Oil-Filled Transformers in High-Rise Buildings	Underground Network Equipment Failure - Transformer Failure	8.7	-	No RSE since program ends before 2023
M2	Venting Manhole Cover Replacements	Addresses consequences, not driver – mitigates explosion in manhole resulting in ejection of manhole cover	12.4	-	No RSE since program ends before 2023
M3	Installation of SCADA Equipment for Safety Monitoring	N/A	26.4	38.8	-
M4	Incremental Primary Network Cable Replacements	Underground Network Equipment Failure - Primary Cable Failure	-	27.0	0.073
M5	Network Component Replacements - Targeted Replacement of Dry-Type Transformers in High-Rise Buildings	Underground Network Equipment Failure - Transformer Failure	-	11.0	4.25E-04
M6	Network Component Replacements - Targeted Replacement of CMD-Type Network Protectors	Underground Network Equipment Failure - Network Protector Failure	-	6.7	0.445
		Total	47.5	83.5	

Note:

- Programs with no activity in 2023-2026 do not have an RSE in the above table
- Foundational mitigations do not have an RSE score since it is not possible to isolate / quantify a risk reduction impact for these programs
- Spend forecast for M2 – Venting Cover Replacements reflects estimated spend on network manhole cover replacements during this period only. The Venting Cover Replacement program also has a broader scope of replacing non-network covers too that extends beyond 2022. Historically, program activity has been tracked in aggregate across network and non-network replacements.

Alternative Mitigation	Description	Rationale for Not Selecting	Program RSE	Cost Estimate	
M5A	Reduce Proposed Rate of Dry-Type Transformer Replacement	<ul style="list-style-type: none"> This alternative mitigation considers the impact of a slower rollout of these replacements over a 6 year period, instead of the current 3 year target. 	<ul style="list-style-type: none"> 3 year plan is considered to be more efficient due to construction costs, crane costs, and the required clearances needed. 	<ul style="list-style-type: none"> RSE: 3.94E-04 	<ul style="list-style-type: none"> \$7.4M from 2023-2026 Total program cost estimated at \$11.45M, through 2028
M7	Install Completely Submersible SCADA Enclosures	<ul style="list-style-type: none"> Continually rising sea-levels could result in more frequent flooding of manholes in PG&Es DUGN system This alternative mitigation considers the feasibility of adding submersible boxes to all underground SCADA systems used for safety monitoring to provide water insulation in such a scenario. 	<ul style="list-style-type: none"> Program is still being scoped out and if feasible and may be included in the next GRC / RAMP as primary mitigation Risk reduction not quantified and RSE not generated 	<ul style="list-style-type: none"> RSE not quantified 	<ul style="list-style-type: none"> \$35.7M from 2023-2026
M8	Replace Network Transformers based on Age instead of Condition	<ul style="list-style-type: none"> PG&E currently monitors the health of the transformers through regular testing This alternative mitigation considers changing from a the industry-standard, condition-based replacement to an age (compliance) based asset replacement program 	<ul style="list-style-type: none"> As there is not an clear age threshold for transformer failure, an age based replacement is expected to increase risk of transformer failure relative to ongoing condition based replacement program 	<ul style="list-style-type: none"> RSE: 6.53E-06 	<ul style="list-style-type: none"> (\$11.1M) from 2023-2026 i.e., annual <u>savings</u> of ~\$2.5M by eliminating transformer condition testing

Note:

- This list indicates individual alternative programs considered. These programs are grouped into alternative mitigation portfolios to calculate portfolio RSEs. Portfolio RSE represents the aggregate Risk Spend Efficiency for a chosen set of mitigation programs

Additional Alternative Mitigations



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M5A – Reduced Proposed Rate of Dry-Type Transformer Replacement

Description

Alternative mitigation to the M5 mitigation of replacing oil-filled network transformers in high-rise buildings, over a six-year period (2023-2028) instead of the three-year period (2023-25).

Drivers, Sub-drivers, and Consequences

This mitigation has the potential to reduce the Underground Network Equipment Failure driver.

Considerations

The 6-year program was estimated to be marginally more expensive due to a larger cost escalation impact over the course of the program, resulting in a slightly lower RSE score. Although not currently modeled, PG&E determined based on past experience with high-rise projects that a six-year program would likely have additional expenses and logistical complexity associated with lengthier labor contracts and installation permits. Ultimately, PG&E concluded that a three-year program is feasible and that completing the work in three rather than six years is preferable because it will reduce risk more quickly.

RSE Analysis

RSE - 3.94E-04

- M5A has a lower RSE compared to M5 – this supports PG&E’s focus on replacing on a 3-year schedule instead of a 6-year schedule.
- The RSE for this program is also likely to be better represented if a separate tranche is created for the dry-type transformer assets.

Mitigation Effectiveness

> 90% Effective on Equipment Failure - Transformer

Description

Installation of completely submersible SCADA enclosures in its manholes to prevent SCADA system components in manholes in San Francisco and Oakland from failing due to saltwater intrusion.

Drivers, Sub-drivers, and Consequences

Failure of DUGN SCADA equipment units due to water intrusion.
 Failure of SCADA equipment increases the risk of failure of other network equipment (e.g. transformers, network cable and network protectors) in that manhole location, due to inability to monitor operating and loading conditions.

Considerations

PG&E is still in the process of modeling the risk reduction associated with SCADA system component failure since these types of failures do not directly result in loss of power (as would be the case for a transformer failure), but rather the ability to monitor the system real-time, which may result in higher risk of asset failure due to changes in operating conditions.

RSE Analysis

RSE - N/A
 At this time, PG&E has not identified a modeling approach to be able to assign a risk reduction score to this program, since there is no direct risk impact from failure of SCADA equipment. Loss of SCADA results in an inability to monitor PG&E network assets but does not directly result in failure of network assets.

Mitigation Effectiveness

> 90% Effective on Equipment Failure – SCADA Equipment



M8 – Replace Network Transformers Based on Age, Instead of Condition

Description

Alternative mitigation of moving from a condition-based replacement to an age-based asset replacement program for network transformers.

Drivers, Sub-drivers, and Consequences

This mitigation has the potential to reduce the Underground Network Equipment Failure driver.

Considerations

Condition-based assessment allows PG&E to make maintenance decisions based on operating conditions (voltage, temperature etc.), which are more significant drivers of transformer operating life than years in service. Switching to an age-based system would eliminate inspections of transformers below a certain age threshold but would not address the risk of premature failures of “younger” transformers which would have been identified and mitigated as part of a condition-based approach. Although inspection costs would be reduced, the overall risk of transformer failure would increase. PG&E does not consider this trade off acceptable.

RSE Analysis

RSE - 6.53E-06

This program has a low RSE but also has a negative risk-reduction (RSE is positive since cost net present value also negative since program creates cost savings). The increased risk is not acceptable for PG&E and is why this program was not chosen.

Mitigation Effectiveness

> 90% Effective on Equipment Failure – Transformer

Financials



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DUGN Mitigation Cost Forecast (\$M)¹

Mitigation	2020	2021	2022	2023	2024	2025	2026	Total	%
M1 Network Component Replacements - Targeted Replacement of Oil-Filled Transformers in High-Rise Buildings	3.47	3.55	1.63	-	-	-	-	8.65	6.6%
M2 Venting Manhole Cover Replacements	2.60	5.53	4.31	-	-	-	-	12.44	9.5%
M3 Installation of SCADA Equipment for Safety Monitoring	8.47	8.87	9.11	9.34	9.57	9.81	10.06	65.22	49.8%
M4 Incremental Primary Network Cable Replacements	-	-	-	6.51	6.67	6.84	7.01	27.03	20.6%
M5 Network Component Replacements - Targeted Replacement of Dry-Type Transformers in High-Rise Buildings	-	-	-	4.08	4.61	2.30	-	10.99	8.4%
M6 Network Component Replacements - Targeted Replacement of CMD-Type Network Protectors	-	-	-	1.62	1.66	1.70	1.74	6.71	5.1%
Total	14.53	17.96	15.05	21.54	22.51	20.65	18.81	131	100%

Note:

- M3 – Installation of SCADA Equipment is currently funded through 2022 under the current GRC cycle. This funding level has been assumed to extend (with 2.5% cost escalation YoY) through the next GRC, which is when this program is expected to be complete

Failure of Electric Distribution Overhead (DOH) Assets

2020 RAMP Post-Filing Workshop

Electric Operations
Jeff Borders
August 27, 2020



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Objective

Provide overview of PG&E's Failure of Electric Distribution Overhead Assets Assessment and Mitigation Program Portfolio going into 2023 General Rate Case

- I. Introduction
- II. Risk Assessment
 - a. *Risk Bowtie Overview*
 - b. *Detailed Breakdown of Equipment Failure and Vegetation Sub-Drivers*
 - c. *Tranches Overview*
 - d. *Cross Cutting Factors*
- III. Controls & Mitigations
- IV. Rapid Earth Fault Current Limiter (REFCL)
- V. Appendix

Definition

Failure of distribution overhead assets or lack of remote operation functionality may result in public or employee safety issues, property damage, environmental damage or inability to deliver energy.

Scope

- **In Scope:** Failure of assets associated with overhead electrical distribution system including Pole/Support Structure, Primary Conductor, Voltage Regulating Equipment, Protection Equipment, Switching Equipment, Transformers and Secondary Conductor. Includes PG&E owned Streetlights.
- **Out of Scope:** Consequences of ignitions associated with OH equipment/ assets (In scope of the Wildfire Risk). The SHED organization, owns the Third Party Safety, Contractor Safety, and Employee Safety risks, where injuries related to employees, contractors and the public are assessed and modeled.

Background

PG&E's Electric Operations line of business manages more than 80,000 circuit miles of primary distribution lines and associated equipment, including 48,000 miles of secondary conductor, 2.3 million wood poles, more than 750,000 transformers, more than 150,000 fuses, more than 75,000 switches and thousands of voltage regulating and other protective devices. Failure of these assets can result in outages and can also have significant public safety impacts.

Historically, PG&E analyzed the risk of electric overhead distribution system asset failures on an asset family basis, with a separate risk profile for each asset type such as primary conductors, poles, transformers, etc. However, in 2018, Electric Operations consolidated the risks associated with individual overhead distribution system asset types into a consolidated Failure of Distribution Overhead Asset risks to include all asset types. This is part of PG&E's migration toward an event-based risk register.



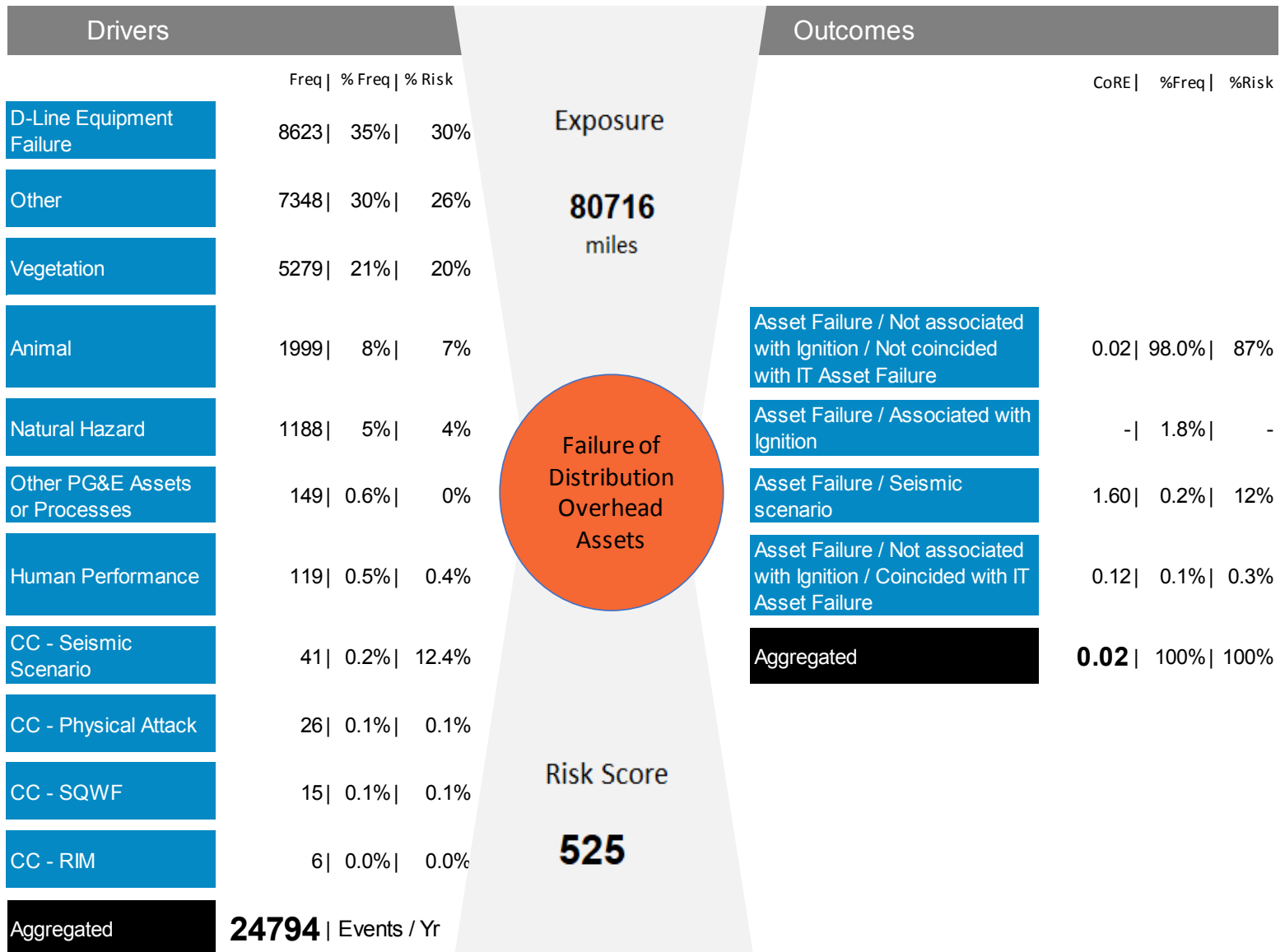
PG&E RAMP Risk Scores

Rank	LOB	Safety Risks	2023 Baseline Score	
			Safety Risk Score	Multi-Attribute Risk Score
1	EO	Wildfire	9,856	25,127
2	SHED	Third Party Safety Incident	887	944
3	GO	Loss of Containment on Gas Transmission Pipeline	128	281
4	SHED	Contractor Safety Incident	94	94
5	SHED	Employee Safety Incident	86	90
6	GO	Loss of Containment on Gas Distribution Main or Service	72	99
7	SS	Real Estate and Facilities Failure	69	97
8	PGEN	Large Uncontrolled Water Release (Dam Failure)	41	70
9	EO	Failure of Electric Distribution Overhead Assets	18	525
10	SHED	Motor Vehicle Safety Incident	16	17
11	EO	Failure of Electric Distribution Network Assets	6	7
12	GO	Large Overpressure Event Downstream of Gas M&C Facility	5	13

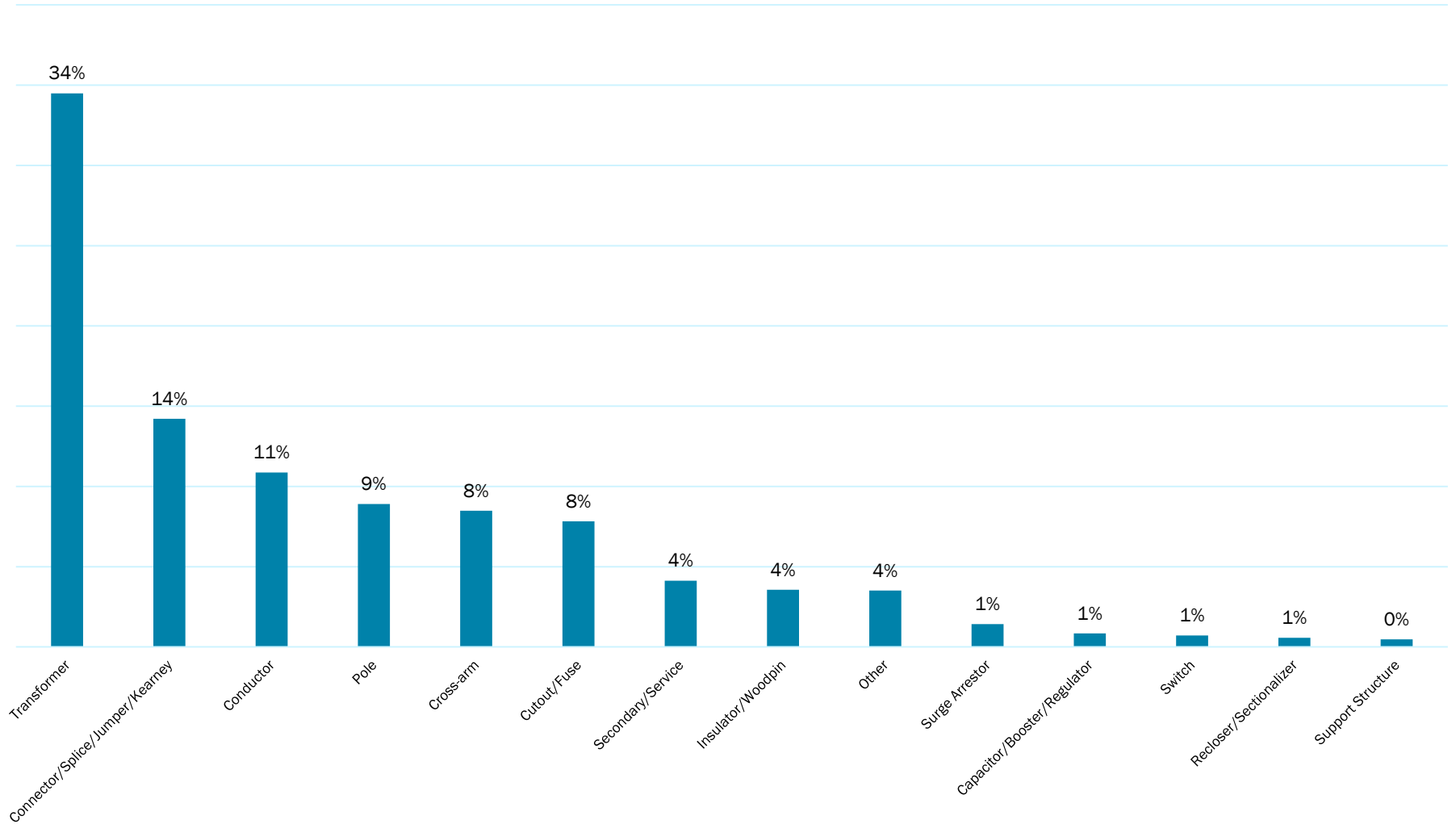
Risk Assessment – Bowtie



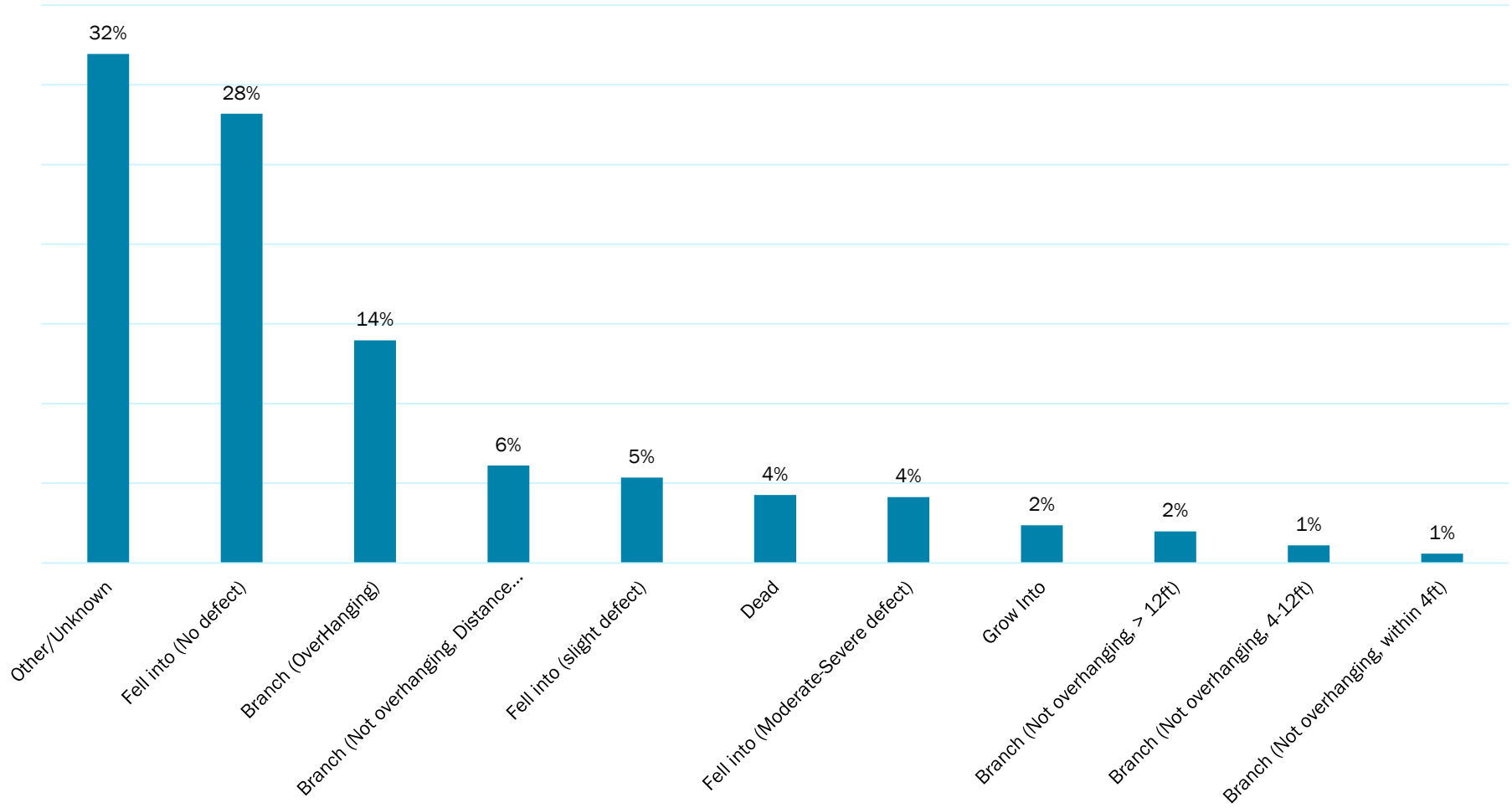
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Equipment Failure Sub-Drivers



Vegetation Sub-Drivers



Tranching is determined by utilizing 2020 EO work plan model as well as incorporating circuits with specific material (ACSR) in corrosive areas (Central Coast and Los Padres) and elevated wire-downs corresponded to small copper conductors. The 2020 EO work plan model ranks circuits based on reliability score with consideration of all circuit components.

