Application: 23-06-008
(U 39 M)
Exhibit No.: PGE-06
Date: October 7, 2024
Witness(es): Various

PACIFIC GAS AND ELECTRIC COMPANY

WILDFIRE AND GAS SAFETY COSTS

EXHIBIT (PG&E-6)

TRACK 1 – WILDFIRE COSTS

REBUTTAL ERRATA TESTIMONY

CHAPTER 15
ATTACHMENT D (PART 3 OF 3) – ATTACHMENT H (PART 1 OF 3)

VOLUME 9 OF 12



PACIFIC GAS AND ELECTRIC COMPANY
WILDFIRE AND GAS SAFETY COSTS
TRACK 1 – WILDFIRE COSTS
REBUTTAL ERRATA TESTIMONY

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PACIFIC GAS AND ELECTRIC COMPANY
WILDFIRE AND GAS SAFETY COSTS
TRACK 1 – WILDFIRE COSTS
REBUTTAL ERRATA TESTIMONY

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2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_100-Q20		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_100-Q20		
Request Date:	February 28, 2019	Requester DR No.:	100
Date Sent:	March 28, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Mark Esguerra	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 – ADVANCED DISTRIBUTION MANAGEMENT SYSTEM (ADMS), GENERAL QUESTIONS

QUESTION 20

ADMS Need and Justification

Will the proposed ADMS system be fully functional based on the requested funding through 2022? If not, please provide the following for expenses:

a. Estimated total funding required,
b. Estimated completion date,
c. Estimated annual funding required per year.

ANSWER 20

PG&E does not anticipate that the proposed ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29) will be fully functional based on the requested funding through 2022.

a. PG&E estimates that the ADMS expense forecast through 2022 (Exhibit-4, WP p. 19-13) will cover approximately 96 percent of expenses required to fully implement the ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29).

   The development of PG&E's ADMS cost estimates was led by a third-party System Integrator hired by PG&E with extensive experience implementing ADMS projects in North America and deep knowledge of typical ADMS implementation costs. The projection that 96 percent of ADMS expenses will be incurred through 2022 is based upon this third-party's proprietary ADMS implementation cost model in conjunction with PG&E's planned ADMS implementation schedule.

b. As stated on Exhibit-4, WP p. 19-16, PG&E estimates the proposed ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29) will be completed in 2025.

c. For ADMS annual expense requirements through 2022, please refer to Exhibit-4, WP p. 19-13. PG&E has not yet developed annual funding requirements for the 2023-2025 GRC Cycle at the project level.

PACIFIC GAS AND ELECTRIC COMPANY
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Data Response

PG&E Data Request No.:	PubAdv_100-Q20		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_100-Q20Supp01		
Request Date:	February 28, 2019	Requester DR No.:	100
Date Sent:	June 25, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Quinn Nakayama	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 – ADVANCED DISTRIBUTION MANAGEMENT SYSTEM (ADMS), GENERAL QUESTIONS

QUESTION 20

ADMS Need and Justification

Will the proposed ADMS system be fully functional based on the requested funding through 2022? If not, please provide the following for expenses:

a. Estimated total funding required,
b. Estimated completion date,
c. Estimated annual funding required per year.

ANSWER 20

PG&E does not anticipate that the proposed ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29) will be fully functional based on the requested funding through 2022.

a. PG&E estimates that the ADMS expense forecast through 2022 (Exhibit-4, WP p. 19-13) will cover approximately 96 percent of expenses required to fully implement the ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29).

   The development of PG&E's ADMS cost estimates was led by a third-party System Integrator hired by PG&E with extensive experience implementing ADMS projects in North America and deep knowledge of typical ADMS implementation costs. The projection that 96 percent of ADMS expenses will be incurred through 2022 is based upon this third-party's proprietary ADMS implementation cost model in conjunction with PG&E's planned ADMS implementation schedule.

b. As stated on Exhibit-4, WP p. 19-16, PG&E estimates the proposed ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29) will be completed in 2025.

c. For ADMS annual expense requirements through 2022, please refer to Exhibit-4, WP p. 19-13. PG&E has not yet developed annual funding requirements for the 2023-2025 GRC Cycle at the project level.

SUPPLEMENTAL 01 ANSWER 20 (a)

a. PG&E's 2020 GRC expense forecast for ADMS was prepared assuming that it would cover approximately 96% of expenses required to fully implement the ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29).

   The ADMS cost estimate prepared for the ADMS Major Project Business case provided to Public Advocates as GRC-2020-PhI_DR_PubAdv_154-Q21Supp01Atch02CONF, which was prepared after the 2020 GRC expense forecast for ADMS, utilized different cost estimation assumptions from the GRC forecast, including the consideration of additional project risks not factored into the preparation of the GRC forecast. These project risks are discussed from pages 15 to 21 of the ADMS Major Project Business Case.

   The estimated Expected Case expense costs required for full ADMS implementation implied by the ADMS Major Project Business case is approximately $30.7 million. PG&E's ADMS expense forecast for the 2020 GRC time period remains unchanged.

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PG&E Data Request No.:	PubAdv_100-Q21		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_100-Q21Supp01		
Request Date:	February 28, 2019	Requester DR No.:	100
Date Sent:	June 25, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Quinn Nakayama	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 – ADVANCED DISTRIBUTION MANAGEMENT SYSTEM (ADMS), GENERAL QUESTIONS

QUESTION 21

ADMS Need and Justification

Will the proposed ADMS system be fully functional based on the requested funding through 2022? If not, please provide the following for capital expenditures:

a. Estimated total funding required,
b. Estimated completion date,
c. Estimated annual funding required per year.

ANSWER 21

PG&E does not anticipate that the proposed ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29) will be fully functional based on the requested funding through 2022.

a. PG&E estimates that the ADMS capital forecast through 2022 (Exhibit-4, WP p. 19-13) covers approximately 96 percent of capital expenditures required to fully implement the ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29).

   The development of PG&E's ADMS cost estimates was led by a third-party System Integrator hired by PG&E with extensive experience implementing ADMS projects in North America and deep knowledge of typical ADMS implementation costs. The projection that 96 percent of ADMS expenses will be incurred through 2022 is based upon this third-party's proprietary ADMS implementation cost model in conjunction with PG&E's planned ADMS implementation schedule.

b. As stated on Exhibit-4, WP p. 19-16, PG&E estimates that the ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29) will be completed in 2025.

c. For ADMS annual capital expenditure requirements through 2022, please refer to Exhibit-4, WP p. 19-13. PG&E has not yet developed annual funding requirements for the 2023-2025 GRC Cycle at the project level.

SUPPLEMENTAL 01 ANSWER 21 (a)

a. PG&E's 2020 GRC capital forecast for ADMS was prepared assuming that it would cover approximately 96% of capital expenditures required to fully implement the ADMS scope as described within the Exhibit-4, Chapter 19 Testimony (p. 19-16 to 19-19) and Workpapers (WP p. 19-16 to 19-29).

   The ADMS cost estimate prepared for the ADMS Major Project Business case provided to Public Advocates as GRC-2020-PhI_DR_PubAdv_154-Q21Supp01Atch02CONF, which was prepared after the 2020 GRC capital forecast for ADMS, utilized different cost estimation assumptions from the GRC forecast, including the consideration of additional project risks not factored into the preparation of the GRC forecast. These project risks are discussed from pages 15 to 21 of the ADMS Major Project Business Case.

   The estimated Expected Case capital costs required for full ADMS implementation implied by the ADMS Major Project Business case is approximately $198.0 million. PG&E's 2020 GRC capital forecast for ADMS remains unchanged.

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PG&E Data Request No.:	PubAdv_100-Q26		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_100-Q26		
Request Date:	February 28, 2019	Requester DR No.:	100
Date Sent:	March 29, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Mark Esguerra	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 – ADVANCED DISTRIBUTION MANAGEMENT SYSTEM (ADMS), GENERAL QUESTIONS

QUESTION 26

ADMS Cost Estimate

If not provided in response to prior questions, please provide workpapers for the cost estimates in lines 6 through 11 of Ex. PG&E-4 WP Table 19-13 which provide details, e.g., units, unit costs, labor costs, material costs, etc., which will allow the CPUC and parties to determine the reasonableness of these estimates.

a. Using WP Table 19-13 as a template, indicate the percentage of each task listed for ADMS implementation that is performed by each of the four sources listed in sub part a above.

ANSWER 26

See GRC-2020-PhI_DR_PubAdv_100-Q26Atch01 for details supporting lines 6 through 8 of Ex. PG&E-4 WP Table 19-13. See GRC-2020-PhI_DR_PubAdv_100-Q26Atch02 for details supporting lines 9 through 11 of Ex. PG&E-4 WP Table 19-13.

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PG&E Data Request No.:	PubAdv_100-Q30		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_100-Q30Supp02		
Request Date:	February 28, 2019	Requester DR No.:	100
Date Sent:	March 29, 2019 (Original) May 6, 2019 (Supplemental 01) July 15, 2019 (Supplemental 02)	Requesting Party:	Public Advocates Office
PG&E Witness:	Quinn Nakayama	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 – ADVANCED DISTRIBUTION MANAGEMENT SYSTEM (ADMS), GENERAL QUESTIONS

QUESTION 30

ADMS Cost Estimate

Please provide documents that show the ADMS software and hardware costs proposed by the preferred vendor and/or accepted by PG&E, including but not limited to the following:

a. Upfront one-time capital costs,
b. Upfront capital costs spread over a payment schedule,
c. Annual capital costs, including licensing fees,
d. Annual expenses,
e. “Per seat” capital costs,
f. “Per seat” expenses.

ANSWER 30

The documents requested contain sensitive commercial information from vendors that PG&E has agreed not to share with anyone outside PG&E without the vendors’ permission. PG&E is attempting to obtain permission from these vendors and will update its response if it is allowed to share the requested documents.

SUPPLEMENTAL 01 ANSWER 30

PG&E attempted to obtain permission to share the requested documents but was not given approval to do so by the vendor accepted by PG&E.

SUPPLEMENTAL 02 ANSWER 30

Attachments to this response have been marked CONFIDENTIAL for reasons identified in the attached Declaration Supporting Confidential Designation, signed July 10, 2019.

PG&E's contract with its preferred ADMS software vendor, executed on May 10, 2019, has a provision which allows PG&E to share it on a confidential basis in Commission proceedings.

Please consult attachment GRC-2020-PhI_DR_PubAdv100-Q30Supp02Atch01CONF, particularly the information beginning at page 25 of the PDF, for the requested information on software costs.

Please note that the software cost information in GRC-2020-PhI_DR_PubAdv100-Q30Supp02Atch01CONF reflects a final, negotiated value which differs from PG&E's software cost estimate on Line No. 2 of WP Table 19-13 in Ex.-4, Ch.19, which was based on an initial vendor quote provided in response to PG&E's ADMS RFP (which PG&E has still not received permission to share).

PG&E's preferred hardware vendor has agreed to allow PG&E to confidentially share a preliminary hardware price estimate it provided to PG&E in June 2019. Please consult attachment GRC-2020-PhI_DR_PubAdv100 Q30Supp02Atch02CONF for this preliminary hardware price estimate.

Please note that the hardware cost information in GRC-2020-PhI_DR_PubAdv100-Q30Supp02Atch02CONF differs from PG&E's hardware cost estimate on Line No. 4 of WP Table 19-13 in Ex.-4, Ch.19 because it is a recent price estimate provided to PG&E that is reflective of changes to PG&E's ADMS hardware requirements that have taken place since the ADMS RFP. PG&E's hardware cost estimate on Line No. 4 of WP Table 19-13 in Ex.-4, Ch.19 was based on an initial vendor quote provided in response to PG&E's ADMS RFP in 2018 (which PG&E has still not received permission to share).

Attachment

GRC-2020-PhI_DR_PubAdv_100-Q30Supp02Atch01CONF

is Confidential in its Entirety

Attachment

GRC-2020-PhI_DR_PubAdv_100-Q30Supp02Atch02CONF

is Confidential in its Entirety

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_128-Q08		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_128-Q08		
Request Date:	March 11, 2019	Requester DR No.:	128
Date Sent:	April 8, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 – DISTRIBUTION GIS ASSET DATA IMPROVEMENT PROJECT

QUESTION 08

Please explain the basis of the forecast for this program and provide the PET data showing how the forecast on WP p. 19-44 of Ex. PG&E-4 was derived.

ANSWER 08

The basis of the forecast can best be described on the 'Project Assumptions' tab of the PET output. In addition, the supporting estimating methodology that discusses the process that supports the PET is at (PG&E-7), pp. 8-85 through pp. 8-87.

See GRC-2020-PhI_DR_PubAdv_128-Q08Atch01 for the PET output supporting the MWC 2F and MWC JV components of the project forecast. See GRC-2020-PhI_DR_PubAdv_128-Q08Atch02 for a comparison of the PET output to the MWC 2F and MWC JV forecasts shown on WP 19-44.

See GRC-2020-PhI_DR_PubAdv_128-Q08Atch03 for the PET output supporting the MWC 63 and MWC HG components of the project forecast. See GRC-2020-PhI_DR_PubAdv_128-Q08Atch04 for a comparison of the PET output to the MWC 63 and MWC HG forecasts shown on WP 19-44.

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PG&E Data Request No.:	PubAdv_130-Q21		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_130-Q21		
Request Date:	March 14, 2019	Requester DR No.:	130
Date Sent:	April 15, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Mark Esguerra	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19, ELECTRIC GENERATION INTERCONNECTION TOOLS

Cost Forecast

QUESTION 21

Page WP 19-32 of Ex. PG&E-4 workpapers states *"PG&E developed the forecast costs for this project, using the Company's application development and infrastructure Project Estimating Tool (PET)0 The PET tools is a bottoms up forecast methodology based on the actual scope of work."* Please provide the bottoms up PET cost estimate.

ANSWER 21

For this project, PG&E created two PET estimates, each reflecting a different component of the project. See GRC-2020-PhI_DR_PubAdv_130-Q21Atch01 and GRC-2020-PhI_DR_PubAdv_130-Q21Atch02 for each PET output. See GRC-2020-PhI_DR_PubAdv_130-Q21Atch03 for a comparison of the combined PET outputs to the forecast shown on WP 19-32.

The cost estimate provided as GRC-2020-PhI_DR_PubAdv_130-Q21Atch01 corresponds to the following scope elements described in Ex-4, Ch. 19 WP p. 19-30 to 19-31:

1. "Electric Load and Generation Interconnection Processes"
2. "Online-Payment Enhancements"
3. "Automated GIS Updates"

The cost estimate provided as GRC-2020-PhI_DR_PubAdv_130-Q21Atch02 corresponds to the following scope elements described in Ex-4, Ch. 19 WP p. 19-30 to 19-31:

1. "Electric Load and Generation Interconnection Processes"
2. "Cloud-Based Integration Capacity Analysis Tools"

Both cost estimates cover portions of the scope described as "Electric Load and Generation Interconnection Processes" in Ex-4, Ch. 19 WP p. 19-30 to 19-31. The two cost estimates were developed as more about the proposed integrated solution became

known. Both components were informed by the Electric Load and Generation Interconnection Processes because that scope carried the basis for the consolidated investment. The first PET is focused on front-end web-portals and backend workflow application enhancements and the second PET is focused on grid impact analysis tool enhancements. For specific details on the scope, see exhibit (PG&E-4), WP 19-30 through 19-31.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
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Data Response

PG&E Data Request No.:	PubAdv_146-Q01		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_146-Q01		
Request Date:	March 27, 2019	Requester DR No.:	146
Date Sent:	April 5, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols (Q01a-c), Joe Sagona Q01d	Requester:	Tom Roberts

SUBJECT: PG&E-4, CHAPTER 19 AND PG&E-7, CHAPTER 8 – INTEGRATED GRID PLATFORM (IGP) COST ESTIMATES

QUESTION 01

Please provide the "specific output from the PET [Project Estimating Tool] for this project" per the following pages of Ex. PG&E-7 workpapers. Given that that the workpapers state that this data is available "upon request," an expedited response date has been requested.

a. Page WP 8-67,

b. Page WP 8-75,

c. Page WP 8-79,

d. Page WP 9-81, assuming PET was used for the IGP Cybersecurity Program. If not, provide all evidence and analysis supporting PG&E's forecast.

ANSWER 01

a. See attachments, per below:

- **GRC-2020-PhI_DR_PubAdv_146-Q01Atch01**: PET output supporting the Data Center & Control Center Infrastructure Preparation component of the project.
- **GRC-2020-PhI_DR_PubAdv_146-Q01Atch02**: Comparison between the PET output in Attachment 01, and the forecast in the associated project summary.
- **GRC-2020-PhI_DR_PubAdv_146-Q01Atch03**: PET output supporting the Field Area Network (FAN) project. Note that while the FAN project was split into two parts (IGP and non-IGP), each with its own project summary, it was estimated as one effort with one PET output.
- **GRC-2020-PhI_DR_PubAdv_146-Q01Atch04**: Comparison between the PET output in Attachment 03, and the forecast in the associated project summaries.
- **GRC-2020-PhI_DR_PubAdv_146-Q01Atch05**: PET output supporting the SCADA Reliability component of the project.

- **GRC-2020-Phl_DR_PubAdv_146-Q01Atch06**: Comparison between the PET output in Attachment 05, and the forecast in the associated project summary.
- **GRC-2020-Phl_DR_PubAdv_146-Q01Atch07**: PET output supporting the Converged Compute Platform component of the project.
- **GRC-2020-Phl_DR_PubAdv_146-Q01Atch08**: Comparison between the PET output in Attachment 07, and the forecast in the associated project summary.

b. See attachments, per below:

- **GRC-2020-Phl_DR_PubAdv_146-Q01Atch09**: PET output for Network Technologies – Asset Lifecycle.
- **GRC-2020-Phl_DR_PubAdv_146-Q01Atch10**: Comparison between the PET output in Attachment 09, and the forecast in the associated project summary.

c. See attachments, per below:

- **GRC-2020-Phl_DR_PubAdv_146-Q01Atch11**: PET output for Network Technologies – Capacity & Reliability Improvements.
- **GRC-2020-Phl_DR_PubAdv_146-Q01Atch12**: Comparison between the PET output in Attachment 11, and the forecast in the associated project summary.

Template Version 4.1803

Conceptual Project Cost Estimate
Estimate Summary

Field Area Network (FAN) - Combined

Deploy Field Area Network nodes to enable communicaitons at the network edge. Includes FAN components necessary to enable PG&E's Integrated Grid Platform as well as other use cases.

Preparer / Point of Contact	Dewey Day (dcdb)
Date of Estimate	4/21/2018

Start Year	2019
End Year:	2022
Target Operative Date	10/15/2021

Complexity	Low
Execution Risk	Medium
Uncertainty	Very Low

Estimate Breakdown	Capital	Expense	Total
Labor	$ 19,310,000	$ 897,000	**$ 20,207,000**
Contracts	$ 500,000	$ -	**$ 500,000**
Materials	$ 24,745,000	$ 21,000	**$ 24,766,000**
Other	$ -	$ 404,000	**$ 404,000**
AFUDC	$ 2,557,000	$ -	**$ 2,557,000**
Escalation	$ 1,911,000	$ 57,000	**$ 1,968,000**
Execution Savings Challenge	$ -	$ -	**$ -**
Total Target Cost	**$ 49,023,000**	**$ 1,379,000**	**$ 50,402,000**

Estimate Confidence
+/- 15%

Target Distribution	2019	2020	2021	2022	
Capital	$ 10,932,985	$ 12,613,525	$ 12,541,750	$ 12,934,740	
Expense	$ 290,840	$ 352,720	$ 362,720	$ 372,720	
Total	**$ 11,223,825**	**$ 12,966,245**	**$ 12,904,470**	**$ 13,307,460**	

(PG&E-18)

AppA-362

15-AtchD-809

TAB COMPLETE

1. Project Assumptions

		RESPONSE / ASSUMPTION	COMMENTS / NOTES	LABOR EFFORT		EXECUTION RISK		COMPLEXITY		UNCERTAINTY	
				Small		Medium		Low		Very Low	
				WEIGHT	SCORE	WEIGHT	SCORE	WEIGHT	SCORE	WEIGHT	SCORE
				46.2		31.4		33.0		20.0	
A. Basic Information											
1.01	Estimate Preparer(s) / Point(s) of Contact:	Dewey Day (dcdb)									
1.02	Date of Estimate:	4/21/2018	Estimate refined over several month period								
1.03	Program / Bucket / Planning Order Name										
1.04	Project / Product Name:	Field Area Network (FAN) - Combined	IGP Enablement: Field Area Network + Network Technologies: Field Area Network								
1.05	Description: (181 characters)	Deploy Field Area Network nodes to enable communicaitons at the network edge. Includes FAN components necessary to enable PG&E's Integrated Grid Platform as well as other use cases.	PG&E's GRC forecast for the FAN is split into two parts, but the work will be executed as one initiative.								
1.06	Start Year:	2019									
1.07	End Year:	2022									
B. Accounting Assumptions											
1.08	Will the majority of the individual hardware/software assets deployed by the project take more than 30 days to become operative (i.e. used and useful)?	Yes (Typical for Application/Software Projects)									
1.09	Target Operative Date:	10/15/2021	Multiple deployments/operative dates expected								
1.10	Will this project be funded from a non-standard source such as a Balancing or Memo Account (e.g. Customer Energy Efficiency, Demand Response, EPIC, etc.)?	No or Don't Know - Normal Cap/Exp Rules Apply									
1.11	Is the entirety of this project a Pilot that will not go into production or a Proof of Concept?	No		9%	9.0						
1.12	Is the solution known? **(All of the following must be true)** - Requirements/biz outcomes are defined/well understood - All RFPs are closed and vendor selection is complete - Technology direction is known, including buy vs. build - A high level solution blueprint has been approved in EDRS	Yes	Tropos radios based upon existing intallation standards	3%	0.0					9%	0.0

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C. General Assumptions

1.13	What is the anticipated labor effort duration?	> 24 months		12%	12.0						
1.14	What is the anticipated split between application-related labor and infrastructure-related labor? **Application:** labor related to deploying, modifying, or retiring software applications **Infrastructure:** labor related to deploying, upgrading, modifying, or decommissioning infrastructure, infrastructure software (e.g. operating systems), or other physical assets (e.g. mobile devices).	Mostly infrastructure with some application						0%	0.0		
1.15	What methodology will be used for application-related work?	Standard IT Methodology (Waterfall/Iterative)		4%	4.0						
1.16	What methodology will be used for infrastructure-related work?	Basic Hardware Lifecycle/Capacity Installation		5%	0.0						
1.17	Which IT organization will be responsible for the majority of the internal labor effort?	Infrastructure & Operations									
1.18	What is the anticipated size of the core project team?	Large (31 - 45)		6%	4.5						
1.19	Excluding business process work, will any Line of Business (non-IT) resources directly contribute to the delivery of the anticipated technology solution?	Yes - Part of extended project team									
1.20	Will this project require new formal training for end-users?	Yes - A medium amount (8-14 hrs per end-user)	Instructor led, job aid review								
1.21	Will the project require PG&E Academy support for training development and/or delivery?	No									
1.22	Will organizational/process change management efforts be included in project costs?	Yes		1%	1.0						
1.23	How many third party vendors (excluding managed service and staff aug resources) do you anticipate will provide services for this project?	1 - 2	Contract RF design and some equipment installations	2%	1.0			4%	2.0		
1.24	Will project costs include any contracts (e.g. fixed-fee labor/consulting, subscriptions, licenses, leases, etc.)?	Yes									
1.25	How many internal end users will be directly impacted by this project?	500 - 1,000	Electric Line Technicians and Telecom Technicians	7%	3.5			7%	4.2		
1.26	How many external (non-PG&E) end users will be directly impacted by this project?	None		5%	0.0			4%	0.0		
1.27	What is the level of criticality of the system to the users and PG&E customers?	Tier 2 (Business Critical)		4%	3.0			6%	4.5		
1.28	Will the project require clearances or generation outages?	No						6%	0.0	5%	0.0
1.29	Does the scope involve NERC CIP assets?	Yes	Substation related assets					1%	1.0	2%	0.0

D. Technology Assumptions

1.30	Will the project leverage or integrate with external, vendor-owned commercial cloud services (SaaS, IaaS, PaaS, etc.)?	No						2%	1.0	2%	0.0
1.31	Will the anticipated solution involve deploying a net new application?	No		6%	0.0			6%	0.0		
1.33	Will the anticipated solution require any net new system integrations?	No		5%	0.0			5%	2.5	2%	0.0
1.34	Will the anticipated solution require new integrations with internal user access mgmt. systems?	No - Internal access mgmt. not applicable or already in place		2%	0.0					2%	0.0
1.35	Will the anticipated solution be collecting, processing, transmitting, and/or storing Confidential or Restricted information?	No		2%	0.0			2%	0.0		
1.36	Will the project implement or modify any system(s) or interface(s) within the Operational Data Network (ODN), the Gas Data Network (GDN), or Diablo Canyon Power Plant (DCPP)?	Yes	FAN extends ODN and GDN wirelessly to Field Devices via separate VRFs on the WAN					4%	4.0		
1.37	Will the anticipated solution require new interconnectivity between networks (UDN, Internet, ODN, GDN, etc.)?	No		3%	0.0			6%	0.0	2%	0.0
1.38	Is the project expected deploy any devices that will generate incremental traffic on PG&E networks?	Yes - More than 1,000 devices	New FAN radios and field devices on electric system	3%	3.0					2%	0.0
1.39	How many PG&E sites/facilities are expected to require network infrastructure upgrades (e.g. equipment, bandwidth, etc.) to support the anticipated solution?	20 - 30	Most Gateway locations that connect the FAN to PG&E's private network.	3%	2.4			3%	2.4		
1.40	Will the anticipated solution require incremental PG&E network infrastructure for redundancy/resiliency purposes?	No		3%	0.0			3%	0.0	2%	0.0
1.41	Will the anticipated solution leverage any PG&E-owned data center computing infrastructure?	Yes - Non-OneCloud (Virtualized)	Tropos database already in place	2%	1.0			6%	3.0	2%	0.0
1.42	Will the project require any PG&E-owned Network Attached Storage (NAS) for content/unstructured data?	No	Tropos database storage already in place							2%	0.0

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1.43	How much of the required PG&E-owned data center infrastructure is already in place?	Almost all of it	Tropos database already in place	4%	0.0			3%	0.0	2%	0.0
E. Execution Assumptions													
1.44	Scope and Objectives (Risk/Uncertainty)	Medium: Scope, objectives, and benefits may be defined but not well documented or understood by majority of stakeholders impacted.				10.0%	3.0			18%	9.0
1.45	Timeline (Risk)	Low: The project timeline is achievable given the scope and resources available the project.				6.0%	1.2				
1.46	Interdependencies (Risk/Complexity)	Low: Minimal or no known touch points with other projects (business or IT).				4.0%	0.8	6%	0.6		
1.47	Project Sponsorship (Risk)	Low: Single executive sponsor who is actively engaged and possesses enterprise decision-making authority.				12.0%	2.4				
1.48	Impacted Lines of Business (Risk/Complexity)	High: More than 2 LOBs impacted by project outcome	Core Operational LOBs, IT			12.0%	12.0	6%	6.0		
1.49	Process/Behavior Change (Risk/Complexity)	Low: Developmental - the future state is primarily an incremental improvement to current state, with no notable process changes and with skills development as the primary human impact.		9%	1.8	6.0%	1.2	6%	0.6		
1.50	Resource Availability (Risk)	Low: Resources for all key Business and IT roles are identified. Resources with all key required skillsets are currently available at PG&E.				8.0%	1.6				
1.51	Team Proficiency (Risk/Uncertainty)	Medium: PG&E IT has some experience with this type of work and will require standard oversight to be successful.				8.0%	2.4			16%	8.0
1.52	3rd Party Involvement (Risk/Uncertainty)	Low: No 3rd parties are involved; or involved 3rd parties have demonstrated success at PG&E in like functionality.	all third parties have established agreements supporting this type of project			4.0%	0.8			12%	1.2
1.53	Technology (Risk/Complexity/Uncertainty)	Low: Known technology with minimal change to infrastructure / architecture.				16.5%	3.3	6%	0.6	18%	1.8
1.54	Data Migration (Risk/Complexity)	Low: Zero or minimal amount of data migration is required.				9.0%	1.8	2%	0.0		
1.55	Integration (Risk/Complexity)	Low: 1 to 3 systems involved or N/A	only scada systems are involved			4.5%	0.9	6%	0.6		
F. Operations & Maintenance Assumptions											
1.56	Will this project require incremental O&M labor to support the solution during the year of deployment?	Yes	Telecom and Division Line Technicians							2%	0.0
1.57	What organization will be primarily responsible for any Internal O&M Labor during deployment?	Infrastructure & Operations									

For questions, technical support, or training requests, please email CEHelp@pge.com

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App Dev/Software Related Costs	Capitalization Threshold
$ 684,000	$ 1,000,000

Labor Rates As Of:	Managed Svcs. Rates As Of:	Overhead Rates As Of:
12/18/2017	7/5/2017	2/13/2018

2a. Cost Assumptions - Labor

A. Base Labor Assumptions

		A1. Base Labor Effort Sizing			A2. Adjusted Labor Effort Sizing	
		Calculated	Manual	Person-Days	Complexity & Risk Modifier	Adjusted Value (Person-Days)
2a.01	Total Project Labor	Small		600	85%	**510**
2a.02	Comments / Notes / Assumptions / Manual Input Justification					

B. Project Labor Split (Excluding Deploy Year O&M)

		B1. % of Total Labor		B2. Person-Days		B3. Adjusted Totals	
	Labor Type	Calculated	Manual	Calculated	Manual	Person-Days	% of Total Labor
2a.03	Application Project Labor	20%		102		~~102~~	~~20%~~
2a.04	Infrastructure Project Labor	80%		408		~~408~~	~~80%~~
2a.05	**Total Project Labor**	**100%**		**510**	**-**	**510**	**100%**
2a.06	Comments / Notes / Assumptions / Manual Input Justification						

C. Application Project Labor

		C1. Application Project Labor Distribution			C2. Person-Days		C3. Adjusted Totals		C4. Fixed-Fee Labor Effort Walk-Out		
	Labor Category	Calculated	Manual	Adjusted %	Calculated	Manual	Person-Days	Labor Distribution	% Under Fixed-Fee Contract	Labor Effort (Non-Fixed-Fee)	Labor Distribution (Non-Fixed-Fee)
2a.07	Project Management	~~13.5%~~		~~13.5%~~	~~14~~	200	200	36.3%		200	**36.3%**
2a.08	Requirements Analysis & Management	~~9.6%~~		~~9.6%~~	10		10	1.8%		10	**1.8%**
2a.09	Technical Design / Engineering	~~7.9%~~		~~7.9%~~	~~8~~	200	200	36.3%		200	**36.3%**
2a.10	Development / Configuration	~~30.5%~~		~~30.5%~~	31		31	5.6%		31	**5.6%**
2a.11	System Testing	~~18.5%~~		~~18.5%~~	~~19~~	50	50	9.1%		50	**9.1%**
2a.12	Defect Removal	~~6.5%~~		~~6.5%~~	7		7	1.2%		7	**1.2%**
2a.13	Implementation & Deployment	~~9.5%~~		~~9.5%~~	~~10~~	50	50	9.1%		50	**9.1%**
2a.14	Training, Data Migration, Process Change, & Other	~~4.0%~~		~~4.0%~~	4		4	0.7%		4	**0.7%**
2a.15	**Total Application Project Labor**	**100%**	**0.0%**	**100%**	~~**102**~~	**500**	**552**	**100%**		**552**	**100%**
2a.16	**Deploy-Year O&M Labor**	13%		13%	13		13	**2%**		13	**2%**
2a.17	Comments / Notes / Assumptions / Manual Input Justification				Appliation labor limited to Supros Support						

D. Infrastructure Project Labor

		D1. Infrastructure Project Labor Distribution			D2. Person-Days		D3. Adjusted Totals		D4. Fixed-Fee Labor Effort Walk-Out		
	Labor Category	Calculated	Manual	Adjusted %	Calculated	Manual	Person-Days	Labor Distribution	% Under Fixed-Fee Contract	Labor Effort (Non-Fixed-Fee)	Labor Distribution (Non-Fixed-Fee)
2a.18	Project Management	~~7.3%~~		~~7.3%~~	~~30~~	1400	1400	8.9%		1400	**8.9%**
2a.19	Requirements Analysis & Management	~~7.1%~~		~~7.1%~~	~~29~~	1400	1400	8.9%		1400	**8.9%**
2a.20	Technical Design / Engineering	~~9.1%~~		~~9.1%~~	~~37~~	1800	1800	11.4%		1800	**11.4%**
2a.21	Construction / Build-Out / Configuration	~~33.8%~~		~~33.8%~~	~~138~~	7500	7500	47.5%		7500	**47.5%**
2a.22	System Testing	~~20.5%~~		~~20.5%~~	~~84~~	500	500	3.2%		500	**3.2%**
2a.23	Defect Removal	~~7.3%~~		~~7.3%~~	~~30~~	500	500	3.2%		500	**3.2%**
2a.24	Implementation & Deployment	~~10.5%~~		~~10.5%~~	~~43~~	2300	2300	14.6%		2300	**14.6%**
2a.25	Training, Data Migration, Process Change, & Other	~~4.4%~~		~~4.4%~~	~~18~~	400	400	2.5%		400	**2.5%**
2a.26	**Total Infrastructure Project Labor**	**100%**	~~**0.0%**~~	**100%**	~~**408**~~	**15800**	**15800**	**100%**		**15800**	**100%**
2a.27	**Deploy-Year O&M Labor**	13%		13%	51		51	**0%**		51	**0%**
2a.28	Comments / Notes / Assumptions / Manual Input Justification				Multi-year effort based upon FAN installation estimates						

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E. Internal Labor Costs (Before Overheads)

	Labor Type	E1. Internal Project Labor: Calculated (% of Total)	E1. Internal Project Labor: Manual (% of Total)	E1. Internal Project Labor: Calculated Person-Days		E2. Internal Deploy-Year O&M Labor: % of Total Calc | Manual		E2. Internal Deploy-Year O&M Labor: Calculated Person-Days		E3. Blended Daily Labor Rates: As of: 12/18/2017		E4. Estimated Internal Labor Costs (Before Overheads): Project Labor	E4. Estimated Internal Labor Costs (Before Overheads): Deploy-Year O&M Labor	E4. Estimated Internal Labor Costs (Before Overheads): Total Internal Labor
2a.29	IT Employee Labor (Blended IT)			0	+			0	x	$ 557	=	$ -	$ -	$ -
2a.30	Business Technology Employee Labor	9.9%		1619	+	20%		13	x	$ 542	=	$ 877,000	$ 7,000	$ 884,000
2a.31	I&O Employee Labor	51.7%		8454	+	80%		51	x	$ 475	=	$ 4,012,000	$ 24,000	$ 4,036,000
2a.32	Cybersecurity Employee Labor	6.3%		1030	+	0%		0	x	$ 531	=	$ 547,000	$ -	$ 547,000
2a.33	Architecture Employee Labor	1.0%		164	+			0	x	$ 678	=	$ 111,000	$ -	$ 111,000
2a.34	LOB Employee Labor (Excl. Academy)	3.9%		638	+			0	x	$ 576	=	$ 367,000	$ -	$ 367,000
2a.35	**Internal Labor Total**	**72.8%**		**11904**		**100.0%**		**64**				**$ 5,914,000**	**$ 31,000**	**$ 5,945,000**
2a.36	Comments / Notes / Assumptions / Manual Input Justification													

F. External Labor Costs (Before Overheads)

	Labor Type	F1. External Project Labor: Calculated (% of Total)	F1. External Project Labor: Manual (% of Total)	F1. External Project Labor: Calculated Person-Days		F2. External Deploy-Year O&M Labor: % of Total Calc | Manual		F2. External Deploy-Year O&M Labor: Calculated Person-Days		F3. Blended Daily Labor Rates: Staff Aug as of: 12/18/2017 Managed Services as of: 7/5/2017			F4. Estimated External Labor Costs (Before Overheads): Project Labor	F4. Estimated External Labor Costs (Before Overheads): Deploy-Year O&M Labor	F4. Estimated External Labor Costs (Before Overheads): Total External Labor
2a.37	Staff Aug Contractor Labor (Blended Rate)	22.2%		3630	+			0	x	$ 1,214		=	$ 4,405,000	$ -	$ 4,405,000
2a.38	Tier 1 Staff Aug Contractor Labor			0	+			0	x	$ 323		=	$ -	$ -	$ -
2a.39	Tier 2 Staff Aug Contractor Labor			0	+			0	x	$ 713		=	$ -	$ -	$ -
2a.40	Tier 3 Staff Aug Contractor Labor			0	+			0	x	$ 1,000		=	$ -	$ -	$ -
2a.41	Tier 4 Staff Aug Contractor Labor			0	+			0	x	$ 1,427		=	$ -	$ -	$ -
2a.42	Tier 5 Staff Aug Contractor Labor			0	+			0	x	$ 1,788		=	$ -	$ -	$ -
2a.43	Managed Services Labor (Blended Rate)									**On-Site Rate**	**Off-Shore Rate**				
2a.44	Project Management Services			0	+			0	x	$ 700	$ 256	=	$ -	$ -	$ -
2a.45	Business/Functional Analysis Services			0	+			0	x	$ 593	$ 221	=	$ -	$ -	$ -
2a.46	Technical Architecture Services			0	+			0	x	$ 878	$ 297	=	$ -	$ -	$ -
2a.47	Solution Architecture Services			0	+			0	x	$ 1,000	$ 1,000	=	$ -	$ -	$ -
2a.48	Development Services			0	+			0	x	$ 604	$ 200	=	$ -	$ -	$ -
2a.49	Testing Services	5.0%		818	+			0	x	$ 544	$ 175	=	$ 445,000	$ -	$ 445,000
2a.50	Support/SysAdmin/DBA Services			0	+			0	x	$ 622	$ 203	=	$ -	$ -	$ -
2a.51	-			0	+			0	x	$ -	$ -	=	$ -	$ -	$ -
2a.52	-			0	+			0	x	$ -	$ -	=	$ -	$ -	$ -
2a.53	-			0	+			0	x	$ -	$ -	=	$ -	$ -	$ -
2a.54	**External Labor Total**	**27.2%**		**4448**		**0.0%**		**0**		**100%**	**0%**		**$ 4,850,000**	**$ -**	**$ 4,850,000**
2a.55	Comments / Notes / Assumptions / Manual Input Justification														

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G. Total Labor Costs by Category (Before Overheads)

	Labor Category	G1. Labor Effort Distribution (Person-Days)			G2. Labor Effort Distribution (%)		G3. Cloud-Related / Exp. Program		G4. Labor Cost Distribution		
		Application	Infrastructure	Total	Application	Infrastructure	Application (%)	Infrastructure (%)	Application	Infrastructure	Total
2a.56	Project Management	200	1400	**1600**	1%	9%			$ 132,000	$ 922,000	**$ 1,054,000**
2a.57	Requirements Analysis & Management	10	1400	**1410**	0%	9%			$ 6,000	$ 922,000	**$ 928,000**
2a.58	Technical Design / Engineering	200	1800	**2000**	1%	11%			$ 132,000	$ 1,185,000	**$ 1,317,000**
2a.59	Development / Construction / Build-Out / Configuration	31	7500	**7531**	0%	46%			$ 20,000	$ 4,937,000	**$ 4,957,000**
2a.60	System Testing	50	500	**550**	0%	3%			$ 33,000	$ 329,000	**$ 362,000**
2a.61	Defect Removal	7	500	**507**	0%	3%			$ 4,000	$ 329,000	**$ 333,000**
2a.62	Implementation & Deployment	50	2300	**2350**	0%	14%			$ 33,000	$ 1,514,000	**$ 1,547,000**
2a.63	Training, Data Migration, Process Change, & Other	4	400	**404**	0%	2%			$ 3,000	$ 263,000	**$ 266,000**
2a.64	**Total Project Labor**	**552**	**15800**	**16352**	**3%**	**97%**			**$ 363,000**	**$ 10,401,000**	**$ 10,764,000**
2a.65	**Deploy-Year O&M Labor**	13	51	**64**	20%	80%			$ 6,000	$ 25,000	**$ 31,000**
2a.66	**Total Labor**	**564**	**15851**	**16415**	**3%**	**97%**			**$ 369,000**	**$ 10,426,000**	**$ 10,795,000**
2a.55	Comments / Notes / Assumptions / Manual Input Justification										

H. Labor Cost Breakdown (Cap/Exp + Overheads)

	Labor Category	H1. Capital (%)			H2. Expense (%)			H3. Labor Cost Distribution		
		Application	Infrastructure	Total	App	Infra.	Total	Capital $	Expense $	Total
2a.67	Project Management	0%	97%	85%	100%	3%	15%	$ 896,000	$ 158,000	**$ 1,054,000**
2a.68	Requirements Analysis & Management	0%	100%	99%	100%	0%	1%	$ 922,000	$ 6,000	**$ 928,000**
2a.69	Technical Design / Engineering	0%	100%	90%	100%	0%	10%	$ 1,185,000	$ 132,000	**$ 1,317,000**
2a.70	Development / Construction / Build-Out / Configuration	0%	100%	100%	100%	0%	0%	$ 4,937,000	$ 20,000	**$ 4,957,000**
2a.71	System Testing	0%	100%	91%	100%	0%	9%	$ 329,000	$ 33,000	**$ 362,000**
2a.72	Defect Removal	0%	100%	99%	100%	0%	1%	$ 329,000	$ 4,000	**$ 333,000**
2a.73	Implementation & Deployment	0%	100%	98%	100%	0%	2%	$ 1,514,000	$ 33,000	**$ 1,547,000**
2a.74	Training, Data Migration, Process Change, & Other	0%	0%	0%	100%	100%	100%	$ -	$ 266,000	**$ 266,000**
2a.75	**Total Project Labor**	0%	**97%**	**94%**	**100%**	**3%**	**6%**	**$ 10,112,000**	**$ 652,000**	**$ 10,764,000**
2a.76	**Deploy-Year O&M Labor**	0%	0%	0%	100%	100%	100%	$ -	$ 31,000	**$ 31,000**
2a.77	**Total Labor**	0%	**97%**	**94%**	**100%**	**3%**	**6%**	**$ 10,112,000**	**$ 683,000**	**$ 10,795,000**
2a.78	Internal Labor Overheads							$ 8,834,000	$ 214,000	**$ 9,048,000**
2a.79	External Labor (Staff Aug) Overheads							$ 364,000	$ -	**$ 364,000**
2a.80	**Total Labor Overheads**							**$ 9,198,000**	**$ 214,000**	**$ 9,412,000**

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2b. Cost Assumptions - Non-Labor

J. Contracts Costs

		Person Days (App)	Person Days (Inf)	Person Days (O&M)
2b.01	**Labor Effort Paid for via Capital Fixed-Fee**	0	0	
2b.02	**Labor Effort Paid for via Expense Fixed-Fee**	0	0	0

	J1. Calculated Contract Costs				J2. Capitalization Rules		J3. Capital/Expense Split	
	Contract Type (See Comment for Definitions)	**Calculated**	**Use Only Manual Input**	**Adjusted**	**Capitalizable?**	**Capitalizable?** (Adjusted)	**Capital $**	**Expense $**
	Capital Contracts	(Override if Cloud)						
2b.03	Fixed-Fee Labor - Application Design/Delivery	$ -		$ -	Maybe	Threshold Not Met	$ -	$ -
2b.04	Fixed-Fee Labor - Infrastructure Design/Construction	$ -		$ -	Yes	Yes	$ -	$ -
	Expense Contracts							
2b.05	Fixed-Fee Labor - Other (e.g. Best Practices Consulting, SaaS Config)	$ -		$ -	No	No	$ -	$ -
2b.06	Maintenance/Support	$ -		$ -	No	No	$ -	$ -
2b.07	**Total**	**$ -**		**$ -**			**$ -**	**$ -**

	J4. Manual Contract Costs			J5. Capitalization Rules			J6. Capital/Expense Split		J7. Post-Project Costs	
	Contract Type (See Comment for Definitions)	**Contract/Vendor Description**	**Project Cost (Procurement)**	**Capitalizable?** Calc | Manual		**Capitalizable?** (Adjusted)	**Capital $**	**Expense $**	**Recurring Cost (Post-Project)**	**Recurrence Period (Years)**
2b.08	Fixed-Fee Labor - Infrastructure Design/Construction	RF Design	$ 500,000	Yes		Yes	$ 500,000	$ -		
2b.09							$ -	$ -		
2b.10							$ -	$ -		
2b.11							$ -	$ -		
2b.12							$ -	$ -		
2b.13							$ -	$ -		
2b.14							$ -	$ -		
2b.15							$ -	$ -		
2b.16							$ -	$ -		
2b.17							$ -	$ -		
2b.18	**Total**		**$ 500,000**				**$ 500,000**	**$ -**		
2b.19	Comments / Notes / Assumptions / Manual Input Justification									

(PG&E-18)

AppA-369

15-AtchD-816

K. Materials Costs

	Infrastructure/Hardware Category	K1. Bulk Materials Cost: Calculated	Manual Input	Adjusted Cost	K2. Unit Cost Total: Unit-Based Cost	Use Unit Cost?	K3. Capital/Expense Split: Capital $	Expense $
2b.20	Network / Telecom	~~$ 2,281,000~~	$ 24,000,000	$ 24,000,000	$ -		$ 24,000,000	$ -
2b.21	Data Center Computing	~~$ 48,000~~	$ 500,000	$ 500,000	$ -		$ 500,000	$ -
2b.22	Personal Computing			$ -	$ -		$ -	$ -
2b.23	Consumer Mobile Devices			$ -	$ -		$ -	$ -
2b.24	Facilities/Phys. Sec./Other			$ -	$ -		$ -	$ -
2b.25	Training Materials	$ 21,000		$ 21,000	$ -		$ -	$ 21,000
2b.26	**Total**	**$ 2,350,000**	**$ 24,500,000**	**$ 24,521,000**	**$ -**		**$ 24,500,000**	**$ 21,000**
2b.27	**Materials Overheads**						**$ 245,000**	**$ -**
2b.28	Comments / Notes / Assumptions / Manual Input Justification	FAN Radio Costs and data center linkages						

	K4. Materials Unit Cost Detail: Unit Description	Unit Category	Unit Price	# of Units	K5. Unit Cost Output: Row Cost	Capital Asset?
2b.29					$ -	
2b.30					$ -	
2b.31					$ -	
2b.32					$ -	
2b.33					$ -	
2b.34					$ -	
2b.35					$ -	
2b.36					$ -	
2b.37					$ -	
2b.38					$ -	
2b.39					$ -	
2b.40					$ -	
2b.41					$ -	
2b.42					$ -	
2b.43					$ -	

L. Other Non-Labor Costs

		L1. Employee-Related Cost Calculation: Calculated %	Manual Input		Total Labor $	L2. Capital/Expense Split: Capital $	Expense $
2b.44	Employee Related Costs (e.g. Meals, Travel, Lodging)	2.0%		x	$ 20,207,000	**$ -**	**$ 404,000**
2b.45	Comments / Notes / Assumptions / Manual Input Justification						

TAB COMPLETE

3. Cost Allocation

A. Labor	Capital $	Expense $	Total $
Project Management	$ 896,000	$ 158,000	$ 1,054,000
Requirements Analysis & Management	$ 922,000	$ 6,000	$ 928,000
Technical Design / Engineering	$ 1,185,000	$ 132,000	$ 1,317,000
Development / Construction / Build-Out / Configuration	$ 4,937,000	$ 20,000	$ 4,957,000
System Testing	$ 329,000	$ 33,000	$ 362,000
Defect Removal	$ 329,000	$ 4,000	$ 333,000
Implementation & Deployment	$ 1,514,000	$ 33,000	$ 1,547,000
Training, Data Migration, Process Change, & Other	$ -	$ 266,000	$ 266,000
Total Project Labor	**$ 10,112,000**	**$ 652,000**	**$ 10,764,000**
Deployment Year O&M Labor	**$ -**	**$ 31,000**	**$ 31,000**
Internal Labor Overheads	$ 8,834,000	$ 214,000	$ 9,048,000
External Labor (Staff Aug) Overheads	$ 364,000	$ -	$ 364,000
Total Labor	**$ 19,310,000**	**$ 897,000**	**$ 20,207,000**

B. Non Labor	Capital $	Expense $	Total $
Fixed-Fee Labor - Application Design/Delivery	$ -	$ -	$ -
Fixed-Fee Labor - Infrastructure Design/Construction	$ 500,000	$ -	$ 500,000
Fixed-Fee Labor - Other (e.g. Best Practices Consulting, SaaS Config)	$ -	$ -	$ -
Subscription(s) - Cloud, Service(s), etc.	$ -	$ -	$ -
Software License(s) - Term (Renewed Periodically)	$ -	$ -	$ -
Software License(s) - Perpetual (Owned for Asset's Life)	$ -	$ -	$ -
Lease(s)	$ -	$ -	$ -
Maintenance/Support	$ -	$ -	$ -
Other Contracts	$ -	$ -	$ -
Total Contracts	**$ 500,000**	**$ -**	**$ 500,000**
Network	$ 24,000,000	$ -	$ 24,000,000
Data Center Computing	$ 500,000	$ -	$ 500,000
Personal Computing	$ -	$ -	$ -
Consumer Mobile Devices	$ -	$ -	$ -
Facilities / Physical Security / Other	$ -	$ -	$ -
Training Materials	$ -	$ 21,000	$ 21,000
Materials Overheads	$ 245,000	$ -	$ 245,000
Total Materials	**$ 24,745,000**	**$ 21,000**	**$ 24,766,000**
Employee Related Costs	$ -	$ 404,000	$ 404,000
Total Other	**$ -**	**$ 404,000**	**$ 404,000**
Total Non-Labor	**$ 25,245,000**	**$ 425,000**	**$ 25,670,000**

C. Total	Capital $	Expense $	Total $
Total Before Escalation	**$ 44,555,000**	**$ 1,322,000**	**$ 45,877,000**
Escalation	$ 1,911,000	$ 57,000	$ 1,968,000
Execution Savings Challenge	$ -	$ -	$ -
Capital AFUDC	$ 2,557,000	$ -	$ 2,557,000
Grand Total	**$ 49,023,000**	**$ 1,379,000**	**$ 50,402,000**

D. Annual Cost Allocation	2019	2020	2021	2022	
Capital Allocation (%)	23%	26%	25%	27%	
Capital Before Escalation	$ 10,113,985	$ 11,361,525	$ 11,138,750	$ 11,940,740	
Capital Escalation	$ -	$ 307,000	$ 610,000	$ 994,000	
Execution Savings Challenge					
Capital AFUDC	$ 819,000	$ 945,000	$ 793,000	$ -	
Total Capital Allocation	**$ 10,932,985**	**$ 12,613,525**	**$ 12,541,750**	**$ 12,934,740**	
Expense Allocation (%)	22%	26%	26%	26%	
Expense Before Escalation	$ 290,840	$ 343,720	$ 343,720	$ 343,720	
Expense Escalation	$ -	$ 9,000	$ 19,000	$ 29,000	
Execution Savings Challenge					
Total Expense Allocation	**$ 290,840**	**$ 352,720**	**$ 362,720**	**$ 372,720**	
Total Cost Allocation	**$ 11,223,825**	**$ 12,966,245**	**$ 12,904,470**	**$ 13,307,460**	
Allocation Comments / Notes / Assumptions	Allocation based on overall portfolio sequencing. FAN intallations escalate with DNP3 conversion and SCADA device installations.				
Execution Savings Challenge Comments / Notes / Assumptions					

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_146-Q02		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_146-Q02		
Request Date:	March 27, 2019	Requester DR No.:	146
Date Sent:	April 5, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: PG&E-4, CHAPTER 19 AND PG&E-7, CHAPTER 8 – INTEGRATED GRID PLATFORM (IGP) COST ESTIMATES

QUESTION 02

Please provide the specific output from the PET for the Distribution Engineering Planning Tools program referenced on page WP 19-39 of Ex. PG&E-4 workpapers.

ANSWER 02

Components of the Distribution Engineering Planning Tools program were estimated separately. As a result, there are 4 different PET outputs, included as:

- GRC-2020-PhI_DR_PubAdv_146-Q02Atch01,
- GRC-2020-PhI_DR_PubAdv_146-Q02Atch02,
- GRC-2020-PhI_DR_PubAdv_146-Q02Atch03, and
- GRC-2020-PhI_DR_PubAdv_146-Q02Atch04

GRC-2020-PhI_DR_PubAdv_146-Q02Atch05 compares the combined output of those 4 attachments with the overall forecast shown in the project summary.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_162-Q07		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_162-Q07		
Request Date:	April 11, 2019	Requester DR No.:	162
Date Sent:	April 25, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Joe Sagona	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 9 – INTEGRATED GRID PLATFORM (IGP) CYBERSECURITY PROJECT

QUESTION 07

PG&E's IGP request includes forecasts for new equipment, including the ADMS, FAN and SCADA. Why is cybersecurity for the IGP included as a separate add-on forecast rather than an integral and embedded component of the new Integrated Grid Platform PG&E seeks to purchase?

ANSWER 07

The primary intent of the IGP cybersecurity project is to secure the IGP platform (ADMS). Additionally, the effectiveness of cybersecurity investments must comprehensively consider the distribution system as a whole, not just core control and distribution management systems. Attack vectors and risks which target the core distribution management system may originate from external systems and environments, such as datacenters, substations, and third-parties. Effective mitigation of these attack vectors and risks may include additional investments beyond those provisioned for ADMS. For these reasons, a strategic decision was made to separate cybersecurity funding and scope to more holistically and effectively manage security risk, ensure appropriate visibility, and provide oversight and control over security implementations.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q01		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q01		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 01

Please provide a diagram of the FAN system that shows all components included in both the TY 2017 request, and the TY 2020 request.

ANSWER 01

GRC-2020-PhI_DR_PubAdv_163-Q01Atch01CONF provides a diagram that shows all requested components. In both the TY 2017 request and the TY 2020 request, the type of technology being deployed is the same. The TY 2020 request builds on the TY 2017 request by deploying the FAN technology to additional geographic locations.

Attachment

GRC-2020-PhI_DR_PubAdv_163-Q13Atch01CONF

is Confidential in its Entirety

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q02		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q02		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 02

Please provide the current status the Network Technologies – FAN program in terms of the Phase Gate Process defined in PG&E Utility Standard PM-101S, or relative to the non-project processes provided in response to data request PubAdv-PG&E-127-TCR.

ANSWER 02

PG&E objects to this question as beyond the scope of the proceeding. The question calls for information about "the current status" of an IT project. PG&E's 2020 GRC was submitted in December 2018 using a forecast that was finalized, with few exceptions, in May 2018 as stated on Exhibit 1, page 2-14, based on the best available information at that time. It would be unreasonable to evaluate PG&E's request based on data not available at that time. Subject to and without waiving PG&E's right to object to the admissibility of this information in the proceeding, PG&E responds as follows.

The Network Technologies – FAN program refers to the non-IGP component of the overall FAN deployment. The non-IGP component of the overall FAN deployment is executed as a series of smaller projects based on specific geographic areas or use cases to be enabled. Each of these smaller projects is separately subject to standard PM-1010S if it meets the applicability requirements laid out in the standard. There were no non-IGP FAN projects in flight as of the end of 2018, and any non-IGP FAN work begun in 2019 has not yet completed Phase Gate 1. Note that the IT organization only began aligning its governance processes to standard PM-1010S in February of 2019. As a result, any work completed prior to February 2019 may not have been fully aligned with the requirements of standard PM-1010S.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q03		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q03		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 03

Please provide program scoping and authorization documents for the Network Technologies – FAN program in terms of the Phase Gate Process defined in PG&E Utility Standard PM-101S, or relative to the non-project processes provided in response to data request PubAdv-PG&E- 127-TCR.

ANSWER 03

PG&E objects to this question as beyond the scope of the proceeding. The question calls for information about "the current status" of an IT project. PG&E's 2020 GRC was submitted in December 2018 using a forecast that was finalized, with few exceptions, in May 2018 as stated on Exhibit 1, page 2-14, based on the best available information at that time. It would be unreasonable to evaluate PG&E's request based on data not available at that time. Subject to and without waiving PG&E's right to object to the admissibility of this information in the proceeding, PG&E responds as follows.

The Network Technologies – FAN program refers to the non-IGP component of the overall FAN deployment. The non-IGP component of the overall FAN deployment is executed as a series of smaller projects based on specific geographic areas or use cases to be enabled. Each of these smaller projects is separately subject to standard PM-1010S if it meets the applicability requirements laid out in the standard. There were no non-IGP FAN projects in flight as of the end of 2018, and any non-IGP FAN work beginning after 2018 has not yet completed Phase Gate 1. Therefore, scoping and authorization documents are not yet available for work beyond 2018. Note that the IT organization only began aligning its governance processes to standard PM-1010S in February of 2019. As a result, any work completed in 2018 may not have been fully aligned with the requirements of standard PM-1010S.

There were 2 FAN projects prior to 2019 that would have met the criteria for the referenced Phase Gate Process had it been in place at that time. GRC-2020-PhI_DR_PubAdv_163-Q03Atch01CONF includes key authorizations for those projects. The table below indicates the scoping documents for those projects that have been provided as attachments.