DOH Tranche Categories	Description	Total Exposure (Miles)	% of Exposure	% of Risk Score
Elevated Wire-downs (small-wire)	Any circuit with 7.5% of its length wired with either 4-CU, 6-CU, or a combination of the two.	22,298	28.6%	23.1%
Corrosive Regions with Specific Material	Circuits with Aluminum Conductor Steel-Reinforced (ACSR) in Corrosion Zones in designated corrosion zones in the Central Coast and Los Padres Divisions; PG&E had previously identified these circuits as having a significantly higher historical failure rate for conductor and connectors that the system average.	4,796	5.9%	10.1%
Poor Reliability Performance	Circuits within 66th to 100th percentile of reliability scores provided in Work Plan 2020	33,349	41.3%	54.5%
Moderate Reliability Performance	Circuits within 33rd to 66th percentile of reliability scores provided in Work Plan 2020	15,798	19.6%	10.9%
High Reliability Performance	Circuits – 0-33rd percentile of reliability scores provided in Work Plan 2020	4,475	5.5%	1.2%
	Total	80,716	100%	100%

Note: The team is working on additional tranches with considerations on HFTD vs. Non-HFTD, and areas of concern.

When quantifying the DOH bowtie, the impact of the 8 crosscutting risks were incorporated as follows:

Crosscutter	Quantitative Treatment in Bowtie?	Rationale / Assumption / Notes
Climate Resiliency	Yes	<ul style="list-style-type: none"> Climate impacts were modelled for the following factors in the DOH bowtie: Rain, Snow/ Ice, Flood, Lightning, Wildfire, Heat Wave To estimate failure frequency associated with the heatwave driver, any failure incidents associated with Connector/Splice/Jumper/Kearney and OH transformers on days with elevated temperatures were remapped to the "Climate - Heatwave" driver, per SME judgement
Seismic	Yes	<p>Siesmic risk was modelled in the DOH bowtie as impacting both drivers and consequences:</p> <ul style="list-style-type: none"> On the drivers section of the bowtie, a failure frequency associated with siesmic events was quantified as the expected # of OH repairs projected in the different earthquake scenarios per PG&E's SERA model On the consequence section of the bowtie, Safety, Reliability and Financial consequences were isolated seperately for siesmic-related events (details in appendix)
IT Asset Failure	Yes	<ul style="list-style-type: none"> Based on SME judgement, an IT Asset failure is not a driver for DOH risk event, but is a consequence multiplier to a DOH risk event. In the event of an IT asset failure in conjunction with an outage, a 5-10x multiplier for reliability consequence has been estimated
Physical Threat	Yes	<ul style="list-style-type: none"> Physical threat has been modelled as a risk driver in the DOH bowtie. Failure frequencies for this driver were estimated by mapping incidents associated with "Electric Contact – Vandalism" to this driver
Cyber Threat	No	<ul style="list-style-type: none"> Based on SME judgement, no impact of Cyber Threat has been quantified for the DOH bowtie
Skilled & Qualified Workforce	Yes	<ul style="list-style-type: none"> Based on SME judgement a fraction of Human Performance incidents were remapped to the Skilled and Qualified Workforce (SQWF) crosscutting driver in the DOH bowtie. RIM is also modeled as impacting a fraction of the consequences in the DOH bowtie
Records & Information Management	Yes	<ul style="list-style-type: none"> PG&E included an additional financial consequence multiplier to capture records management costs necessary to respond appropriately to Risk Events. This multiplier reflects the state of records management maturity for each organization as indicated by the current records management practices in each LOB
Emergency Preparedness & Response	Yes	<ul style="list-style-type: none"> EP&R is modelled as a crosscutting mitigation that impacts consequences in the DOH bowtie For DOH bowtie, 100% incident application was assumed for asset failures occur during seismic events, and 10% incident application was assumed for asset failures occur during other time based on historical EOC/MA activation data. EOC activation was estimated to <1%-10% reduction in severity of consequences

Risk Assessment – Controls & Mitigations



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C1

Vegetation Management – Distribution Overhead

Routine compliance-based vegetation management, including periodic inspections, clearing of vegetation around lines and around poles with equipment that poses a fire risk, and quality assurance.

C2

Vegetation Management – Catastrophic Emergency Memorandum Account

Additional inspections and tree work in areas of PG&E's service territory that are at higher risk for tree mortality or wildfire, including HFTD areas, State Responsibility Areas, and Wildland-Urban Interface.

C3

Equipment Preventive Maintenance and Replacement – Distribution Overhead:

Proactive identification and repair or replacement of critical overhead distribution equipment, such as cross-arms, transformers, capacitors, reclosers and switches

C4

Overhead Conductor Replacement

Replaces spans of conductor that have failed or are likely to fail, based on historical events and conductor attributes that include number of splices, fault duty, and exposure to harsh environments, such as coastal salt and fog.

C5

Patrols and Inspections – Distribution Overhead

Identifies damaged assets, compelling abnormal conditions, regulatory conditions, and third-party caused infractions that negatively impact safety or reliability, including conditions that may pose a risk of equipment failure.

C6

Overhead Infrared Inspections

Targets the physical inspection of overhead conductors using thermographic technology to identify damaged or deteriorated conductors and connectors.

C7

Supervisory Control and Data Acquisition

Includes the installation, upgrade and replacement of remotely controlled automation and protection equipment in distribution substations and on feeder circuits.

C8

Annual Protection Reviews

Covers electric distribution engineering and planning work which supports a variety of asset management activities and is necessary to safely and reliably plan, design, and operate PG&E's electric distribution system.

C9

Electric Distribution Line and Equipment Capacity

The primary purpose of PG&E's capacity program is to mitigate existing or projected overloads and voltage levels, these anomalies can also lead to equipment failure. When overloaded line equipment and conductors fail, service reliability is reduced and public safety concerns (such as wires down) can be created. These effects are mitigated by addressing potential overload conditions before they occur by installing and/or replacing equipment to increase capacity. These projects also sometimes include conductor replacement.

C10

Design Standards

General standards for proper installation, maintenance and operation of equipment to ensure safe and reliable operation.

C11

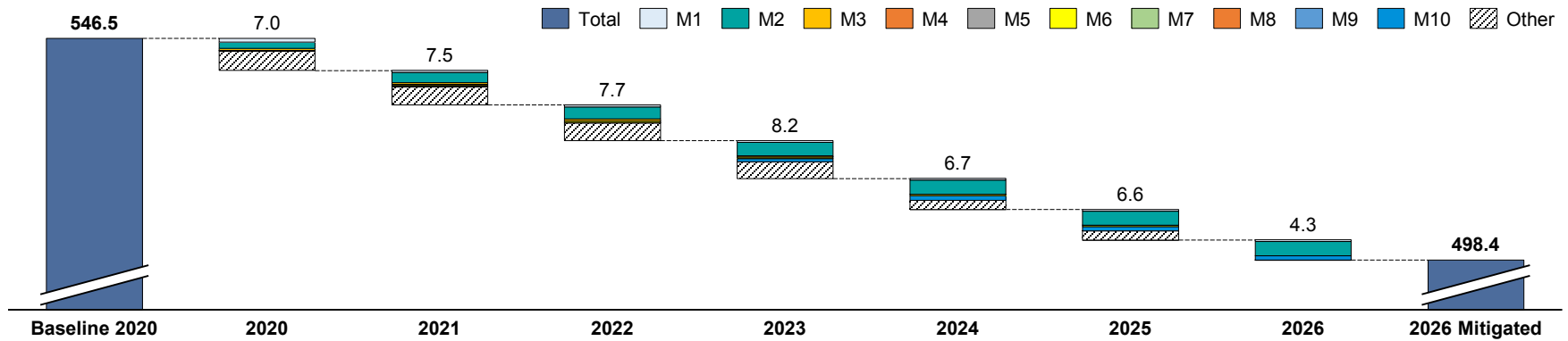
Pole Programs

Includes multiple activities related to distribution poles, including intrusive testing, remediation, and loading assessment. Distribution wood poles are remediated (through replacement or reinforcement) when necessary, based on observed degradation.

C12

Targeted Reliability Program

Includes targeted work to improve reliability. Typically, the work involves a combination of new fuse and line recloser installations, conductor replacements, installation of fault indicators, reframing of poles to increase phase separation, installation of bird/animal guards, and other maintenance, inspection, and vegetation management work.



#	Mitigation Program	Cumulative Risk Reduction						
		2020	2021	2022	2023	2024	2025	2026
M1	Enhanced Vegetation Management (EVM)	0.777	1.194	1.608	1.981	2.352	2.721	3.093
M2	System Hardening	1.419	3.654	6.245	9.137	12.222	15.269	18.339
M3	Non-Exempt Surge Arrester Replacement	0.396	0.776	1.194	1.444	1.434	1.424	1.421
M4	Expulsion Fuse Replacement	0.010	0.019	0.028	0.037	0.046	0.055	0.063
M5	Additional Asset Data Capture – Outage Information Reporting, Outage Cause, and Failure Analysis	-	-	-	-	-	-	-
M6	Grasshopper and KPF Switch Replacement	0.02	0.33	0.62	0.92	1.21	1.49	1.48
M7	Regulated Outpost (RO) Streetlight Replacement Program	-	-	-	6.5E-07	6.5E-07	6.4E-07	6.4E-07
M8	Ceramic Post Insulator Replacement Program	0.192	0.332	0.471	0.529	0.525	0.522	0.520
M9	Improved Distribution Risk Model (formerly STAR)	-	-	-	-	-	-	-
M10	3A and 4C Line Recloser Controller Replacement	-	0.028	0.055	0.779	1.750	2.706	3.660
Other	Crosscutting mitigations and Remote Grid pilot program	4.145	8.125	11.951	15.560	17.563	19.539	19.496
Total		7.0	14.5	22.2	30.4	37.1	43.7	48.1

Note: 1. Foundational programs have zero risk reduction by definition (M5 and M9).

Questions?

Rapid Earth Fault Current Limiter (REFCL)



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Background:

- REFCL technology can reduce the current flow from an energized line to ground fault to below half an amp, greatly reducing the risk of a fire ignition (based on ignition testing gone in Australia)
- Based on a small subset of 12 kV circuits in Tier 2 and 3 fire areas, REFCL could potentially reduce the risk of ignition by 58%
- Australian utilities have reported REFCL technology has successfully mitigated potential ignitions from line to ground faults

PG&E Calistoga Pilot Project Status

- Substations construction in progress and forecast to be complete by end of September
 - COVID-19 work restrictions have delayed delivery of key equipment from Sweden (ground fault neutralizer) and Australia (capacitive balancing units) pushing testing and commissioning to December 2020
- Distribution construction in progress and targeted for completion by middle of November

APPENDIX



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Mitigation Details



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M1 – Enhanced Vegetation Management Overview

Description

The EVM Program is targeted at overhead distribution lines in Tier 2 and Tier 3 HFTD areas and exceeds the requirements of PG&E’s annual Routine Vegetation Management that maintains compliance with CPUC mandated clearances.

Drivers, Sub-drivers, and Consequences

This mitigation targets the vegetation driver.

RSE Analysis

RSE – 2.429

RSE for this program reflects total risk reduction from both Wildfire and Distribution Overhead. The primary risk reduction for these programs is from Wildfire, they are represented here since they have ancillary DOH risk reduction benefit as well.

Mitigation Changes

There is no change to this mitigation.

Mitigation Effectiveness

Effectiveness varies by sub-driver.

Description

The System Hardening Program is an ongoing, long-term capital investment program to rebuild portions of PG&E’s overhead electric distribution system to reduce fire risk.

Drivers, Sub-drivers, and Consequences

This mitigation targets the Equipment Failure driver, with additional benefits mitigating Vegetation, Animal, and Other drivers.

RSE Analysis

RSE – 7.383

RSE for this program reflects total risk reduction from both Wildfire and Distribution Overhead. The primary risk reduction for these programs is from Wildfire, they are represented here since they have ancillary DOH risk reduction benefit as well

Mitigation Changes

PG&E plans to continue to increase the pace of system hardening with a goal of completing approximately 2,118 circuit miles in the 2023-2026 period.

Mitigation Effectiveness

Effectiveness varies by sub-driver.



System Hardening Mitigation Effectiveness - Outage

Outage Cause	Sub-Cause	Level 1 System Hardening Effectiveness	Level 2 Hybrid Effectiveness	Level 2 Percent Effective	Level 3 Firming Effectiveness	Level 3 Percent Effective
Other	Patrol - found nothing	90%	Step down	72%	Low	20%
	Patrol - not conducted	90%	Step down	72%	Low	20%
Other PG&E Assets or Processes	Generator	20%	same as SH	20%	None	0%
	Metering Equipment	0%	None	0%	None	0%
	Other Circuits	0%	None	0%	None	0%
	Return Circuit Normal	0%	None	0%	None	0%
Physical Threat	Vandalism	68%	step down	54%	None	0%
RIM	RIM - Mapping Errors	0%	None	0%	None	0%
	RIM - Other	0%	None	0%	None	0%
Third Party	Aircraft	53%	step down	42%	None	0%
	Car pole	63%	step down	50%	None	0%
	Contact with intact	75%	step down	60%	None	0%
	Customer equipment	38%	step down	30%	None	0%
	Dig in- 3rd party	48%	step down	39%	None	0%
	Fire- house or bldg.	40%	step down	32%	None	0%
	Gun Shot	42%	step down	33%	None	0%
	Kite	90%	Medium	40%	Low	20%
	Metallic Balloon	89%	Medium	40%	Low	20%
	Other	76%	step down	61%	Low	20%
	Thrown Object	85%	step down	68%	Low	20%
	Tree - cutting- 3rd party	67%	step down	54%	Low	20%
	Branch (OverHanging)	71%	same as SH	70%	None	0%
	Branch (Not overhanging, > 12ft)	73%	same as SH	73%	None	0%
Vegetation	Other/Unknown	68%	same as SH	68%	None	0%
	Fell into (No defect)	56%	same as SH	56%	None	0%
	Grow Into	73%	same as SH	73%	None	0%
	Fell into (slight defect)	55%	same as SH	55%	None	0%
	Fell into (Moderate-Severe defect)	57%	same as SH	57%	None	0%
	Dead	67%	same as SH	67%	None	0%
	Branch (Not overhanging, Distance Unknown)	69%	same as SH	69%	None	0%
	Branch (Not overhanging, 4-12ft)	70%	same as SH	70%	None	0%
	Branch (Not overhanging, within 4ft)	59%	same as SH	59%	None	0%



System Hardening Mitigation Effectiveness - Outage

Outage Cause	Sub-Cause	Level 1 System Hardening Effectiveness	Level 2 Hybrid Effectiveness	Level 2 Percent Effective	Level 3 Firming Effectiveness	Level 3 Percent Effective
Animal	Animal contact	77%	step down	61%	Medium	40%
	Bird Contact	74%	step down	59%	Medium	40%
D-Line Equipment Failure	Capacitor/Booster/Regulator	44%	None	0%	None	0%
	Conductor	54%	step down	44%	Low	20%
	Connector/Splice/Jumper/Kearney	70%	step down	56%	Low	20%
	Cross-arm	86%	step down	69%	step down	69%
	Cutout/Fuse	78%	None	0%	None	0%
	Insulator/Woodpin	85%	step down	68%	Medium	40%
	Other	77%	Low	20%	Low	20%
	Pole	63%	step down	50%	Low	20%
	Recloser/Sectionalizer	40%	None	0%	None	0%
	Secondary/Service	22%	None	0%	None	0%
	Support Structure	81%	step down	65%	Low	20%
	Surge Arrestor	90%	None	0%	None	0%
	Switch	71%	None	0%	None	0%
	Transformer	70%	None	0%	None	0%
Human Performance	Construction Activity	0%	None	0%	None	0%
	Contact with High Voltage- company	0%	None	0%	None	0%
	Coordination failure	0%	None	0%	None	0%
	Improper Construction	0%	None	0%	None	0%
	Operating error	0%	None	0%	None	0%
	Personnel- company	0%	None	0%	None	0%
Natural Hazard	Fire- Forest/Grass	27%	step down	21%	None	0%
	Flood/Erosion	42%	step down	33%	Low	20%
	Heat Wave	71%	step dow	57%	None	0%
	Ice or snow	90%	same as SH	90%	step down	72%
	Lightning	68%	None	0%	None	0%
	Seismic / Earth Movement / Landslide (Seismic Related) / Liquefaction	70%	step down	56%	Low	20%
	Water	56%	same as SH	56%	step down	45%

Description

The Non-exempt Surge Arrestor Program will replace non- exempt surge arresters with new exempt surge arresters, and correct abnormal grounding conditions where necessary.

Drivers, Sub-drivers, and Consequences

This mitigation targets the D-Line Equipment Failure driver.

RSE Analysis

RSE - 0.09

RSE for this program reflects total risk reduction from both Wildfire and Distribution Overhead. The primary risk reduction for these programs is from Wildfire, they are represented here since they have ancillary DOH risk reduction benefit as well.

Mitigation Changes

PG&E expects to complete all replacements in the program by 2023.

Mitigation Effectiveness

PG&E assumes that replacing non-exempt surge arresters with exempt surge arresters will eliminate 90% of Equipment Failure - Lightning Arrester.

Description

Beginning in 2019, PG&E is targeting replacement of 625 non-exempt fuses per year for seven years on poles located in HFTD areas.

Drivers, Sub-drivers, and Consequences

This mitigation targets the Vegetation and D-Line Equipment Failure driver.

RSE Analysis

RSE - 2.6

RSE for this program reflects total risk reduction from both Wildfire and Distribution Overhead. The primary risk reduction for these programs is from Wildfire, they are represented here since they have ancillary DOH risk reduction benefit as well.

Mitigation Changes

There is no change to this mitigation

Mitigation Effectiveness

PG&E assumes that replacing non-exempt fuses with exempt fuses would eliminate ignition risk associated with non-Exempt Fuses, at 90% effectiveness for all Fuse related failures. Fuse is only 42% of cutout/Fuse sub-driver. Effectiveness at Cutout/Fuse sub-driver is $90\% * 42\% = 37.6\%$

Description

The Grasshopper and KPF Switch Replacement program is targeted at replacing these switches that are obsolete, as PG&E is eliminating these from its system.

Drivers, Sub-drivers, and Consequences

This mitigation targets the Equipment Failure driver.

RSE Analysis

RSE - 3.68
 Grasshopper switches have a high risk-reduction per dollar spent, relative to other DOH programs (>~3x). Over the scope of this program, all remaining grasshopper & KPF switches will be replaced in PG&Es OH system.

Mitigation Changes

There is no change to this mitigation.

Mitigation Effectiveness

Capability of grasshopper switches is limited to picking up customers on a dead line. Newer switches (600-900 Amps) can pick up customers on load-bearing lines as well at 90% effectiveness.

Description

The RO Streetlight Replacement program is designed to replace a small number of antiquated RO streetlights that PG&E owns and operates in San Francisco.

Drivers, Sub-drivers, and Consequences

This mitigation has the potential to reduce the Other PG&E Assets or Processes driver.

RSE Analysis

RSE - 1.85E-06

The low RSE for this program does not accurately reflect the true risk/ risk reduction from replacing the remaining 49 RO streetlights in downtown SF. PG&E may potentially tranche out these assets separately when calculating RSEs, to better represent the true risk reduction.

Mitigation Changes

PG&E is planning to resume work in this program and complete all replacements in 2023.

Mitigation Effectiveness

Replacing the existing RO streetlights w/ newer 120V streetlights mitigates the risk of streetlight failure at 90% effectiveness, especially the risk of series failure for RO units which is not an issue for conventional streetlights.