Project Name	Scoping Document(s)
IO – 2016 Field Area Network	GRC-2020-PhI_DR_PubAdv_163-Q03Atch02CONF GRC-2020-PhI_DR_PubAdv_163-Q03Atch03CONF GRC-2020-PhI_DR_PubAdv_163-Q03Atch04CONF GRC-2020-PhI_DR_PubAdv_163-Q03Atch05CONF This project was broken up into multiple workstreams. The four attachments represent different workstreams within the project.
IO – 2018 Field Area Network	GRC-2020-PhI_DR_PubAdv_163-Q03Atch06CONF Note that this project was originally approved under the name “2017 Field Area Network”, seen in this attachment. The project name was subsequently updated to “IO – 2018 Field Area Network”.

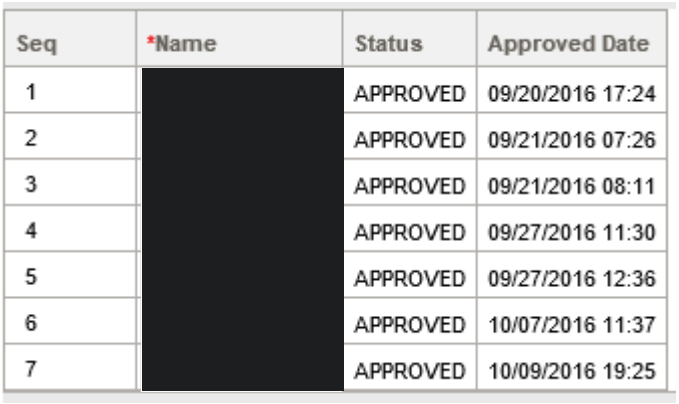
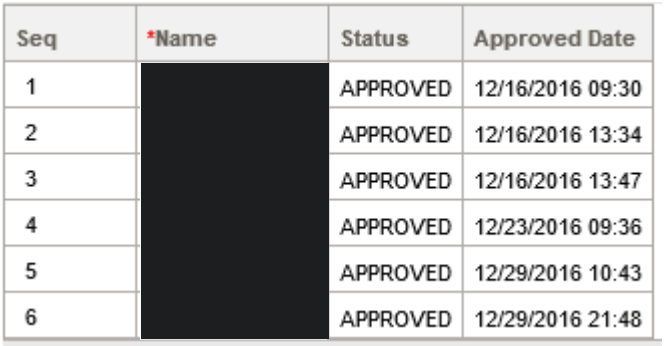
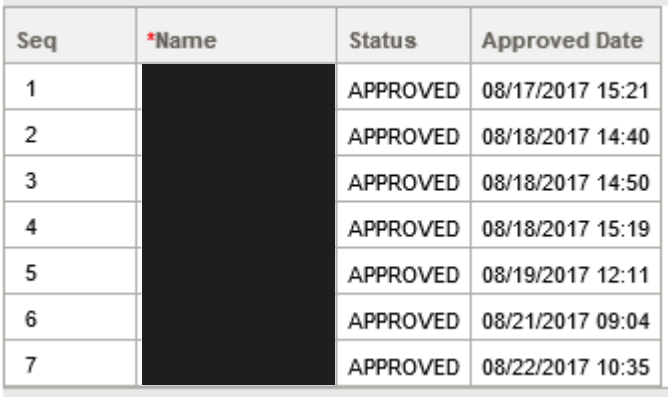
The following are system snapshots of key authorizations associated with the indicated projects.

Project	Authorization Snapshot
IO – 2016 Field Area Network	**Project Change Request - #168901** **Description:** Job Estimate PCR (1 of 5) - 2016 Field Area Network - SCADA #1 Clayton/Concord Use Case [redacted] **Project Change Request - #168902** **Description:** Job Estimate PCR (2 of 5) - 2016 Field Area Network - SCADA #2 Morag/Sobrante Use Case [redacted] **Project Change Request - #168903** **Description:** Job Estimate PCR (3 of 5) - 2016 Field Area Network - Hydro #1 Manton Use Case [redacted]

Seq	*Name	Status	Approved Date
1	[redacted]	APPROVED	09/20/2016 16:49
2		APPROVED	09/21/2016 07:24
3		APPROVED	09/21/2016 08:12
4		APPROVED	09/27/2016 11:20
5		APPROVED	09/27/2016 12:34
6		APPROVED	09/30/2016 23:16
7		APPROVED	11/07/2016 14:36

Seq	*Name	Status	Approved Date
1	[redacted]	APPROVED	09/20/2016 16:49
2		APPROVED	09/21/2016 07:23
3		APPROVED	09/21/2016 08:11
4		APPROVED	09/27/2016 11:23
5		APPROVED	09/27/2016 12:33
6		APPROVED	09/30/2016 23:16
7		APPROVED	10/06/2016 18:08

Seq	*Name	Status	Approved Date
1	[redacted]	APPROVED	09/20/2016 17:08
2		APPROVED	09/21/2016 07:26
3		APPROVED	09/21/2016 08:10
4		APPROVED	09/27/2016 11:29
5		APPROVED	09/27/2016 12:36
6		APPROVED	09/30/2016 23:15
7		APPROVED	10/06/2016 18:06

	Project Change Request - #168904 **Description:** Job Estimate PCR (4 of 5) - 2016 Field Area Network - Hydro #2 Cottonwood Use Case  **Project Change Request - #173124** **Description:** JE - IO - 2016 Field Area Network 
IO – 2018 Field Area Network	**Project Change Request - #183586** **Description:** Job Estimate PCR - 2017 Field Area Network  **Project Change Request - #191562** **Description:** Revised Job Estimate PCR - 2018 Field Area Network

Seq	*Name	Status	Approved Date
1	[redacted]	APPROVED	09/20/2016 17:24
2		APPROVED	09/21/2016 07:26
3		APPROVED	09/21/2016 08:11
4		APPROVED	09/27/2016 11:30
5		APPROVED	09/27/2016 12:36
6		APPROVED	10/07/2016 11:37
7		APPROVED	10/09/2016 19:25

Seq	*Name	Status	Approved Date
1	[redacted]	APPROVED	12/16/2016 09:30
2		APPROVED	12/16/2016 13:34
3		APPROVED	12/16/2016 13:47
4		APPROVED	12/23/2016 09:36
5		APPROVED	12/29/2016 10:43
6		APPROVED	12/29/2016 21:48

Seq	*Name	Status	Approved Date
1	[redacted]	APPROVED	08/17/2017 15:21
2		APPROVED	08/18/2017 14:40
3		APPROVED	08/18/2017 14:50
4		APPROVED	08/18/2017 15:19
5		APPROVED	08/19/2017 12:11
6		APPROVED	08/21/2017 09:04
7		APPROVED	08/22/2017 10:35

Seq	*Name	Status	Approved Date
1	[redacted]	APPROVED	02/22/2018 09:17
2		APPROVED	03/23/2018 08:30
3		APPROVED	03/23/2018 08:57
4		APPROVED	03/27/2018 21:57
5		APPROVED	04/04/2018 07:07

Pacific Gas and Electric Company™

Information Technologies

Communication Requirement

ISSUING DEPARTMENT:	**IT TNS**	ISSUED DATE:	**4/5/2016**
CREATED BY:	[redacted]	ORDER NO:	**70030521**
		REVISION #:	**1.0**

Project: Wireless Broadband Pilot Deployment (FAN) Field Area Network

Document File Name: Field Area Network Pilot Deployment –Telecom Requirements (Rev1-0).doc

Site: [redacted] – SCADA #1, [redacted] – SCADA #2

Overview

PG&E will be modernizing the network technologies used in their T&D communications infrastructure. This modernization is in support of upcoming Smart Grid Pilot projects and the sun setting of carrier provided technologies. As an initial step, PG&E has identified the need for a Field Area Network(FAN) to be created and released to assess the technical capabilities to meet their Smart Grid pilot and connectivity needs.

Transmission Automation strategies aims to enhance O&M efficiency, safety and compliance. Having a fully automated and integrated electric transmission and distribution grid will support value-added response capabilities and applications.

In order to improve the quality and efficiency of our electric distribution system it is recommened to provide increased visibility at these Substations. The Scope of Work will include adding full SCADA monitoring and control to all breakers and switches. The level of automation will be determined by the project team and approved by the System Automation Department.

[redacted] has been indentified as a potential “takeout site”. Takeout sites will be the aggregation sites where the Tropos Mesh Gateways (router) will aggregrate and connect to the MPLS infrastructure. At each take-out site there is a need for a Multi-VRF router to support the FAN network. As part of this project, IT will retire the existing [redacted] ODN router, reconfigure and rename the existing [redacted] UDN router to be the new Multi-VRF router and install a new [redacted] switch and provide four Ethernet ports to connect the Tropos Router. IT will also retire the ODN and UDN circuit and install a new Multi-VRF circuit from [redacted] where there are two MPLS CE routers.

The contractor (ABB) will install and test two Tropos Mesh Gateways.

[redacted] has been indentified as a potential “takeout site”. Takeout site will be the aggregation site where the Tropos Mesh Gateways (router) will aggregrate and connect to the MPLS infrastructure. As part of this project IT procure and install a [redacted] switch and provide four Ethernet ports on the [redacted] switch. The contractor ([redacted]) will install and test two Tropos Mesh Gateways.

Assumptions

[redacted] MPAC Building:

1. No changes/additions to the existing transmission infrastructure.
2. Sufficient DC Plant. Telecom Eng to field verify.

[redacted]:

1. No changes/additions to the existing MW infrastructure.
2. Two existing MPLS CE routers are available with sufficient ports.
3. Sufficient DC Plant. 62Amps

Scope of Work

[redacted]

IT Telecom Responsibilities:

MPAC Building:

1. Procure and install a [redacted] for the FAN network.
   a. The [redacted] will be installed between the Cisco Multi-VRF router and Tropos Mesh Gateways.
   b. Will need to reserve 4 Ethernet ports for the Tropos Mesh Gateways. Two 10/100 Ethernet ports per Tropos Mesh Gateway and one Gig port to connect to the upstream router.
2. Work with the Network Specialist to reconfigure and rename the UDN [redacted] router into the new Multi-VRF router.
3. Work with the Network Specialist to retire the ODN router [redacted] once the [redacted] has been reconfigured into as the new Multi-VRF router. Telecom Engineer to confirm with product specialist if router will be reused before sending the router for DA.
4. Migrate connections from ODN router to the Multi-VRF router.
5. Identify power source for Tropos routers. Telecom Engineer to work with [redacted] for details.
6. Retire the two T1 circuits; ODN 211681, UDN 209349.
7. Build a new Multi-VRF 9Mbs FAN circuit 212803

Substation Responsibilities:

1. Provide trench, conduit and entrance into the MPAC building from Steel Lattice Tower. Refer to:
   a. J-0001 [redacted] Trench
   b. J-0002 [redacted] Trench MPAC
   c. V-0002 [redacted] Trench

Concord SC

IT Telecom Responsibilities:

Microwave Tower:

8. The Tropos router will be installed on the [redacted] Tower (by [redacted]), as with PG&E standard IB 2026 Structural Analysis Requirements for Microwave Towers/Monopoles shall be used as a guide due to this being a Pilot Project.

    a. Structural Analyst by approved Civil Engineering group.

Com Room

1. Identify router ports off the two existing MPLS CE routers. Telecom Engineer will need to purchase SFP if needed.
2. Procure and install a [redacted] for the FAN network. Telecom Engineer to work with product specialist.
    a. The [redacted] will be installed between the MPLS CE router and Tropos Mesh Gateways.
    b. Reserve 4 Ethernet port for the Tropos Mesh Gateways. Two Ethernet ports per Tropos Mesh Gateway and one Gig port for the upstream router.

Contractor Responsibilities:

1. NOTE: Placement of the Tropos Mesh Gateways are subject to change at the Clayton Sub site. Once the exact location has been identified, changes to the below requirements will be amended.
2. [redacted] is the contractor for this site. [redacted]'s responsibility:
    a. Installing and testing the two Tropos Mesh Gateways at each site.
    b. More information can be found on the SharePoint:

    [link]
3. **NOTE: At [redacted] -** Installations on PG&E steel lattice are not installed like other types of communication towers. The Tropos are installed inside the PG&E power zone (outside of the communications zone). Refer to PG&E document 068190.
    a. Contact T-Line Engineer for proper installation on Steel Lattice. PM and/ or IT Engineer will assist.
    b. Some general guilde line:
        i. Tropos shall be mounted on PG&E Steel Lattice with brackets.
        ii. Maintain 10' vertical clearance from top of the Tropos to the primary conductor(s).
        iii. Vertical runs and risers cannot be in climbing space.
        iv. Cable Supported every three feet with beam clamp and snap-ins instead of "Waveguide Cushions".
4. [redacted] shall perform the following when installing on PG&E Structure with entry into the MPAC / Communication building.
    a. Outdoor rated ETHERNET Installation.
        i. Perform a sweep with an Anritsu Site Master to verify that the outdoor rated ETHERNET still meets manufacturer's specification (i.e. attenuation, Return Loss, etc.). The minimum bend radius of the outdoor rated ETHERNET is not to be exceeded during installation.

b. Grounding Kits – The outdoor rated ETHERNET must be grounded at three points (minimum) while it is exposed to the outdoors. The grounding kits must be installed at the following points:

   i. At the top of the vertical run

   ii. At the bottom of the vertical run

   iii. Once prior to entry into building/comm. Vault. A ground bar connected to station ground must be present.

   iv. For vertical outdoor rated ETHERNET runs longer than 200', a grounding kit should be installed in the middle of the run.

c. Waveguide Entry Panel and Entry Boots – Waveguide entry panel will have a 4" diameter opening and have a port layout of 2 x 4. All unused ports require a weatherproof sealing cap to keep moisture, debris and pests from entering the communication room. The waveguide entry panel must be grounded to station ground using #2/0 AWG Bare Stranded copper wire. Use weatherproof sealing tape around edges of entry panel to keep moisture from entering the comm room. Entry boots provide support and a weather-tight seal around the transmission line as it enters the communictions room. All entry boots should be ordered to fit in a 4" diameter opening of the entry panel.

Reference

Reference #	Revision #	Title

Reference Drawings

Drawing #	Revision #	Title
4081885	1	Interconnection Diagram Special Protection Scheme [redacted] New Control Building
V-0001		2016 FAN – [redacted] IC diagram
V-0002		2016 FAN – [redacted] Trench
V-0003		2016 FAN – [redacted] rack elevation
V-0004		2016 FAN – [redacted] IC diagram

Pacific Gas and Electric Company	Information Technologies
	Communication Requirement
ISSUING DEPARTMENT: **ITIS TNS**	ISSUED DATE: **4/5/2016**
CREATED BY: [redacted]	ORDER NO: **70030586** REVISION #: **1.0**

Project: Wireless Broadband Pilot Deployment (FAN) Field Area Network

Document File Name: Field Area Network Pilot Deployment –Telecom Requirements (Rev1-0).doc

Site: [redacted] – SCADA #2

Overview

PG&E will be modernizing the network technologies used in their T&D communications infrastructure. This modernization is in support of upcoming Smart Grid Pilot projects and the sun setting of carrier provided technologies. As an initial step, PG&E has identified the need for a Field Area Network(FAN) to be created and released to assess the technical capabilities to meet their Smart Grid pilot and connectivity needs.

Transmission Automation strategies aims to enhance O&M efficiency, safety and compliance. Having a fully automated and integrated electric transmission and distribution grid will support value-added response capabilities and applications.
In order to improve the quality and efficiency of our electric distribution system it is recommened to provide increased visibility at these Substations. The Scope of Work will include adding full SCADA monitoring and control to all breakers and switches. The level of automation will be determined by the project team and approved by the System Automation Department.

[redacted] has been indentified as an potential “takeout site”. Takeout sites will be the aggregation sites where the Tropos Radios will aggregrate and connect to the MPLS infrastructure. As part of this project, IT will install a new Multi-VRF router and Cisco Switch and provide four Ethernet ports to connect the Tropos Router. The contractor ([redacted] will install and test two Tropos Mesh Gateways.

Assumptions

[redacted]:

1. No changes/additions to the existing infrastructure.
2. Sufficient DC Plant. 22.3amps being used out of 100amps.

Scope of Work

[redacted]

IT Telecom Responsibilities:

Com Room:

1. Procure and install Telect Breaker Panel
2. Procure and install Multi-VRF router, [redacted].
3. Procure and install a [redacted] DC power switch for the FAN network.
    a. The Cisco Switch will be installed between the Multi-VRF router and Tropos Mesh Gateways.
    b. Will need to supply 4 Ethernet port for the Tropos. Two Ethernet ports per Tropos Mesh Gateway.
4. Retire UDN and ODN router.
5. Migrate all connections from UDN router and ODN router to New Multi-VRF router.
6. Procure and purchase two [redacted] electrical SFP for the [redacted] card at Moraga Sub and FFIOC. Telecom Engineer to work with Product Specialist; Kevin Fennelley for part number.
7. Identify power source for Tropos Router. Telecom Engineer to work with ABB for router specs.

Contractor Responsibilities:

1. [redacted] is the contractor for this site.
    a. Installing and testing the two Tropos Mesh Gateways.
    b. More information can be found on the SharePoint:

    [link]
2. [redacted] shall perform the following when installing on PG&E infrastructure.
    a. Grounding Kits – Outdoor rated RJ45 must be grounded at three points (minimum) while it is exposed to the outdoors. The grounding kits must be installed at the following points:
        i. At the top of the vertical run
        ii. At the bottom of the vertical run
        iii. Once prior to entry into building/comm. Vault. A ground bar connected to station ground must be present.
        iv. For vertical transmissionline runs longer tahtn 200', a grounding kit should be installed in the middle of the run.
    b. Outdoor rated RJ45 Installation.
        i. Perform a line sweep with an Anritsu Site Master to verify that the outdoor RJ45 still meets manufacturer's specification (i.e. attenuation, Return Loss, etc.). The minimum bend radius of the transmission line is not to be exceeded during installation.
    c. Waveguide Entry Panel and Entry Boots – Waveguide entry panel will have a 4" diameter opening and have a port layout of 2 x 4. All unused ports require a weatherproof sealing cap to keep moisture, debris and pests from entering the communication room. The waveguide entry panel must be grounded to station ground using #2/0 AWG Bare Stranded copper wire. Use weatherproof sealing tape around edges of entry panel to keep moisture from entering the comm room. Entry boots provide support and a weather-tight seal around the transmission line as it enters the communictions room. All entry boots should be ordered to fit in a 4" diameter opening of the entry panel.

Reference

Reference #	Revision #	Title

Reference Drawings

Drawing #	Revision #	Title
4042658	3	Arrangement & Diagram of Connections Partial Plans & Rack Face Elevations Main Control Building
V-0001		2016 FAN – [redacted]

Pacific Gas and Electric Company™

Information Technologies

Communication Requirement

ISSUING DEPARTMENT:	**IT TNS**	ISSUED DATE:	**4/18/2016**
CREATED BY:	[redacted]	ORDER NO:	**70030587**
		REVISION #:	**1.0**

Project: Wireless Broadband Pilot Deployment (FAN) Field Area Network

Document File Name: Field Area Network Pilot Deployment –Telecom Requirements (Rev1-0).doc

Site: [redacted] - Hydro #1

Overview

PG&E will be modernizing the network technologies used in their T&D communications infrastructure. This modernization is in support of upcoming Smart Grid Pilot projects and the sun setting of carrier provided technologies. As an initial step, PG&E has identified the need for a Field Area Network(FAN) to be created and released to assess the technical capabilities to meet their Smart Grid pilot and connectivity needs.

Transmission Automation strategies aims to enhance O&M efficiency, safety and compliance. Having a fully automated and integrated electric transmission and distribution grid will support value-added response capabilities and applications.
In order to improve the quality and efficiency of our electric distribution system it is recommened to provide increased visibility at these Substations. The Scope of Work will include adding full SCADA monitoring and control to all breakers and switches. The level of automation will be determined by the project team and approved by the System Automation Department.

[redacted] has been identified as a potential "takeout site". Takeout sites will be the aggregation site where the Tropos Radios will aggregrate and connect to the MPLS infrastructure. As part of this project, IT will reconfigure the existing UDN Cisco 2921 as the new Multi-VRF router, install a Cisco WS-3850-24P PoE+ switch and provide four Ethernet ports to connect the Tropos Mesh Gateways and test the Multi-VRF circuit from [redacted] IT shall reuse the [redacted] and [redacted] to support the Multi-VRF FAN circuit. The contractor ([redacted]) will install and test two Tropos Mesh Gateways off the existing MW pole.

Assumptions

[redacted]

1. No changes/additions to the existing transmission infrastructure.
2. Microwave 8T capacity where 7T are being used for UDN.
3. DC Plant – 8.4AMPS out of 50Amps available

Scope of Work

[redacted]

IT Telecom Responsibilities:

Com Room

1. Reconfigure the existing UDN [redacted] router; [redacted] as the new Multi-VRF router.
    a. May need to purchase additional EWIC cards.
2. Procure and install a Cisco WS-3850-24P PoE+ switch for the FAN network.
    a. The [redacted] switch will be installed between the Multi-VRF router and Tropos Mesh Network.
    b. Will need to supply 4 Ethernet port for the Tropos. Two Ethernet ports per Tropos Mesh Gateway.
3. Identify power source for Tropos routers. Telecom Engineer to work with [redacted] for details.
4. Reuse the existing [redacted] and [redacted].
5. Rename the existing UDN circuit 211738 as the new Multi-VRF FAN circuit.

Contractor Responsibilities:

1. [redacted] is the contractor for this site. They're responsible for:
    a. Installing and testing two Tropos Mesh Gateways. More information can be found about the Tropos on the SharePoint:

[link]

2. [redacted] shall perform the following when installing on PG&E towers with entry into the communications room.
    a. Outdoor rated RJ45 Installation.
        i. Perform a line sweep with an Anritsu Site Master to verify that the outdoor rated RJ45 still meets manufacturer's specification (i.e. attenuation, Return Loss, etc.). The minimum bend radius of the outdoor rated RJ45 is not to be exceeded during installation.
    b. Grounding Kits – The outdoor rated RJ45 must be grounded at three points (minimum) while it is exposed to the outdoors. The grounding kits must be installed at the following points:
        i. At the top of the vertical run
        ii. At the bottom of the vertical run
        iii. Once prior to entry into building/comm. Vault. A ground bar connected to station ground must be present.
        iv. For vertical transmissionline runs longer tahtn 200', a grounding kit should be installed in the middle of the run.
    c. Waveguide Entry Panel and Entry Boots – Waveguide entry panel will have a 4" diameter opening and have a port layout of 2 x 4. All unused ports require a weatherproof sealing cap to keep moisture, debris and pests from entering the communication room. The waveguide entry panel must be grounded to station ground using #2/0 AWG Bare Stranded copper wire. Use weatherproof sealing tape around edges of entry panel to keep moisture from entering the comm room. Entry boots provide support and a weather-tight seal around the transmission line as it enters the communictions room. All entry boots should be ordered to fit in a 4" diameter opening of the entry panel.

Reference

Reference #	Revision #	Title
IB 2026	0	Structural Analysis Requirements for Microwave Towers/Monopoles
IT2010	0	Waveguide Pressurization and Microwave System Integrity

Reference Drawings

Drawing #	Revision #	Title
464683	14	Arangement for Communication Equipment [redacted] Operating HQ
498694	6	IC Diagram LAN & Radio Control [redacted] Operating HQ
V-0001		2016 FAN – [redacted] - IC Diagram
V-0002		2016 FAN – [redacted] rack elevation

Pacific Gas and Electric Company™

Information Technologies

Communication Requirement

ISSUING DEPARTMENT:	**IT TNS**	ISSUED DATE:	**4/18/2016**
CREATED BY:	[redacted]	ORDER NO:	**70030588**
		REVISION #:	**1.0**

Project: Wireless Broadband Pilot Deployment (FAN) Field Area Network

Document File Name: Field Area Network Pilot Deployment –Telecom Requirements (Rev1-0).doc

Site: [redacted] –Hydro #2

Overview

PG&E will be modernizing the network technologies used in their T&D communications infrastructure. This modernization is in support of upcoming Smart Grid Pilot projects and the sun setting of carrier provided technologies. As an initial step, PG&E has identified the need for a Field Area Network(FAN) to be created and released to assess the technical capabilities to meet their Smart Grid pilot and connectivity needs.

Transmission Automation strategies aims to enhance O&M efficiency, safety and compliance. Having a fully automated and integrated electric transmission and distribution grid will support value-added response capabilities and applications.
In order to improve the quality and efficiency of our electric distribution system it is recommened to provide increased visibility at these Substations. The Scope of Work will include adding full SCADA monitoring and control to all breakers and switches. The level of automation will be determined by the project team and approved by the System Automation Department.

[redacted] has been identified as a potential "takeout site". IT will procure the two new Cisco ISR4451router as the new Multi-VRF routers, install two [redacted] switches, install one [redacted] switch for the Tropos Mesh Gateways, provide four Ethernet ports and install one [redacted] DC switch as the aggregation switch for the existing UDN switches. IT will retire the existing UDN router and two ODN routers. IT will rename the existing UDN circuit as the new Muilt-VRF FAN circuit to [redacted] over the existing MW link D246 to [redacted] Com Room. IT will use the existing [redacted] and [redacted] to support the new circuit. IT will migrate all necessary PG&E circuits to the new routers and switches. The contractor ([redacted]) will install and test two Tropos Mesh Gateways off the existing MW tower.

Assumptions

1. No changes/additions to the existing transmission infrastructure.
2. Sufficient DC plant. 49Amps being used out of 150Amps.

Scope of Work

IT Telecom Responsibilities:

Com Room

1. Procure and install the two new routers to be the new Multi-VRF routers. **NOTE: The two will be replacing the UDN router, and the two ODN routers; and .**
2. Procure and install a switch for the FAN network.
   a. The switch will be installed between the Multi-VRF router and Tropos Mesh Gateways.
   b. Will need to supply 4 Ethernet port for the Tropos. Two Ethernet ports per Tropos Mesh Gateway.
3. Procure and install a switch as the aggregation switch for the UDN switches.
4. Procure and install two switches to replace the and Ethernet router inserts.
5. Identify power source for the Tropos Router. Telecom Engineer to work with for details.
6. Reconfigure the existing UDN circuit 211738 as the new Multi-VRF FAN circuit from Cottonwood Sub to over the existing Microwave link D246.
7. Retire the existing router; , two ODN routers and .

Contractor Responsibilities:

1. is the contractor for this site. They're responsible for:
   a. Installing and testing two Tropos Mesh Gateways at each site.
   b. More information can be found on the SharePoint:

   [link]
2. shall perform the following when installing on PG&E towers with entry into the communications room.
   a. Outdoor rated RJ45 Installation.
      i. Perform a line sweep with an Anritsu Site Master to verify that the outdoor rated RJ45 still meets manufacturer's specification (i.e. attenuation, Return Loss, etc.). The minimum bend radius of the outdoor rated RJ45 is not to be exceeded during installation.
   b. Grounding Kits – The outdoor rated RJ45 must be grounded at three points (minimum) while it is exposed to the outdoors. The grounding kits must be installed at the following points:

i. At the top of the vertical run

ii. At the bottom of the vertical run

iii. Once prior to entry into building/comm. Vault. A ground bar connected to station ground must be present.

iv. For vertical transmissionline runs longer tahtn 200', a grounding kit should be installed in the middle of the run.

c. Waveguide Entry Panel and Entry Boots – Waveguide entry panel will have a 4" diameter opening and have a port layout of 2 x 4. All unused ports require a weatherproof sealing cap to keep moisture, debris and pests from entering the communication room. The waveguide entry panel must be grounded to station ground using #2/0 AWG Bare Stranded copper wire. Use weatherproof sealing tape around edges of entry panel to keep moisture from entering the comm room. Entry boots provide support and a weather-tight seal around the transmission line as it enters the communictions room. All entry boots should be ordered to fit in a 4" diameter opening of the entry panel.

Reference

Reference #	Revision #	Title
IB 2026	0	Structural Analysis Requirements for Microwave Towers/Monopoles
IT2010	0	Waveguide Pressurization and Microwave System Integrity

Reference Drawings

Drawing #	Revision #	Title
498694	6	IC Diagram LAN & Radio Control [redacted] Operating HQ
4017165	5	Arrangement Microwave Tower [redacted]
4014571	12	Arrangement Indoors [redacted] Communication Building
V-0001		2016 FAN – [redacted] – IC Diagram
4019242	39	System Diagram WAN (Wide Area Network) [redacted] Vicinity
4003629	10	IC Diagram LAN/WAN [redacted] Com Room

Pacific Gas and Electric Company	IT TNS (Telecom and Network Services) IT Requirements

ISSUING DEPARTMENT:	**IT JET**	ISSUED DATE:	**08/10/2017**
CREATED BY:	[redacted]	ORDER NO:	
REVIEWED BY:	**JET**	REVISION #:	**1**

Project: 2017 Field Area Network

Project Overview:

FAN project will has identified Take-Off sites as part of the RoadMap. All sites on project has been indentified as a"takeout site". Takeout site will be the aggregation site where the Tropos Mesh Network will aggregrate and connect to the MPLS infrastructure.