Description

This program will replace ceramic post insulators manufactured prior to 1972.

Drivers, Sub-drivers, and Consequences

This program targets the mitigate the D-Line Equipment Failure driver.

RSE Analysis

RSE - 0.72

The ceramic post insulator program has a lower RSE relative to other DOH programs. PG&E continues to execute this program in tandem with surge arrester replacements as there are synergies from executing these programs in tandem.

Mitigation Changes

There are no changes to this mitigation.

Mitigation Effectiveness

PG&E believes that replacing older, ceramic post insulators with newer, composite insulators will be very effective at minimizing risk of insulator failure as a result of asset age and material properties at 90% effectiveness.

Description

PG&E uses line reclosers across its electric distribution overhead system to manage, locate, and isolate faults and to re-energize circuits in the event of an outage. Some of these line recloser units use older model 3A or 4C controllers, which have limited functionality compared to newer controller models.

Drivers, Sub-drivers, and Consequences

This mitigation targets the vegetation driver.

RSE Analysis

RSE - 1.39

The 3A 4C line recloser program is a new DOH program that PG&E intends to roll-out in the next GRC cycle. The RSE score for this program is among the higher ones in DOH and supports the investment in this program.

Mitigation Changes

PG&E plans to incorporate lessons learned from the pilot replacements in 2021 and 2022 to launch a full-scale replacement program in 2023. PG&E is targeting replacement of all remaining 3A and 4C controllers over a 10-year period beginning in 2023, replacing approximately 81 units per year.

Mitigation Effectiveness

Replacing the 3A and 4C controller with newer controllers is expected to reduce the risk of recloser failure, since newer units are expected to have a lower failure rate than older 3A/4C units at 90% effectiveness.

Alternative Mitigations and Pilot Control



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Description

Remote grid is an effort to use decentralized energy sources to permanently supply energy to certain remote customers instead of using hardened traditional utility infrastructure for electricity delivery.

Drivers, Sub-drivers, and Consequences

This mitigation targets the Equipment Failure, Vegetation, Animal, and Other drivers.

Project Status

Pilot Assessment Phase

Considerations

PG&E is evaluating the program efficiency by conducting M11 pilot projects. If successful, PG&E proposes to expand the mitigation to additional feeders in 2021-2022 and subsequently 2023-2026

RSE

RSE: 17.8

Mitigation Effectiveness

95% of all drivers

Description

Focuses on failure mechanisms identified from the Failure Mode Engineering Analysis (FMEA). The Enhanced Inspection program was implemented in December 2018 and deployed for all of High-Fire Threat Districts, as well as nearby structures in close proximity. Building on this foundation, PG&E is incorporating the Enhanced Inspection processes and tools into the Routine Inspection and Maintenance Program.

Drivers, Sub-drivers, and Consequences

This mitigation targets the D-Line Equipment Failure and Vegetation drivers.

Considerations

"PG&E estimated the effectiveness of this control by analyzing the number of inspections, preventive tags created and find rate for the 2019 Wildfire Safety Inspection Program (WSIP)-Distribution program.

Step 1: Estimate the number of tags created by Enhanced Inspection Program in 2020. To estimate the no of tags created PG&E used the program scope in Tier 3, Tier 2 and Non-HFTD areas. Estimated Tags in each region = 2020 Expected Find Rate per Mile in each region X Scope of work in 2020 X No of Miles in each region.

Step 2: Multiplying the number of tags estimated in each tier with tag to outage ratio, PG&E estimated the number of outages prevented by the Enhanced Inspection Program.

Step 3: Control effectiveness is the ratio of the number of outages prevented to average Equipment Failure outages per year.

Mitigation Effectiveness

40% for HFTD
57% for Non-HFTD

Tier 3

Tier 3	DOH Miles (approx)	2019 Total Tags Found from Enhanced Inspections	2019 Tag Find Rate (/mile)	2020 Find Rate vs 2019	Estimated Tag Find Rate (/ mile)	Annual Work Scope	Estimated Tags to be found	Tag to outage Ratio	Estimated Outage to be Prevented	Estimated # Outage to be prevented/mile
A	7,100	145	0.020	100%	0.020	100%	145	70%	102	0.014
B		1,712	0.241	25%	0.060		428	50%	214	0.030
E+F		44,665	6.291	25%	1.573		11,166	1%	112	0.016
Total							11,739		427	0.060

Tier 2 + Zone 1 + Buffer Zone

Tier 2+Zone1+Buffer Zone	DOH Miles (approx)	2019 Total Tags Found from Enhanced Inspections	2019 Tag Find Rate (/mile)	2020 Find Rate vs 2019	Estimated Tag Find Rate (/ mile)	Annual Work Scope	Estimated Tags to be found	Tag to outage Ratio	Estimated Outage to be Prevented	Estimated # Outage to be prevented/mile
A	18,310	224	0.012	100%	0.012	33%	75	70%	52	0.009
B		2,759	0.151	25%	0.038		230	50%	115	0.019
E+F		115,859	6.328	25%	1.582		9,655	1%	97	0.016
Total							9,960		264	0.043

Non-HFTD

Non-HFTD	DOH Miles (approx)	2019 Total Tags Found in HFTD from Enhanced Inspections	2019 HFTD Tag Find Rate (/mile)	2020 Find Rate vs 2019	Estimated Tag Find Rate (/ mile)	Annual Work Scope	Estimated Tags to be found	Tag to outage Ratio	Estimated # Outage to be Prevented in 2020	Estimated # Outage to be prevented/mile
A	55,300	369	0.014522	100%	0.015	20%	161	70%	112	0.010
B		4,471	0.175954	100%	0.176		1,946	50%	973	0.088
E+F		160,524	6.317355	100%	6.317		69,870	1%	699	0.063
Total							71,977		1784	0.161

Outages Prevented

Item	Units
Equipment Failure Outages per year:	8784
Outages prevented in 2020:	2475
(Scope-adjusted) Average Effectiveness	28%

Aggregated Effectiveness

Item	<u>Overall</u>	<u>non-HFTD</u>	<u>HFTD</u>
Equipment Failure Outage	8,784	6,788	1,995
Total Miles	80,710	55,300	25,410
Equipment Failure outages prevented due to existing control	10,250	8,921	1,330
Equipment Failure Outage per mile including prevented	0.24	0.28	0.13
Control Effectiveness	54%	57%	40%

Financials



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DOH Mitigation Cost Forecast (\$M)¹

Mitigation	2020	2021	2022	2023	2024	2025	2026	Total	%
M1 Additional Asset Data Capture – Outage Information Reporting, Outage Cause, and Failure Analysis	4.20	1.23	1.26	1.29	1.32	1.36	1.39	12.1	0.1%
M2 Enhanced Vegetation Management (EVM)	494.63	506.99	519.67	532.66	545.98	559.63	573.62	3,733.2	40.8%
M3 System Hardening	366.72	565.64	698.36	796.32	850.04	868.05	889.75	5,034.9	55.1%
M4 Non-Exempt Surge Arrester Replacement	70.58	67.65	62.63	47.68	-	-	-	248.5	2.7%
M5 Expulsion Fuse Replacement	5.42	5.56	5.69	5.84	5.98	6.13	6.29	40.9	0.4%
M6 Grasshopper and KPF Switch Replacement	0.03	1.14	1.17	1.19	1.22	1.25	-	6.0	0.1%
M7 Regulated Outpost (RO) Streetlight Replacement Program	-	-	-	5.28	-	-	-	5.3	0.1%
M8 Ceramic Post Insulator Replacement Program	3.44	2.62	2.69	1.31	-	-	-	10.1	0.1%
M9 Improved Distribution Risk Model (formerly STAR)	2.90	1.44	1.47	1.51	1.55	1.58	1.62	12.1	0.1%
M10 3A and 4C Line Recloser Controller Replacement	-	0.51	0.53	8.72	8.94	9.16	9.39	37.3	0.4%
Total	947.9	1,152.8	1,293.5	1,401.8	1,415.0	1,447.2	1,482.1	9,140.2	100%

Controls		2019 Recorded Expense Costs	2019 Recorded Capital Costs
C3	Equipment Preventative Maintenance and Replacement	\$ 54,527,907	\$ 168,214,063
C4	Overhead Conductor Replacement	N/A	\$ 9,664,627
C7	Supervisory Control and Data Acquisition	\$ 8,309,071	\$ 56,471,996
C8	Annual Protection Reviews	\$ 9,101,284	N/A
C9	Electric Distribution Line and Equipment Capacity	N/A	\$ 73,441,286
C11	Pole Programs	\$ 16,828,529	\$ 243,911,126
C12	Targeted Reliability Program	N/A	\$2,710,851

Wildfire 2020 RAMP Post-Filing Workshop

Electric Operations
Mark Esguerra
July 30, 2020



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Objective | Provide overview of PG&E's Wildfire Risk Assessment and Mitigation Program Portfolio going into 2023 General Rate Case

- I. Introduction
 - a. *Definition & RAMP Risk Scores*
 - b. *Regulatory Proceedings & Risk Modeling Summary*
- II. Risk Assessment
 - a. *Risk Bowtie Overview*
 - b. *Exposure/Tranches*
 - c. *Drivers and Sub-drivers*
 - d. *Consequences*
 - e. *Cross Cutting Factors*
- III. Mitigations and Controls
 - a. *Enhanced Vegetation Management*
 - b. *System Hardening and Non-Exempt Equipment Replacement*
 - c. *Public Safety Power Shutoff*
 - d. *Inspections*
- IV. Appendix

Definition

PG&E assets or activities that may initiate a fire that is not easily contained, endangering the public, private property, sensitive lands or environment.

Scope

- **In Scope:** PG&E assets or activities that may initiate a fire that is not easily contained, endangers the public, private property, sensitive lands or environment
- **Out of Scope:** Fire ignitions and associated impacts not related to PG&E electric system assets

Background

Changes in weather and vegetation growth and tree mortality patterns brought on by climate change, coupled with increased development in formerly wildland areas have led to increased consequences related to wildfire ignitions in recent years. As discussed in PG&E's 2020 GRC testimony on the Wildfire risk, 15 of the 20 most destructive wildfires in California's history have occurred since 2000, including 10 since 2015. PG&E's overhead electrical transmission and distribution assets are potential sources of wildfire ignition. PG&E faces significant wildfire challenges because of the size and geography of its service area. PG&E serves approximately 5.5 million electric customers across a service territory of approximately 70,000 square miles, more than half of which is included in HFTD areas.

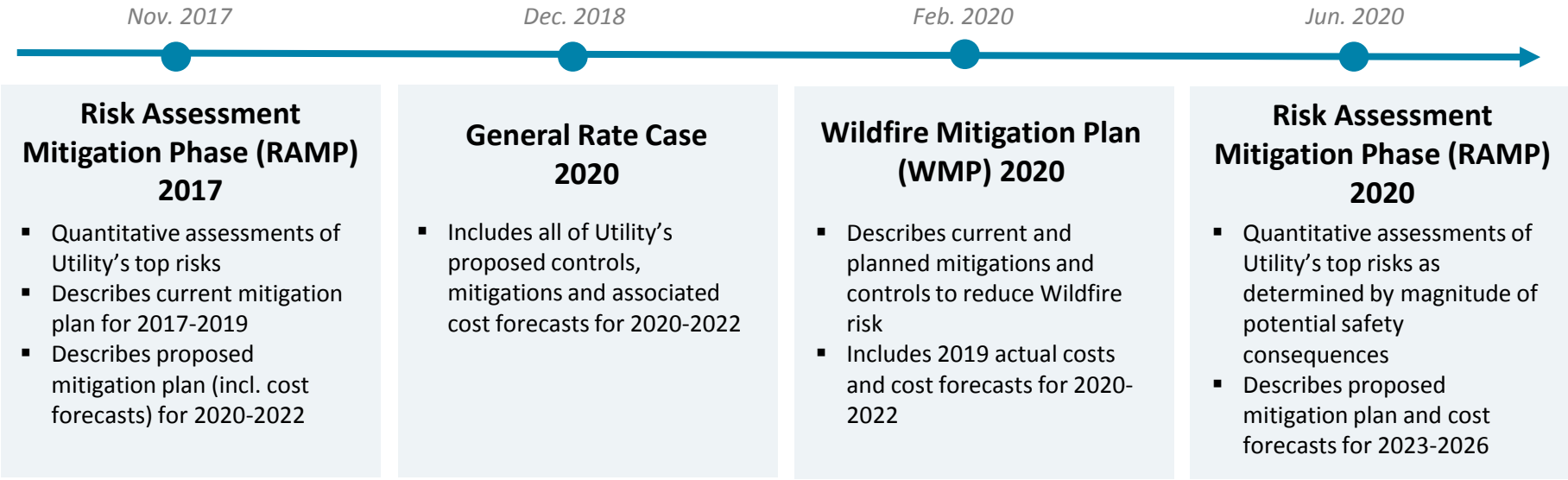


PG&E RAMP Risk Scores

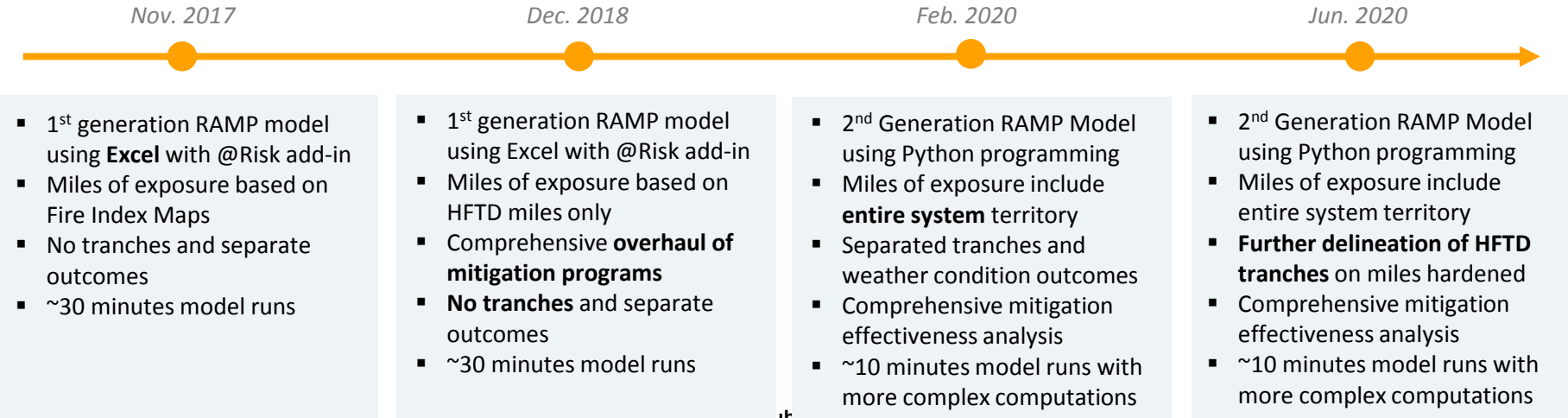
Rank	LOB	Safety Risks	2023 Baseline Score	
			Safety Risk Score	Multi-Attribute Risk Score
1	EO	Wildfire	9,856	25,127
2	SHED	Third Party Safety Incident	887	944
3	GO	Loss of Containment on Gas Transmission Pipeline	128	281
4	SHED	Contractor Safety Incident	94	94
5	SHED	Employee Safety Incident	86	90
6	GO	Loss of Containment on Gas Distribution Main or Service	72	99
7	SS	Real Estate and Facilities Failure	69	97
8	PGEN	Large Uncontrolled Water Release (Dam Failure)	41	70
9	EO	Failure of Electric Distribution Overhead Assets	18	525
10	SHED	Motor Vehicle Safety Incident	16	17
11	EO	Failure of Electric Distribution Network Assets	6	7
12	GO	Large Overpressure Event Downstream of Gas M&C Facility	5	13

The Wildfire risk modeling has evolved since the RAMP 2017 filing, across various regulatory proceedings