Site Specific

Existing MPLS Routers: All 17 sites have been identified as Tier 1 sites and should already be configured for Multi-VRF.

- **Network Specialist to configure new FAN VRF on existing CE routers.**
- **Network Specialist to configure new [redacted] Fan Switch.**

FAN Switch

- **T300 install a new [redacted] DC switch**
- **T300 Provide network connectivity from new FAN switch to existing MPLS CE router.**
- **T300 install and power to existing DC Plant.**

Tropos Routers

- **T300 install (2) Tropos Routers on existing Towers.**
- **T300 install (4)** outdoor rated Cat 6 RJ45 cables from Tropos router to Lightning Supressor.
- **T300 install (4) Outdoor rated Cat 6 cables from Lightning suppressor to new [redacted] Fan Switch.**

Structural:

- **Each site could require possible Strcutural Analysis and RF Engineering. Defer to Mark Goto with discussion of each tower and possible modifications.**

Assumptions:

1. **No changes/additions to existing Transmission infrastructure.**
2. **Sufficient DC Plant. Assigned Tcom Engineer to verify**

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q04		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q04		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 04

Please provide all cost estimates and other evidence supporting PG&E's forecast for the Network Technologies – FAN program, including the "specific output from the PET for this project" and the three assumptions listed on page WP 8-84 of Ex. PG&E-7 workpapers.

ANSWER 04

PG&E objects to this request as vague, ambiguous, overbroad and unduly burdensome to the extent it asks for "all" cost estimate and other evidence supporting its forecast. Subject to and notwithstanding these objections, and without waiving its right to object to the admission of its response into evidence, PG&E responds as follows:

PG&E provided the referenced PET output, which encompasses the Network Technologies – FAN program as well as the FAN component of IGP, in GRC-2020-PhI_DR_PubAdv_146-Q01Atch03 and GRC-2020-PhI_DR_PubAdv_146-Q01Atch04. Aside from the PET output provided in that response, PG&E has created no other cost estimates supporting the forecast for the Network Technologies – FAN program.

The three assumptions listed on WP 8-84 and listed below were used by PG&E subject matter experts to develop the PET output and assess its reasonableness.

1. "Cost evaluation from the completed pilot and the first set of deployments" – PG&E reviewed recorded costs from prior FAN deployments when developing the forecast. These recorded costs are shown on WP 8-85.
2. "Vendor quotes that contain engineering, field installation services and cost of material." – To clarify: PG&E did not obtain vendor quotes for work within the forecast period. Instead, vendor quotes received for 2016 and 2017 FAN deployments informed assumptions for future year deployments. If Public Advocates wishes to review the vendor quotes for past deployments, PG&E can contact the vendors and request permission to share them.
3. "The number of FAN gateway locations (takeout points), mesh nodes to be deployed per gateway location, and migration of field devices within the proximity

of the mesh over to FAN" – For the overall program, PG&E assumed FAN deployments at 25-50 locations per year (inclusive of both IGP and non-IGP use cases), with 50 to 150 mesh nodes per location, depending on the number of field devices within the range.

Other evidence that PG&E determined necessary to support the forecast for the program has been included in testimony and workpapers supporting Exhibit (PG&E-7), Chapter 8.

To the extent Public Advocates believes this evidence is inadequate, PG&E would be happy to provide responses to specific requests for information.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q05		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q05		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols, Mark Esguerra	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 05

The "Network Technologies - FAN" program is not included in PG&E's Grid Modernization Classification Table (Ex. 4 workpaper page WP 19-49.) Is this because all FAN investments attributable to Grid Modernization as defined in D.18-03-023 are included separately within the IGP Enablement (IT Infrastructure) program? If not, please explain.

ANSWER 05

Yes, all FAN investments attributable to Grid Modernization as defined in D.18-03-023 are included separately within the IGP Enablement (IT Infrastructure) program.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q06		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q06		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 06

Page WP 8-84 of Ex. PG&E-7 workpapers states that "Costs to deliver the FAN have been split into two pieces [IGP and non-IGP], though the work will be executed as a single strategy." Regarding the FAN request:

a. Please explain how PG&E allocated FAN costs between IGP and non-IGP,

b. Please provide a breakout of the annual FAN forecast by planning order, and identify which are IGP vs. non-IGP,

c. If planning orders cannot be used to identify IGP vs. non-IGP FAN work, please explain how PG&E will be able to differentiate IGP related recorded costs for FAN in the future?

d. Please provide a description of the work included in each planning order provided in response to subpart b above, if not provided in PG&E's workpapers. (If a description is already provided in PG&E's workpapers, please indicate the associated workpaper pages.)

e. For each of the planning orders provided in response to subpart b above, provide a report, data export or screen print of all fields associated with the order in SAP or any other PG&E accounting or program management system(s).

ANSWER 06

a. PG&E's overall implementation strategy for FAN involves deploying FAN coverage at specific locations based on the use cases and demand for FAN at those locations. PG&E's 2019-2022 forecast assumed that the annual pace of deployments for non-IGP FAN locations/use cases would roughly follow that of 2016 and 2017 deployments and gradually escalate over time. This would involve deployments at approximately 5 to 10 locations per year, to be determined during execution based on Company priorities and network demands at applicable locations. To support IGP use cases for FAN, PG&E assumed a pace ranging from 20 to 40 locations per year, aligned with the overall IGP implementation strategy.

FAN costs over the 2019-2022 period were split between IGP and non-IGP use cases based on these assumptions.

b. GRC-2020_PhI_DR_PubAdv_163-Q06Atch01 provides the requested breakout and work paper references.

c. Planning orders can be used to identify IGP vs. non-IGP FAN work.

d. See PG&E's response to subpart b.

e. GRC-2020_PhI_DR_PubAdv_163-Q06Atch02 is a report of all fields associated with each order in SAP.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q07		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q07		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 07

Page WP 8-68 of Ex. PG&E-7 workpapers indicates that IGP related FAN funding will not begin until 2019, but Page WP 8-85 of Ex. PG&E-7 workpapers shows FAN recorded expenditures starting in 2014. Please explain why none of the recorded FAN costs, and 2018 forecast costs, are attributed to IGP.

ANSWER 07

FAN costs prior to 2018 are not attributed to IGP because IGP did not exist as a discrete program prior to 2018. 2018 FAN costs attributed to IGP are included in the forecast identified on WP 8-68 as “2018 Program Costs”. They are not broken out because PG&E did not initially forecast 2018 IT infrastructure program costs for IGP as separate initiatives.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q08		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q08		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 08

PG&E forecast funding for FAN in the TY 2017 GRC (Ex. PG&E-7, pp. 9-41 to 9-42 and workpapers pp. WP 9-184 to WP 9-189.) Have the objectives or scope of work for FAN changed since the TY 2017 GRC application? If so, please explain and provide supporting evidence in terms of PG&E work authorization documents.

ANSWER 08

The overall objectives and scope of the FAN program have not changed materially since the TY 2017 GRC application, though PG&E's original implementation strategy and pacing have evolved to incorporate the specific requirements and timelines of IGP. PG&E still plans to implement the FAN program as a series of smaller projects, each scoped based on a specific geographic location and/or set of use cases to be enabled. These projects and their scopes were intended to be defined periodically throughout execution of the program to align with specific business needs and Company priorities at the time of implementation. At the time of the 2017 GRC filing, these smaller projects and their scopes had not yet been defined.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_163-Q09		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_163-Q09		
Request Date:	April 12, 2019	Requester DR No.:	163
Date Sent:	April 26, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 09

PG&E's forecast funding for FAN in the TY 2017 GRC listed six planning orders (Ex. PG&E-7 workpapers, p. WP 9-184), none of which appear in the TY 2020 application, correct? If not, please explain. If so:

a. Please provide a description of the work included in each of the six TY 2017 planning orders, if not provided in PG&E's workpapers. (If a description is already provided in PG&E's workpapers, please indicate the associated workpaper pages.)

b. For each of the six TY 2017 planning orders please provide a report, data export or screen print of all fields associated with the order in SAP or any other PG&E accounting or program management system(s).

c. Please provide a map between the TY 2017 FAN planning order numbers and the TY 2020 planning order numbers.

ANSWER 09

Yes, it is correct that none of the six planning orders used to forecast the FAN funding in the 2017 GRC appear in the 2020 GRC application.

a. A description of the work included in each of the six TY 2017 planning orders is provided in PG&E's 2017 GRC, Exhibit (PG&E-7), WP 9-184 through WP 9-189.

b. GRC-2020_PhI_DR_PubAdv_163-Q09Atch01 is a report of all fields associated with each order in SAP.

c. The TY 2017 FAN planning order numbers (shown in Table 1 below) are not directly mappable to the TY 2020 planning order numbers (shown in Table 2 below). In their entirety, the planning orders in Table 1 represent the forecast for FAN deployments over the 2017 GRC period at the time of the 2017 GRC filing. In their entirety, the planning orders in Table 2 represent the forecast for FAN deployments over the 2020 GRC period at the time of the 2020 GRC filing. In that sense, the two sets of planning orders are comparable, but not at an individual planning order level.

Table 1:

2017 GRC FAN PLANNING ORDERS	
Planning Order	**Planning Order Description**
5762898	NT_FAN AUTH, SECURITY AND MONITOR(C)
5762899	NT_FAN BACKHAUL DEPLOYMENTS PH1(C)
5762900	NT_FAN BACKHAUL DEPLOYMENTS PH2(C)
5762901	NT_FAN BACKHAUL DEPLOYMENTS PH3(C)
5762902	NT_FAN BACKHAUL DEPLOYMENTS PH4(C)
5762903	NT_FAN BACKHAUL DEPLOYMENTS PH5(C)

Table 2:

2020 GRC FAN PLANNING ORDERS	
Planning Order	**Planning Order Description**
5779973	Field Area Network 2020
5779974	Field Area Network 2021
5779975	Field Area Network 2022
5780061	NT_Field Area Network 2019
5778856	IGP Field Area Network 2019 Ph1 (C)
5779982	IGP Field Area Network 2019 Ph2 (C)
5779983	IGP Field Area Network 2020 Ph1 (C)
5779984	IGP Field Area Network 2020 Ph2 (C)
5779985	IGP Field Area Network 2021 Ph1 (C)
5779986	IGP Field Area Network 2021 Ph2 (C)
5779987	IGP Field Area Network 2022 Ph1 (C)
5779988	IGP Field Area Network 2022 Ph2 (C)
5259798	IGP Field Area Network (E)

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QUESTION 10

PG&E forecast in the TY 2017 GRC that the FAN would be completed in three years, ending by 2020, for a total capital expenditure of $26.9 million. (Ex. PG&E-7 workpapers pp. WP 9-184 and WP 9-188.) PG&E forecast in the TY 2020 GRC that the FAN will be completed by Oct. 2022 for a total capital expenditure of $55.4 million. (Ex. PG&E-7 workpapers pp. WP 8-65 to 8-85: $34.8 million IGP, p. WP 8-68, plus $20.6 million non-IGP, p. WP 8-85.) Please explain the increase in the forecast since the last rate case.

ANSWER 10

There are three primary drivers for forecast differences between the FAN program described in the 2017 GRC and the FAN program described in the 2020 GRC: (1) the time period covered by the forecast, (2) PG&E's change in cost model methodology, and (3) a change in implementation pacing to align with the Grid Modernization Plan and IGP.

1. In the 2017 GRC, PG&E stated that the FAN, as a holistic program, would be on-going over several rate case periods. Actual deployment of the FAN occurs through multiple smaller projects focused on specific locations and/or use cases. These smaller projects are defined periodically based on LOB priorities and areas of high demand. The 2017 GRC forecast only addressed FAN deployments within the 2017 GRC forecast period (i.e. 2016-2019). It did not include forecasts for deployments in 2020, 2021, or 2022, which are included in the 2020 GRC forecast. This is the key driver of the difference between the 2017 GRC forecast and the 2020 GRC forecast.
1. PG&E provided the 2017 GRC forecast in September of 2015. In 2016, PG&E changed its cost model methodology.[1] The change in cost model methodology makes direct comparability between the two forecasts challenging. For purposes of this filing, 2013-2015 recorded costs were converted into the new cost model, but PG&E did not convert forecasts generated during this period.
2. At the same time that PG&E began pilot deployments for the FAN during the 2017 GRC period, PG&E was in the process of developing its Grid Modernization

Plan and IGP strategy. During that time, PG&E altered the pace of implementation for FAN to better align with the timelines of that program.

[1] See Exhibit (PG&E-12), Chapter 3 for further discussion on the cost model methodology.

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QUESTION 11

Is it correct that there were no recorded expenditures for any type of Field Area Network prior to 2014? If not, please explain and provide the annual recorded expenditures per planning order number.

ANSWER 11

Yes, it is correct that there were no recorded expenditures for any type of Field Area Network prior to 2014.

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QUESTION 12

Please list the communication networks to be replaced by the FAN program, and provide a brief description of each.

ANSWER 12

PG&E does not currently plan to fully replace any existing communication networks via the FAN program. Instead, the FAN will provide broadband connectivity and coverage in new geographic locations and augment existing communication networks in others. In some locations, PG&E will transition existing, legacy network technologies to FAN technology. The communication networks that FAN will augment include the following:

- Supervisory Control and Data Acquisition (SCADA) Network: In some locations, FAN will carry traffic from existing electric and gas assets that currently communicate via the SCADA network. The priority will be on augmenting SCADA master stations that have capacity issues because of the number of SCADA remotes they currently support.
- Advanced Metering Infrastructure (AMI) Network: In some locations, FAN will replace third party cellular or satellite connections that currently carry meter traffic back to PG&E from Access Points and Data Collection Units on the AMI network.

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QUESTION 13

Page WP 8-82 of Ex. PG&E-7 work papers states that *"the growth forecast in field communications was established to occur at the rate of 300%. This forecast remains valid."* Regarding this statement:

a. Rates include an element of time, e.g., per year, over the GRC period, etc. Please identify the time period associated with "rate of 300%",

b. Please provide the analysis supporting the original forecast growth rate,

c. Please provide the evidence that the original forecast growth rate has not changed.

ANSWER 13

a. The growth forecast originated from an analysis that PG&E conducted in 2012 that determined "within the next 5 to 10 years, bandwidth demand is projected to increase by an average of 300%"
b. See Attachment GRC-2020-PhI_DR_PubAdv_163-Q13Atch01CONF
c. Over the 2017 GRC period, the device count in SCADA has grown from just over 8,000 devices to just over 20,000 devices presently. Additionally, newer devices are consuming more bandwidth than older devices because they are reporting more information to the operators. Weather stations, video cameras for fire/smoke detection, and facility video surveillance have begun being deployed across the service territory and are contributing significantly to the growth of bandwidth on the network. These technologies were largely non-existent on the network prior to the last GRC. Projections from all LOBs indicate that these technologies will continue to be deployed at similar or higher rate in the upcoming years. LOBs are also projecting the addition of new technologies, such as micro-grids and resiliency zones in high fire threat areas, which will further the network bandwidth demands across the service territory. Based on the validations and projections provided, PG&E has concluded that the original forecast growth rate has not changed substantially and should still be considered a viable measure for the current plan.

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SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 14

Within a given geographic region, will the FAN components installed through the proposed FAN system require replacement if actual data throughput is greater than forecast, or is the system modular such that additional data throughput can be provided by installing supplemental equipment? Please identify any FAN devices that are not modular and expandable.

ANSWER 14

All FAN devices are modular and expandable. Helper nodes can be installed in the mesh to increase coverage range of the mesh. New gateways can be added to existing gateway locations to increase throughput/capacity, thereby increasing the amount of FAN radios that can be deployed within an existing mesh. In addition, PG&E deploys new gateways (and mesh) in new locations across the service territory to increase the amount of territory covered by FAN.

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QUESTION 15

Page WP 8-82 of Ex. PG&E-7 work papers states that the project will be completed by October 2022 and also that "deployment of the FAN technology is expected to continue through several GRC cycles." Please address this apparent contradiction in terms of the total duration of FAN deployment, and the associated cost.

ANSWER 15

In the 2017 GRC, PG&E stated that the FAN, as a holistic program, would be on-going over several rate case periods. Actual deployment of the FAN occurs through multiple smaller projects focused on specific locations and/or use cases.

The "Project Completion Date" in PG&E's workpapers for Exhibit (PG&E-7) refers to the completion of FAN deployments within the 2020 GRC forecast period (2018-2022) only. Additional deployments within the FAN program will continue beyond the 2020 GRC rate case period. In this 2020 GRC, PG&E has only forecast FAN deployments and associated costs through 2022.

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QUESTION 16

What is the useful life for FAN devices that:

a. PG&E uses in its evaluation of FAN costs and benefits?

b. PG&E hopes to achieve in practice?

ANSWER 16

	a.	**b.**
FAN Devices	**Useful Life (used in evaluation)**	**Useful Life (hoping to achieve in practice)**
Communication Network Equipment (FAN Gateways, FAN Helper Nodes, FAN Field Radios)	7-15 years	7-15 years
Application Servers (Backend)	3-7 years	3-7 years

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QUESTION 17

Page WP 8-82 of Ex. PG&E-7 work papers discusses a "FAN pilot." Please identify the EPIC or DRP project that corresponds to the FAN Pilot. If the pilot was not an the EPIC or DRP project, please provide the following:

a. Project name,

b. Project ID number,

c. Any reports resulting from the pilot,

d. Recorded annual costs per planning order number for the FAN pilot.

ANSWER 17

The referenced "FAN Pilot" was not an EPIC or DRP project.

a. PG&E considers two projects part of the FAN pilot deployments: (1) Wireless Broadband Pilot Deployment and (2) IO – 2016 Field Area Network.
b. PG&E did not establish Project ID numbers for these investments.
c. PG&E did not produce any documented reports on the results of the pilot. In this case, "pilot" refers to the deployment of FAN in a limited number of locations for a sub-set of use cases in order to validate capabilities and identify and resolve any major issues with the technology before deploying it more broadly. The pilot was not an R&D effort like pilots in the EPIC program.
d. The costs associated with the FAN pilot deployments represent a portion of the recorded costs associated with Planning Order 5768821 (NT_Field Area Network). See the table below for a breakout of these costs within PO 5768821.

	($000)			
	2014 Actuals	2015 Actuals	2016 Actuals	2017 Actuals
Wireless Broadband Pilot Deployment	258	144	125	
IO – 2016 Field Area Network			2051	977
TOTAL	**258**	**144**	**2176**	**977**

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QUESTION 18

If not provided in response to prior Public Advocates Office data requests, provide the planned characteristics of the completed FAN, including but not limited to the scale of deployment (e.g., percentage of service territory covered, percentage of circuits and substations covered, number of end uses by type that can use the FAN, etc.) and performance characteristics of the completed system (e.g. latency, bandwidth, etc.).

ANSWER 18

PG&E currently expects to deploy between 200 and 350 FAN gateway locations, depending on business needs and demand across PG&E territory. Each gateway location is designed to cover up to 7 to 10 miles radius with the aid of helper nodes that extend the coverage range. PG&E expects to deploy 50 to 150 FAN radios within each mesh surrounding a typical gateway location. The number of FAN radios within each mesh depends on the number of end devices that can be reached within the coverage range of the mesh. The coverage range of the mesh depends on the population density (e.g. dense urban, urban, rural) and corresponding physical structures of the mesh area, as well as the topography (e.g. flat, hilly, mountainous) of the mesh area. The FAN is expected to support connections to over 50,000 devices, including electric, gas, and hydro SCADA devices; grid sensors; weather stations; reclosers; capacitor banks; voltage regulators; switches; gas regulators; SmartMeter Access Points and Data Collection units, security cameras; mobile devices; and more.

In terms of performance characteristics, the design criteria are to accomplish at least 3Mbps of throughput at substations with FAN deployed and at least 1Mbps at each end device location with a FAN radio – while maintaining reasonable latency. To summarize, the minimum performance benchmark is shown below:

- Latency: < 50 ms field device-to-field device
- Latency: < 100 ms field device-to-control center
- Throughput: 1 Mbps bandwidth to a field device
- Throughput: 3 Mbps bandwidth to Substation/Powerhouse

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QUESTION 19

Please provide PG&E's cost benefit analysis for the FAN program.

ANSWER 19

The Testimony, Exhibit (PG&E-7), pages 8-41 through 8-42, and Workpapers, Exhibit (PG&E-7), WP 8-82 through WP 8-86, associated with the Network Technologies – FAN program and Testimony, Exhibit (PG&E-4), pages 19-21 through 19-23, and Workpapers, Exhibit (PG&E-7), WP 8-65 through WP 8-70, associated with the Integrated Grid Platform Enablement (IT Infrastructure) program are themselves PG&E's cost-benefit analysis showing for this program.

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QUESTION 20

Please provide the analysis supporting PG&E's comparison of alternatives for FAN discussed on page WP 8-85 of Ex. PG&E-7 workpapers.

ANSWER 20

PG&E did not complete a formally documented analysis for the alternatives discussed on WP 8-85. PG&E met with AT&T and Nokia in 2017 to discuss the option of deploying a private LTE network using licensed frequency spectrum from AT&T with Nokia as the equipment vendor. Based on this discussion, PG&E determined that the long-term cost implication for a private LTE network would be much higher than that of a private Field Area Network. This is primarily because, in addition to the costs of deploying the network infrastructure, a private LTE network would require recurring operating expenses to retain access to licensed frequency spectrum, which are not required with the FAN. The licensed frequency spectrum would have been leased for a period of time (10 years with 5-year renewable option) from the third-party cellular carrier (AT&T). Leasing spectrum for a limited period of time doesn't provide sustainable network assurance and continued reliability/availability for a critical network infrastructure. With FAN, there is no leased spectrum, as the spectrum used is the unlicensed frequency used in the Wi-Fi technology standard. As a result, PG&E elected to continue with the FAN strategy as originally planned.

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QUESTION 21

Based on PG&E's current plans and best estimates, please provide the number of FAN gateway locations ("takeout points"), and mesh nodes ("to be deployed per gateway location") that will be served upon completion of the FAN program via 1) an existing private network; 2) a new private network to be built as part of FAN; and 3) public carrier solutions.

ANSWER 21

FAN gateways and mesh nodes are components of the FAN, which is a new extension of PG&E's private data network.

- Estimated # of Gateway Locations (Take Out Points): 200 to 350
- Estimated # of mesh nodes per gateway location: 50 to 150

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QUESTION 22

Is it correct that PG&E installed a wireless mesh network as part of its Advanced Metering Infrastructure (AMI) deployment? If not, please describe how the Silver Spring AMI network differs from a wireless mesh network.

ANSWER 22

A wireless mesh network is a typical communications network made up of radio devices organized in a 'mesh' topology. The 'mesh' is an interconnection among the radio nodes and this provides redundancy by increasing communication pathways; meaning that any node can connect to any node as long as they operate in the same frequency band and share the same mesh ID (a unique identifier for a particular mesh).

By that definition, the component of the current electric AMI network provided by Silver Spring (now Itron) that connects SmartMeters to Access Points (APs) is a wireless network mesh. However, it differs from the FAN network mesh in the following ways:

- It operates in 900MHz unlicensed band, while FAN mesh operates in 2.4GHz and 5.8GHz bands.
- It operates at a much lower radiated power and lower RF range compared to the FAN mesh.
- It has a much lower overall system throughput and capacity compared to the FAN mesh. This is because the electric AMI 900MHz band has fewer channels and smaller bandwidth compared to the 2.4GHz and 5.8GHz bands that are used for the FAN mesh.

The component of the AMI network that connects APs to the backend AMI servers is not part of the SmartMeter mesh network (which connects SmartMeters and APs). The APs typically connect to the AMI backend via standard third-party cellular or satellite connections. In the long term, the FAN mesh will provide an alternate way for APs to connect to the AMI backend. It will not connect SmartMeters and APs.

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QUESTION 23

Regarding PG&E's Silver Spring AMI network:

a. How many smart meters are included in PG&E's distribution system?

b. How many PG&E smart meters currently communicate data via this network?

c. How many PG&E smart meters currently communicate data via a network other than the Silver Spring mesh network?

d. How many smart meters will communicate via the FAN based on PG&E's current plans upon completion of the FAN program?

ANSWER 23

a. Approximately 5.4 million electric SmartMeters and 4.5 million gas SmartMeters

b. Approximately 5.4 million electric SmartMeters

c. Approximately 4.5 million gas SmartMeters communicate outside of the Silver Spring (now Itron) mesh network

d. PG&E does not plan to connect SmartMeters directly to the FAN. Electric SmartMeters will continue to connect to Access Points (APs) via the Silver Spring (now Itron) mesh network and Gas Aclara SmartMeters will continue to connect with Data Collection Units (DCUs) via the gas AMI network. The FAN will provide an alternate way for APs and DCUs to connect with AMI backend servers in the data centers (as opposed to via third-party cellular and satellite connections). PG&E refers to these connections as "backhaul" connections. Based on current plans, PG&E expects to be able to migrate backhaul connections for approximately 50% of APs and DCUs to the FAN. Note that not all of these migrations will be completed within the 2020 GRC period.

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QUESTION 24

Page WP 8-66 of Ex. PG&E-7 workpapers states that "FAN Mesh radios will also be installed in field devices (switches, reclosers, capacitor banks, DERs, etc.) to allow the information from these devices to be conveyed over the FAN Mesh." Regarding this statement:

a. Will existing SCADA communication devices be replaced by FAN Mesh radios, or is this work to add communications to these field devices for the first time?

b. Will FAN radios be added to existing switches, reclosers, capacitor banks, DERs, etc., or will the existing field devices need to be replaced with units that incorporate FAN Mesh radios?

ANSWER 24

a. At a high-level, PG&E's legacy SCADA network consists of SCADA RTUs (the end points), which connect to SCADA remote radios, which connect to SCADA master stations, which connect to the SCADA back-end servers. Depending on the requirements of a given location (e.g. if existing SCADA network capacity is no longer adequate to support increasing RTU counts or bandwidth consumption at the location), PG&E may replace SCADA remote radios and master stations with FAN mesh radios and FAN gateways. In locations where SCADA RTUS are being installed for the first time and the location meets the requirements for FAN, then FAN will add communications to the field devices for the first time.

b. The FAN radios will be deployed at locations with existing switches, reclosers, capacitor banks, DERs, etc., and these assets will be connected to the FAN mesh network via these FAN radios (either by direct IP or serial connection) as wired clients.

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PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 25

The table on Page WP 8-68 of Ex. PG&E-7 workpapers has a line item for FAN and one for SCADA Reliability. Please explain, beyond the limited explanations on pages WP 8-66 and WP 8-67, how providing FAN communication for field devices isn't the same, or nearly the same, as the listed changes to the SCADA system.

ANSWER 25

The FAN network is a new private network that has more throughput than the SCADA network. However, it has limitations in terms of range and radio frequency (RF) propagation compared to SCADA. PG&E does not plan to replace every single SCADA device with FAN. Where it's not feasible to migrate existing SCADA devices to FAN, the SCADA Reliability program will continue to replace old SCADA radios with new next generation SCADA radios (master stations and remotes) that have improved RF technology and better Internet Protocol (IP) interoperability than legacy SCADA.

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PG&E Data Request No.:	PubAdv_163-Q26		
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Request Date:	April 12, 2019	Requester DR No.:	163
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PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 26

Page WP 8-69 of Ex. PG&E-7 workpapers provides FAN specifications. Provide evidence that the specifications are sufficient (performance not too low) and required (performance not excessively high).

ANSWER 26

There are 3 performance characteristics of the FAN discussed on WP 8-69: (1) throughput (aka bandwidth), (2) number of devices it can support, and (3) latency of the connection between end points.

1. **Throughput:** The FAN is designed to be modular and scalable. As a result, PG&E can scale the FAN mesh at any location to meet the anticipated throughput needs at that location. In this way, the specified throughput performance of FAN is sufficient. Because bandwidth needs are assessed on a location by location basis, PG&E can avoid FAN deployments in locations where there is insufficient throughput demand. Because the range of a FAN mesh is extendable, PG&E can also scale coverage at a given location to fully take advantage of the throughput capacity available. In this way, PG&E can deploy FAN capacity and coverage in an area in such a way as to meet—but not excessively exceed—the throughput required in that area.
2. **Number of devices:** In a similar way, because the FAN is modular and scalable and deployable at many locations across PG&E's service territory, it is sufficient to support any number of field devices and can be sized appropriately to the required number of devices it must support. PG&E's forecast that the FAN will eventually need to support more than 50,000 devices is based on a growing field asset base that already numbers in the tens of thousands. This includes electric, gas, and hydro SCADA devices; grid sensors; weather stations; reclosers; capacitor banks; voltage regulators; switches; gas regulators; SmartMeter Access Points and Data Collection Units; security cameras; mobile devices; and more. FAN technology also uses industry standard connection protocols, making it easily compatible with a vast range of device types.