PG&E Regulatory Filings addressing Risks



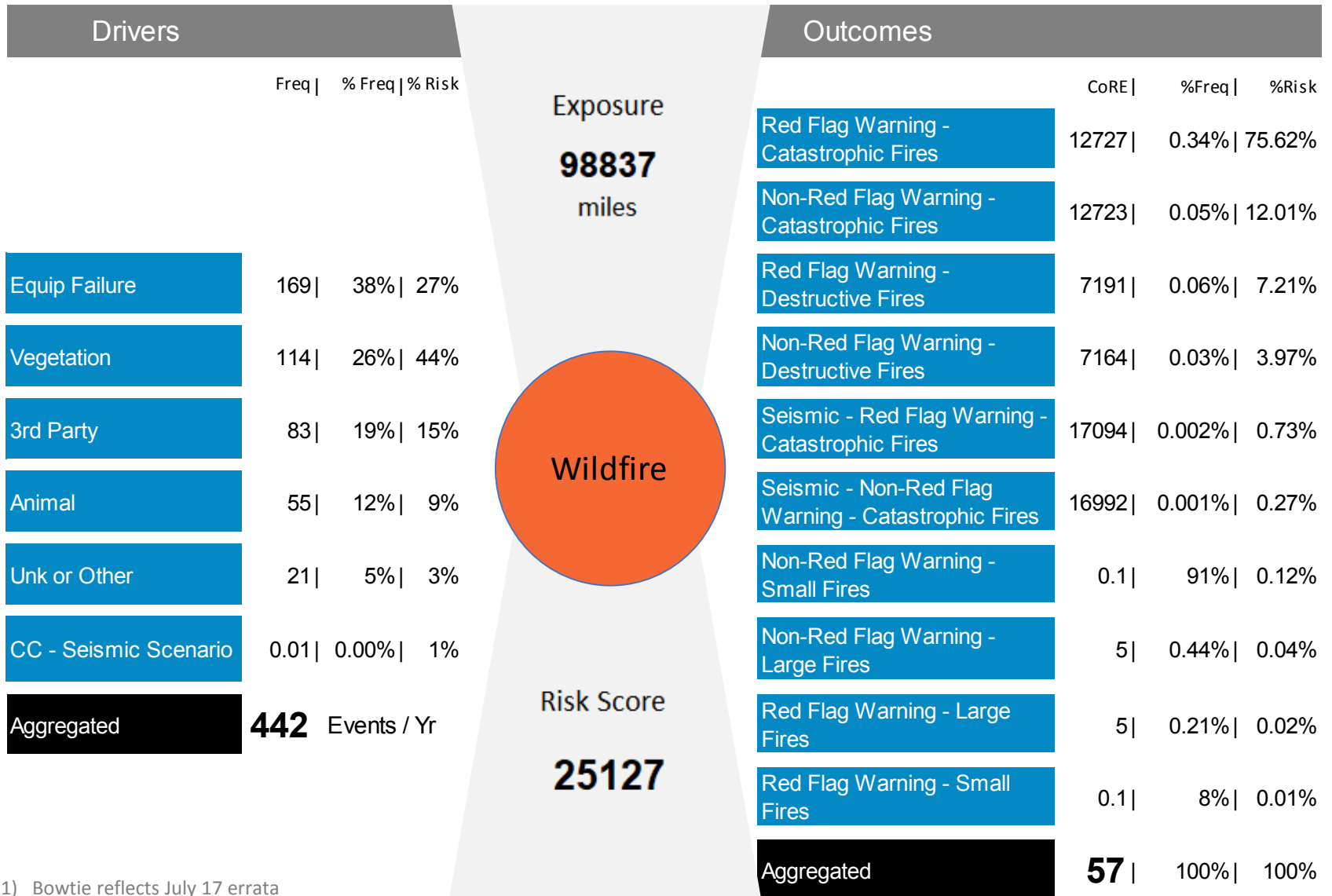
Evolution of Wildfire risk modeling



Risk Assessment – Bowtie Development

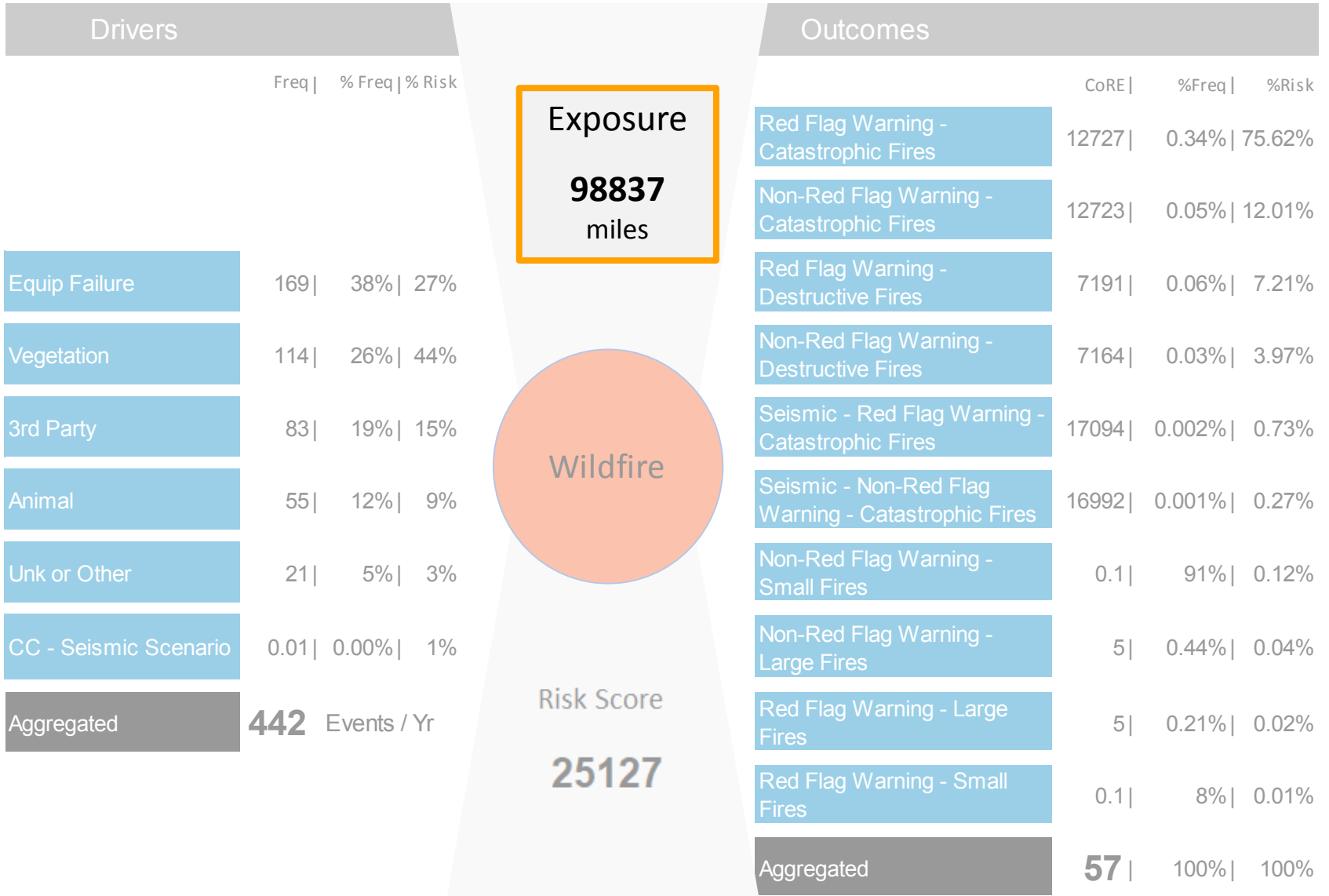


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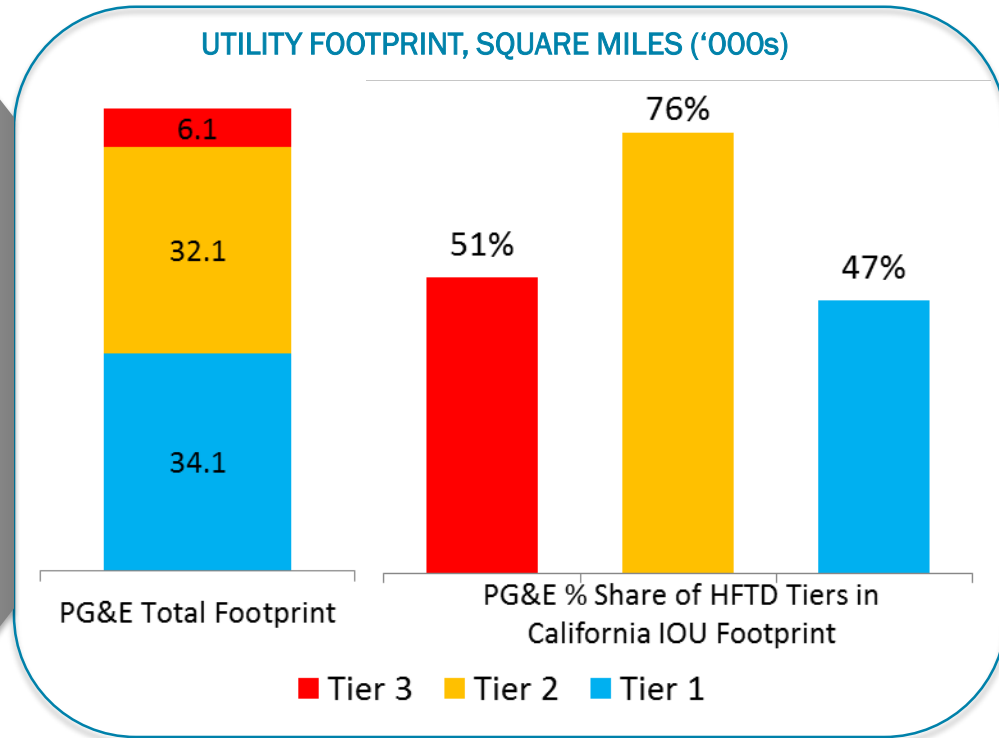
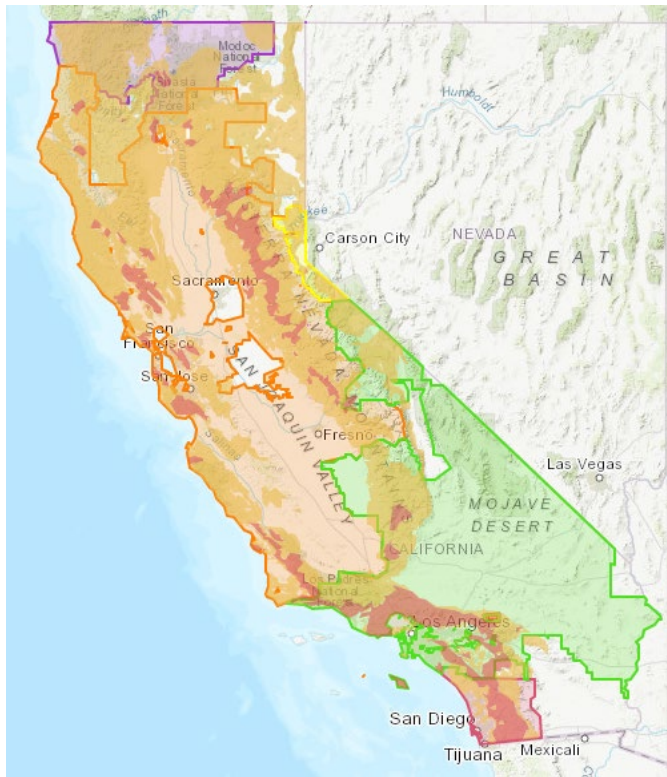
(1) Bowtie reflects July 17 errata

(2) Risk score represents Test Year Baseline Risk Score for 2023 (i.e. pre-mitigation risk score for 2023, post 2020-2022 mitigations, post all controls)



Wildfire Risks in PG&E's Service Area

Fire Threat Tiers by California IOUs

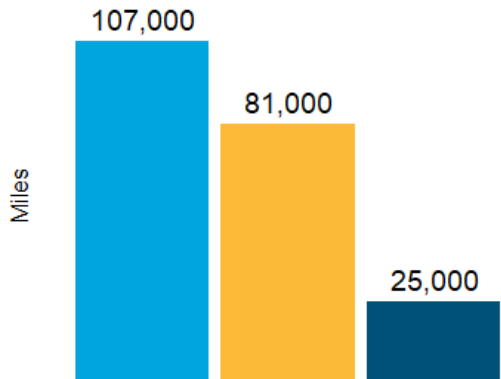


- Pacific Gas & Electric
- Southern California Edison
- San Diego Gas and Electric
- CPUC Tier 2
- CPUC Tier 3

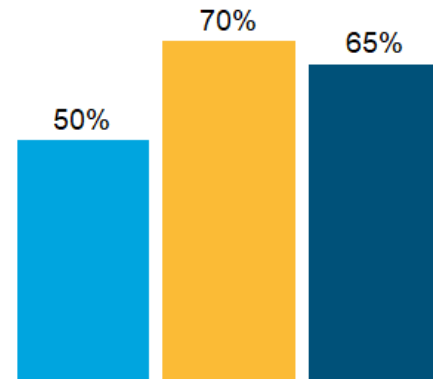
Sources: PG&E – Company data, SCE – Grid Safety and Resiliency Program Application; SDG&E – PG&E analysis

Distribution Circuit Miles

PG&E SERVICE TERRITORY



PG&E % SHARE OF CALIFORNIA IOU DISTRIBUTION CIRCUIT MILES



KEY

- Primary distribution circuit miles
- Overhead distribution circuit miles
- Overhead distribution circuit miles in High Fire Threat Areas

OBSERVATIONS

- PG&E has the largest population of the overhead conductors in the fire threat areas of the California IOUs.

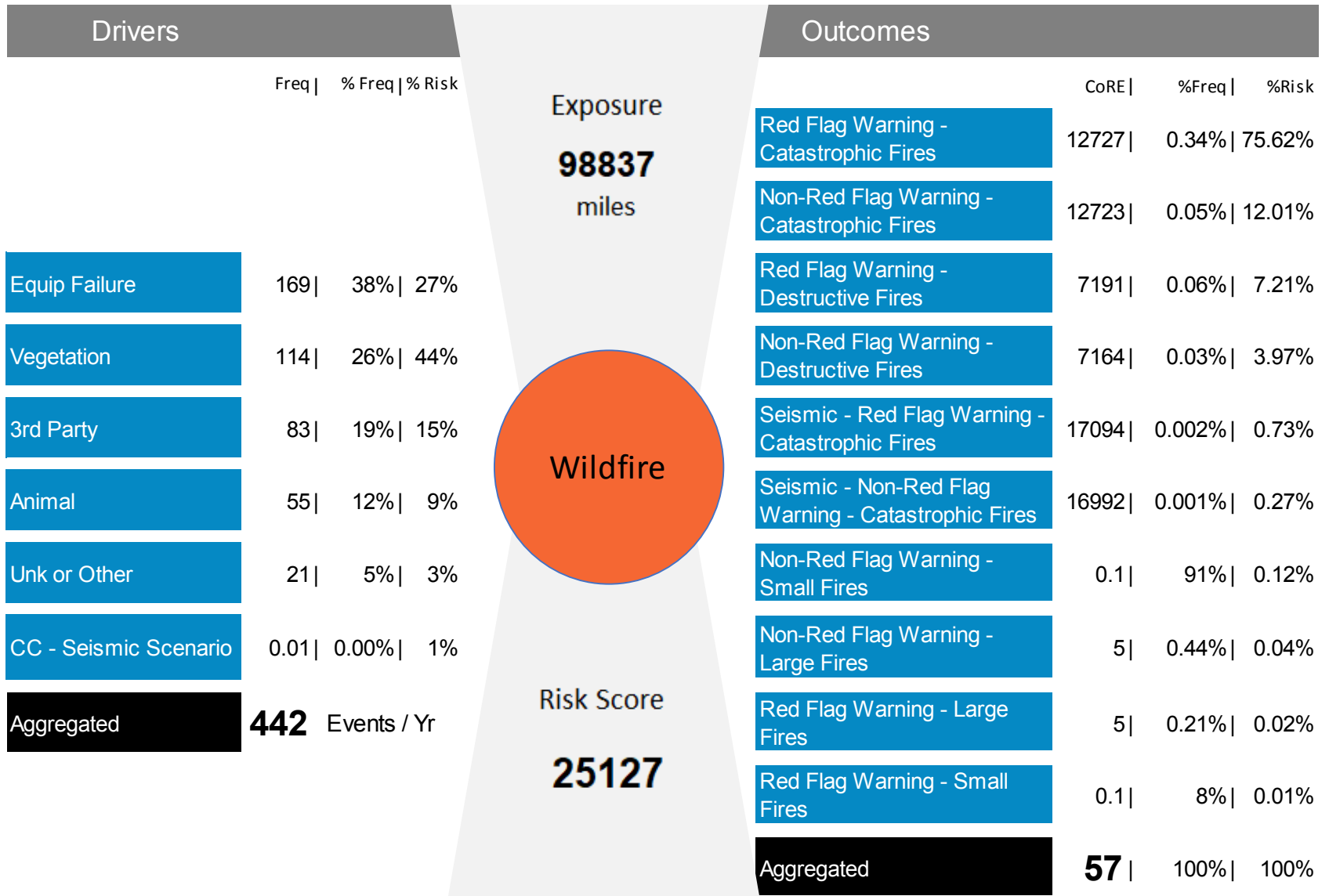
Note: (1) California IOUs is comprised of PG&E, SCE, and SDG&E. PG&E Fire Threat Area mileage is defined as HFTD Tier 3, 2, and Zone 1. SCE Fire Threat Area is defined as High Fire Risk Area (HFRA), which contains Tier 3 and Tier 2 areas and additional areas selected by SCE. SDG&E Fire Threat Area is defined as Fire Threat Zone as established in its 2016 RAMP Filing. Sources: PG&E: RAMP Filing 2017, company data; SCE: Grid Safety and Resiliency Program, September 2018; SDG&E: RAMP Filing 2016

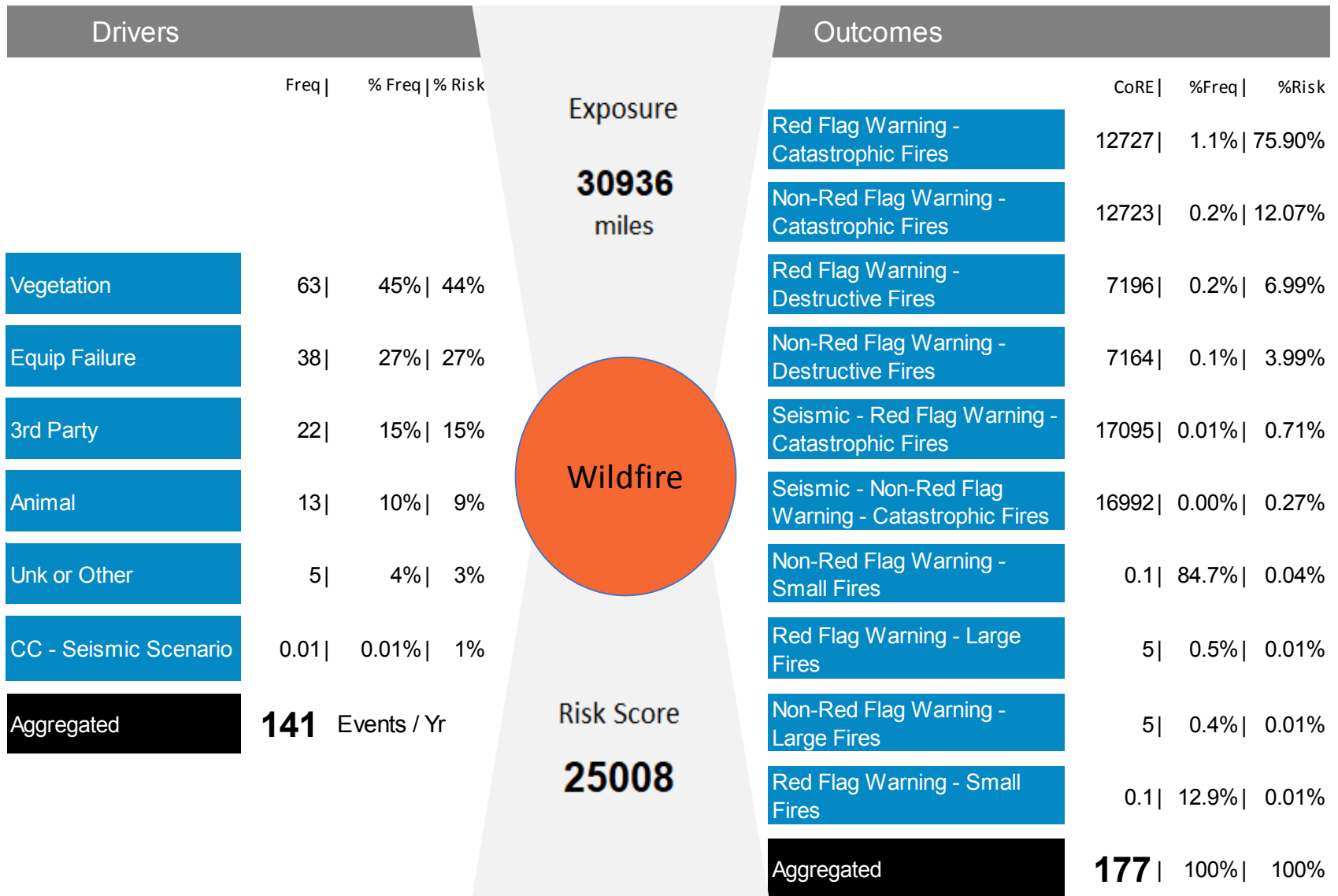
Exposure area of risk consists of 99,000 miles of overhead primary circuit miles.
Exposure is divided into eight tranches.

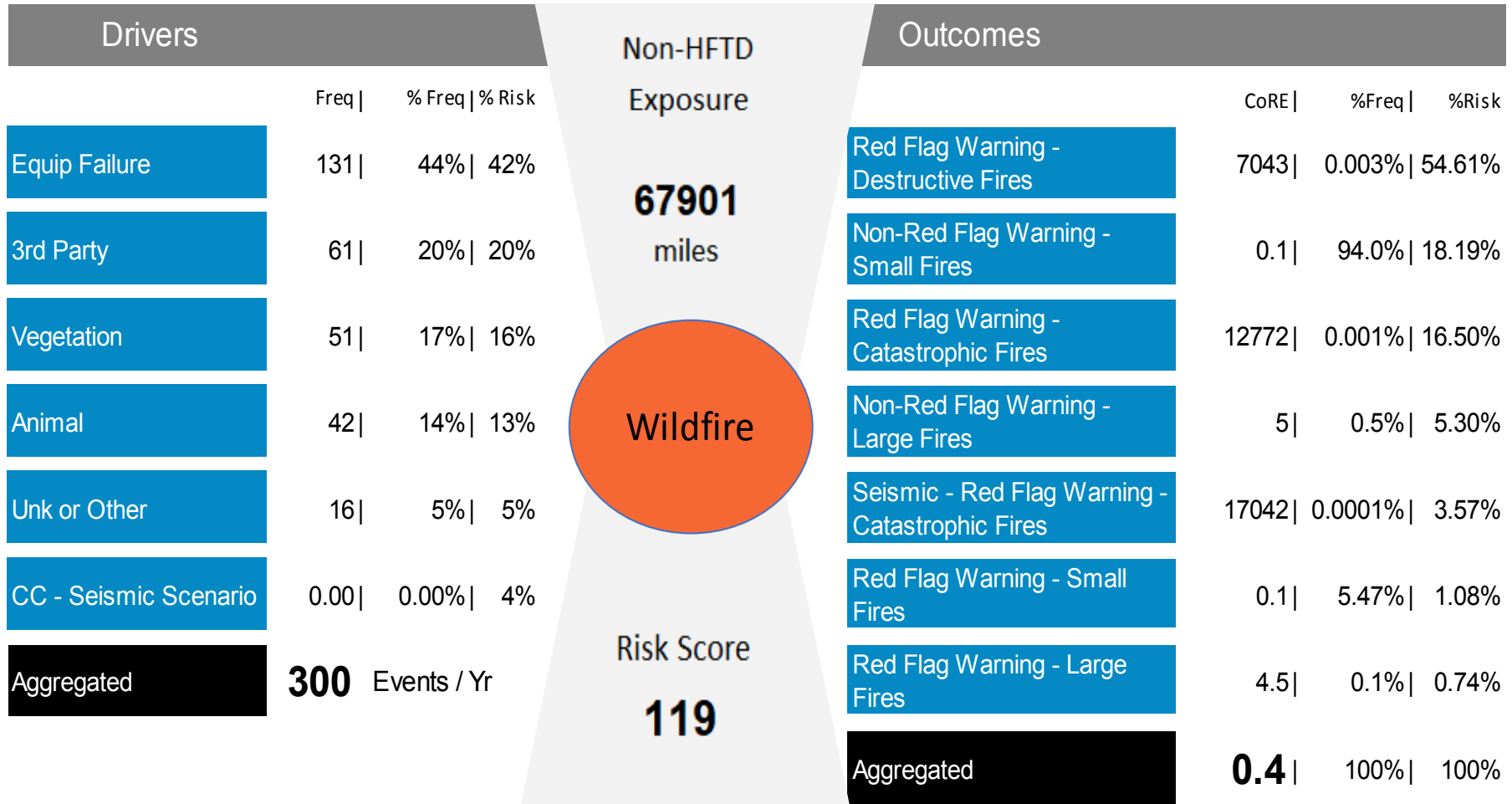
- This total consists of approximately 81,000 distribution overhead circuit miles and 18,000 transmission overhead circuit miles
- Prior models only included approximately 52,000 circuit miles identified as Fire Index Areas prior to adoption of HFTD
- Current model includes all circuit miles in PG&E territory, separating between HFTD and non-HFTD territories
- Allows PG&E to understand the magnitude of the risk between parts of the system, and better differentiate risk spend efficiency analysis

	Distribution	Transmission	Substation ¹
HFTD	25,400	5,525	203
Non-HFTD	55,300	12,600	739
Total	80,710	18,125	942

(1) Substations includes switching stations and other facilities; assigned 1 circuit mile of lines for modeling purposes.





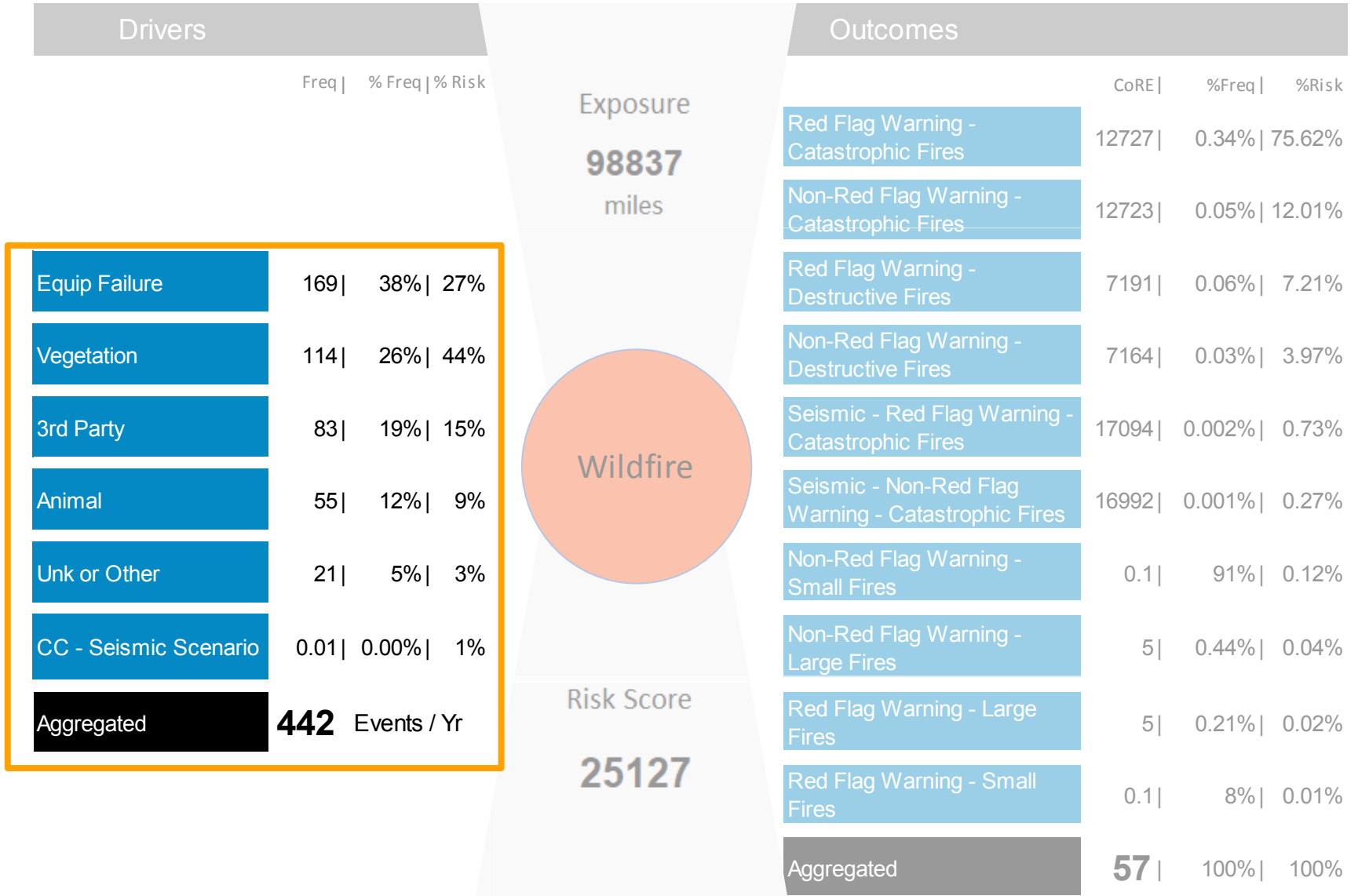


Eight tranches were developed that segment the PG&E asset system, thus better understanding and modeling the causes and consequences of ignitions

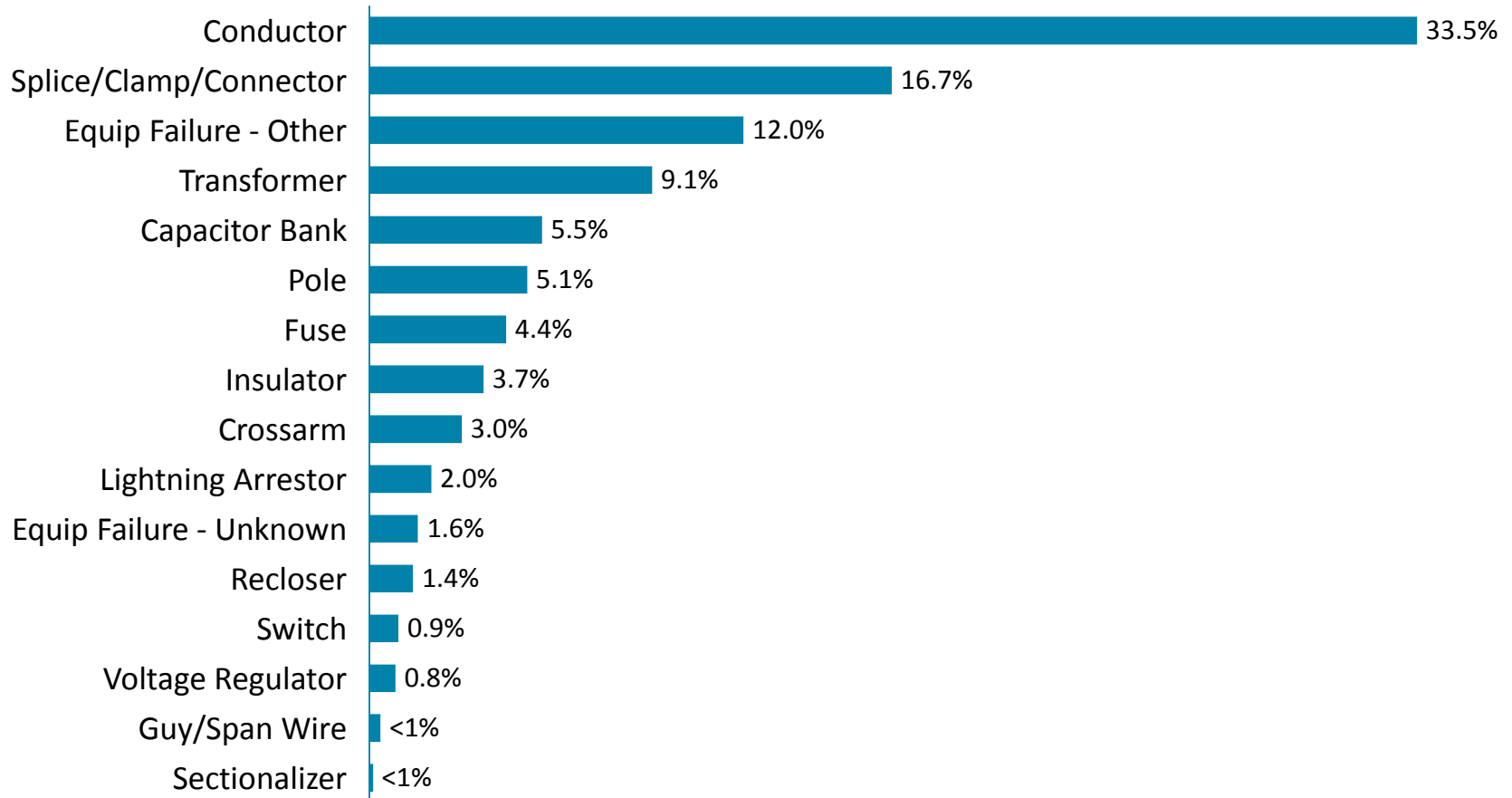
Wildfire Tranche Categories	Description	Mile Exposure	% of Mile Exposure	% of Risk Score
HFTD-Distribution – Hardened	Distribution lines in HFTD areas already hardened as of 2019	171	0.17%	0.60%
HFTD-Distribution – To be Hardened	Distribution lines in HFTD areas that will be in scope of System Hardening program	6,929	7.01%	45.41%
HFTD-Distribution – Remainder	Distribution lines in HFTD areas that are outside scope of System Hardening program	18,310	18.53%	47.01%
HFTD – Transmission	Transmission lines in HFTD areas	5,525	5.59%	6.51%
HFTD – Substation¹	Substations located in HFTD areas	1	0.00%	0.00%
Non-HFTD Distribution	Distribution lines in non-HFTD areas	55,300	55.95%	0.46%
Non-HFTD Transmission	Transmission lines in non-HFTD areas	12,600	12.75%	0.02%
Non-HFTD Substation¹	Substations located in non-HFTD areas	1	0.00%	0.00%
Total		98,837	100%	100%

(1) Substations assigned 1 circuit mile of lines for modeling purposes.

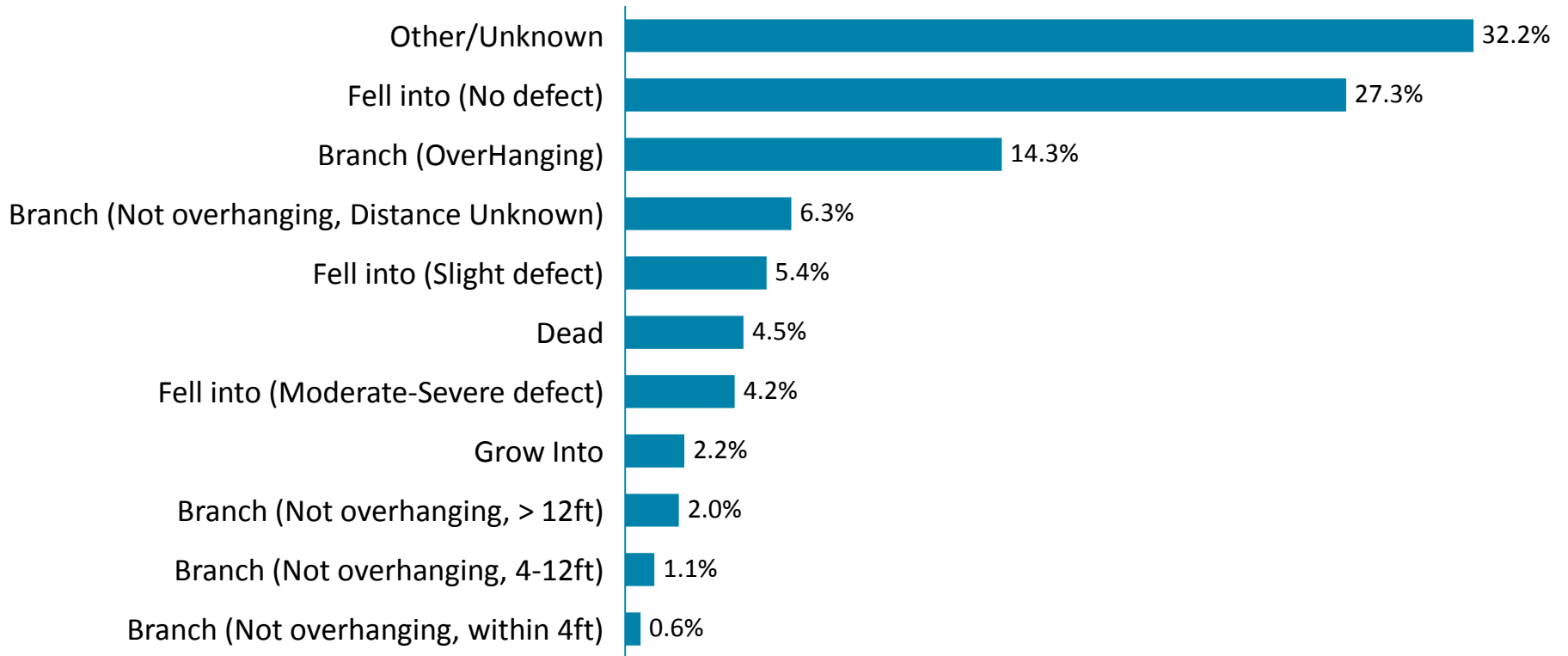
(2) % of Exposure and % of Risk Score as of July 17th errata

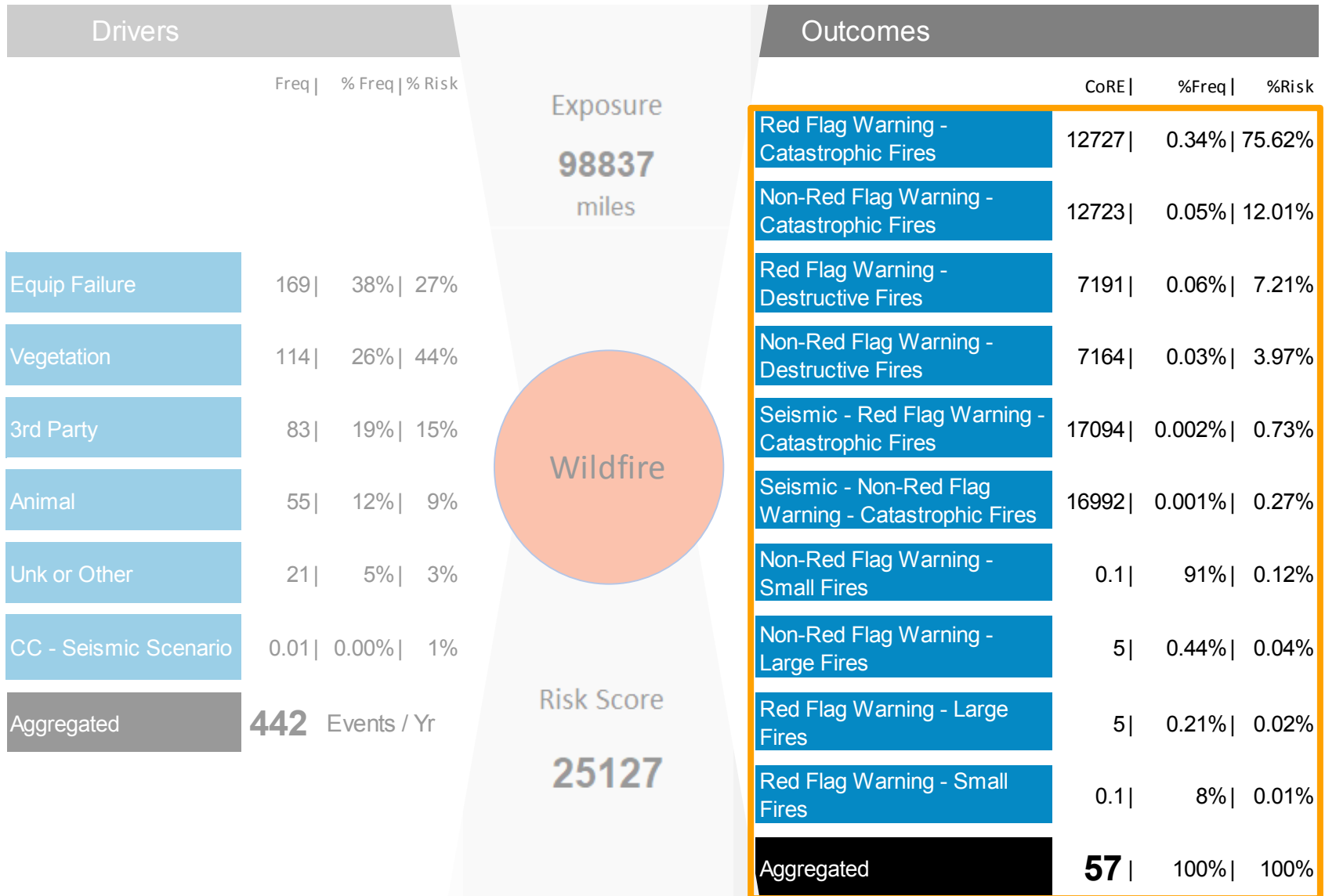


Equipment Failure Sub-drivers



Vegetation Sub-drivers



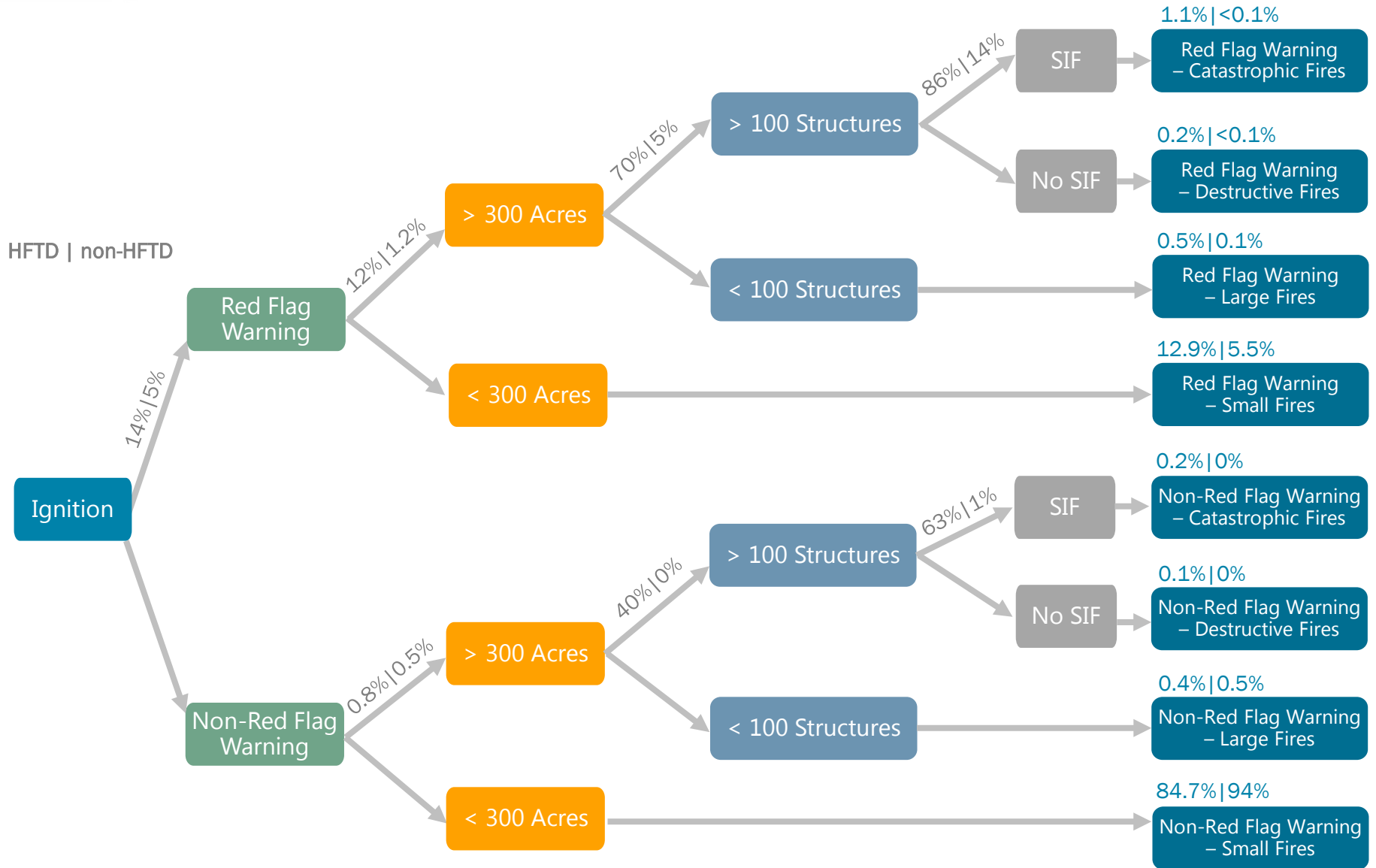


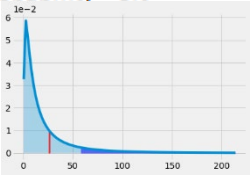
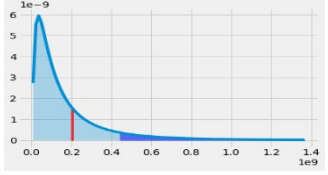
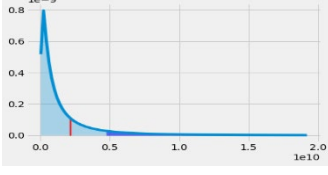
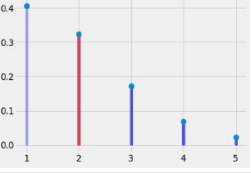
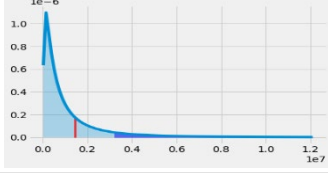
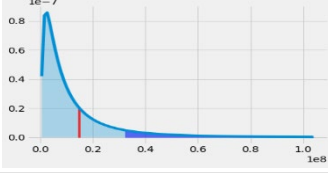
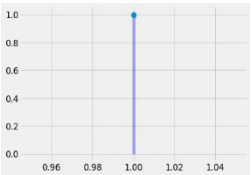
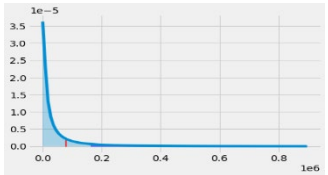
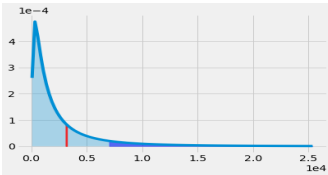
Unlike in the 2017 RAMP, where PG&E considered all ignitions as a single category, in the 2020 RAMP PG&E is providing a more granular view of ignitions in terms of three variables: (1) size/destructiveness, (2) whether the ignition took place during Red Flag Warning, (3) association with a seismic event