3. **Latency:** Unlike throughput and device connectivity, latency is not scalable, meaning the baseline performance must meet the requirements of the most demanding use case. PG&E plans to use the FAN to enable real-time monitoring and control of its gas and electric systems. For this reason, near-real-time latency between end points on the FAN is required. The latency of FAN technology is in the millisecond range, which is typical for Internet Protocol (IP)-based networks. This latency is sufficient for real-time communications.

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PG&E Witness:	John Nichols	Requester:	Tom Roberts

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 AND EXHIBIT (PG&E-7), CHAPTER 8 – IT INFRASTRUCTURE FOR INTEGRATED GRID PLATFORM (IGP), FIELD AREA NETWORK (FAN)

QUESTION 27

Please provide a timeline of when, by year, FAN is needed, and provide evidence to support the purported timing of the FAN needs.

ANSWER 27

The timeline for FAN and pace of implementation is driven by LOB demand for data network connectivity at field locations and LOB-specific work plans and business needs. This demand for connectivity has been growing over the past 5-7 years and will continue to grow over the next 10+ years based on the increasing variety of use cases and capabilities the LOBs plan to enable at field locations. These capabilities and use cases include electric grid control and automation, gas system control and automation, hydro generation SCADA, weather monitoring and wildfire detection, condition-based monitoring of assets, video feeds from security cameras, SmartMeter data backhaul in areas with limited cellular coverage, reliable network connectivity for field-crew mobile devices, and more. PG&E determined that deploying FAN technology as an extension of PG&E's private data network would provide a standard and consistent approach to enabling these use cases in locations where current network capabilities are not sufficient and other network technologies are not feasible or cost-effective.

The FAN is designed to be modular and scalable. Now that foundational FAN functionality has been established and successfully installed at pilot locations, PG&E can expand the FAN to any number of field locations based on LOB requirements and the timelines of business initiatives such as Grid Modernization. PG&E's deployments at field sites are synchronous with LOB demand at those field sites; in any given year, PG&E will determine which sites are in scope for that year based on LOB priorities, work plans, and the use cases they wish to enable.

Looking beyond 2018, PG&E expects to use FAN technology to enable and support the following use cases. Note that the timing is not precise, as earlier deployments at some locations will support and enable future use cases at those locations.

- Electric Grid automation and control (e.g. IGP, SCADA, sensors, control devices, etc.): In-flight and ongoing
- Hydro generation SCADA: In-flight and ongoing
- Weather monitoring and wildfire detection: Beginning in 2019
- Gas automation and control: Beginning in 2020
- Condition-based monitoring of assets: Beginning in 2020
- Wi-Fi enablement for mobile users in the field: Beginning in 2020
- SmartMeter data backhaul in underserved cellular coverage areas: Beginning in 2021
- Video feeds from security cameras: Beginning in 2022
- Other emerging use cases: As identified and prioritized by the LOBs

Attachment

GRC-2020-PhI_DR_PubAdv_163-Q01Atch01CONF

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PG&E Data Request No.:	PubAdv_203-Q01		
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Request Date:	May 13, 2019	Requester DR No.:	203
Date Sent:	May 28, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Nick Petrakis	Requester:	Thomas Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FOLLOW UP TO DATA REQUEST PUBADV-PG&E-146-TCR

QUESTION 01

Page 10 the Project Estimating Tool (PET) outputs provided in response to data request PubAdv-PG&E-146-TCR, Q.1, attachments 3, 9, and 11, show a single line item for Internal Labor Overheads and a single line item for External Labor Overheads, both in dollars. Regarding PET overhead calculations:

a. Is this display of overhead estimates the same for all PET estimates listed on WP page 8-161 of Ex. PG&E-7 workpapers? If not, please explain.

b. Where are the calculations and data that support the overhead estimates shown on page 10?

c. Is it correct that labor overheads are calculated using overhead burden rates and estimated direct labor costs? If not, please explain.

d. Is it correct that labor overheads are driven by estimated person-days and daily labor rates, since these two values drive direct labor costs? If not, please explain.

ANSWER 01

a. Yes, the display of Internal and External Labor Overheads on page 10 of the referenced attachments is the same for all PET estimates listed on WP 8-161 of Exhibit (PG&E-7).
b. For this response, PG&E uses GRC-2020-PhI_DR_PubAdv_146-Q01Atch03 as an example, but the same is respectively true for all referenced attachments. Attachment GRC-2020-PhI_DR_PubAdv_203-Q01Atch01 is the complete PET workbook in Excel format that contains all calculations, input factors, and supporting tabs that produced the values shown in the Field Area Network PET output originally provided as GRC-2020-PhI_DR_PubAdv_146-Q01Atch03. In GRC-2020-PhI_DR_PubAdv_203-Q01Atch01, the calculations for the overhead estimates are located in Cells R107, R108, S107, and S108 on the tab labelled "2_Cost-Assumptions". The calculations leverage the following data points:

Data Point	Location in GRC-2020-Phl_DR_PubAdv_203-Q01Atch01
Percentage of internal labor costs attributed to project labor	Tab “2_Cost-Assumptions”, Cell U54
Percentage of internal labor costs attributed to deploy-year O&M labor	Tab “2_Cost-Assumptions”, Cell V54
Percentage of external labor costs attributed to project labor	Tab “2_Cost-Assumptions”, Cell U76
Percentage of external labor costs attributed to deploy-year O&M labor	Tab “2_Cost-Assumptions”, Cell V76
Project labor costs attributed to capital	Tab “2_Cost-Assumptions”, Cell R104
Deploy-year O&M labor costs attributed to capital	Tab “2_Cost-Assumptions”, Cell R105
Project labor costs attributed to expense	Tab “2_Cost-Assumptions”, Cell S104
Deploy-year O&M labor costs attributed to expense	Tab “2_Cost-Assumptions”, Cell S105
Internal capital labor overhead rate	Tab “C_Rates”, Cell D33
Internal expense labor overhead rate	Tab “C_Rates”, Cell D34
External capital labor overhead rate	Tab “C_Rates”, Cell D35
External expense labor overhead rate	Tab “C_Rates”, Cell D36

c. Yes, labor overheads are calculated using overhead burden rates and estimated direct labor costs
d. Yes, estimated person-days and daily labor rates drive direct labor costs, which in turn drive the labor overhead calculation

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PG&E Witness:	Nick Petrakis	Requester:	Thomas Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FOLLOW UP TO DATA REQUEST PUBADV-PG&E-146-TCR

QUESTION 02

Are the same overhead burden rates used for all PET outputs provided in response to PubAdv-PG&E-146-TCR? If so, provide a sample calculation in Excel for the FAN PET discussed in question 3 below that shows all data and calculations. If not, provide the overhead calculations for the PET outputs discussed in questions 3, 5, and 6 below.

ANSWER 02

Yes, the same overhead burden rates are used for all PET outputs provided in response to PubAdv-PG&E-146-TCR. Note, however, that the overhead rate differs depending on whether the labor costs are for internal PG&E resources or for external (staff augmentation) resources and whether the labor costs are capital or expense.

Attachment GRC-2020-PhI_DR_PubAdv_203-Q01Atch01 is the complete PET workbook in Excel format that contains all calculations, input factors, and supporting tabs that produced the values shown in the Field Area Network (FAN) PET output originally provided as GRC-2020-PhI_DR_PubAdv_146-Q01Atch03. The calculations for the overhead estimates are located in Cells R107, R108, S107, and S108 on the tab labelled “2_Cost-Assumptions”.

Attachment GRC-2020-PhI_DR_PubAdv_203-Q02Atch01 provides a simplified, decomposed view of the same calculations.

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PG&E Witness:	Nick Petrakis	Requester:	Thomas Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FOLLOW UP TO DATA REQUEST PUBADV-PG&E-146-TCR

QUESTION 03

Attachment 3 to PG&E's response to data request PubAdv-PG&E-146-TCR, Q.1 provided the PET (Project Estimating Tool) for the Network Technologies Field Area Network (FAN) program and the FAN component of the IGP Enablement program. Regarding this PET:

a. Is it correct that the material cost of $24.670 million on page 10 is largely driven by the manual entry of $24 million on page 9? If not, please explain.

b. Please explain the $2.281 million calculated value for Network/Telcom material on page 9, including how this value is calculated and the data used in the calculation.

c. Is it correct that the labor cost of $20.207 million on page 10 is largely driven by the manual entry of 32,000 person-days on page 5 and the daily labor rates on page 6? If not, please explain.

d. Please explain the 510 person-days calculated for Total Project Labor on page 5, including how this value is calculated and the data used in the calculation.

ANSWER 03

Note: If Public Advocates finds any of these responses hard to follow, PG&E would be happy to meet in person to discuss.

a. PG&E's response assumes the question was meant to state "the material cost of $24.766 million on page 10". Yes, the material cost is largely driven by the manual entry of $24 million on page 9.

b. The $2.281 million calculated value is determined based on the responses/assumptions entered on pages 2, 3, and 4 of GRC-2020-PhI_DR_PubAdv_146-Q01Atch03 (Tab "1_Project-Assumptions" of GRC-2020-PhI_DR_PubAdv_203-Q01Atch01). Attachment GRC-2020-PhI_DR_PubAdv_203-Q03Atch01 decomposes the calculation that produced the value into its component parts. The calculation is intended to generate an approximation of incidental network infrastructure costs that a project might incur

(a) as a result of deploying technology at sites not adequately equipped to meet network needs, or (b) as a result of deploying additional network-connected devices that would generate incremental network traffic. The calculation is not intended to determine the materials costs for an infrastructure-focused project. Instead, for infrastructure-focused projects, the PET requires the estimator or subject matter expert to determine materials costs based on the expected scope/scale of the infrastructure deployment. They then have the option to add those costs to the calculated value or override the calculated value entirely with their estimate.

c. PG&E is unable to locate the referenced 32,000 person-days on page 5. PG&E's response assumes the question is referring to the manual entry of 17,300 person-days on page 5. That said, it is correct that the labor cost of $20.207 million on page 10 is largely driven by the manual entry of person-days on page 5 and the daily labor rates on page 6. Other major contributors to the labor cost of $20.207 million on page 10 are the labor overhead costs calculated on page 7. See PG&E's responses to GRC-2020-PhI_DR_PubAdv_203-Q01 and GRC-2020-PhI_DR_PubAdv_203-Q02 for more information on the labor overhead cost calculation.

d. The 510 person-day calculated value represents the adjusted base labor effort calculated by the PET based on the responses/assumptions entered on pages 2, 3, and 4 of GRC-2020-PhI_DR_PubAdv_146-Q01Atch03 (Tab "1_Project-Assumptions" of GRC-2020-PhI_DR_PubAdv_203-Q01Atch01). Attachment GRC-2020-PhI_DR_PubAdv_203-Q03Atch02 decomposes the calculation that produced the value into its component parts. In summary, there are 2 primary components of the calculation: (1) the Base Labor Effort Sizing, and (2) the Complexity & Risk Modifier.

There are 5 different potential calculated values for the Base Labor Effort Sizing. These values represent the midpoint of a range of labor effort values that PG&E associates with typical stand-alone projects.

Labor Effort Sizing	**Range of Labor Effort in Person-Days**	**Calculated Base Value in Person-Days**
Very Small	200-400	300
Small	400-800	600
Medium	800-2000	1400
Large	2000-4000	3000
Very Large	4000-10500	7250

The PET calculation assumes the midpoint values represent stand-alone projects with typical (i.e. medium) complexity and typical (i.e. medium) execution risk. Because of this, PG&E applies a Complexity & Risk Modifier for projects that have higher or lower than typical complexity and risk and therefore require more or less than the typical labor effort to execute. This modifier can range from 65% to 145%, depending on Complexity and Execution Risk factors calculated by the PET (see attachment GRC-2020-PhI_DR_PubAdv_203-Q03Atch02 for more detail).

It is important to note that the calculated base labor effort values are intended to provide a starting point for estimators to refine based on their expertise and knowledge of the scope of work they are estimating. Also, as mentioned, these base values are modeled after typical stand-alone projects. When estimating a larger, multi-year initiative that will ultimately be executed as several smaller stand-alone projects (as is the case with the Field Area Network initiative), it is often necessary for the estimator to manually enter a labor effort forecast that addresses the full scope of the effort over the time period covered by the estimate.

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PG&E Data Request No.:	PubAdv_203-Q04		
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PG&E Witness:	Nick Petrakis	Requester:	Thomas Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FOLLOW UP TO DATA REQUEST PUBADV-PG&E-146-TCR

QUESTION 04

Attachment 4 to PG&E's response to data request PubAdv-PG&E-146-TCR, Q.1 shows that PG&E splits the total FAN forecast between the Network Technologies Field Area Network (FAN) program, WP page 8-85, and the FAN component of the IGP Enablement program, WP page 8-68. Please explain how PG&E performed this split and provide any supporting assumptions, data or other evidence.

ANSWER 04

Please see PG&E's response to PubAdv-PG&E-163-TCR, Question 6, sub-part a, which outlines the assumptions upon which the cost allocation was based. PG&E subject matter experts determined what costs to allocate to each program each year using those assumptions.

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PG&E Witness:	Nick Petrakis	Requester:	Thomas Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FIELD AREA NETWORK (FAN)

QUESTION 01

PG&E's workpapers and discovery responses to date use different terms to define the FAN scope of work. For example Ex. PG&E-7 workpapers, p. WP 8-66 indicates that 150-200 meshes will be installed for IGP over five years and PG&E's response to PubAdv-PG&E-163- TCR, question 21 provides an estimated # of Gateway Locations (Take Out Points): 200 to 350. Regarding the scope of work:

a. Please explain the relationship between meshes, take out points, gateway locations, mesh nodes, and devices consistent with PG&E's response to PubAdv-PG&E-163- TCR, question 21, PG&E testimony and workpapers, and other discovery responses,

b. Please provide the proposed annual scope of work for FAN in terms of meshes for i) IGP and ii) non-IGP programs,

c. Please provide the proposed annual scope of work for FAN in terms of take out points for i) IGP and ii) non-IGP programs,

d. Please provide the proposed annual scope of work for FAN in terms of mesh nodes for i) IGP and ii) non-IGP programs,

e. Please provide the current estimate for the total number of FAN meshes for i) IGP and ii) non-IGP programs.

ANSWER 01

a. A FAN mesh is made up of a set of gateways (installed at a gateway location) and the mesh nodes (field radios that connect in a mesh to each other and to the gateway). There is typically 1 mesh associated with each gateway location.

   A takeout point is the same thing as a gateway location. As the name implies, that's the location where the FAN gateways are installed. These gateways connect to the rest of PG&E's data network, thereby acting as the data 'takeout point' for the entire mesh they support. There is typically one takeout point/gateway location per mesh.

Mesh nodes are the field radios that make up the mesh. They connect to each other in a mesh topology to maintain consistent connectivity. Most mesh nodes are FAN radios that have direct connection (either by IP or Serial) to a field device (e.g. a SCADA control point). There are also helper nodes, which are mesh nodes that extend the FAN mesh connection but don't have any end devices connected directly to them.

PG&E uses the term devices primarily in reference to sensors, control points, and other end points at the edge of the network that produce or consume the data transmitted via the FAN.

See GRC-2020-PhI_DR_PubAdv_216-Q02Atch01CONF for an illustration of the different components mentioned above.

b. The proposed scope of work for FAN is to build out a total of 25 to 50 meshes per year. Of these, 20 to 40 meshes support IGP programs, and 5 to 10 meshes support non-IGP programs.

c. As discussed, there is typically one takeout point per mesh. Therefore, the proposed scope of work for FAN includes a total of 25 to 50 takeout points per year (i.e., 1 takeout point per mesh). Of these, 20 to 40 support IGP programs, and 5 to 10 support non-IGP programs.

d. PG&E plans to deploy between 50 and 80 mesh nodes per mesh per year, depending on the number of field devices to be connected at a given location. The proposed scope of 25 to 50 meshes per year therefore equates to a total of 1250 to 4000 mesh nodes per year. Of these, 1000 to 3200 support IGP programs, and 250 to 800 support non-IGP programs.

e. Ultimately, PG&E plans to deploy between 200 and 350 FAN meshes. Of these, 150 to 200 support IGP programs, and 50 to 150 support non-IGP programs.

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PG&E Witness:	Nick Petrakis	Requester:	Thomas Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FIELD AREA NETWORK (FAN)

QUESTION 02

Please provide a version of Attachment 1 to PubAdv-PG&E-163-TCR, question 1 that identifies a mesh, mesh node, device, take out point and gateway location.

ANSWER 02

See GRC-2020-PhI_DR_PubAdv_216-Q02Atch01CONF.

Attachment

GRC-2020-PhI_DR_PubAdv_216-Q02Atch01CONF

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SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FIELD AREA NETWORK (FAN)

QUESTION 03

Please provide a figure that illustrates multiple meshes, take out points and gateway locations over a given geographic region.

ANSWER 03

See GRC-2020-PhI_DR_PubAdv_216-Q03Atch01CONF.

Attachment

GRC-2020-PhI_DR_PubAdv_216-Q03Atch01CONF

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SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FIELD AREA NETWORK (FAN)

QUESTION 04

PG&E's TY 2017 GRC does not appear to provide the forecast scope of work for FAN (Ex. PG&E-7 pp. 9-41-42; Ex. PG&E-7 workpapers pp. WP 9-184 to 9-189.) Please provide the FAN scope associated with the TY 2017 FAN forecast from the following sources, and provide a complete citation to the source where applicable:

a. PG&E TY 2017 testimony and workpapers,

b. TY 2017 discovery responses,

c. Any other TY 2017 data source,

d. Analysis outside of the record in the TY 2017 GRC.

ANSWER 04

a. The only citations within PG&E's TY 2017 testimony and workpapers that discuss FAN deployment are those referenced in the question: Exhibit (PG&E-7), Chapter 9, pp. 9-41 to 9-42 and supporting workpapers pp. WP 9-184 to 9-189.

b. See below for a list of TY 2017 discovery responses regarding the FAN.

- GRC-2017-PhI_DR_ORA_020-Q20 subparts A and B
- GRC-2017-PhI_DR_ORA_182-Q06
- GRC-2017-PhI_DR_ORA_182-Q15
- GRC-2017-PhI_DR_ORA_185-Q11 subpart C
- GRC-2017-PhI_DR_ORA_188-Q01
- GRC-2017-PhI_DR_ORA_188-Q02 subparts A, B, C, D, and E

c. PG&E is not aware of any other TY 2017 GRC data source that discussed the FAN scope of work.

d. PG&E is not aware of any other analysis produced outside the record in the TY 2017 GRC regarding the scope of the FAN program. PG&E was in the early stages of the FAN pilot phase at the time of the 2017 GRC filing and had not yet forecast the full scope of the program.

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PG&E Witness:	Nick Petrakis	Requester:	Thomas Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FIELD AREA NETWORK (FAN)

QUESTION 05

PG&E's response to PubAdv-PG&E-154-TCR, question 8 states that "none of the specifications or planned capabilities for any of the IGP IT Infrastructure components are currently planned to address direct network connection to third-party owned DERs." However, PG&E's response to PubAdv-PG&E-163-TCR, question 14 indicates that all FAN devices are modular and expandable, and that new gateways can be added to existing gateway locations to increase throughput/capacity. If PG&E develops the ability in the future to control smaller DERs with Smart Inverters, for example using a DERMS, could the FAN system be augmented to provide connectivity to these devices? If so:

a. Can the FAN transmit information per IEEE 2030.5, IEEE 1815, IEC 61850-7-420 or other DER-focused communication protocols?

b. Would the incremental scope in terms of hardware, installation and other costs be proportional to incremental increase in devices within any given FAN mesh? If not, please explain.

c. Would there be additional incremental costs for meshes that had already been deployed, versus those designed to accommodate third-party DERs prior to FAN deployment? If so, please explain.

d. Would there be additional incremental costs outside of a given mesh, for example to connect to other meshes or to the WAN? If so, please explain.

e. Is it correct that augmenting FAN to accommodate third-party DERs would increase the cost per mesh and total FAN costs compared to PG&E's forecasts in this GRC and the TY 2017 GRC? If not, please explain.

ANSWER 05

Yes. If PG&E develops the ability in the future to control smaller DERs with Smart Inverters, for example using a DERMS, the FAN system could be augmented to provide connectivity to these devices

a. Yes. The FAN system is a transport network that conveys data information from one location to another. As long as the communication protocol exists within the

Open System Interconnection (OSI) protocol stack[1] and supports (or can be adapted to support) Internet Protocol (IP) communication, the FAN can convey that information.

b. For an existing FAN mesh, yes, incremental scope would be roughly proportional to the incremental increase in devices being deployed. However, if incremental scope were to require a new mesh at a new gateway location, the incremental scope may not necessarily be proportional to the incremental increase in devices being deployed. This would depend on the location in question, the infrastructure currently available at that location, and whether or not additional labor or materials are necessary to enable that location to support a FAN mesh.

c. For an existing mesh to accommodate DERs, PG&E would need to deploy additional mesh nodes to connect to each DER device. Depending on the number of DER devices added to a given mesh, PG&E may also need to deploy additional gateways in an existing mesh to support the increased number of mesh nodes. Excluding factors such as inflation and standard escalation, the cost to deploy additional equipment in an existing FAN mesh would be similar regardless of when the equipment is deployed.

d. Each FAN mesh is connected at its gateway location to PG&E's Wide Area Network (WAN), which links multiple FAN meshes to the back-end infrastructure at PG&E data centers. To support DERs within an existing mesh, PG&E would incur incremental costs outside a given mesh only if the WAN connection in question did not have sufficient capacity to accommodate the number of DERs being added. In some cases, if DER devices to be connected are outside existing mesh coverage, PG&E may need to deploy an additional mesh, which would then need to be connected to other meshes or to the WAN. However, this would be the case anytime a new mesh is added and is not unique to enabling DERs.

e. Yes. To accommodate third-party DERs on the FAN network, new mesh nodes would need to be installed to connect to the DER devices. These new mesh nodes might be installed within existing meshes or require PG&E to deploy a new mesh at a new gateway location.

[1] The OSI protocol stack is a model developed by the International Standards Organization (ISO) that governs the protocols that operate on networks.

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PG&E Data Request No.:	PubAdv_216-Q06		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_216-Q06		
Request Date:	May 23, 2019	Requester DR No.:	216
Date Sent:	June 7, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Nick Petrakis	Requester:	Thomas Roberts

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 – FIELD AREA NETWORK (FAN)

QUESTION 06

PG&E quantifies FAN costs incurred for FAN deployment in its FAN forecasts. Please provide a comparable quantification of the cost savings that will result from FAN deployment. If PG&E cannot quantify these benefits, then provide a full list of the types of costs that will be reduced or eliminated, and whether each is currently an expense or capital expenditure.

ANSWER 06

As a foundational technology, the FAN in and of itself is not intended as a cost savings initiative. The connectivity it provides may enable PG&E to deliver cost savings via other initiatives, but direct cost savings from the FAN initiative are expected to be minimal.

As one example, PG&E expects to see direct costs savings as a result of transitioning a portion of SmartMeter Advanced Metering Infrastructure (AMI) data backhaul from third-party cellular and satellite networks to the FAN. When complete, this transition is expected to produce expense savings of $1 million to $1.5 million per year. No other direct cost savings opportunities have been identified or quantified at this time.

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PG&E Data Request No.:	PubAdv_225-Q01		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_225-Q01		
Request Date:	June 4, 2019	Requester DR No.:	225
Date Sent:	June 18, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Quinn Nakayama	Requester:	Thomas Roberts

SUBJECT: IGP

QUESTION 01

Is it correct that WP Table 19-14 in Ex. PG&E-4 workpapers provides the cost to perform point to point testing on 90% (9,456/10,507) of all electric distribution SCADA devices at PG&E in the current general rate case, and the balance in subsequent general rate cases, such that 100% of SCADA endpoints will be tested point to point? If not, please explain.

ANSWER 01

It is correct that WP Table 19-14 in Ex. PG&E-4 workpapers provides the cost to perform point-to-point testing on 90% (9,456/10,507) of all electric distribution SCADA devices at PG&E in the current general rate case, and the balance in subsequent general rate cases, such that 100% of SCADA endpoints will be tested point-to-point.

It should be noted that while PG&E's point-to-point testing cost estimate assumed all devices and endpoints would be point-to-point tested using back-office testing methods (described further below), it assumed that only 10% of IEDs and 15% of RTUs would undergo field-based point-to-point testing, which involves a PG&E field technician inputting signals at the RTU or IED in the field and another technician verifying accurate database mapping of these signals in the back-office. Conducting some level of field-based point-to-point testing is important for building confidence in the accuracy of the database migration but is very costly to perform across all devices.

PG&E intends to utilize the following two back-office point-to-point testing methods across 100% of SCADA devices and endpoints:

"Listen Mode": This mode of point-to-point testing is characterized by side-by-side comparison of values between the existing RT-SCADA database and the new ADMS SCADA database. Validation is performed by a PG&E SCADA Specialist who will visually compare the value populated in the new SCADA database versus the value in the existing SCADA database. This mode of testing is primarily used for validation of analog points which exhibit more frequent rates of change than status or position points.

"Simulation Mode": This mode of point-to-point testing is characterized by use of specialized SCADA simulation test software to simulate random changes in copies of

the RT-SCADA and new ADMS SCADA database. Validation is performed by a PG&E SCADA Specialist who will utilize the simulation test software to screen for inconsistencies across the databases. Through forcing random changes in the database, this mode of testing is particularly useful for validation of status or position points, which exhibit less frequent rates of change than analog points under typical circumstances.

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PG&E Data Request No.:	TURN_013-Q07		
PG&E File Name:	GRC-2020-PhI_DR_TURN_013-Q07Supp01		
Request Date:	April 24, 2019	Requester DR No.:	013
Date Sent:	May 8, 2019 (Original) July 15, 2019 (Supplemental)	Requesting Party:	The Utility Reform Network
PG&E Witness:	Quinn Nakayama	Requester:	Marcel Hawiger

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19 – GRID MOD

QUESTION 07

Refer to PG&E Exh. 4, Chapter 19 workpapers, page WP 19-27 in "Advanced Distribution Management System (ADMS)" generally. The "ADMS software" is forecast at a capital cost of $13.777 million from 2018 to 2022. Provide any details and explanations supporting this cost forecast.

ANSWER 07

The development of PG&E's ADMS cost estimates was led by a third-party System Integrator hired by PG&E with extensive experience implementing ADMS projects in North America and deep knowledge of typical ADMS implementation costs. The ADMS hardware and software costs provided in WP Table 19-13 are based upon this third party's proprietary ADMS implementation cost model, which draws upon their experience with ADMS hardware and software costs for ADMS implementation projects at other utilities.

SUPPLEMENTAL 01 ANSWER 07

Attachments to this response contains CONFIDENTIAL information provided pursuant to the executed NDA.

PG&E's contract with its preferred ADMS software vendor, executed on May 10, 2019, has a provision which allows PG&E to share it on a confidential basis in Commission proceedings.

Please consult attachment GRC-2020-PhI_DR_TURN_013-Q07Supp01Atch01CONF, particularly the information beginning at page 25 of the PDF, for the requested information on software costs.

Please note that the software cost information in GRC-2020-PhI_DR_TURN_013-Q07Supp01Atch01CONF represents a final, negotiated contract value and therefore

differs from PG&E's software cost estimate on Line No. 2 of WP Table 19-13 in Ex.-4, Ch.19.

Although TURN did not ask for information supporting PG&E's hardware cost estimate on Line No. 4 of WP Table 19-13 in Ex.-4, Ch.19, PG&E is voluntarily sharing additional details supporting this cost forecast so as to provide TURN with the same information that other intervenor parties, including Public Advocates, have been provided.

PG&E's preferred hardware vendor has agreed to allow PG&E to confidentially share a preliminary hardware price estimate it provided to PG&E in June 2019. Please consult attachment GRC-2020-PhI_DR_TURN_013-Q07Supp01Atch02CONF for this preliminary hardware price estimate.

Please note that the hardware cost information in GRC-2020-PhI_DR_TURN_013-Q07Supp01Atch02CONF differs from PG&E's hardware cost estimate on Line No. 4 of WP Table 19-13 in Ex.-4, Ch.19 because it is a recent price estimate provided to PG&E that is reflective of changes to PG&E's ADMS hardware requirements that have taken place since the ADMS RFP. PG&E's hardware cost estimate on Line No. 4 of WP Table 19-13 in Ex.-4, Ch.19 was based on an initial vendor quote provided in response to PG&E's ADMS RFP in 2018 (which PG&E has still not received permission to share).