Fire Type	Red Flag Warning	Seismic Event	Frequency	% of Risk
Catastrophic	Yes	No	0.34%	75.81%
Catastrophic	No	No	<0.10%	12.05%
Catastrophic	Yes	Yes	<0.10%	0.72%
Catastrophic	No	Yes	<0.10%	0.27%
Destructive	Yes	N/A	<0.10%	7.06%
Destructive	No	N/A	<0.10%	3.90%
Large	Yes	N/A	0.21%	0.02%
Large	No	N/A	0.44%	0.05%
Small	Yes	N/A	7.8%	0.01%
Small	No	N/A	91%	0.12%

Additional Considerations:

- 83% of the total Wildfire risk is from ignitions on RFW days that lead to catastrophic or destructive fires
- PG&E’s decision to invest in PSPS, which is targeted at reducing ignitions when RFW conditions, aligns with mitigating highest percentage of risk
- This also supports PG&E’s investment in situational awareness mitigations, such as improvements in meteorology, that will improve PG&E’s ability to predict and respond to conditions that have the greatest potential for ignitions to turn into more dangerous fires



		Safety	Electric Reliability	Financial
Catastrophic / Destructive	Source	CAL FIRE & SME Input	PG&E Data	CAL FIRE
	Distribution	Catastrophic: Sampling Probability = 100% Destructive: Sampling Probability = 0% SIF [Lognormal] Mean = 26 STD = 49 Fatality/SIF = 50% 	Sampling Probability = 100% [Lognormal] Mean = 199 M STD = 295 M 	Sampling Probability = 100% [Lognormal] Mean = 2.1 B STD = 4.7 B 
CoRE		5,622	434	6,685
Large	Source	CAL FIRE & SME Input	PG&E Data	CAL FIRE
	Distribution	Sampling Probability = 2% SIF [Zero-trunc Poisson] Mean = 2 Prob(Fatality SIF) = 50% 	Sampling Probability = 100% [Lognormal] Mean = 1.4 M STD = 2.8 M 	Sampling Probability = 30% [Lognormal] Mean = 14 M STD = 23 M 
CoRE		1	1	2
Small	Source	CAL FIRE	PG&E Data	CAL FIRE
	Distribution	Sampling Probability = 0.1% SIF [Deterministic] Mean = 1 Prob(Fatality SIF) = 50% 	Sampling Probability = 96% [Lognormal] Mean = 76 K STD = 279 K 	Sampling Probability = 100% [Lognormal] Mean = 3 K STD = 6 K 
CoRE		0.040	0.035	0.002

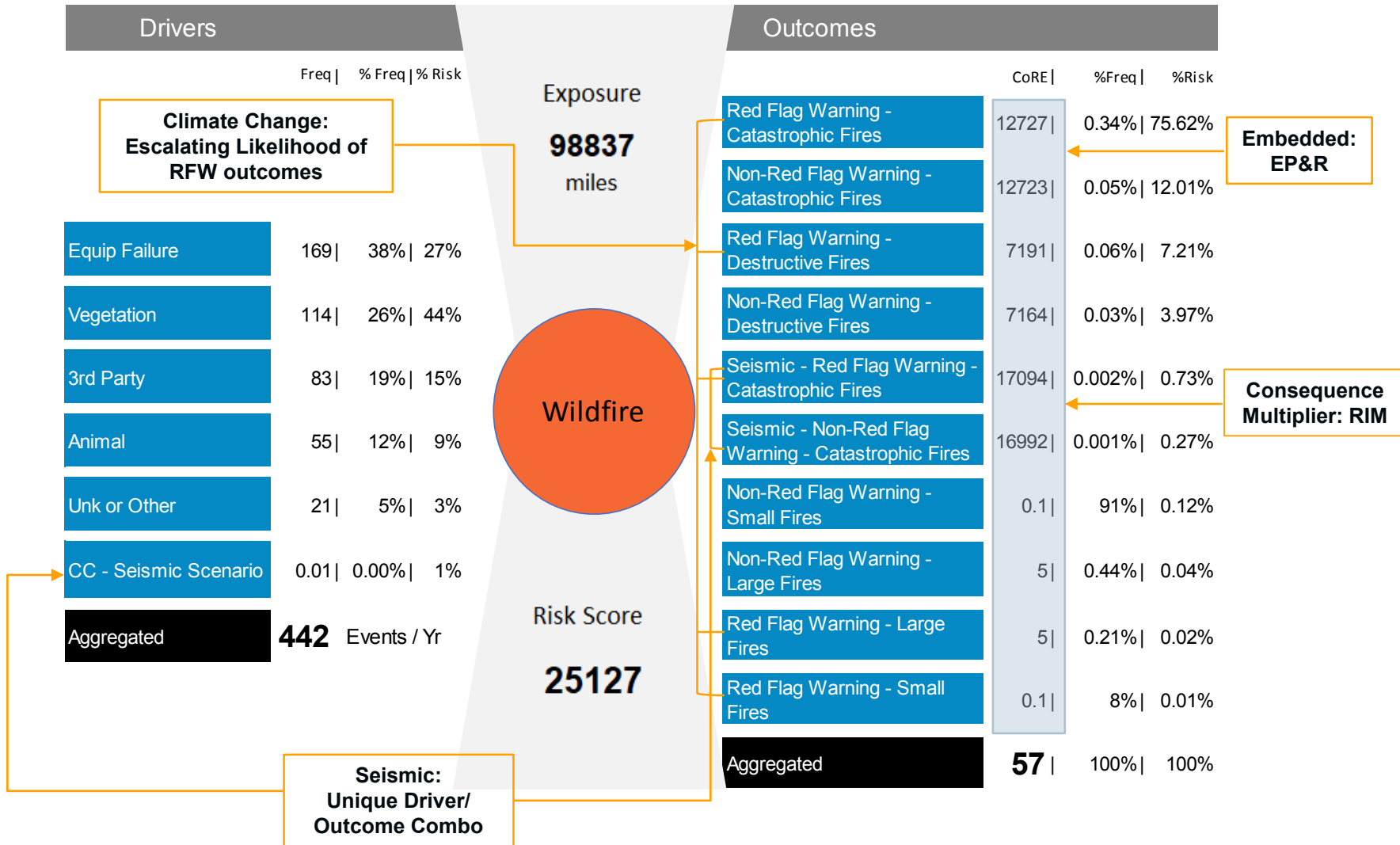
- SIF denotes Serious Injuries or Fatalities.
- Except for small fire outcomes, the financial consequence is estimated as the product of dollar damage per structure destroyed and number of structures destroyed. Dollar damage of \$1M per structure is assumed based on total dollar damage divided by total number of structures destroyed in 2017 CAL FIRE Redbook, CA total.
- For small fire outcomes, the financial consequence is estimated using 2014-2017 average dollar damage per fire by fire size bucket.
- For the catastrophic fires associated with seismic events, a multiplier (1.3 for safety and 1.5 for reliability and financial) was applied to consequence in natural units.
- On the charts, the red line indicates the mean level, and the darker shaded area indicates the tail above 90th percentile.

Four cross-cutting factors were quantified in the Wildfire risk model

Cross-Cutting Factor	Impacts Likelihood	Impacts Consequence	Methodology
Climate Change	X		Wildfire forecasts used to reallocate fire occurrences into increasing Red Flag Warning days; fires during RFW were modelled to have more severe consequences
Emergency Preparedness and Response		X	EP&R modelled as a mitigation that lessens consequences of most severe fires
Records and Information Management		X	A 2.9% multiplier was applied to heighten Financial Consequences, reflecting the state of records management maturity based on the current records management practice
Seismic	X	X	Historical likelihood of catastrophic fire given ignition is elevated to estimate frequency of catastrophic fires caused by seismic events. In addition, more severe consequences are assumed for seismic driven catastrophic fires than non-seismic driven ones.

Additional Cross-Cutting Considerations:

- **Cyber Attack and IT Asset Failure:** Data was not yet at maturity to quantify in the risk model for RAMP 2020 process; PG&E intends to integrate this cross-cutting risk as part of the GRC filing



Climate Change Integration with Wildfire Risk Additional Background

Data Source: California’s 4th Climate Assessment
(Westerling et al., 2018)

Native Metric: Average annual area burned (hectares)

Metric for Bowtie: Change in Red Flag Warnings (RFW)

Key Assumption: RFW likelihood is correlated with annual area burned by wildfire.

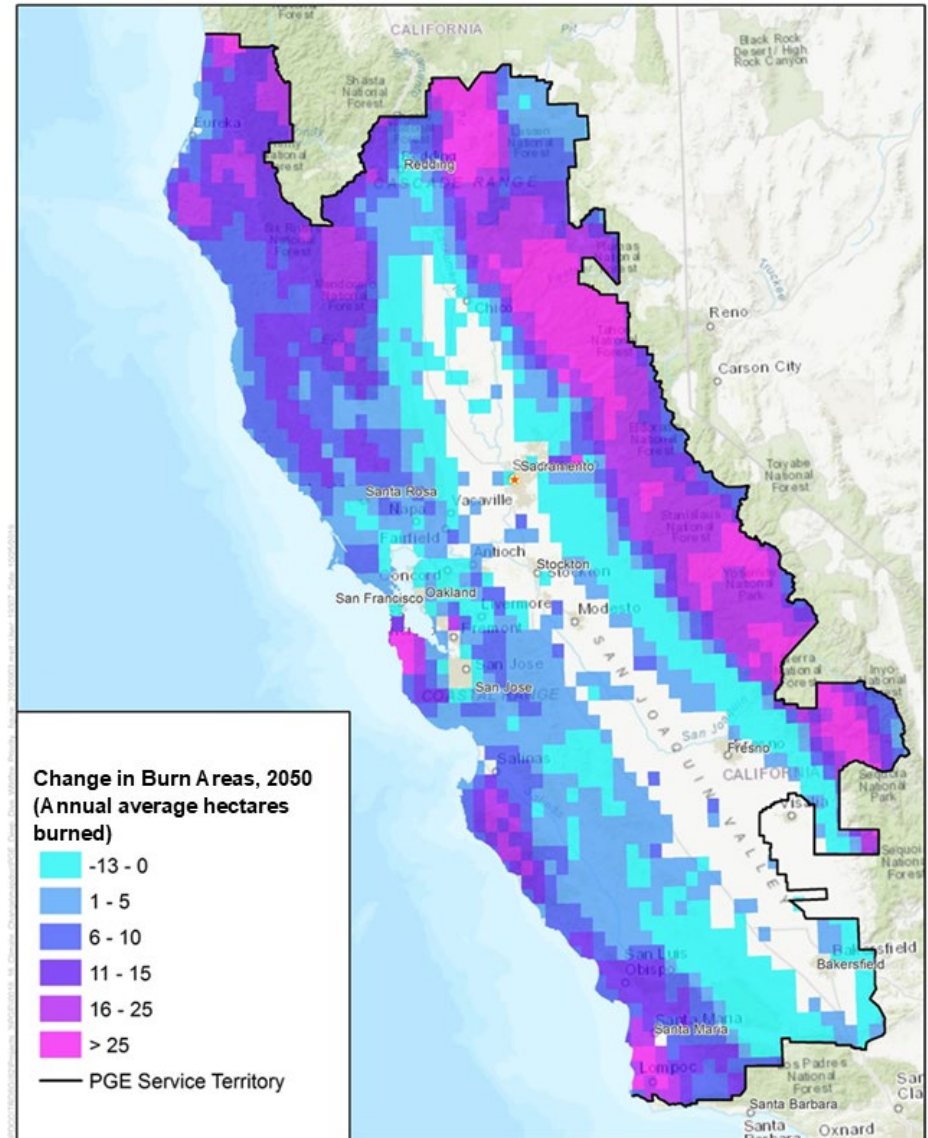
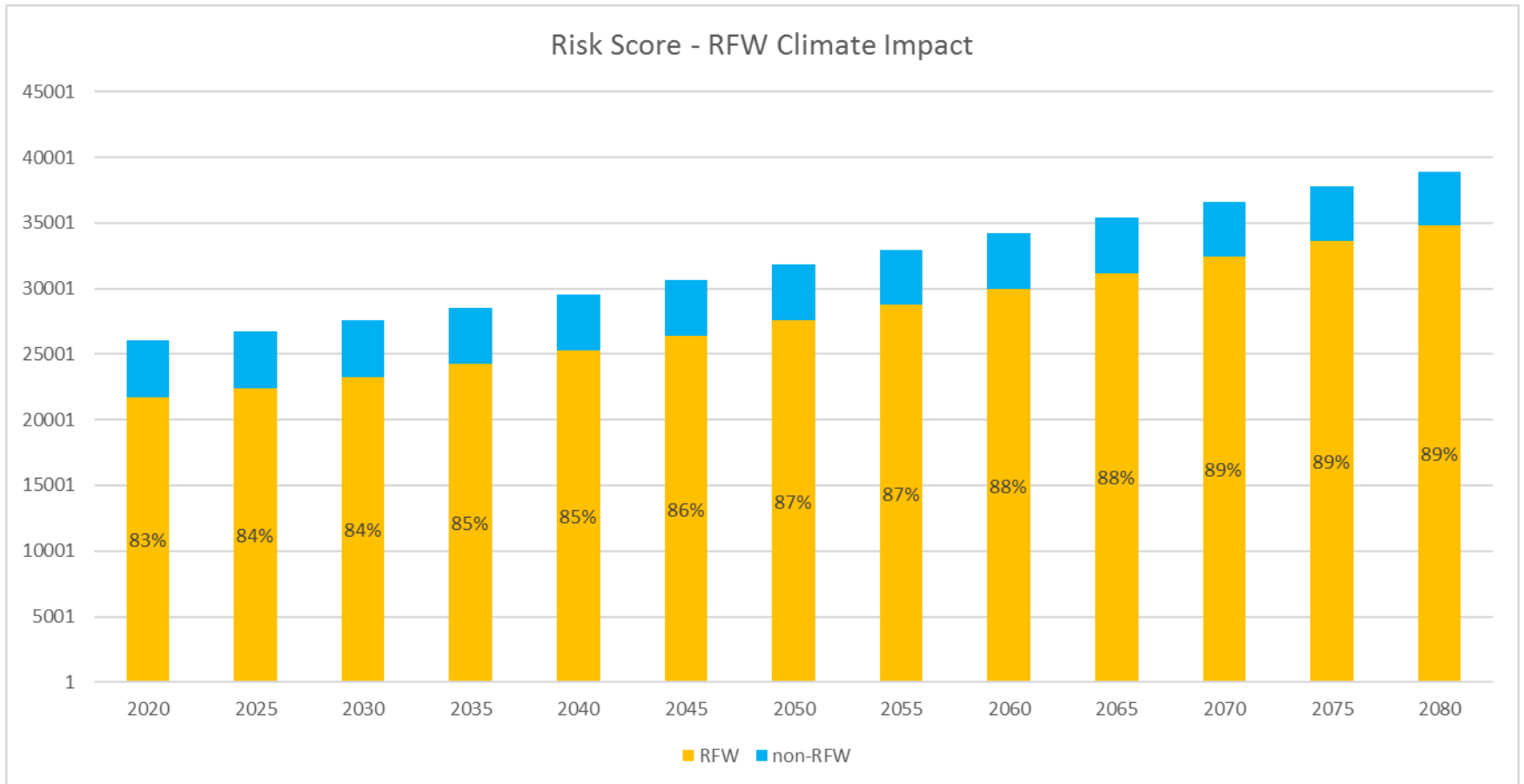


Figure 1. Projected Change in Annual Area Burned by 2050 Relative to Historical Baseline (areas that lack shading indicate no future wildfire projection; Maps for 2025 and 2035 available in Appendix)

If no further action is taken, the likelihood of Red Flag Warning days grow in PG&E's service territory, causing the overall Wildfire Risk to go up.



1

Breakdown of our ~99,000 circuit miles into 8 tranches representing various levels of risk

2

Breakdown of drivers in HFTD and non-HFTD territory
Top 2 drivers: Equipment Failure and Vegetation

3

Consequence of Risk Events vary from small to catastrophic, with varying likelihoods based on weather conditions

4

Integration of Climate Change into long-term Wildfire risk outlook

Risk Assessment – Controls & Mitigations



Together, Building
a Better California



Wildfire Mitigation Programs Overview

Wildfire has 11 mitigation programs identified for 2020 RAMP; of these, Enhanced Vegetation Management and System Hardening are the largest proportion of 2020-2026 spend

ID	Mitigation Program
M1	Enhanced Vegetation Management
M2	System Hardening
M3	Non-Exempt Surge Arrester Replacement Program
M4	Expulsion Fuse Replacement
M5	Public Safety Power Shutoff
M6	Public Safety Power Shutoff Impact Reduction Initiatives
M7	Situational Awareness and Forecasting Initiatives
M8	Safety and Infrastructure Protection Teams
M9	Community Wildfire Safety Program Project Management Office
M10	Additional System Automation and Protection
M11	Remote Grid

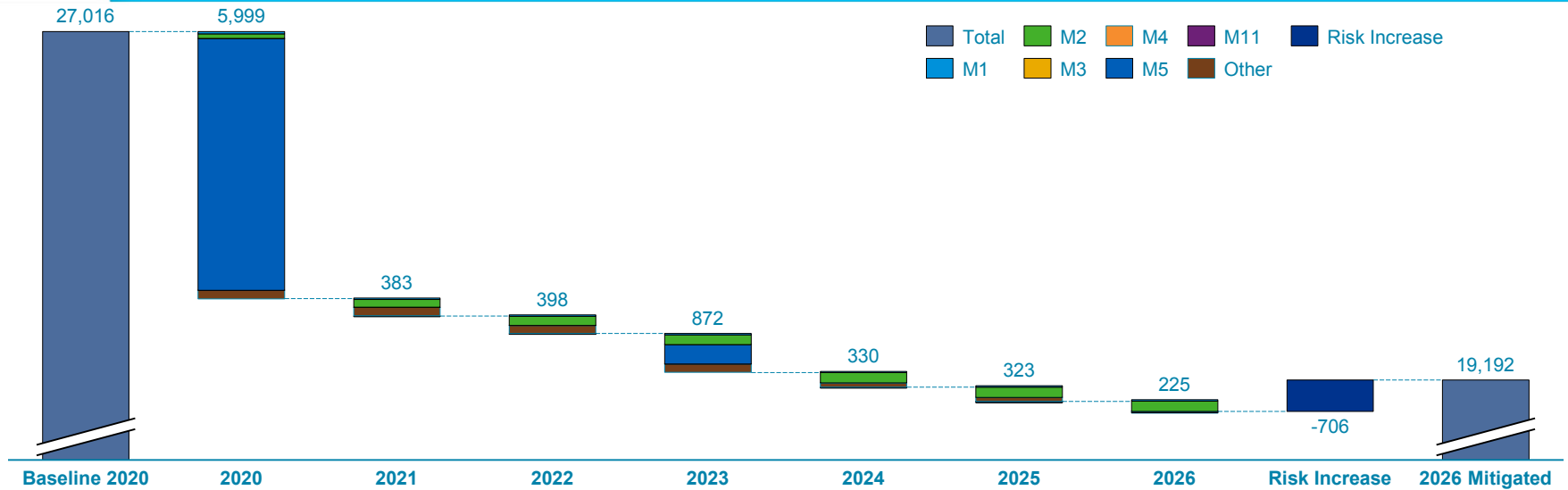
Wildfire Mitigation Cost Forecast 2020-2026 (\$M)¹



(1) Nominal values with cost escalation of 2.5% applied; includes both capital and expense.



Risk Reduction Overview



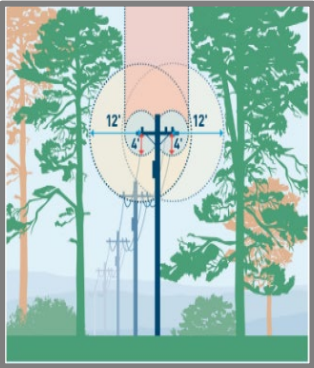
#	Mitigation Programs ¹	2020	2021	2022	2023	2024	2025	2026
M1	Enhanced Vegetation Management	50	81	114	141	168	196	228
M2	System Hardening	105	276	477	700	931	1161	1394
M3	Non-Exempt Surge Arrester Replacement Program	5	13	14	14	14	14	14
M4	Expulsion Fuse Replacement	0	0	0	1	1	1	1
M5	Public Safety Power Shutoff ²	5649	5634	5615	6046	6024	5996	5972
M11	Remote Grid	1	1	1	1	1	1	1
Other	Cross-cutting mitigation programs	189	376	559	750	844	936	920
	Risk Increase due to Climate Factors in Baseline	0	0	0	-706	-706	-706	-706
	Total	5999	6382	6780	6946	7276	7599	7824

(1) Excludes Foundational Mitigations.
 (2) Includes PSPS's Reliability Impact as reducing overall risk reduction.
 (3) Risk reduction by program reflects July 17th errata.



Reducing the risk of catastrophic wildfires from electrical equipment by mitigating the known causes of ignitions

Enhanced Vegetation Management



- Conduct 1,800 line-miles of 12 foot radial clearance and remove high-risk trees and overhangs
- Focus on expanding Rights-of-Way on lower voltage transmission to reduce wildfire risk and footprint of future PSPS events

System Hardening

- Replacing line-miles of existing overhead conductor through asset elimination, installing covered conductors with stronger and more resilient poles, or targeted undergrounding

Asset Repair and Inspection

- Incorporating enhanced inspection process and tools from 2019 Wildfire Safety Inspection Program into routine inspection program: annual inspection of Tier-3 areas and 3-year cycles for Tier-2

System Automation

- Continuing to SCADA-enable devices and reclosers to allow operators to remotely prevent a line from automatically reenergizing after a fault

Public Safety Power Shutoffs

- Utilizing PSPS during extremely high-risk conditions to eliminate ignition risks; 2020 PSPS events will be smaller in scope, shorter in duration, and smarter in performance

Description

The EVM Program is targeted at overhead distribution lines in Tier 2 and Tier 3 HFTD areas and exceeds the requirements of PG&E’s annual Routine Vegetation Management that maintains compliance with CPUC mandated clearances.

Drivers, Sub-drivers, and Consequences

This mitigation targets the vegetation driver.

Tranche Level Analysis

Analysis of effectiveness was calculated per outage and ignition by tranche. Application of program in HFTD only.

RSE Analysis

RSE 2.6
EVM targets the largest driver to risk events in HFTD short term, while establishing ongoing control for further clearance long term.

Mitigation Changes

PG&E reduces scope of EVM from 2,498 miles in 2019 to 1,800 miles. PG&E plans to conduct 1,800 miles per year from 2020-2026.

Mitigation Effectiveness

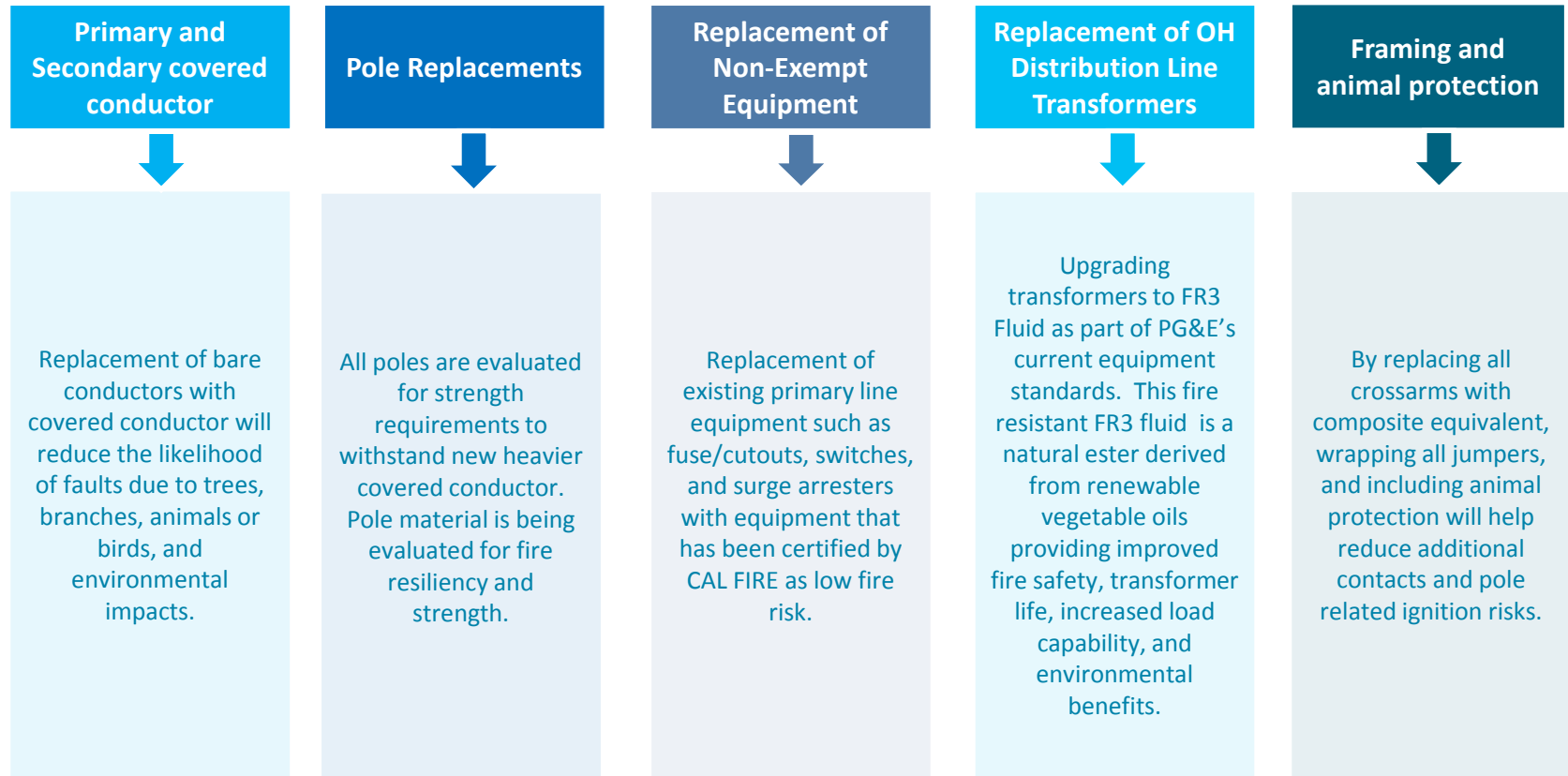
Varies per Vegetation Sub-driver

Details Chapter 10 workpaper ‘EO-WF-25_Mitigation Effectiveness WP’

- Based on justification of effectiveness by Veg Sub-Driver Category
- Applied justification criteria against historical vegetation caused events
- Determined effectiveness per vegetation caused category

Vegetation Sub-driver	RFW	non RFW	Effectiveness	Justification for Effectiveness
Branch (Not overhanging, > 12ft)	1.9%	1.3%	0%	Includes hazard tree removal, increased clearance, overhang elimination and associated tree removals.
Branch (Not overhanging, 4-12ft)	0.8%	0.6%	50%	Includes hazard tree removal, increased clearance, overhang elimination and associated tree removals.
Branch (Not overhanging, Distance Unknown)	7.0%	4.7%	0%	Includes hazard tree removal, increased clearance, overhang elimination and associated tree removals.
Branch (Not overhanging, within 4ft)	0.4%	0.3%	90%	Includes hazard tree removal, increased clearance, overhang elimination and associated tree removals.
Branch (Overhanging)	17.1%	12.1%	90%	EVM scope designed to eliminate 100% of overhang outages. Estimate a 90% effectiveness rate.
Dead	7.8%	4.9%	0%	Routine and Catastrophic Emergency Memorandum Account (CEMA) scopes already designed to prevent all instances of dead trees. Added EVM patrol not expected to further reduce occurrence.
Fell into (Moderate-Severe defect)	5.4%	5.2%	95%	Includes hazard tree removal, increased clearance, overhang elimination and associated tree removals.
Fell into (No defect)	24.9%	34.8%	0%	The removal of healthy trees with no sign of defect falls outside of the EVM hazard tree removal scope.
Fell into (slight defect)	6.6%	6.9%	50%	Includes hazard tree removal, increased clearance, overhang elimination and associated tree removals.
Grow Into	0.8%	0.5%	50%	Routine scope already designed to prevent all instances of growth into primary. Added EVM patrol expected to reduce occurrence by estimated 50%.
Other/Unknown	27.2%	28.8%	0%	Includes hazard tree removal, increased clearance, overhang elimination and associated tree removals.

PG&E's Fire Rebuild Design Guidance is based on these foundational elements:





M3/M4 – Non-Exempt Surge Arrestor & Expulsion Fuse Replacement

Description

M3 mitigation program replaces non-exempt surge arresters with exempt surge arrestors
M4 mitigation program replaces non-exempt expulsion fuses with exempt fuses
Both reduces the potential for release of electrical arcs, sparks, or hot material

Drivers, Sub-drivers, and Consequences

These mitigations targets a subset of the Equipment Failure driver incidents.

Tranche Level Analysis

These two mitigations focus in HFTD for Wildfire risk.
Non-exempt surge arrestor program continues in non-HFTD for public safety as part of Distribution Overhead Risk.

RSE Analysis

M3 Surge Arrestor RSE: 2.7 (up through 2021) | M4 Expulsion Fuse RSE: 1.0
Programs target non-exempt equipment that causes ignition

Mitigation Changes

PG&E continues replacement of non-exempt equipment in HFTD areas until replacements are complete.

Mitigation Effectiveness

M3: 90% effective on Equipment Failure – Arrestor
M4: 90% effective on Equipment Failure – Cutout/Fuse

<p>Description</p>	<p>The System Hardening Program is an ongoing, long-term capital investment program to rebuild portions of PG&E’s overhead electric distribution system to reduce fire risk.</p>
<p>Drivers, Sub-drivers, and Consequences</p>	<p>This mitigation targets the Equipment Failure driver, with additional benefits mitigating Vegetation, Animal, and Other drivers.</p>
<p>Tranche Level Analysis</p>	<p>Analysis of effectiveness was calculated per outage and ignition by tranche. Application of program in HFTD only.</p>
<p>RSE Analysis</p>	<p>RSE: 7.4 System hardening targets the largest drivers to risk events and provides long term mitigation benefits</p>
<p>Mitigation Changes</p>	<p>PG&E plans to progressively increase the pace of program from 241 miles in 2020 up to 509 miles by 2026.</p>
<p>Mitigation Effectiveness</p>	<p>Varies Per Sub-Driver; details in further slide</p>



A3/A4 – Targeted System Upgrades & System Hardening Hybrid

Description

A3 alternative where PG&E does not replace its existing bare wire but focuses on system modifications to reduce the potential for outages that could result in ignitions.

A4 alternative is a package of system modifications that falls somewhere between the existing M2 System Hardening and the A3 alternative.

Drivers, Sub-drivers, and Consequences

Targets the Equipment Failure driver, with additional benefits mitigating Vegetation, Animal, and Other drivers to a lesser extent compared to M2.

A3 does not target Vegetation driver.

Project Status

Evaluation of this option is still in early stages; no pilot or workplan yet developed

Considerations

Allows for wider deployment of fire resilience programs; to be deployed in combination with M2 System Hardening.

RSE

A3 Wildfire – Targeted System Upgrades RSE: 5.1

A4 System Hardening Hybrid RSE: 7.6

Mitigation Effectiveness

Varies Per Sub-Driver; details in further slide



System Hardening Mitigation Effectiveness - Ignition

Ignition Cause	Sub-Cause	Level 1 System Hardening Effectiveness	Level 2 Hybrid Effectiveness	Level 2 Percent Effectiveness	Level 3 Firming Effectiveness	Level 3 Percent Effectiveness
3rd Party	3rd Party - Other	44%	same as SH	44%	None	0%
	3rd Party - Unknown	41%	same as SH	41%	None	0%
	Balloons	77%	Medium	40%	Low	20%
	Vehicle	47%	step down from SH	37%	Low	20%
Animal	Animal	60%	step down from SH	48%	Medium	40%
Equipment Failure	Capacitor Bank	8%	None	0%	None	0%
	Conductor	50%	step down from SH	40%	Low	20%
	Crossarm	68%	Medium	40%	Medium	40%
	Equip Failure - Other	41%	same as SH	41%	None	0%
	Equip Failure - Unknown	73%	same as SH	73%	None	0%
	Fuse	70%	None	0%	None	0%
	Guy/Span Wire	73%	Medium	40%	None	0%
	Insulator	53%	Medium	40%	Medium	40%
	Lightning Arrestor	90%	None	0%	None	0%
	Pole	52%	step down from SH	42%	Medium	40%
	Recloser	62%	None	0%	None	0%
	Sectionalizer	40%	None	0%	None	0%
	Splice/Clamp/Connector	70%	step down from SH	56%	Low	20%
	Switch	69%	None	0%	None	0%
	Transformer	73%	None	0%	None	0%
	Voltage Regulator	35%	None	0%	None	0%
Unknown or Other	Unk or Other - Other	34%	same as SH	34%	Low	20%
	Unk or Other - Unknown	55%	same as SH	55%	Medium	40%
Vegetation	Branch (Not overhanging, > 12ft)	65%	same as SH	65%	None	0%
	Branch (OverHanging)	54%	same as SH	54%	None	0%
	Dead	48%	same as SH	48%	None	0%
	Fell into (Moderate-Severe defect)	46%	same as SH	46%	None	0%
	Fell into (No defect)	55%	same as SH	55%	None	0%
	Fell into (slight defect)	38%	same as SH	38%	None	0%
	Grow Into	20%	same as SH	20%	None	0%
	Other/Unknown	53%	same as SH	53%	None	0%
Vegetation - Unknown	37%	same as SH	37%	None	0%	

Details Chapter 10 workpaper 'EO-WF-25_Mitigation Effectiveness WP'

- Based on justification of effectiveness by Cause, Equipment, and Condition Combination
- Over ~4000 combinations of incidents reviewed
- Applied criteria against historical ignition and outage events
- Determined effectiveness per driver category

Pacific Gas and Electric Company
 2020 RAMP Report
 Mitigation Effectiveness Workpapers - M2 System Hardening SME Input
 Wildfire

Line No.	Basic Cause	Supplemental Cause	Failed/Involved Equipment	Equipment Condition	System Hardening	Narrative
2529	Equipment Failure/Involved	Overhead	Capacitor	Broken	Low	Capacitors are routinely inspected. Hardening is not addressing the equipment specifically but replaces non exempt fuses.
2530	Equipment Failure/Involved	Overhead	Capacitor	Broken- wire on ground	Medium	Significant external force broke the conductor and brought wire to the ground/object. System Hardening will make circuitry more robust. System Hardening moderately reduce ignition risk.
2531	Equipment Failure/Involved	Overhead	Capacitor	Broken- wire on object	Medium	Significant external force broke the conductor and brought wire to the ground/object. System Hardening will make circuitry more robust. System Hardening moderately reduce ignition risk.
2532	Equipment Failure/Involved	Overhead	Capacitor	Burned/flushed	Low	Capacitors are routinely inspected. Hardening is not addressing the equipment specifically but replaces non exempt fuses.
2533	Equipment Failure/Involved	Overhead	Capacitor	Leaking	Low	Capacitors are routinely inspected. Hardening is not addressing the equipment specifically but replaces non exempt fuses.
2534	Equipment Failure/Involved	Overhead	Capacitor	Normal	All	Covered conductor will eliminate the line slap and risk associated with this outage.
2535	Equipment Failure/Involved	Overhead	Conductor- Overhead	Annealed	All	Covered conductor will eliminate the line slap and risk associated with this outage.
2536	Equipment Failure/Involved	Overhead	Conductor- Overhead	Arcing	All	Covered conductor will eliminate the line slap and risk associated with this outage.

Description

PG&E’s PSPS Program proactively de-energizes select transmission and distribution circuit segments within Tier 2 and Tier 3 HFTD areas when elevated fire danger conditions occur. De-energization is determined necessary to protect public safety when PG&E reasonably believes there is an imminent and significant risk of strong winds impacting PG&E assets, and a significant risk of a catastrophic wildfire should an ignition occur.

Drivers, Sub-drivers, and Consequences

This mitigation targets the Equipment Failure and Vegetation drivers, only during Red Flag Warning conditions.

Tranche Level Analysis

Focused on HFTD

Cost / RSE Analysis

RSE: 15.0 (Combined with M6)
 PSPS targets the drivers that lead risk during Red Flag Warning conditions; takes into account adverse reliability impacts and M6 PSPS impact reductions

Mitigation Changes

Further described in M6 – PSPS Impact Reduction Initiatives

Mitigation Effectiveness

89% effective based on 2019 events; only possible for execution in select conditions

EVENT DETAILS	JUNE 8 - 9	SEPT 23 - 26	OCT 5 - 6	OCT 9 - 12	OCT 23 - 25	OCT 26 - NOV 1	NOV 20 - 21
CUSTOMERS IMPACTED	~22,000	~50,000	~12,000	~735,000	~179,000	~968,000	~49,000
COUNTIES IN SCOPE	5	7	3	35	17	38	11
CRCs OPEN	4	8	3	33	28	77	34
PEAK WIND GUSTS	63 mph	58 mph	51 mph	77 mph	80 mph	102 mph	75 mph
DAMAGE/HAZARDS	5	4	2	116	26	554	15
AVG. OUTAGE DURATION AFTER ALL CLEAR	5 HRS	7 HRS	4 HRS	25 HRS	5 HRS	14 HRS ¹	10 HRS
AVG. OUTAGE DURATION TOTAL	16 HRS	16 HRS	14 HRS	37 HRS	25 HRS	55 HRS	25 HRS

Note: All data is subject to change based on ongoing data reconciliation.

¹Restoration time is calculated using the "all clear" time associated with the Oct 29 event after which final restoration occurred for customers who were impacted by both Oct 26 and Oct 29 events but not restored between events. Further analysis of outage metrics for these consecutive events in progress.

Description

The key objective of the PSPS Program is to implement measures to reduce the customer impacts of PSPS events as much as possible while still getting the full fire risk reduction benefits of PSPS. PG&E's goal in 2020 is to reduce PSPS event impact so that fewer customers are affected than would have been for a comparable weather event in 2019 and to restore power more quickly after a PSPS event.

Drivers, Sub-drivers, and Consequences

Minimizing Reliability Consequence during M5 Public Safety Power Shutoff

Tranche Level Analysis

Focused on HFTD

Cost / RSE Analysis

RSE: 15.0 (Combined with M5)
 PSPS targets the drivers that lead risk during Red Flag Warning conditions; takes into account adverse reliability impacts and M6 PSPS impact reductions

Mitigation Changes

In 2020 and beyond, PG&E will be building on lessons learned in 2019 to expand and refine its initiatives to reduce the scope and duration of PSPS events.

Mitigation Effectiveness

30% Reduction in Customer Minutes Interrupted



Make any future PSPS events smaller in scope, shorter in duration and smarter in performance

Reduce Frequency

- More accurate weather and fire risk forecasting plus improvements that continue to drive down ignition risks can reduce need for PSPS
- Analyzing all ~550 transmission lines in HFTDs to determine if risk has been reduced enough that the PSPS threshold for a line could be materially increased.

Reduce Duration

- Deploying additional helicopters to speed daylight post-PSPS inspections and fixed-wing aircraft with infrared technology to allow for nighttime inspections
- Improving restoration goal by 50%, to 12 daylight hours

Reduce Impacted Customers

- Improving meteorological data and forecasting
- Safely minimizing transmission impacts
- Deploying customer-centric solutions that include:
 - Temporary and permanent generation at substations
 - Mid-feeder microgrids
 - Supporting community-enabled microgrids
- Installing additional automated sectionalizing devices to separate the distribution grid into smaller sections – helps with emergency response, outages and microgrid operations
- Targeting to have any 2020 PSPS events affect ~1/3rd fewer customers than a comparable event would have in 2019 (based on an analysis of planned programs under the conditions of October 2019 PSPS events).

Improve Coordination with and Support Communities and Customers

- Continued extensive county and tribal engagement
- Additional community open houses
- Additional listening sessions
- Additional joint identification of critical facilities
- Designated PG&E community and government liaisons
- Improve access and functional needs (AFN) community support



Mitigation RSE and Risk Reduction Summary

Mitigation	Risk Reduction ¹	Cost Forecast \$ Millions (2023-2026)	RSE ¹ (2023-2026)	Commentary
M1 Enhanced Vegetation Management	4,301	2,211.89	2.6	<ul style="list-style-type: none"> Focuses on largest driver in HFTD
M2 System Hardening	18,499	3,400.80	7.4	<ul style="list-style-type: none"> Focuses on largest drivers overall in HFTD
M3 Non-Exempt Surge Arrester Replacement Program	3	-	-	<ul style="list-style-type: none"> Focuses on specific equipment failures that causes sparks
M4 Expulsion Fuse Replacement	19	24.72	1.0	<ul style="list-style-type: none"> Focuses on specific equipment failures that causes sparks
M5 Public Safety Power Shutoff	17,712	1,593.55 ²	15.0	<ul style="list-style-type: none"> Focuses on risk events during Red Flag Warning conditions Considers adverse reliability impacts and M6 PSPS impact reductions initiatives

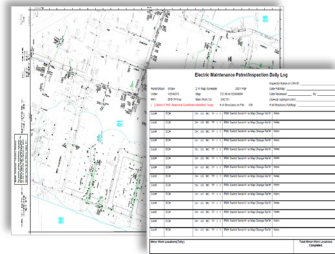
(1) Results reflect July 17 errata

(2) Includes costs of M6 PSPS Impact Reduction Initiatives

Wildfire has 17 control programs identified for 2020 RAMP

ID	Control Program	Summary
C1 – C3	Patrols and Inspections	PG&E patrols and inspects its facilities to identify damaged facilities, compelling abnormal conditions, regulatory conditions, and third-party-caused infractions that may negatively impact safety or reliability, including conditions that could cause a wildfire ignition.
C4 – C7	Vegetation Management	The program includes “routine” compliance-based vegetation management, including periodic inspections, clearing of vegetation around lines and around poles with equipment that poses a fire risk, and quality assurance.
C8 – C10	Equipment Preventative Maintenance and Replacement	Proactive identification and repair or replacement of critical overhead Equipment is identified through the Patrol and Inspections control or through ad hoc inspection. In 2019, the inspection program was accelerated and significantly improved in Tier 2 and Tier 3 HFTD areas. This enhanced scope and process will continue to be used in 2020 and going forward.
C11	Animal Abatement	The installation of new equipment or retrofitting of existing equipment with protection measures intended to reduce animal contacts.
C12	Pole Programs	This control includes multiple activities related to distribution poles, including intrusive testing, remediation, and loading assessment.
C13	Transmission Structure Maintenance and Replacement	This control covers the maintenance repairs and targeted replacements of PG&E’s approximately 150,000 transmission structures (steel towers and transmission wood poles).
C14	System Automation and Protection	The installation of new equipment (e.g., fuses, reclosers, and SCADA installations enabling remote operation) that isolates equipment when abnormal system conditions are detected.
C15	Reclose Blocking	To reduce ignition risk, beginning in 2018, PG&E disabled the automated reclosing functionality during elevated fire conditions on all reclosing devices located in protection zones that intersect with Tier 2 and Tier 3 HFTD areas.
C16	Design Standards	This control relates to the general standards for proper application of equipment to ensure safe and reliable operation in high fire-threat areas.
C17	Restoration, Operational Procedures and Training	This control relates to work standards for high fire-threat areas. Utility Standard TD-1464S establishes requirements for PG&E employees and contractors to follow when travelling over, performing work on, or operating in any forest, brush, or grass-covered lands.