Attachment

GRC-2020-
PhI_DR_TURN_013-
Q07Supp01Atch01CONF

is Confidential in its Entirety

Attachment

GRC-2020-
PhI_DR_TURN_013-
Q07Supp01Atch02CONF

is Confidential in its Entirety

Attachment

GRC-2020-
PhI_DR_TURN_013-
Q09CONF

is Confidential in its Entirety

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PG&E Data Request No.:	TURN_017-Q01		
PG&E File Name:	GRC-2020-PhI_DR_TURN_017-Q01		
Request Date:	May 1, 2019	Requester DR No.:	017
Date Sent:	May 14, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Nick Petrakis	Requester:	Marcel Hawiger

SUBJECT: PG&E-7, CHAPTER 8, IT

QUESTION 01

Refer to PG&E Exh. 7, Chapter 8, page 8-16 at line 14 which states "By leveraging modern methodologies to build a single solution for multiple LOBs, this product development approach enables PG&E to minimize redundant investments, increase IT delivery efficiency, optimize IT support, and standardize and streamline business processes."

a. Provide any evidence that PG&E applied the product development approach described to communications network planning, investment, and operations generally.

b. Provide any analyses (costs, risks, benefits) PG&E may have completed evaluating new low cost, low power, wide area networks (LPWA) available from commercial carriers to satisfy the growing communications needs described throughout Chapter 8. (LPWA is based on proven 4G technology, is upgradable to 5G, and has been designed specifically as a low-cost approach for communications with devices fixed in place.)

c. Provide any analyses (costs, risks, benefits) PG&E may have completed evaluating the use of new smart SIM cards, which are remotely upgradable and configurable for new network technologies as commercial carriers roll them out, for smart metering and Integrated Grid Platform Enablement.

ANSWER 01

a. The product development approach discussed on page 8-16 through 8-18 of Exhibit (PG&E-7), Chapter 8 specifically relates to software development initiatives (as mentioned on page 8-16, line 10) that address cross-functional business needs. Work involving the communications network continues to use existing processes and methodologies that are designed to enable efficient and effective delivery of infrastructure work. For IT project work, PG&E selects the delivery methodology that best suits the technology in question and the business requirements defined by the requesting LOB.

b. Low-power wide-area network (LPWAN) technology is a group of wireless wide-area network technologies that are designed to allow long range communications at a low bit rate among connected objects. The low power, low bit rate makes this different from other types of wireless wide-area networks which typically connect users or businesses, carry more data, and use relatively more power. The LPWAN data rate ranges from 0.3 kbit/s to 50 kbit/s per channel.

   There are several key reasons why PG&E is not considering LPWAN at this time:

   1. Utility-Specific Network Requirements: PG&E's telecom network needs to support a variety of utility-specific use-cases (e.g. electric line protection, distribution automation, emergency response, gas monitoring, etc.) that have unique network security, reliability, availability, and capability requirements. Because commercial cellular networks are designed for public use, they are not guaranteed to meet these requirements or provide the requisite quality of service. Commercial cellular networks also do not provide PG&E with the necessary level of control the Company needs to effectively manage and operate critical business functions. As a result, PG&E requires a dedicated private network to support utility-specific communication needs and critical infrastructure. While there are a few non-critical cases where PG&E uses commercial cellular networks to fill in communication gaps, they are not adequate for the majority of use cases PG&E needs to support.
   2. Low Capacity & Throughput: As discussed, LPWAN offers very low data throughput rates. PG&E's growing communications needs require far greater throughput rates than LPWAN is currently designed to support. PG&E's networks also require the versatility to support a variety of different use cases simultaneously, which is not currently possible with LPWAN's limited throughput. These use cases include but are not limited to the following:
      - SCADA communication to field and substation devices (for electric and gas assets)
      - Voice over IP
      - Access/Ability to use PG&E applications on smart devices
      - SmartMeter data backhaul
      - Communication to distribution feeders and DERs
   3. Maturity & Commercial Viability: PG&E currently views LPWAN as an emerging wireless technology that currently lacks commercial viability and technological maturity. This means that there are few (if any) utility equipment vendors that deploy and support this technology. Before PG&E can consider LPWAN as a viable option, utility equipment vendors will need to update their products to demonstrate interoperability with LPWAN technology, and LPWAN vendors will need to demonstrate their ability to adequately support utility-specific use cases and technologies using LPWAN.

   In summary, while LPWAN has strong potential for some use-cases, it is not currently a viable option for PG&E considering the Company's specific communications needs and priorities. As LPWAN technology matures, however,

PG&E will continue to explore how it might fit into the Company's overall network landscape.

c. PG&E has not completed a formal analysis evaluating the use of new smart SIM cards for smart metering and Integrated Grid Platform Enablement. Currently, smart SIM cards have not been widely deployed and have limited applications. In addition, the private Field Area Network (FAN) that PG&E is deploying has the capability to address use-cases the smart SIM cards could enable. Because the FAN does not require the use of SIM cards, an evaluation of smart SIM cards was not considered. As smart SIM technology matures and gains wider commercial adoption, PG&E may re-evaluate the technology and its applicability for PG&E use cases.

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PG&E Data Request No.:	TURN_017-Q05		
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Request Date:	May 1, 2019	Requester DR No.:	017
Date Sent:	May 14, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Nick Petrakis	Requester:	Marcel Hawiger

SUBJECT: PG&E-7, CHAPTER 8, IT

QUESTION 05

Refer to PG&E Exh. 7, Chapter 8, Workpaper "Project Summary: Integrated Grid Platform Enablement (IT Infrastructure)". WP 8-68 includes a table entitled "Major Project Spending Estimates". SCADA network reliability capital under MWC 2F is listed at $21.684 million from 2019-2022. Provide any analysis PG&E may have completed comparing the present value of revenue requirements for PG&E-owned SCADA reliability upgrades to the use of new low power wide area networks available from commercial carriers.

a. Refer to PG&E Exh. 7, Chapter 8, Workpaper "Project Summary: Integrated Grid Platform Enablement (IT Infrastructure)" and pp. WP 8-67 and 8-68. Do the capital costs shown for "converged infrastructure" on WP 8-68 relate directly to the "converged compute platform" described on WP 8-67? If not, please explain fully what is included in the "converged infrastructure."

b. Please disaggregate the forecast capital costs for "converged infrastructure" into any major components (software, hardware, materials, labor, etc.)

c. Is the total $16.599 million for the "pilot" or "proof of concept"? If yes, does it fully cover the "pilot" of "proof of concept"? If no, please explain.

d. Please explain the scope of the pilot. How many substations will it cover?

e. Please provide any benefit-cost analysis PG&E may have completed comparing the present value of revenue requirements for Converged Infrastructure to the benefits of Converged Infrastructure over the expected useful life of Converged Infrastructure benefits.

f. Describe the alternatives available to Converged Infrastructure and provide any analysis of the Present Value revenue requirements for such alternatives.

ANSWER 05

For the reasons discussed in PG&E's response to sub-part b of GRC-2020-PhI_DR_TURN_017-Q01, PG&E does not currently consider LPWA networks to be viable technical alternatives to PG&E's existing and proposed network technologies. As

a result, PG&E has not conducted any comparative cost analyses between LPWA networks and PG&E-owned SCADA reliability upgrades.

a. Yes—the forecast costs labeled as “Converged Infrastructure” on WP 8-68 represent the forecast costs for the Converged Compute Platform discussed on WP 8-67.

b. Attachment GRC-2020-PhI_DR_TURN_017-Q05Atch01 is the PET output for the Converged Compute Platform, which provides a high-level breakdown of costs for the workstream. Attachment GRC-2020-PhI_DR_TURN_017-Q05Atch02 provides a comparison of the PET output to the forecast labeled “Converged Infrastructure” shown on WP 8-68.

c. Yes, the $16.599 million will cover the pilot efforts associated with the Converged Compute Platform, as well as initial production deployments.

d. The scope of the Converged Compute Platform Pilot is to deploy a modern consolidated IT infrastructure, leveraging virtualization and “software-defined” technologies, at three substations within 5 years.

e. PG&E has not yet conducted a formal cost-benefit analysis for the Converged Compute Platform workstream, but experience with the technology and industry data suggests that converged infrastructure does provide cost savings compared to traditional approaches. PG&E intends to conduct a more formal cost-benefit analysis as part of the pilot efforts.

f. The primary alternative to the Converged Compute Platform would be to continue with the status quo, which involves deploying stand-alone platforms for each specific project and effort. PG&E expects to perform a cost comparison analysis of the alternatives as part of the pilot effort.

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PG&E Data Request No.:	TURN_022-Q04		
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Request Date:	May 17, 2019	Requester DR No.:	022
Date Sent:	June 5, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Nick Petrakis	Requester:	Marcel Hawiger

SUBJECT: EXHIBIT (PG&E-7), CHAPTER 8 (IT)

QUESTION 04

Refer to PG&E's response to DR TURN_17-Q01(b), which states "PG&E's telecom network needs to support a variety of utility-specific use-cases (e.g. electric line protection, distribution automation, emergency response, gas monitoring, etc.) that have unique network security, reliability, availability, and capability requirements." PG&E's response to DR TURN_17-Q01(b) also states "PG&E's networks also require the versatility to support a variety of different use cases simultaneously, which is not currently possible with LPWAN's limited throughput."

a. Provide the security, reliability, availability, capability, throughput, and latency standards PG&E has established for each of the following use cases:
    i. SCADA communication to field and substation devices (for electric and gas assets)
    ii. Voice over IP
    iii. Access/Ability to use PG&E applications on smart devices
    iv. SmartMeter data backhaul
    v. Communication to distribution feeders and DERs
b. Provide a list of the field and substation devices with which the PG&E network must communicate, and a list of software applications for each. For each application listed, provide throughput and latency requirements.
c. Explain why PG&E can't use standard cellular voice communications using public networks instead of Voice over IP using PG&E's communications network.
d. Provide a list of the smart device applications which require communications using the PG&E network. For each application listed, provide throughput and latency requirements.
e. Provide
    i. A list of applications which require smart meter data and the number of smart meters associated with each. For each application, provide throughput and latency requirements.

ii. The extent (meter counts) to which public networks are used to backhaul smart meter data today

iii. The annual smart meter data backhaul costs currently being incurred from public network providers today.

f. Provide a list of the distribution feeder and DER devices with which the PG&E network must communicate, and a list of software applications for each. For each application listed, provide throughput and latency requirements.

ANSWER 04

As a reference for the responses below:

Throughput refers to the amount of data or information that can pass through a network circuit within a given timeframe, typically expressed in bits per second (bps), kilobits per second (kbps), or megabits per second (Mbps). The lower the throughput, the longer it takes for the data or information to reach its destination. Higher throughput allows for larger amounts of data to be transmitted within the timeframe that is required by the user or system. The higher the concentration of connected devices, systems, or users generating traffic on a circuit, the higher the throughput required. The type of data being transmitted also impacts the throughput required; for example, transmitting video, image, or audio data requires higher throughput than transmitting text or numerical data. For this reason, throughput requirements vary across PG&E's data network; they tend to be lower at the network edge (e.g. field sites and remote locations), higher at network hubs/aggregation points (e.g. regional sites and larger substations), and highest at core locations (e.g. data centers, contact centers, and large offices). PG&E does not typically establish throughput requirements at an individual application level—throughput requirements are determined at a given location based on expected demand from end points and users at that location.

Latency refers to the time it takes for a signal to traverse between two network end points—for example, between an application and an edge device, between devices in the field, or between a user and an application. Latency is typically expressed in milliseconds (ms) or seconds (s). For "real-time" applications, latency must be consistent and as low as possible. For example, if an electric system operator gives a command, the system must respond immediately.

a. To clarify, PG&E's statement regarding "unique network security, reliability, availability, and capability requirements" was not made specifically in reference to the use cases listed in subpart a. That said, PG&E's network infrastructure is expected to comply with PG&E's internal requirements for network security (e.g. access control, encryption, traffic monitoring, etc.). In addition, PG&E must comply with NERC security requirements for Critical Infrastructure Protection. See exhibit PG&E-7, Chapter 9 for further discussion of PG&E's security program.

   PG&E's network reliability/availability service level standards are based on tiers (platinum, gold, silver, bronze) that align to the criticality of the site in question.

See GRC-2020-PhI_DR_TURN_022-Q04Atch01 for an overview of PG&E's network service level standards by tier.

Capability requirements are determined by the use case in question, and include requirements such as redundant network paths, high voltage protection, logical network segmentation, and more. Throughput and latency requirements are listed below for each of the individual use cases. Note that PG&E's network must provide sufficient capacity to support many instances of these (and other) use cases simultaneously.

	Use Case	**Throughput/Latency Requirements**
i.	SCADA communication to field and substation devices (for electric and gas assets)	Throughput: 9.6 - 200 kbps per device, depending on generation of device Latency: Less than 100 ms
ii.	Voice over IP	Throughput: 24 - 80 kbps per call Latency: Less than 60 ms
iii.	Access/Ability to use PG&E applications on smart devices	Throughput: 1 - 200 Mbps Latency: Less than 300 ms
iv.	Smart Meter data backhaul	Throughput: Greater than 500 kbps per Access Point or Data Collection Unit Latency: Less than 100ms
v.	Communication to distribution feeders and DERs	Throughput: 9.6 kbps - 1 Mbps per device, depending on the generation of the device Latency: Less than 100 ms

b. Due the large variety of equipment installed on PG&E's electric grid, an exhaustive list of devices and applications would be overly burdensome to provide. That said, some examples of devices include:

- Substation switches
- Substation relays
- Substation power quality monitors
- Substation circuit breakers
- Substation transformers
- Substation physical security equipment
- Substation load tap changers
- SCADA control points
- Environmental equipment
- Line reclosers
- Capacitor Banks
- Switches
- Voltage regulators

Applications associated with these devices include RT-SCADA, which is used to monitor power flows and control points by operators. Engineers, and specialist use other applications such as EnerVista, AcSELerator to adjust equipment settings and update firmware.

As discussed above, PG&E does not typically establish throughput and latency requirements at an individual application level. Throughput and latency requirements are determined on a per location basis based on the number/type of devices and/or number of users at any given location at any given time. Field locations and substations typically require less than 100 ms latency and can require throughput between 9.6 kbps and 100 Mbps, depending on the specifics of the location.

c. To clarify, PG&E did not state that standard cellular voice communications using public networks could not be used instead of Voice over IP (VoIP) using PG&E's communications network. PG&E's statement was that LPWAN technology specifically (as opposed to cellular technology in general) was not sufficient to support VoIP and other PG&E use cases simultaneously.

   That said, while PG&E does use public networks for cellular voice communications, PG&E still requires a separate private telephony system (for which VoIP is PG&E's current standard) to provide voice communication capabilities for key functions. Some of these functions include: customer contact center communications, electric and gas control center communications, emergency operation center communications, security operations control center communications, energy trading, standard office communications (particularly in areas without adequate cellular coverage), and more. A private telephony system with wired connections at most locations provides PG&E with the necessary levels of control, reliability, and availability to provide the functions listed above. Wireless public cellular networks cannot guarantee the quality of service PG&E requires for all of its telephony needs, particularly during an emergency situation.

d. Due the large variety of systems and applications that PG&E users access from smart devices, an exhaustive list of applications would be overly burdensome to provide. That said, some key examples of application types include:

Application Type	**Throughput/Latency Requirements**
Mapping/geospatial applications	Throughput: 50 - 200 Mbps per user Latency: Less than 300 ms
Email, messaging, and productivity applications	Throughput: Greater than 1 Mbps Latency: Less than 300 ms
Internet applications	Throughput: Greater than 1 Mbps Latency: Less than 300 ms
Other internal PG&E applications	Throughput: Greater than 1 Mbps Latency: Less than 100ms

e. See subparts i, ii, and iii below.

i. There are two primary applications that directly communicate with PG&E's SmartMeter network: UIQ for the electric SmartMeter network, and Aclara Star for the gas SmartMeter network.

Application	Associated Devices	Throughput/Latency Requirements
UIQ	~1600 Access Points, which aggregate data from ~5.4 million electric SmartMeters	Throughput: Greater than 500kbps per Access Point Latency: <100ms
Aclara Star	~5000 Data Collection Units, which aggregate data from ~4.5 million gas SmartMeters	Throughput: Greater than 500kbps per Data Collection Unit Latency: <100ms

ii. All SmartMeter data is currently backhauled using public networks (mostly cellular). See i. above for meter count information.

iii. It costs PG&E approximately $2 million to $3 million per year to backhaul SmartMeter data over public carrier networks.

f. Due the large variety of equipment installed on PG&E's electric grid, an exhaustive list of devices and applications would be overly burdensome to provide. That said, some examples of devices include:

- Environmental equipment
- Line reclosers
- Line sensors
- Capacitor Banks
- Switches
- Voltage regulators
- Smart inverters

Applications associated with these devices include RT-SCADA, which is used to monitor power flows and control points by operators. Engineers, and specialist use other applications such as EnerVista, AcSELerator to adjust equipment settings and update firmware.

As discussed above, PG&E does not typically establish throughput and latency requirements at an individual application level. Throughput and latency requirements are determined on a per location basis based on the number/type of devices and/or number of users at any given location at any given time. Distribution feeder and DER devices typically require less than 100 ms latency

and can require throughput between 9.6 kbps and 1 Mbps, depending on the generation of equipment.

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PG&E Data Request No.:	TURN_023-Q14		
PG&E File Name:	GRC-2020-PhI_DR_TURN_023-Q14		
Request Date:	May 17, 2019	Requester DR No.:	023
Date Sent:	June 3, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Quinn Nakayama	Requester:	Marcel Hawiger

SUBJECT: EXHIBIT (PG&E-4), CHAPTER 19

QUESTION 14

Refer to the confidential ADMS Major Project Business Case provided in response to DR TURN_013-001. Page 32, which states "Add the data necessary for ADMS into PG&E's Geographic Information System (GIS) data repository application, improve the quality of the data, and develop an as-switched electric distribution system network model in ADMS."

a. Are there additional new expectations/data requirements of the GIS systems, in order for the ADMS systems, including D-SCADA, DMS, OMS, FLISR and "*as-switched"* models, to properly operate, in excess of those required by existing systems?

b. What are these new expectations/data requirements?

c. What is the cost of making provisions for these new requirements?

d. How will these new requirements be maintained?

e. What is the estimated cost of maintaining these requirements?

f. Has the cost of maintaining these requirements been included in the cost estimates for the new proposed ADMS systems, including D-SCADA, DMS, OMS, FLISR and "*as-switched"* models?

g. What are the consequences, if these requirements are not maintained?

h. What is the cost of these consequences?

i. Has PG&E estimated the overall accuracy of its existing GIS databases? If so, please provide the estimates of that overall accuracy.

j. Has PG&E found inaccuracies in its existing GIS databases?

k. How often does PG&E find inaccuracies in its existing GIS databases.

l. What are the procedures for correcting errors in the existing GIS databases.

m. Has the existing GIS database inaccuracies caused problems/inaccurate reporting, with its existing SCADA, DMS, OMS, or FLISR systems?

n. What is the nature of the problems/inaccuracies caused by the existing GIS database inaccuracies on its existing SCADA, DMS, OMS, or FLISR systems?

o. What is the cost of correcting these problems/inaccuracies?

p. What level of accuracy of the GIS databases, will need to be maintained for the new ADMS systems, including D-SCADA, DMS, OMS, FLISR, and "*as-switched"* models to properly operate?

q. Has PG&E calculated the required level of accuracy for the new ADMS systems, including D-SCADA, DMS, OMS, FLISR and "*as-switched"* models, to properly operate? If so, what is that calculated level of accuracy?

r. How will PG&E maintain the needed levels, of GIS database system accuracies, for the new ADMS systems, including D-SCADA, DMS, OMS, FLISR and "*as-switched"* models, to properly operate?

s. What guarantee can PG&E make that proper levels of GIS information, including any new requirements, will be maintained to properly support the functionality of the new ADMS systems, including D-SCADA, DMS, OMS, FLISR and "*as-switched"* models.

ANSWER 14

a. Yes, additional GIS data requirements must be fulfilled to enable the full functionality of PG&E's proposed ADMS.

b. PG&E's 2020 GRC request is focused on addressing data requirements related to Phase ID and Substation Asset Specification data, which PG&E has identified as the requirements most important for enabling the full functionality of an ADMS.

   PG&E discusses these additional GIS data requirements and makes a funding request to address these requirements under the project entitled "Distribution GIS Asset Data Improvement" in its 2020 GRC filing. For a full description of this project, please refer to Ex.-4, Ch. 19, WP pgs. 19-41 to 19-45.

c. Please refer to the cost table on Ex.-4, Ch. 19, WP pg. 19-44.

d. Once the Phase ID portion of the "Distribution GIS Asset Data Improvement" project discussed in Ex.-4, Ch.19 is completed, the results of a continuously operating phase identification prediction algorithm will be used to maintain accurate phasing information in PG&E's GIS system.

   Changes to Substation Asset Specification data are less frequent, but when changes do occur the data will be maintained through the standard processes outlined in the response to part l of this question.

e. PG&E anticipates there will be minimal-to-no ongoing costs associated with maintaining these data requirements.

f. No ongoing maintenance costs associated with these data requirements have been incorporated in PG&E's cost estimates for either its ADMS proposal or the "Distribution GIS Asset Data Improvement" project proposal. See also PG&E's response to part e, above.

g. If these data requirements are not maintained, the quality of power flow solutions within PG&E's ADMS will deteriorate and PG&E may not realize the full benefit of the grid optimization and automation applications that an ADMS enables, including automated switch plan development, Volt-Var Optimization, fully automated/model-based FLISR, constraint violation warnings on non-telemetered system points, and control/dispatch of DERs for mitigation of system constraints.

h. PG&E has not estimated the costs associated with not maintaining the additional GIS data requirements discussed in the "Distribution GIS Asset Data Improvement" project in Ex.-4, Ch.19.

i. PG&E has not measured the overall accuracy of its existing GIS database. This information cannot be determined without a comprehensive field inventory. See PG&E's response to part l, below for a discussion of how GIS data is validated and corrected.

j. Yes, processes that use GIS data have found discrepancies with the data that require corrections.

k. PG&E processes approximately 1,047 map correction requests from tools built into GIS viewers in an average month. In addition, PG&E operators create approximately 1,745 GIS tags per month.

l. PG&E uses two primary avenues to identify incorrect data in GIS: 1) Field employees submit map correction requests using tools built into the GIS viewers, or 2) Distribution Operators submit GIS tags in DMS for mapping issues they become aware of during the course of business.

   Once a GIS data error is identified through one of the avenues noted above, it is routed to PG&E's Electric Distribution Asset Data Maintenance department who make the necessary database updates in a verifiable and traceable process to ensure completeness and accuracy. Please refer to Ex.4, Ch.18 WP pg. 18-14 for PG&E's forecast associated with Electric Distribution Mapping activities in the 2020 GRC period.

   In addition to these ad-hoc updates, PG&E regularly looks for patterns in the types of GIS data errors encountered and will utilize logic-based scripts to implement data corrections en masse across the GIS database where appropriate.

   Finally, the Field Asset Inventory proposed in PG&E's 2020 GRC (refer to Ex.-4, Ch.18 WP pgs. 18-17 to 18-20) will improve the accuracy and completeness of PG&E's GIS data by correcting discrepancies found between assets in the field and PG&E's GIS records.

m. Errors in the existing GIS database can lead to problems and inaccurate reporting. For example, mis-assigned customers to transformers can cause outage prediction to show multiple transformers out of power when only one transformer is actually out. PG&E has implemented filtering processes of the GIS data to avoid these conditions, however not all data errors such as this can be resolved without updating the GIS itself to accurately portray field conditions.

n. Some of the types of operational problems that have occurred because of inaccurate GIS data include: incorrectly inferred outages, unintended de-energization of parts of the distribution grid due to equipment locations not matching GIS, longer field restoration times due to equipment locations not matching GIS, and inability to assess capacity on certain lines and equipment due to missing equipment property attributes that may affect load transfer decisions.

o. PG&E does not track costs associated with the correction of GIS data in a manner that allows for the requested information to be provided.

p. PG&E has not calculated a specific GIS data accuracy level required for ADMS and is not aware of any accepted industry standard that specifies a required level of GIS data accuracy for ADMS to properly operate. PG&E also has not specified a target GIS data accuracy level for PG&E's ADMS to properly operate.

   PG&E notes that neither the Phase ID nor Substation Asset Specification projects covered under the "Distribution GIS Asset Data Improvement" request in Ex.-4, Ch.19 aim to improve the accuracy level of existing GIS data; rather; these projects aim to add additional types of data to what is currently in GIS.

q. See PG&E's response to part p, above.

r. Please refer to PG&E's response to part d of this question for a description of maintenance practices associated with the new GIS data elements added from the "Distribution GIS Asset Data Improvement" project. Please refer to PG&E's response to part l of this question for a description of maintenance practices associated with existing GIS data.

s. PG&E objects to this question as vague, ambiguous, argumentative and calling for speculation. Subject to this objection, PG&E responds as follows:

   PG&E's response above explains how it addresses inconsistent data in GIS and makes improvements to the quality of that data.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	TURN_025-Q05		
PG&E File Name:	GRC-2020-PhI_DR_TURN_025-Q05		
Request Date:	May 22, 2019	Requester DR No.:	025
Date Sent:	June 6, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Quinn Nakayama	Requester:	Marcel Hawiger

SUBJECT: PG&E-04, CH. 19 (GRID MOD)

QUESTION 05

Refer to the confidential ADMS Major Project Business Case provided in response to DR TURN_013-001, "Executive Project Committee (EPC) Action Recommended" page 4, "Objective Statement", which states "ADMS will modernize PG&E's distribution control systems **to improve** cybersecurity, situational awareness, operational efficiency, and **Distributed Energy Resource (DER) integration capabilities** starting in July 2018 and completing the project closure by December 2024, for a high-case authorization not to exceed $484.7M."

a. Provide the number of outages that have occurred on the distribution system, as a result of DER related issues.

b. Provide the number of voltage complaints that have occurred, as a result of DER related issues.

c. Provide the number of customer complaints that have occurred associated with reverse power flows on the distribution system as a result of DER installations.

d. Provide the number of instances where PG&E was unable to integrate DER into its distribution system to date.

e. Describe each instance in which PG&E was unable to integrate DER into its distribution to date, including background of the DER involved, attempts PG&E made and/or approaches PG&E considered to integrate it, reasons why the DER could not be integrated, and other information PG&E considers relevant to the inability to integrate the DER in each instance.

ANSWER 05

a. PG&E does not track the number of outages that have occurred as a result of DER-related issues.

   Although an exact count of outages caused by DER-related issues cannot be provided, DER-related outages do sometimes occur on PG&E's system despite the robust interconnection review process designed to prevent these occurrences. If PG&E does not invest in solutions such as ADMS that facilitate

the integration of DERs onto the grid, these instances are expected to become more common, and more costly to prevent, as the penetration of DERs continues to rise in coming years.

b. PG&E does not currently track the number of voltage complaints that have occurred as a result of DER-related issues. However, pursuant to CPUC Resolution E-4898 Ordering Paragraph (OP) 5[1] and as discussed in PG&E Advice Letter 5395-E[2], PG&E is currently in the process of updating its voltage complaint tracking methods to include reporting capability on whether the voltage complaint is made by a DER customer.

   Although an exact count of voltage complaints caused by DER-related issues cannot be provided, DER-related voltage complaints do sometimes occur on PG&E's system despite the robust interconnection review process designed to prevent these occurrences. If PG&E does not invest in solutions such as ADMS that facilitate the integration of DERs onto the grid, these instances are expected to become more common, and more costly to prevent, as the penetration of DERs continues to rise in coming years.

c. PG&E does not track the number of customer complaints that have occurred as a result of DER-related reverse power flows.

d. To date, PG&E has never denied a DER application due to an inability to integrate the proposed DER into the distribution system. However, applicants do occasionally choose to withdraw or downsize their DER proposal if it will cause distribution system impacts that the applicant is unwilling to pay for.

   PG&E does not specifically track the number of DER interconnection requests that are withdrawn or downsized because the applicant is unwilling to pay for related grid upgrades. However, PG&E does track the number of DER interconnection requests that are withdrawn after failing an initial grid impact review. Although this statistic does not directly track the number of interconnection requests withdrawn *because* of the cost of related grid upgrades, it may provide an approximate annual count of these instances. Subject to this caveat, PG&E has averaged 105 DER interconnection requests withdrawn per year after failing an initial grid impact review.

e. As discussed in part d of this response, to date PG&E has never been unable to integrate a DER into its distribution system, but some DER proposals are withdrawn or downsized due to the cost of grid integration.

   The fact that PG&E has never been unable to integrate a DER into its distribution system does not diminish the need for investment in solutions such as ADMS that facilitate the integration of DERs onto the grid. As the penetration of DERs on the distribution system continues to rise over the coming years, PG&E anticipates that DER-related grid issues—including masked load, voltage and capacity violations, protection system miscoordination, and bi-directional power

[1] http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M213/K658/213658887.PDF

[2] https://www.pge.com/tariffs/assets/pdf/adviceletter/ELEC_5395-E.pdf

flow—will become more frequent and that the cost of integrating DERs into the distribution system will rise as DER integration capacity decreases.