Pre-WSIP & date-driven 2018 & prior



- ✓ **Reliability and compliance focused inspection process**
 - Asset inspection & maintenance cycles based on date-driven compliance
 - Inspection criteria leveraged expertise of QEWs
 - Inspection results aggregated to plat (map) level
 - Asset-specific data collected only for corrective actions (identify and fix only compelling issues)

Maintenance / Planning Assumptions

- ✓ **Inspections:** asset field condition will remain consistent between 5-year inspection cycle
- ✓ **Patrols:** used to detect actual or imminent failures that occur between inspections

WSIP & wildfire risk-driven 2019

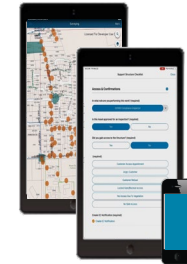


- ✓ **Wildfire-risk focused approach and process enhancements**
 - Detailed and objective inspection criteria based on asset wildfire risk analysis (e.g., FMEA)
 - Visual enhanced inspections on all overhead HFTD T2 and T3 assets
 - GO 165 inspections in non-HFTD areas
 - Expanded EC tag creation guidance (5-year horizon) led to subsequent field reassessments

Maintenance / Planning Assumptions

- ✓ **Inspections:** perform inspections in all High Fire Threat Districts to prevent asset failures

Risk-informed & data-driven 2020 & beyond



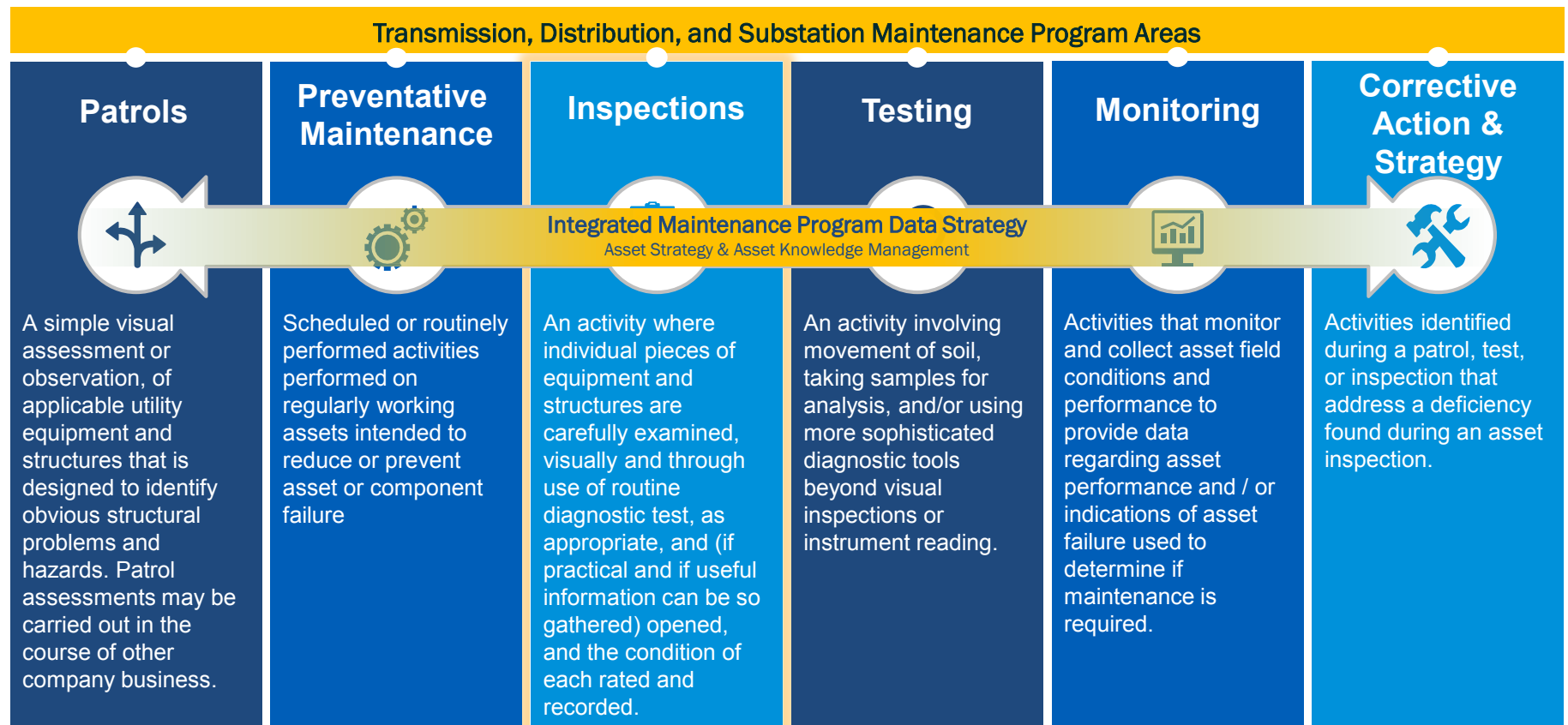
- ✓ **Expansion of WSIP inspection approach to include public safety & reliability risks**
 - Detailed and objective inspection criteria based on increased understanding of field conditions and failure modes
 - Broadened risk consideration to beyond wildfire and using data for targeted inspection cycles
 - Condition assessments of tags with gradients beyond repair / replace
 - Introduce detection technology to optimize measurement methods

Maintenance / Planning Objectives

- ✓ **Inspections:** use data to determine the appropriate inspection cycle commensurate to risk
- ✓ **Other maintenance programs:** coordinate cycles and methods across multiple maintenance programs

What does a complementary maintenance program look like?

The combination of improved (1) data quality for field data inventories with (2) defined criteria / triggers for each maintenance activity will allow for the strategic planning of efficient maintenance strategies at each asset (e.g., an enhanced pole test & treat process to meet GO 165 and detailed inspection requirements at a single asset).



2020 Focus

Questions?

APPENDIX



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2023 Test Year Baseline Count



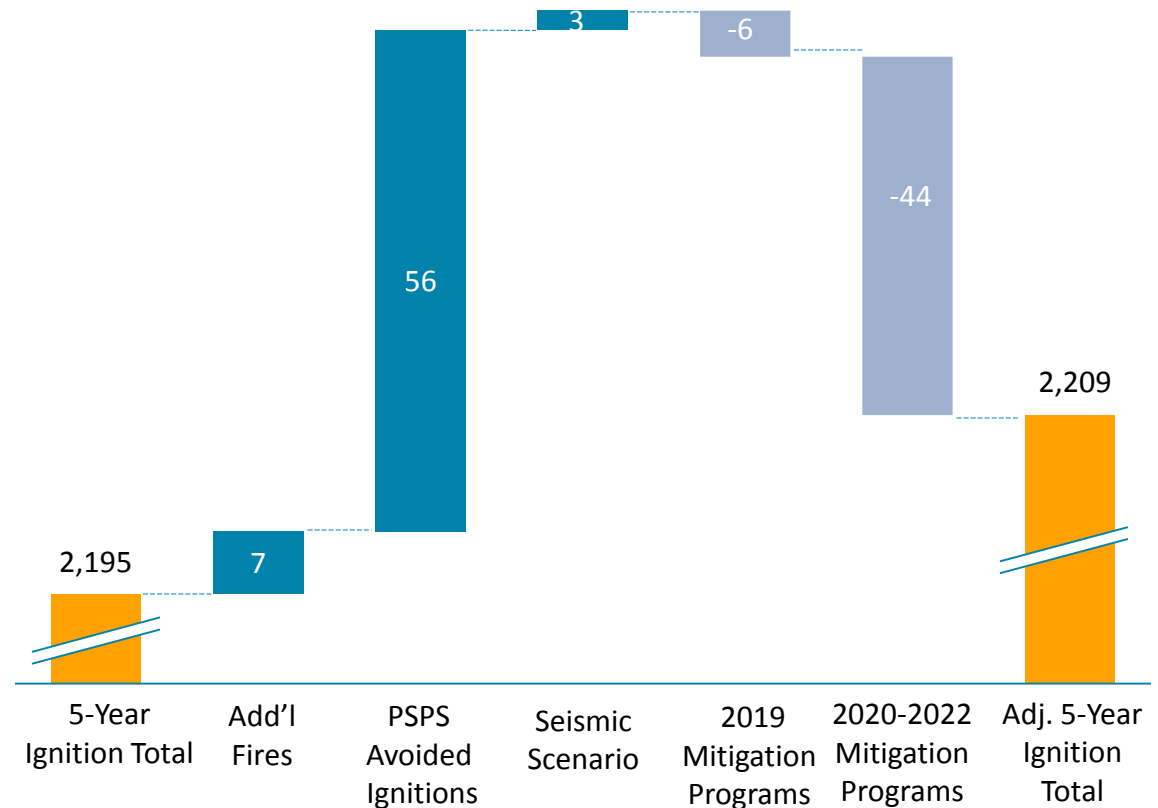
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442 risk events (ignitions) are expected per year in the Test Year 2023 Baseline case.

This estimate was developed by adjusting the historical 2,195 reported ignitions associated with PG&E facilities during the 5-year period of 2015-2019.

Adjustments

- **Additional Fires.** 7 additional fires previously unreported due to events being under investigation
- **PSPS.** Ignitions added to account for ignitions avoided in 2019 due to PSPS.
- **Seismic Scenario.** Ignitions added to account for estimate of possible ignitions due to a Seismic scenario
- **2019 Mitigations.** Ignitions subtracted to account for ignition frequency reduction due to 2019 programs.
- **2020 Mitigations.** Ignitions subtracted (approx. 8 / year) to account for annual ignition frequency reduction due to 2020 programs.



Adjustments net new 5-year estimate of 2,209, or baseline of 442 ignitions per year

Foundational Mitigations



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Improving understanding of upcoming and real-time weather and fire conditions, to reduce fire ignitions, respond faster, and minimize PSPS event scope

Situational Awareness

- Create highly localized weather and fire risk forecasts (2x better granularity than 2019) and real-time conditions to identify high-risk locations, share with first responders and activate field response
- additional weather stations
- additional HD cameras
- Wire-down detection
- Automated rapid earth fault current limiters
- Access to multiple real-time weather feeds

Wildfire Safety Operations Center and Meteorology



- Operate 24/7 Wildfire Safety Operations Center to monitor fire threats
- Coordinate and mobilize response efforts with first responders, government, media and others during potential or active wildfires
- Using satellite fire detection system that compiles data from 5 satellites and one of the largest, high-resolution climatological datasets in the utility industry
- Direct operational modifications and fire safety resources

Foundational Mitigations

Description

	Foundational Mitigations	Description
M7	Situational Awareness and Forecasting Initiatives	PG&E proposes several mitigations related to forecasting and situational awareness, including additional weather stations, cameras, sensors, and advanced modeling of weather and fire conditions. Taken together, these mitigations will help PG&E identify times and areas of high fire risk, which will inform decisions about PSPS timing and scope and provide information that will be valuable for asset management and risk analysis.
M8	Safety and Infrastructure Protection Teams	SIPTs consist of two-person crews composed of International Brotherhood of Electrical Workers-represented employees who are trained and certified safety infrastructure protection personnel. They provide standby resources for PG&E crews performing work in high fire hazard areas, pretreatment of PG&E assets during an ongoing fire, fire protection to PG&E assets, and emergency medical services.
M9	Community Wildfire Safety Program Project Management Office	The CWSP PMO was established in 2018 to oversee and coordinate multiple lines of business' implementation of PG&E's wildfire risk mitigation activities. The CWSP PMO is focused on project and program development and management for wildfire mitigation efforts.
M10	Additional System Automation and Protection	The additional system automation and protection mitigation consists of additional system and protection work. This includes installation of SCADA capability on reclosing devices in HFTD areas to support remote Reclose Blocking. This mitigation also includes evaluating new system protection technologies that may reduce wildfire risk.

Foundational Mitigation: Because these programs support other mitigations that reduce Wildfire risk, but do not reduce the risk themselves, PG&E considers them foundational and does not calculate a risk reduction or RSE.

System Protection & Wire Down Detection

- **Automatic Recloser Disablement** deactivating reclosing capability, primarily through remote device control, based on fire risk forecast
- **Fast Trip Alternate Settings** deploying system protection settings and schemes to trip (de-energize) faster during high risk seasons
- **SmartMeters** using enhanced wire-down detection technology and data to flag high-risk outages and specify locations to send field crews; Program will expand from the ~4.4 million today to ~5.4 million by Q2 / Q3 2020 (capturing all SmartMeters in PG&E's service territory)
- **Rapid Earth Fault Current Limiter (REFCL)** can automatically reduce the electrical current in a downed wire, reducing likelihood of a fire; technology anticipated to be operable by summer 2020

Advance Modeling

- **Predictive Models** using multiple data inputs (GIS, weather, SmartMeter, SCADA and others) to predict line maintenance work
- **Neural Networks** – computer systems modeled on the human brain – to enhance our vegetation management efforts by identifying tree species that have a higher risk of breaking or falling on powerlines
- **Machine learning vision analysis** using millions of high-resolution photos of PG&E electric assets taken during wildfire safety inspections to build models and algorithms to help detect assets that require repair

Additional Alternative Mitigations



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Description

Remote grid is an effort to use decentralized energy sources to permanently supply energy to certain remote customers instead of using hardened traditional utility infrastructure for electricity delivery.

Drivers, Sub-drivers, and Consequences

This mitigation targets the Equipment Failure, Vegetation, Animal, and Other drivers.

Project Status

Pilot Assessment Phase

Considerations

PG&E is evaluating the program efficiency by conducting M11 pilot projects. If successful, PG&E proposes to expand the mitigation to additional feeders in 2021-2022 and subsequently 2023-2026

RSE

RSE: 17.8

Mitigation Effectiveness

95% of all drivers

Description

PG&E is evaluating the use of commercially available long-term chemical fire retardants to pre-treating right of ways, areas around equipment and devices, switchyards, substations and critical facilities to reduce the potential for ignition and fire spread and potentially limit the need for PSPS.

Drivers, Sub-drivers, and Consequences

This mitigation targets the Equipment Failure, Vegetation, Animal, and Other drivers.

Project Status

Pilot Assessment Phase

Considerations

PG&E is evaluating the program efficiency by conducting pilot project.

RSE

RSE: 2.2

Mitigation Effectiveness

10% for HFTD – Distribution
22% for HFTD - Transmission

Financials



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2020-2026 Proposed Mitigation Plan Financials

Wildfire Mitigation Cost Forecast (\$M)¹

Mitigation	2020	2021	2022	2023	2024	2025	2026	Total	%
M1 Enhanced Vegetation Management	494.63	506.99	519.67	532.66	545.98	559.63	573.62	3,733.17	28.8%
M2 System Hardening	366.72	565.64	698.36	796.32	850.04	868.05	886.39	5,031.53	38.9%
M3 Non-Exempt Surge Arrester Replacement Program	62.45	53.29	0.00	0.00	0.00	0.00	0.00	115.74	0.9%
M4 Expulsion Fuse Replacement	5.42	5.56	5.70	5.84	6.14	6.29	6.45	41.39	0.3%
M5 Public Safety Power Shutoff	170.70	174.97	179.34	183.82	188.42	193.13	197.96	1,288.34	9.9%
M11 Remote Grid	4.75	0.00	0.00	0.00	0.00	0.00	0.00	4.75	0.0%
M6 Public Safety Power Shutoff Impact Reduction Initiatives	385.49	353.69	331.00	261.95	218.19	174.21	175.87	1,900.40	14.7%
M7 Situational Awareness and Forecasting Initiatives	43.39	44.75	38.65	38.50	39.47	40.45	41.46	286.67	2.2%
M8 Safety and Infrastructure Protection Teams	24.34	38.21	41.29	42.32	43.38	44.46	45.57	279.56	2.2%
M9 Community Wildfire Safety Program Project Management Office	18.53	19.07	19.63	20.12	20.62	21.13	21.66	140.76	1.1%
M10 Additional System Automation and Protection	15.90	17.57	17.91	18.35	18.92	19.39	19.88	127.92	1.0%
Total	1,592.33	1,779.74	1,851.53	1,899.89	1,931.15	1,926.75	1,968.85	12,950.23	100%

(1) Nominal values with cost escalation of 2.5% applied; includes both capital and expense.



2019 Recorded Costs for Controls

	Controls	2019 Recorded Expense Costs	2019 Recorded Capital Costs
C1 – C3	Patrols and Inspections	\$470,243,683	\$270,883,643
C4 – C7	Vegetation Management	\$867,569,101	\$271,089,530
C8 – C10	Equipment Preventative Maintenance and Replacement	\$409,432,715	\$763,049,684
C11	Animal Abatement	\$23,287,243	\$245,636,220
C12	Pole Programs	\$20,583,370	\$114,297,726
C13	Transmission Structure Maintenance and Replacement	\$314,207,710	\$269,729,157
C14	System Automation and Protection	\$1,320,600	\$111,715,554
C15	Reclose Blocking	\$108,434,904	N/A
C16	Design Standards	N/A	N/A
C17	Restoration, Operational Procedures and Training	\$2,065,529	\$193,655

Mitigation and Control Mapping



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Control Name and Number	2017 RAMP (2016 Controls)	2020 RAMP (2020-2022)	2020 RAMP (2023-2026)
C1 (2017) – Overhead Patrols and Inspections	X	Split into C1-C3	
C2 (2017) – Vegetation Management	X	Split into C4-C6	
C3 (2017) – Catastrophic Event Memorandum Account - Vegetation Management	X	Becomes C7	
C4 (2017) – Non-Exempt Equipment Replacement	X	Becomes M4	
C5 (2017) – Overhead Conductor Replacement	X	Replaced by M2	
C6 (2017) – Animal Abatement	X	Becomes C11	
C7 (2017) – Protective Equipment	X	Included in C14	
C8 (2017) – Overhead Equipment Replacement	X	Split into C8-C10	
C9 (2017) – Pole Replacement	X	Becomes C12	
C10 (2017) – Wood Pole Bridging	X	Incorporated into C12	
C11 (2017) – Design Standards	X	Becomes C16	
C12 (2017) – Restoration, Operational Procedures and Timing	X	Becomes C17	
C1 – Patrols and Inspections – Distribution Overhead (was part of C1 (2017))		X	X
C2 – Patrols and Inspections – Transmission Overhead (was part of C1 (2017))		X	X
C3 – Patrols and Inspections – Substation (was part of C1 (2017))		X	X

Mitigation Mapping from 2017 RAMP to 2020 RAMP

Mitigation Name and Number	2017 RAMP (2016 Controls)	2020 RAMP (2020-2022)	2020 RAMP (2023-2026)
M1 (2017) – Wildfire Reclosing Operation Program (System Control and Data Acquisition (SCADA) Programming)	X		
M2 (2017) – Wildfire Reclosing Operation Program (SCADA Capability Upgrades)	X		
M3 (2017) – Fuel Reduction and Powerline Corridor Management	X		
M4 (2017) Overhang Clearing	X		
M5 (2017) Non-Exempt Surge Arrester Replacement	X	Becomes M3	
M7 (2017) – Targeted Conductor Replacement (WF)	X		
M10 (2020 GRC) – Resilience Zones		Becomes part of M6	
M11 (2020 GRC) – Light Duty Steel Poles for Transmission Lines		Becomes part of C13	
M12 (2020 GRC) Wildfire System Hardening		Becomes M2	
M13 (2020 GRC) – Public Safety Power Shut Off		Becomes M5	
M14 (2020 GRC) – Reclose Blocking		Becomes C15	
M15 (2020 GRC) – Automation and Protection		Some of this becomes M6, some becomes M10 and some becomes part of C15	