Investments like ADMS that help facilitate the integration of DER are not just about avoidance of negative grid impacts from DER; these investments also lay a foundation upon which the full benefits from DER can be realized. For example, the real-time power flow modeling, load forecasting, and grid optimization capabilities provided by an ADMS are foundational to any future ability to proactively mitigate distribution system issues by controlling DER via a DERMS and/or to any future establishment of a market for distribution grid services.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	TURN_056-Q03		
PG&E File Name:	GRC-2020-PhI_DR_TURN_056-Q03		
Request Date:	June 20, 2019	Requester DR No.:	056
Date Sent:	July 3, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Nick Petrakis	Requester:	Marcel Hawiger

SUBJECT: EXHIBIT (PG&E-4) AND EXHIBIT (PG&E-7)

QUESTION 03

RE: Exhibit (PG&E-7), Ch. 8

Refer to PG&E Exh. 7, Chapter 8 testimony, page 8-41, which states "Since the 2017 GRC, PG&E has successfully completed a FAN pilot program in several Tier 1 substation locations."

a. Provide a list of questions the FAN pilot program was intended to answer.

b. Provide all plans, reports, summaries, examinations, outcomes, questions answered, and other documentation related to the FAN pilot program.

c. Did PG&E conduct any pilots or tests related to the use of third party, Low Power WAN technologies, such as Verizon's Cat M1, to satisfy PG&E's field area communications needs?

ANSWER 03

a. The primary purpose of the FAN pilot was to verify performance criteria, design parameters, and the technical feasibility of the selected technology. In addition, the pilot sought to gain understanding of implementation and resource requirements, architecture requirements, deployment issues and risks, standard installation practices, and other unknowns. See documents provide in response to subpart B below for more information.

b. PG&E objects to the request for "all plans, reports, summaries, examinations, outcomes, questions answers, and other documentation" on the grounds that it is unduly vague and potentially burdensome. Notwithstanding the foregoing, PG&E responds as follows:

PG&E did not produce any official reports on the results of the pilot. In this case, the pilot was not so much an R&D effort (like pilots in the EPIC program) as it was a deployment strategy to test the technology in a limited number of locations in order to validate capabilities and identify and resolve any major issues with the technology before deploying it more broadly.

That said, PG&E has attached the following key documents produced as part of the pilot implementations:

Attachment	Description
GRC-2020-PhI_TURN_056-Q03Atch01CONF	This document lists the detailed functional requirements for the FAN pilot deployments as well as the overall FAN.
GRC-2020-PhI_TURN_056-Q03Atch02CONF	This document lists the detailed non-functional requirements for the FAN pilot deployments as well as the overall FAN.
GRC-2020-PhI_TURN_056-Q03Atch03CONF	This is the solution blueprint for the FAN pilot deployments
GRC-2020-PhI_TURN_056-Q03Atch04CONF	This document lists the detailed functional requirements for the FAN pilot location 1 of 4
GRC-2020-PhI_TURN_056-Q03Atch05CONF	This document lists the detailed functional requirements for the FAN pilot location 2 of 4
GRC-2020-PhI_TURN_056-Q03Atch06CONF	This document lists the detailed functional requirements for the FAN pilot location 3 of 4
GRC-2020-PhI_TURN_056-Q03Atch07CONF	This document lists the detailed functional requirements for the FAN pilot location 4 of 4
GRC-2020-PhI_TURN_056-Q03Atch08CONF	This document lists the detailed test plan for the FAN pilot.
GRC-2020-PhI_TURN_056-Q03Atch09CONF	This document is a project update report for the 2016 FAN pilot project.
GRC-2020-PhI_TURN_056-Q03Atch10CONF	This document is a project update report for the 2015 FAN pilot project.
GRC-2020-PhI_TURN_056-Q03Atch11CONF	This document is a status report on the detailed test plan for the FAN pilot.
GRC-2020-PhI_TURN_056-Q03Atch12CONF	This document lists the detailed test results for the FAN pilot.

c. No, PG&E did not conduct any pilots or tests related to the use of third party, Low Power WAN technologies. See PG&E's response to GRC-2020-PhI_DR_TURN_017-Q01, subpart (b.) for a high-level evaluation of Low Power WAN technology and why PG&E does not currently consider the technology a viable option for PG&E use cases.

PACIFIC GAS AND ELECTRIC COMPANY
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Data Response

PG&E Data Request No.:	TURN_056-Q04		
PG&E File Name:	GRC-2020-PhI_DR_TURN_056-Q04		
Request Date:	June 20, 2019	Requester DR No.:	056
Date Sent:	July 3, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Nick Petrakis	Requester:	Marcel Hawiger

SUBJECT: EXHIBIT (PG&E-4) AND EXHIBIT (PG&E-7)

QUESTION 04

RE: Exhibit (PG&E-7), Ch. 8

Refer to PG&E Exh. 7, Chapter 8 testimony, page 8-42, which indicates $13.663 million in general FAN network capital, and workpaper page WP 8-68, which indicates and additional $34.763 million in FAN network capital related to IGP enablement.

a. What percent of PG&E's electric service territory will be served by the FAN completed with these amounts of capital?

b. What percent of PG&E's gas service territory will be served by the FAN completed with these amounts of capital?

c. How many field devices does PG&E estimate it will be able to connect with these amounts of capital?

d. What additional amount of capital does PG&E expect it will invest to complete the FAN serving its electric service territory?

e. What additional amount of capital does PG&E expect it will invest to complete the FAN serving its gas service territory?

f. How many additional field devices does PG&E estimate it will be able to connect with these additional amounts of capital?

ANSWER 04

a. PG&E does not measure FAN deployments in terms of service territory covered, but rather in terms of locations of FAN gateways and surrounding FAN meshes. For the capital amounts indicated, PG&E expects to deploy between 100 and 200 gateway locations with surrounding FAN meshes. A typical gateway location is designed to connect to FAN radios within a 7- to 10-mile radius. PG&E expects approximately 70-80% of FAN deployments will address Electric Operations locations/use-cases and another 5-10% will address Power Generation locations/use-cases. Because the FAN is a multi-purpose network, each mesh location will also have the capability support additional common use-cases as needed.

b. Please see response to subpart a above. PG&E expects approximately 10-15% of FAN deployments will address Gas Operations locations/use-cases. Because the FAN is a multi-purpose network, each mesh location will also have the capability support additional common use-cases as needed.

c. PG&E expects to deploy between 50 and 150 FAN radios per gateway location/mesh. About 70% of these are expected to connect directly to field devices; the remaining 30% or so serve as helper nodes that extend the range of the mesh. This amounts to between 3,500 and 21,000 devices, with actual deployments likely in the 8,000 to 15,000 range.

d. PG&E has not yet forecast FAN implementation costs beyond 2022, and the final number of deployments is heavily dependent on the number of devices the FAN will ultimately need to connect. PG&E currently expects to deploy an additional 100 to 250 FAN meshes beyond 2022 to reach a total of 200 to 350 locations. As indicated in subpart a above, PG&E expects approximately 70-80% of FAN deployments will address Electric Operations locations/use-cases and another 5-10% will address Power Generation locations/use-cases.

e. Please see response to subpart d above. As indicated in response to subpart b above, PG&E expects approximately 10-15% of FAN deployments will address Gas Operations locations/use-cases.

f. PG&E has not yet forecast FAN implementation costs beyond 2022. That said, PG&E expects the FAN will ultimately connect between 20,000 and 35,000 devices, with the potential to go as high as 50,000. This is ultimately dependent on business needs and demand across PG&E territory.

PACIFIC GAS AND ELECTRIC COMPANY
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Data Response

PG&E Data Request No.:	TURN_065-Q03		
PG&E File Name:	GRC-2020-PhI_DR_TURN_065-Q03		
Request Date:	July 1, 2019	Requester DR No.:	065
Date Sent:	July 10, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Quinn Nakayama	Requester:	Marcel Hawiger

SUBJECT: PG&E-04, CHAPTER 19

QUESTION 03

Please refer to PG&E-04, ch. 19, Workpaper Table 19-13: Assume that you are replacing the present RT_SCADA system, including all of the P2P testing for the existing RTSCADA points, and you are not including any new SCADA points or testing of those points associated with the proposed D-SCADA that would support a new IGP system, including ADMS, OMS, DMS, and associated communications systems. i.e. that you are replacing only the existing SCADA system.

a. In row 6 “Distribution SCADA and DMS,” please provide a breakdown of the dollar amounts in the columns for each year “2018 thru 2022” indicating the portions of these dollars that would be required for the new ADMS and associated systems, and which portions would be required for a SCADA only replacement.

b. In row 9 “OMS,” please provide a breakdown of the dollar amounts in the columns for each year “2018 thru 2022” indicating the portions of these dollars that would be required for the new ADMS and associated systems, and which portions would be required for a SCADA only replacement.

c. In row 12 “Distribution SCADA Point to Point Testing and Integration,” please provide a breakdown of the dollar amounts in the columns for each year “2018 thru 2022” indicating the portions of these dollars that would be required for the new ADMS and associated systems, and which portions would be required for a SCADA only replacement.

d. In row 15 “Distribution SCADA Display Migration,” please provide a breakdown of the dollar amounts in the columns for each year “2018 thru 2022” indicating the portions of these dollars that would be required for the new ADMS and associated systems, and which portions would be required for a SCADA only replacement.

ANSWER 03

a.) PG&E objects to TURN’s request to provide costs associated with Row 6 of PG&E-04, Ch. 19, Workpaper Table 19-13 under the alternate project scenario described in TURN’s question as unduly burdensome because it would require

PG&E to forecast costs associated with a hypothetical program that PG&E is not proposing within this general rate case.

Without waving its right to object to the use or admissibility of its response, PG&E responds as follows:

The “Distribution SCADA and DMS” subcomponent of PG&E’s GRC ADMS cost forecast covers the cost of integrating existing SCADA and DMS functionality within the new ADMS application and enabling advanced applications. This full scope of work would not be required under the scenario described in the question, but a component of the work related to design and commissioning of a new SCADA database would still be needed.

b.) PG&E objects to TURN’s request to provide costs associated with Row 9 of PG&E-04, Ch. 19, Workpaper Table 19-13 under the alternate project scenario described in TURN’s question as unduly burdensome because it would require PG&E to forecast costs associated with a hypothetical program that PG&E is not proposing within this general rate case.

Without waving its right to object to the use or admissibility of its response, PG&E responds as follows:

The “OMS” subprogram within PG&E’s GRC ADMS cost forecast covers the cost of integrating existing OMS functionality within the new ADMS application. This scope of work would not be required under the scenario described in the question.

c.) PG&E objects to TURN’s request to provide costs associated with Row 12 of PG&E-04, Ch. 19, Workpaper Table 19-13 under the alternate project scenario described in TURN’s question as unduly burdensome because it would require PG&E to forecast costs associated with a hypothetical program that PG&E is not proposing within this general rate case.

Without waving its right to object to the use or admissibility of its response, PG&E responds as follows:

The “Distribution SCADA Point to Point Testing” subprogram within PG&E’s GRC ADMS cost forecast covers the cost of the point-to-point testing required for quality assurance testing of the new SCADA database. This full scope of work would be required under the scenario described in the question.

d.) PG&E objects to TURN’s request to provide costs associated with Row 15 of PG&E-04, Ch. 19, Workpaper Table 19-13 under the alternate project scenario described in TURN’s question as unduly burdensome because it would require PG&E to forecast costs associated with a hypothetical program that PG&E is not proposing within this general rate case.

Without waving its right to object to the use or admissibility of its response, PG&E responds as follows:

The “Distribution SCADA Display Migration” subprogram within PG&E’s GRC ADMS cost forecast covers the cost of building operator displays within the new SCADA software that conforms to PG&E’s requirements and standards. This full scope of work would be required under the scenario described in the question.

PACIFIC GAS AND ELECTRIC COMPANY
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Data Response

PG&E Data Request No.:	TURN_056-Q05		
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Request Date:	June 20, 2019	Requester DR No.:	056
Date Sent:	July 3, 2019	Requesting Party:	The Utility Reform Network
PG&E Witness:	Nick Petrakis	Requester:	Marcel Hawiger

SUBJECT: EXHIBIT (PG&E-4) AND EXHIBIT (PG&E-7)

QUESTION 05

RE: Exhibit (PG&E-7), Ch. 8

Refer to PG&E Exh. 7, Chapter 8 workpapers, page WP 8-68, in which indicates in the table "Major Project Spending Estimates" that PG&E proposes to spend $16.6 million in capital to conduct a converged computing platform proof of concept and pilot.

a. Provide a list of questions the proof of concept and pilot are intended to answer.
b. Provide physical and logical diagrams of typical PG&E substation IT and communications assets and operations today.
c. Provide physical and logical diagrams of likely PG&E substation IT and communications assets and operations in the future if the proof of concept and pilot are successful.
d. Provide the details of any plans PG&E has to test the use of third party, Low Power WAN technologies, such as Verizon's Cat M1, in this or any other proof of concept testing or pilots PG&E's IT function will conduct from 2019 through 2022.
e. Explain why spending on proofs of concept and pilots are considered capital spending and not operations and maintenance spending.

ANSWER 05

a. The primary purpose of the converged compute platform proof of concept and pilot is to assess the performance and technical feasibility of the selected technology. In addition, the proof of concept and pilot seeks to gain understanding of implementation and resource requirements, technical architecture and security requirements, deployment issues and risks, standard installation practices, and other unknowns. Potential cost savings versus the current state design will also be assessed.

b. See page 1 of GRC-2020-PhI_DR_TURN_056-Q05Atch01CONF

c. See page 2 of GRC-2020-PhI_DR_TURN_056-Q05Atch01CONF

d. At this time, PG&E's IT function has no plans to test third-party, Low Power WAN technologies in any proof of concept or pilot. As discussed in PG&E's response to GRC-2020-PhI_DR_TURN_017-Q01, subpart (b.), PG&E does not currently consider the technology a viable option for PG&E use cases. That said, PG&E will continue to monitor the technology as it matures and may reconsider it at a future date.

e. Per PG&E's Capital Accounting guidance on "Software – Research and Development Costs," hardware pilots and proofs of concept that are approved to proceed into production can be considered capital. In this instance, PG&E expects the solution will proceed into production. For a description of this guidance, see GRC-2020-PhI_DR_TURN_056-Q05Atch02.

PACIFIC GAS AND ELECTRIC COMPANY

CHAPTER 15

ATTACHMENT E

PG&E'S ACTIVITY BASED FORECASTING METHODOLOGY

PACIFIC GAS AND ELECTRIC COMPANY

CHAPTER 2

ELECTRIC DISTRIBUTION FORECAST AND INVESTMENT PLANNING

PACIFIC GAS AND ELECTRIC COMPANY
CHAPTER 2
ELECTRIC DISTRIBUTION FORECAST
AND INVESTMENT PLANNING

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CHAPTER 2
ELECTRIC DISTRIBUTION FORECAST
AND INVESTMENT PLANNING

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key areas. The primary increases to EO's POR targets as approved by PG&E's Operating Plan Committee (OPC)[17] are:

- Field Metering added additional funding to address gas meter module failures;
- EO Operational Management and Operational Support had increases for wildfire mitigation costs;
- Acceleration of the rebuild of Butte County in the Community Rebuild Program; and
- EO NB/WRO added additional funding to align with updated economic models and comply with a California Public Utilities Commission (Commission)-approved settlement.:

E. Cost Forecasting Approach

1. Cost Forecasting Methods

The forecast costs presented in Chapters 4 to 23 of this Electric Distribution exhibit generally include four cost types:

a) Unit costs for work that is recorded and forecast by unit (e.g., miles of conductor hardened, number of poles inspected);

b) Non-unitized costs for work that does not lend itself to unit cost estimation and, therefore, is recorded and forecast at a total MWC/MAT level (e.g., emergency response work, new programs for which there are no historical costs);

c) Project based forecasts for work that is forecast at the individual project level; and

d) Costs that are calculated by other methods (e.g., IT projects, work at the request of others).

---

[17] PG&E's OPC is responsible for governance of the Operating Rhythm, an integrated enterprise-wide structure focused on planning, performance management and governance in order to provide clear line of sight to performance execution and accountability. The OPC is comprised of PG&E's senior leaders including the Chief Executive Officer, Chief Financial Officer, Chief Risk Officer, and Chief Operating Officer. See Exhibit (PG&E-2), Ch. 3 for more information about the Operating Rhythm and OPC.

The forecasting method for each of these cost types is described below.[18] Additional information is provided in the individual forecast chapters.

The 2021 forecast amounts in PG&E's 2023 GRC presentation are based on EO's approved 2021 budget. The budget represents a balanced portfolio that prioritizes risk mitigation work, compliance work, and regulatory and other commitments while staying within corporate capital and expense targets.

a. Method for Forecasting Unit Cost Work

Much of the work forecast in Electric Distribution is based on the costs to complete a unit of work. The unit cost forecasts are mostly presented at the MAT code level where there is a single unit cost for each MAT. For certain types of work the unit costs are presented at MWC level (e.g., field metering). In other cases, there are very different types of work in a single MAT that cannot be represented by a single unit cost. In these cases, PG&E develops a unit cost for each unique type of work, based on historical averages and incorporating planned changes to the way the work will be conducted and opportunities to reduce unit costs.

b. Method for Forecasting Non-Unitized Work

Certain MWCs and MAT codes in the Electric Distribution portfolio are not tracked at a unit-cost level. For example, the costs recorded to MAT code 05 (Tools and Equipment) are for miscellaneous capital tools and equipment used on Electric Distribution projects across PG&E's service area. Capital tools and equipment are purchased as needed based on the different types of work occurring, and to replace tools and equipment that are worn or broken. The costs forecast in this MAT code do not lend themselves to the unit-cost forecasting methodology because tools and equipment are considered more of a commodity type

[18] PG&E's 2022 forecast for base electric distribution expense work (work that is not included in balancing memorandum accounts) is, for the most part, equal to the 2021 forecast. The 2022 forecast for non-base expense and capital work was developed as described in Section E.

item as opposed to specific numbers and types of tools and equipment that can be reasonably forecast.

PG&E forecasts non-unitized work, also referred to as program work, based on historic costs. Since the work in the program is generally the same from year-to-year, PG&E uses the historic spend as a basis for the forecast program work. Generally, program cost forecasts are based on two prior years of historic spend, adjusted for known program changes, and escalates the forecast using the approved GRC forecast rates.

c. Method for Forecasting Project Based Work

PG&E's forecast includes individual projects such as adding capacity in strategic locations to improve system flexibility and limit the number of customers on a circuit. These individual project forecasts are based on individual project estimates using historic cost data from similar projects, vendor quotes, and/or engineering estimates.

d. Methods for Forecasting Other Work

The following three types of cost forecasts in PG&E's Electric Distribution portfolio are calculated using different forecasting methods because the type of work does not lend itself to any of the methods described above.

1) Information Technology (IT) Projects – The IT cost forecast for Electric Distribution is developed as a bottom-up forecast for each IT project forecast in the rate case. PG&E uses its Project Estimating Tool (PET) to develop each project forecast. The PET and IT forecasting methodology are discussed in Exhibit (PG&E-7), Chapter 8.
2) NB/WRO – The NB and WRO forecasts for Electric Distribution are based on economic and government spending indices and historic PG&E cost data. PG&E also works with a leading independent real estate economics consulting firm which has developed a model to forecast certain portions of the NB/WRO portfolio. More information about the NB/WRO forecasting methodology is included in Exhibit (PG&E-4), Chapter 18.

3) NB/WRO – State Infrastructure Projects – PG&E forecasts costs for large-scale projects with schedules and scope dictated by third parties, typically state and local governments. An individual forecast for each project is developed based on the best information available at the time and includes varying levels of cost assumptions. More information about the NB/WRO State Infrastructure Projects is included in Exhibit (PG&E-4), Chapter 18.

2. Escalation Calculation

Forecasts in this exhibit are escalated. For expense, PG&E developed a blended escalation rate between Labor and Non-Labor, using escalation rates developed by Global Insight,[19] and applied it to all electric distribution expense forecasts (with exceptions noted below). For capital, PG&E used a combined Labor and Non-Labor escalation rate developed by Global Insight and applied it to all electric distribution capital forecasts (again with exceptions).

Two program areas, Emergency Preparedness and Response (EP&R) and VM, have a significantly different mix of work from other programs and their escalation rates were calculated accordingly.

EP&R work is considered Administrative and General (A&G) work and is primarily labor, so PG&E used Global Insight's A&G-related escalation factors to calculate a blended escalation rate for this work. For capital components of EP&R costs, PG&E used a combined Labor and Non-Labor common plant escalation rate instead of the Labor and Non-Labor electric distribution only escalation rate.

Most VM work is performed by contractors, who are treated as a Non-Labor expense. Therefore, PG&E calculated a blended escalation rate for VM based on a Labor and Non-Labor split specific to the expense forecast for the VM Program.

Details of PG&E's methodology for calculation of escalation rates are provided in workpapers.[20] For a description of escalation calculations for IT projects included in this exhibit, see Exhibit (PG&E-7), Chapter 8.

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19 See Exhibit (PG&E-12), Chapter 3.

20 See Exhibit (PG&E-4), WP 2-37.

F. Compliance With Section 5.2 of the 2020 GRC Settlement "Deferred Work Principles"

The purpose of this Section is to describe how Electric Operations manages its budget and balances its portfolio of rate case funded work over the rate case period to ensure that all safety and reliability work is performed. The Section also presents the results of Electric Operations' deferred work analysis as required by Section 5.2 of the 2020 GRC Settlement "Deferred Work Principles." The section is organized as follows:

- Section F.1 – Balancing Electric Operations Portfolio of Work;
- Section F.2 – Addressing Changing Priorities;
- Section F.3 – Analysis of "Deferred Work";
- Section F.4 – Showing Required for Deferred Work; and
- Section F.5 – Consistency of EO's Funding Request with the Six Principles of Deferred Work.

1. Balancing Electric Operations Portfolio of Work

In Section D, PG&E describes the Electric Operations Investment Planning process which leads to an annual Electric Operations budget that is approved by the executive leadership team before the budget year begins. Balancing the Electric Operations portfolio includes allocating funding to the highest priority work, mandatory work, and new work by identifying programs with available funding. Higher priority work is determined through the processes described in Section D above and/or addressing changing priorities across the Electric Operations portfolio.

2. Addressing Changing Priorities

PG&E's 2020 GRC presented forecasts for a portfolio of work which included substantial investments for the Community Wildfire Safety Program and the foundation of an Integrated Grid Platform, while continuing to help connect customers to the grid and maintain reliability. In late 2018, after the 2020 GRC was filed, PG&E began implementing the WSIP, a risk-based approach to inspections of overhead distribution assets and substations in high fire risk areas of its service territory. As described in PG&E's Updated

Progress Report – Wildfire Mitigation Plan,[21] the WSIP resulted in essential findings about components in HFTD areas that could pose a risk of fire ignition. These enhanced inspections and resulting maintenance tags, which were not included in the 2020 GRC forecast or imputed adopted amounts, required PG&E to reprioritize some investments planned in the 2020 GRC period in order to complete this higher priority risk mitigation work. Additionally, building on the WSIP foundation, PG&E is incorporating the enhanced inspection processes and tools into routine compliance inspection and maintenance and using risk-informed maintenance cycles going forward.

2020 presented additional challenges for work execution due to the global COVID-19 pandemic. In order to protect the health and safety of our employees, contractors and the general public, Electric Operations developed COVID-19 work plan guidelines describing work that should continue and work types that should be paused during shelter-in-place protocols. These work plan guidelines prioritized critical work such as emergency response, PSPS and wildfire mitigation work, critical new business needs, and critical operating equipment work. As noted in Chapter 1, EO will continue to work throughout this GRC cycle to complete the work that was paused due to shelter-in-place guidelines.

As has been common in the last few years, 2020 had a devastating fire season. In 2020, PG&E conducted six PSPS events. While PG&E succeeded in making PSPS events shorter by reducing the average time to restore power once the severe weather cleared, these events required crews to inspect lines for damage prior to restoring power.

This mix of factors during the first year of the 2020 GRC cycle affected the planned work for 2020 and subsequent years. As shown in Table 2-2 below, between 2020 and 2022, across the entire Electric Distribution portfolio of work, PG&E expects to spend:

- Approximately $6.3 billion in expense, which is $3.2 billion more than the imputed amount for expense projects and programs;[22] and

---

21 Rulemaking (R.) 18-10-007, PG&E's Updated Progress Report – Wildfire Mitigation Plan (Jan. 15, 2020), pp. 3, 12, 13.

22 See Exhibit (PG&E-4), WP 2-35, line 60.

PACIFIC GAS AND ELECTRIC COMPANY

CHAPTER 15

ATTACHMENT F

WILDFIRE COSTS DUE TO ENHANCED INSPECTIONS PROGRAM

PG&E Request

	Expense	Capital
Ch 2	$133,391	$0
Ch 3	$3,664	$33,986
Ch 4	$66,519	$858,424
Ch 5	$109,030	$386,871
Subtotals	$312,604	$1,279,281
Total Request	$723,777	$1,525,344
%	43%	84%

Exp and Cap Subtotal	$1,591,885
Exp and Cap Request	$2,249,121
Exp and Cap %	71%

Adjustments*

	Expense	Capital
Ch 4 Pole Loading	$52,740	$3,250
Ch 4 Intrusive Inspect	$17,049	$0
Ch 5 Bird Safe	$208	$14
Ch 5 COE	$1,789	$32,277
Ch 5 Maintenance	$2,881	$1,224
Ch 5 Idle Facilities	$0	$8,417
Subtotals	$74,667	$45,182
Adjusted Request	$237,937	$1,234,099
%	33%	81%

ADJUSTED:	
Exp and Cap Subtotal	$1,472,036
Exp and Cap Request	$2,249,121
Exp and Cap %	65%

*to remove costs not due to inspections

Chapter	Program	Due to Inpsections?
2	Overhead Patrols	Yes
2	Detailed Overhead Inspections	Yes
2	Overhead Infrared Inspections	Yes
2	Inspection Support Costs	Yes
3	Emergency Repair of Damaged Facilities	Yes
4	Pole Loading and Wind Loading Analysis	No
4	Intrusive Inspection & Pole Restoration Program	No
4	Pole Replacement Program	Yes
5	Overhead Non Pole Corrective Maintenance	Yes
5	Bird Safe Installation, Replacements, and Retrofits	No
5	Overhead Critical Operating Equipment	No
5	Maintenance Support Costs	No
5	Idle Facilities Removal	No

PACIFIC GAS AND ELECTRIC COMPANY

CHAPTER 15

ATTACHMENT G

PG&E'S RESPONSE TO DATA REQUEST

CALADVOCATES_055-Q001REV01, DATED MARCH 6, 2024

PACIFIC GAS AND ELECTRIC COMPANY
Wildfire and Gas Safety Costs
Application 23-06-008
Data Response

PG&E Data Request No.:	CalAdvocates_055-Q001		
PG&E File Name:	WildfireandGasSafetyCosts_DR_CalAdvocates_055-Q001Rev01		
Request Date:	January 10, 2024	Requester DR No.:	PubAdv-PGE-055-ECN
Date Sent:	January 31, 2024 Rev01: March 6, 2024	Requesting Party:	Public Advocates Office
PG&E Witness:	Heather Duncan	Requester:	Emily Chen

SUBJECT: OVERHEAD ELECTRIC DISTRIBUTION ASSET INSPECTIONS

QUESTION 001

Similar to PG&E's response to Cal Advocates data request PubAdv-PGE-019-ECN, Q2, provide the transaction level line-item breakdown for the 2020 Total Spending amount of $0.971 million for MAT IG#. Each line item/entry should provide the description of the program/activity, MAT code, and associated expense adding up to $0.971 million.

ANSWER 001 REVISION 01

Please see attachment *"WildfireandGasSafetyCosts_DR_CalAdvocates_055-Q001Rev01Atch01.xlsx"* for the line-item detail report of the 2020 total spending amount for MAT IG# in the amount of $0.971 million relating to Overhead Electric Distribution Asset Inspections.

Please note that the Balancing Account RCC field (BARCC) in the line-item reports is an indicator if the current year (e.g., 2024) costs for the specific orders included in the reports are associated with a balancing or memorandum account at the time the reports are generated from SAP. This BARCC field is not the appropriate indicator for a historical mapping of costs of the orders (e.g., 2020) to a balancing or memorandum account. The memorandum account information provided in PG&E's testimony reflect the appropriate memorandum account information for costs at issue. As such, we removed the BARCC values from the line-item reports attached that were generated in January 2024 from the SAP system to avoid confusion.

ATTACHMENT

WildfireandGasSafetyCosts_DR_CalAdvocates_055-Q001Rev01Atch01.xlsx

ANSWER 001

Please see attachment *"WildfireandGasSafetyCosts_DR_CalAdvocates_055-Q001_Atch01.xlsx"* for the line-item detail report of the 2020 total spending amount for MAT IG# in the amount of $0.971 million relating to Overhead Electric Distribution Asset Inspections.

Please note that the Balancing Account RCC field (Column C) is an indicator if costs are associated with any balancing or memorandum account. This field can only reflect the most current mapping and not the historical mapping. Order 5056849 was re-mapped in December 2023 from WMPMA to "PGE1/#" after this Application is filed due to the implementation of the 2023 GRC Decision (issued on November 17, 2023), effective retroactively January 1, 2023. The 2023 GRC Decision authorized wildfire mitigation activities starting 2023 through 2026 to be recorded under accounts such as the WMBA or in routine/baseline GRC scope instead of the wildfire memorandum accounts (WMPMA or FRMMA). The 2023 GRC decision doesn't impact the recording or cost recovery of the wildfire activities incurred prior to 2023, which are the costs that PG&E is seeking cost recovery for in this proceeding.

ATTACHMENT

WildfireandGasSafetyCosts_DR_CalAdvocates_055-Q001Atch01.xlsx

PACIFIC GAS AND ELECTRIC COMPANY

CHAPTER 15

ATTACHMENT H

PG&E'S 2022 WILDFIRE MITIGATION PLAN UPDATE – REVISED

Pacific Gas and Electric Company ™

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July 26, 2022

Via E-Mail
melissa.semcer@energysafety.ca.gov

Melissa Semcer, Deputy Director
Office of Energy Infrastructure Safety
California Natural Resources Agency
715 P Street, 20th Floor
Sacramento, CA 95814

Re: PG&E 2022 Wildfire Mitigation Plan – Final Revision Notice Responses (Docket #2022-WMPs)

Dear Deputy Director Semcer:

In compliance with The Office of Energy Infrastructure Safety's (Energy Safety) Revision Notice for Pacific Gas and Electric Company's 2022 Wildfire Mitigation Plan Update (Revision Notice), we are providing responses to the following Critical Issues:

- RN-PG&E-22-04: PG&E does not provide planned undergrounding locations beyond 2023, nor adequately demonstrate that it is currently prepared to meet its ambitious undergrounding goals; and,

- RN-PG&E-22-09: PG&E has failed to provide plans to mature in certain vegetation management capabilities

In addition to our Critical Issue responses, we are providing the following documents in response to Energy Safety's request:

- A revised version of our 2022 Wildfire Mitigation Plan (2022 WMP) that includes all changes resulting from the Revision Notice responses, in both a redlined and a clean version of the document.

- A single updated WMP and auxiliary Excel file updating tables required in the WMP submissions that incorporates all required changes across all Critical Issues and

submitted errata. The Excel file includes a clean version of the file and a change log that documents all adjustments to the file.

Consistent with the Revision Notice direction, we are submitting these items to the 2022 Wildfire Mitigation Plan Updates Docket (#2022-WMPs) and to the California Department of Forestry and Fire Protection.

Below, we provide additional information and context relating to some of the items being submitted today with the 2022 WMP.

First, we have incorporated each of the thirteen Critical Issues identified in the Revision Notice into the 2022 WMP. Following the Table of Figures, we include a table identifying where each Critical Issue response has been incorporated. In several instances, we have created new sections (*e.g*. Sections 7.3.4.17 to 7.3.4.19) to include Critical Issue responses into the relevant portion of the 2022 WMP. The new sections are not initiatives, but rather additional sections to the 2022 WMP where the Critical Issue response appeared to fit most appropriately.

Second, in addition to addressing the Critical Issues, we have included in the 2022 WMP changes to reflect the four errata we previously submitted since February 25, 2022. These changes are included in the red-line and clean version of the 2022 WMP that we are providing today. Changes made from the four errata are included in Attachment A to this cover letter.

Third, we have revised selected portions of the 2022 WMP in light of information presented in response to the thirteen Critical Issues raised by Energy Safety. These changes are included in the red-line and clean version of the 2022 WMP.

Fourth, some of the responses to Critical Issues required new attachments to the 2022 WMP. We include those new attachments with the submission of our 2022 WMP. Our submission also includes any original attachments that have been revised as a result of the Critical Issues raised by Energy Safety. Updates to attachments have been identified in the change log.

We appreciate Energy Safety's careful review of our 2022 WMP. Please let us know if you need any additional materials or clarifications.

Sincerely,

/s/ Jay Leyno

Jay Leyno

Cc: California Department of Forestry and Fire Protection
(CALFIREUtilityFireMitigationUnit@fire.ca.gov)
2022 Wildfire Mitigation Plan Updates Docket (#2022-WMPs)

ATTACHMENT A
ERRATA INCORPORATED INTO 2022 WMP[1]

	Issue	Location in WMP	Source
1	Data Entry Error	2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch01_R1 (Table 2)	3/18/2022 Errata
2	Data Entry / Transposing Errors (multiple)	2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch01_R1 (Table 12)	3/18/2022 Errata
3	RSE Score / Financial Correction (multiple)	2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch06_R1 (Section 7.3.5.2)	3/31/2022 Errata
4	KMZ File Mapping Error	2022-02-25_PGE_2022_WMP-Update_R0_Section 8.6_Atch01_R1	3/31/2022 Errata
5	Enhanced Powerline Safety Settings language	Section 7.3.6.8	3/31/2022 Errata
6	Update to Values (multiple)	Figure PG&E-ES-2: Key Quantitative Commitment Results	3/31/2022 Errata
7	New and Emerging Technology: Footnote Error	Section 7.1.E	4/25/2022 Errata
8	Target Language Update for 7.3.5.2	Table PG&E-5.3-1(A)	4/25/2022 Errata
9	Target Language Update for 7.3.5.2	Section 7.3.5.2	4/25/2022 Errata
10	Enhanced Powerline Safety Settings	Section 5.3.A	4/29/2022 Errata
11	Enhanced Powerline Safety Settings	Section 7.3.6.8	4/29/2022 Errata

[1] Please note that this table does not include: (1) additional information included in the 2022 WMP in response to the Revision Notice which is identified in Table of Revision Notice below the Table of Figures; and (2) changes to the WMP tables resulting from our Revision Notice responses, which are included in a separate change log.

2022 Wildfire Mitigation Plan Update – Revised











Pacific Gas and Electric Company®

July 26, 2022

PACIFIC GAS AND ELECTRIC COMPANY
2022 WILDFIRE MITIGATION PLAN

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PACIFIC GAS AND ELECTRIC COMPANY
2022 WILDFIRE MITIGATION PLAN

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RN-PG&E-22-01	PG&E has not adequately documented the causes of, or direct lessons learned from, PG&E ignited catastrophic wildfires	For each PG&E-ignited catastrophic wildfire (greater than 500 acres) since 2017, PG&E must: a) List the cause(s) of each catastrophic wildfire and any associated lessons learned, and b) Detail the specific measures PG&E is taking to i) directly mitigate the causes of past PG&E-ignited catastrophic wildfires, and ii) integrate lessons learned from past PG&E-ignited wildfires into its wildfire mitigation strategy.	Section 4.1(h)
RN-PG&E-22-02	PG&E did not report on the amount of work being completed in top-risk areas	PG&E must provide an update of Table 5.3-1(A) with top-risk percentages based solely on risk model output. a) The revised table must specifically provide the percentage of each type of work being completed in the top-risk circuits defined by risk model outputs. This must be done without conflating the percentages of top-risk circuits with other criteria, including PSPS-impacted locations, fire rebuild projects, and PSS-identified locations. b) Separate from Table 5.3-1(A), PG&E must provide information to demonstrate that PSPS-impacted locations are correlated with the top risk.	Section 5.3
RN-PG&E-22-03	PG&E is not adequately focusing grid hardening work, particularly undergrounding, on highest-risk areas based on risk model output	1. PG&E must revise its system hardening plan to adequately demonstrate prioritization based on highest-risk areas. PG&E must provide details of, and commit to, a more aggressive 2022–2024 goal of locating undergrounding in its top 20 percent risk-ranked circuits, on par with its peers. The undergrounding goal must not include any undergrounding associated with fire rebuild miles. 2. If PG&E takes any additional risks into account when developing this more aggressive undergrounding goal, aside from those already considered as part of the risk model output, PG&E must: a) Identify the percentage of undergrounding work that will be driven by these additional risk categories (i.e., PSPS, open work tags, Public Safety Specialist selected, etc.)	Section 7.3.3.16

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Critical Issue No.	Critical Issue Title	Required Remedies	Location of PG&E's Response
		b) Explain why PG&E's existing risk model output does not sufficiently cover these additional risks.	
RN-PG&E-22-04	PG&E does not provide planned undergrounding locations beyond 2023 and does not adequately demonstrate that it is currently prepared to meet its ambitious undergrounding goals	1. PG&E must provide an update of its planned undergrounding projects in 2024, following a similar format as PG&E-21-14 from the 2021 WMP Final Action Statement. This should be in the form of a spreadsheet with the following information: • Location • Status of the project (scoping, design permitting, etc.) • Relevant Circuit Protection Zones (CPZs)/Risk Score • Circuit ranking based on 2021, 2022, and 2023 risk model output • Measured effectiveness of ignition risk reduction projected to result from undergrounding at that circuit segment • Planned length • Risk-type identified for prioritization of the project (top 20 percent of risk buydown curve, fire rebuild, PSPS mitigation, public safety specialist identified, or non-risk related, or combination of the proceeding). 2. PG&E must include a timeline for the frequency with which it will determine undergrounding mileage and locations based on updated risk model output, factoring in RSE comparison with other initiatives. a) The timeline must continue past 2024. b) If the above information for the targeted 400 miles in 2023 and 800 miles in 2024 is not available, PG&E must i) provide justification as to why it is unable to provide any of the missing information and ii) provide a timeline for when the information will be available.	Section 7.3.3.16 Attachments: 2022-07-26_PGE_22-04_RNR_R3_Atch01CONF, or 2022-07-26_PGE_22-04_RNR_R3_Atch01_Redacted

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Critical Issue No.	Critical Issue Title	Required Remedies	Location of PG&E's Response
RN-PG&E-22-05	PG&E has a significant backlog of repairs and needs a more aggressive plan to address the poor health of its infrastructure	1. PG&E must create a plan that demonstrates consistent progress on reducing the number of open tags and improve the health of its infrastructure. a) To ensure that PG&E is reducing its backlog of work orders, PG&E must have a plan to complete more remediations than findings found. 2. PG&E must provide a resource plan, including timeline and quantitative targets for either a number or percentage of tags PG&E plans to resolve per quarter for the remainder of 2022 as well as 2023. a) The plan must include a description of how PG&E prioritizes completion based on risk analysis and modeling and where resources are being diverted from other efforts, if applicable. 3. PG&E must also provide a spreadsheet of all open work orders as of the date of its response to this Revision Notice that were generated in HFTD as well as all remediations in HFTD that have been completed in 2021. a) This data must include: • Date work order was generated • Priority of Work Order • HFTD Tier • Remediation Due Date • Date Remediation Completed (if applicable) • Latitude • Longitude	Section 7.3.4.17 Attachments: 2022-07-11_PGE_22-05_RNR_R2_Atch01 2022-07-11_PGE_22-05_RNR_R2_Atch02 2022-07-11_PGE_22-05_RNR_R2_Atch03 2022-07-11_PGE_22-05_RNR_R2_Atch04 2022-07-11_PGE_22-05_RNR_R2_Atch05 2022-07-11_PGE_22-05_RNR_R2_Atch06 2022-07-11_PGE_22-05_RNR_R2_Atch07
RN-PG&E-22-06	PG&E does not sufficiently explain its increase in distribution-level ignitions from equipment failure,	1. PG&E must provide a plan to address increases in ignitions from equipment failures categorized by equipment type, which must include the following: a) Conductors b) Switches c) Crossarms	Section 7.3.4.18

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Critical Issue No.	Critical Issue Title	Required Remedies	Location of PG&E's Response
	nor provide a remediation plan	d) Reclosers e) Connection devices 2. The plan must include any additional efforts, if any, PG&E will undertake that are informed by a root cause analysis outside those efforts PG&E completes as part of its routine maintenance program or as part of program-level WMP initiatives. a) As applicable, PG&E must include descriptions of root analyses completed by equipment type and explain any trends that inform changes to its inspections and maintenance programs. b) If such root cause analyses have not already been performed, PG&E must explain why, as well as how it has otherwise identified trends and reoccurring issues. 3. PG&E must explain why it does not predict decreases in ignitions for equipment failures from 2022 to 2023, broken down by equipment type. 4. PG&E must also explain how mitigations it is implementing for all equipment types affect predicted ignition rates.	
RN-PG&E-22-07	PG&E's ignition projections do not account for its ignition mitigation measures	1. PG&E must revise and resubmit Table 7.2 from PG&E's 2022 Update to project 2022 and 2023 ignitions factoring in risk reduction benefits of mitigation measures, including (but not limited to) EPSS, undergrounding, and covered conductor. 2. PG&E must also provide a narrative description for what factors are considered when calculating ignition projections, inclusive of WMP mitigation measure implementation, the weights of such factors and effects on projected ignitions.	Section 4.3 Attachments: 2022-06-27_PGE_22-07_RNR_R1_Atch01 2022-06-27_PGE_22-07_RNR_R1_Atch02
RN-PG&E-22-08	PG&E has high find and failure rates in its quality assurance and quality	PG&E must explain actions taken to improve its quality control processes. Specifically, PG&E must:	Section 7.3.4.19

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Critical Issue No.	Critical Issue Title	Required Remedies	Location of PG&E's Response
	control of asset inspections	a) For all listed actions to increase the quality of its asset inspections, provide an update on progress and timeline for implementation. b) Provide quarterly quantitative asset management QA/QC goals for both findings and reducing failure rates for the remainder of 2022 and 2023. c) Explain whether there is a failure rate threshold at which PG&E will take remedial or disciplinary action on an inspector. If so, provide that threshold and describe the action that PG&E takes to address inspectors with high failure rates. d) Provide a detailed description of how PG&E escalates non-adherence to asset inspections processes and procedures. e) Provide actions to improve training for both internal inspectors and contractors in PG&E's asset inspection and management program based on repeat QA/QC findings. f) Provide an update on PG&E's QA/QC findings and failure rates for asset inspections completed since the 2022 WMP Update filing.	
RN-PG&E-22-09	PG&E has failed to provide plans to mature in certain vegetation management capabilities	1. PG&E must benchmark its use of predictive and risk modeling in VM with SCE and SDG&E. a) PG&E should also consider benchmarking with at least one electric utility outside California. 2. PG&E must report on practices learned from benchmarking regarding the use of predictive and risk modeling in VM and discuss the initial steps that it will take to incorporate those practices into its VM programs.	Section 7.3.5.6
RN-PG&E-22-10	PG&E does not report targets for its vegetation management quality assurance and quality verification	1. PG&E must provide targets in accordance with PG&E-21-24 and the 2022 WMP Guidelines for its QA/QV program and number of poles brushed per PRC 4292. a) For the QA/QV targets, PG&E may provide either the percentage of vegetation inspections audited (as prescribed by the Guidelines) or the number of audits/reviews	Section 7.3.5.13

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Critical Issue No.	Critical Issue Title	Required Remedies	Location of PG&E's Response
	program or for poles brushed	it plans to perform (as described in Data Request OEIS-PG&E-22-005, Answer 6, and reiterated in Table 8). 2. PG&E must establish an Acceptable Quality Level (AQL) for performance for each QA/QV program listed in Table 8. The AQL for each program may be no lower than 95 percent. 3. Targets and associated AQLs must be presented in a revised WMP Table 5.3-1.	
RN-PG&E-22-11	PG&E has failed to implement the vegetation management refresher curriculum it committed to implement in its 2021 WMP Update	PG&E must provide a progress update, a summary of the curriculum, and a timeline to complete the implementation of its VM refresher training in 2022.	Section 7.3.5.14
RN-PG&E-22-12	PG&E has failed to provide sufficient evidence to support its extensive use of Enhanced Powerline Safety Settings and instead relies on the findings of a time-limited pilot deployed in 2021	PG&E is required to take action in the following areas: 1) explain how it will analyze EPSS deployment and modify settings; 2) reassess customer impacts associated with more widespread use of EPSS; 3) explain its EPSS customer impact mitigation plan; 4) detail its customer outreach plan; 5) present an EPSS staffing and resourcing plan; 6) detail an EPSS benchmarking plan; and 7 submit monthly EPSS data reports through the end of 2022	Section 7.3.6.8 Attachments: 2022-07-11_PGE_22-12_RNR_R2_Atch01CONF, or 2022-07-11_PGE_22-12_RNR_R2_Atch01_Redacted 2022-07-11_PGE_22-12_RNR_R2_Atch02 2022-07-11_PGE_22-12_RNR_R2_Atch03CONF, or 2022-07-11_PGE_22-12_RNR_R2_Atch03_Redacted 2022-07-11_PGE_22-12_RNR_R2_Atch04 2022-07-11_PGE_22-12_RNR_R2_Atch05
RN-PG&E-22-13	PG&E does not provide	1. PG&E must separately provide detailed costs, miles previously treated, a range for miles	Section 7.1.G

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Critical Issue No.	Critical Issue Title	Required Remedies	Location of PG&E's Response
	disaggregated data on its system hardening initiatives	planned to be treated, and RSE estimates for covered conductor installation, undergrounding, line removal, and any other system hardening initiatives currently presented together as one value in PG&E's 2022 Update. 2. Table 12 must be revised to provide the required information for each initiative listed in Energy Safety's 2022 WMP Guidelines.	Attachments: 2022-06-27_PGE_22-13_RNR_R1_Atch01 2022-06-27_PGE_22-13_RNR_R1_Atch02

PACIFIC GAS AND ELECTRIC COMPANY

2022 WILDFIRE MITIGATION PLAN

EXECUTIVE SUMMARY

PACIFIC GAS AND ELECTRIC COMPANY
2022 WILDFIRE MITIGATION PLAN
EXECUTIVE SUMMARY

A. Introduction

Our stand is that catastrophic wildfires shall stop. In 2021, we made significant progress, but the wildfire risk continues to change and so our efforts must evolve also. Our 2022 Wildfire Mitigation Plan (WMP) reflects our learnings, new ideas and feedback from stakeholders including the Office of Energy Infrastructure Safety (Energy Safety), the California Public Utilities Commission (CPUC or Commission), our Federal Monitor, the Governor's operational observer, and other engaged stakeholders. Our WMP outlines our broad program to reduce wildfires, with many complementary parts that work together to boldly address this risk.

In 2020 and 2021, California had its 5th and 2nd driest water years, respectively, in the last century.[1] Climate scientists at the University of California, Los Angeles recently concluded that for the Western United States "2000-2021 [was] the driest 22-year period since 800 A.D., which is as far as the data goes back."[2] PG&E's entire service area experienced extreme and severe drought conditions through much of 2021 prior to the rainstorms that occurred in the latter part of the year.

California experienced unprecedented increases in the wildfire risk as a result of drought and the ongoing impacts of climate change. For example, on non-Red Flag Warning (RFW)[3] days in 2021, there was a more than 500 percent increase in acreage burned, as compared to the average acreage in the prior four years. Simply put, the wildfire threat is growing, and it is PG&E's mission to reduce the risk of this threat to keep our customers and communities safe. This means our programs must evolve commensurate with the risks.

As outlined in this 2022 WMP, we are deploying a comprehensive and multi-faceted wildfire safety strategy, utilizing programs and actions that have proven effective at reducing wildfire risk and expanding innovative programs and actions initiated in prior years, such as:

- **Moving Forward to Underground Powerlines and Harden Our System** – Aggressively moving forward with our program to underground 10,000 circuit miles of distribution lines in High Fire Threat Districts (HFTD)—which effectively eliminates the ignition risk for overhead lines that have been placed underground

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1 Water years run from October 1 to September 30. See Water Year 2021: An Extreme Year (ca.gov).

2 How Bad Is the Western Drought? Worst in 12 Centuries, Study Finds – The New York Times (nytimes.com).

3 A RFW indicates a level of wildfire risk from weather conditions, as declared by the National Weather Service.

and hardening additional miles with covered conductor or line removal using a risk-ranked approach to prioritize work. We will be working closely with federal, state and local agency partners, such as Cal Trans, as well as other stakeholders to build strong relationships and coordinate efforts for this innovative and bold program;

- **Expanding Enhanced Powerline Safety Settings (EPSS) to All Risk Areas** – Expanding the scope of EPSS, where we re-engineer electrical equipment settings to rapidly, automatically shut off power if an object comes into contact with a distribution line until we can patrol the line to ensure there is no wildfire ignition risk. These safety settings resulted in an 80 percent reduction in ignitions compared to the prior three-year average in our 2021 pilot program. In 2022, we will implement EPSS on all of our distribution lines in HFTD areas and High Fire Risk Areas (HFRA), as well as select non-HFTD areas that are adjacent to HFTD areas and HFRA. Much like the work we have done to improve the PSPS program, we will continue to adjust these safety settings, undertaking a more surgical approach to only activate the settings in areas most at risk and to limit reliability impacts to our customers;

- **Applying New Mitigation Technology** – Deploying equipment to reduce the potential for wildfire ignitions and mitigate wildfire impacts, such as Supervisory Control and Data Acquisition (SCADA)-enabled automated sectionalizing devices, single phase recloser sets, and advanced system sensors;

- **Continuing Aggressive Vegetation Management Practices** – Continuing our extensive vegetation management that is above and beyond regulatory requirements, such as our Enhanced Vegetation Management (EVM) program;

- **Performing Enhanced Inspections and Risk Modelling** – Conducting enhanced detailed inspections (i.e., inspections that include significantly more detail than traditional detailed inspections completed prior to 2020) of our facilities in HFTD areas and deploying the most up to date risk modeling capabilities to support our data-driven, risk-informed approach to wildfire mitigation;

- **Improving Situational Awareness** – Maximizing the use of cameras and weather stations to identify potential wildfire ignitions and risk and expand the situational awareness capabilities of PG&E, the California Department of Forestry and Fire Protection (CAL FIRE), first responders and the public; and,

- **Utilizing PSPS as a Final Safety Action** – Continuing to implement as a measure of last resort our data-driven, model-based Public Safety Power Shutoff (PSPS) protocols that resulted in more targeted and smaller PSPS events in 2021.

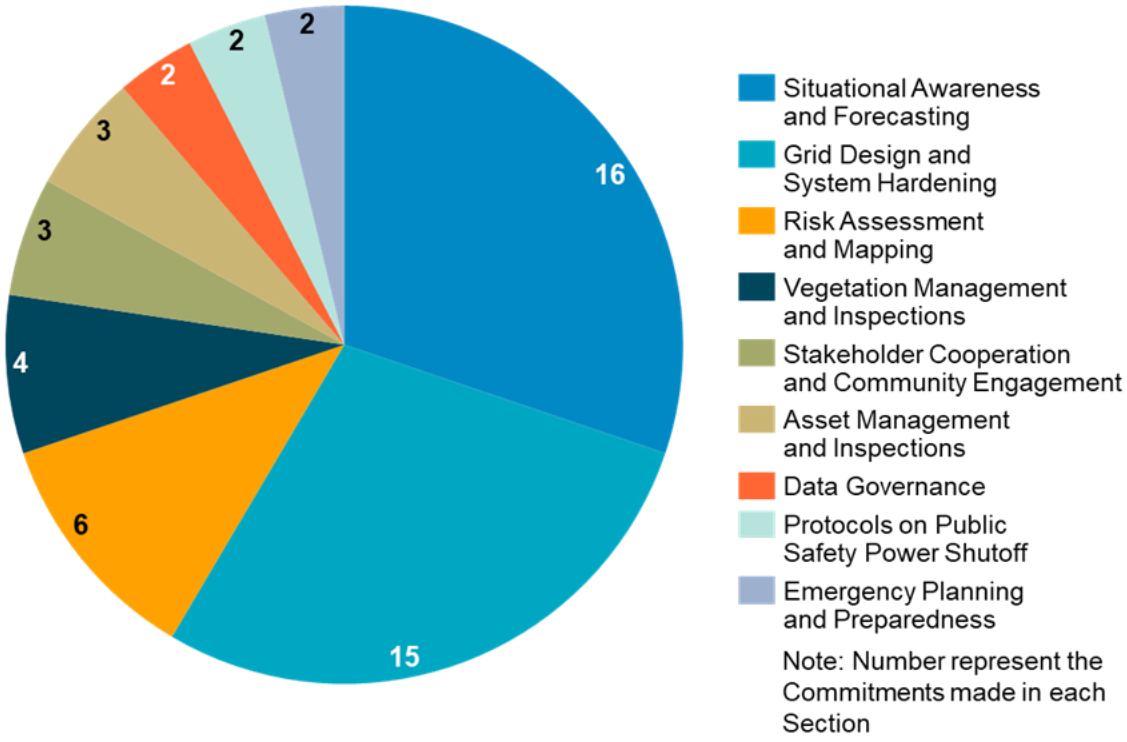
As with the 2021 WMP, our 2022 WMP includes multiple short- and long-term actions and programs critical to increasing safety and reducing risk. Thus, we carry forward our strategy of deploying a series of integrated programs designed to flex and evolve to meet the changing climate conditions and other learnings.

Below, we provide a summary of our WMP progress and additional steps taken in 2021, an overview of our 2022 WMP, and a discussion of the challenges ahead.

B. Overview of 2021 WMP Progress

The 2021 WMP included 53 commitments focused on wildfire mitigation activities such as risk modeling, system hardening, EVM, PSPS, and situational awareness. Despite the challenges posed by the COVID-19 pandemic, our team, including both PG&E coworkers and our contractor partners, was able to complete all of the commitments by year end 2021 and exceeded unit targets in a number of cases. From a timing perspective, 50 of the commitments were completed by the initial target date specified in the 2021 WMP. The remaining 3 commitments were completed later than the target date included in the 2021 WMP but were completed by the end of 2021. Our 53 commitments included a comprehensive set of wildfire mitigation programs developed to holistically address wildfire risks, as reflected in Figure PG&E-ES-1 below:

FIGURE PG&E-ES-1:
2021 WMP COMMITMENTS



In addition, many of our quantitative commitments were exceeded as shown in Figure PG&E-ES-2 below:

FIGURE PG&E-ES-2:
KEY QUANTITATIVE COMMITMENT RESULTS

Plan Area	Wildfire Mitigation Plan Commitment	Target	Actual	% of Plan
Situational Awareness and Forecasting	Enhancements to Weather Station Project (Installations and Optimization)	300	308	103%
	HD Cameras	135	153	113%
Grid Design and System Hardening	PSPS Mitigation – Temporary Distribution Microgrids	5	5	100%
	PSPS Mitigation – Substation Distribution Microgrids	8	9	113%
	Emergency Back-up Generation – PG&E Service & Materials Distribution Centers	23	32	139%
	Remote Grid	1	1	100%
	Distribution Sectionalizing (automated devices)	250	269	108%
	Transmission Switches	29	38	131%
	Distribution line legacy 4C controllers	81	81	100%
	Fuse Savers (Single phase reclosers)	70	71	101%
	Expulsion Fuse Replacement (non-exempt equipment)	1,200	1,429	119%
	Surge Arrester Replacements	15,000	15,465	103%
	System Hardening (line miles)	180	211	117%
	Butte County Rebuild	23	24	104%
	System Hardening - Transmission Conductor	92	104	113%
Asset Management and Inspections	Distribution HFTD Inspections (poles)	480,749	480,749	100%
	Substation HFTD Inspections (substations)	142	142	100%
	Transmission HFTD Inspections (structures)	26,826	26,826	100%
	Infrared Inspections of Transmission Electric Lines and Equipment	4,215	4,211*	100%
Vegetation Management and Inspections	EVM (line miles)	1,800	1,983	110%
	VM Transmission Right of Way Expansion	200	218	109%

Note: We did not perform four miles of the infrared inspections of transmission electric lines due to the lines being de-energized at the planned time of inspection and not being re-energized until 2022. By the end of 2021, we had completed the 4,211 miles that were energized.

Note 2: Figure was updated based on our 3/31/2022 errata submission.

We also implemented improvements to our risk modeling and risk-informed planning, including:

- Deploying significant improvements in our risk modeling capabilities to inform our workplans on programs such as system hardening and EVM;
- Prioritizing risk-ranked repairs by evaluating maintenance tags using factors such as wildfire ignition likelihood and consequences and achieving a risk score reduction of 62 percent by the end of 2021 as a result of successful tag execution.
- Increasing the granularity of mitigation initiatives and corresponding Risk Spend Efficiency (RSE) scores so that we can provide the greater risk reduction for every customer dollar invested; and,
- Continuing to reduce the number of customers impacted by PSPS events, as we implemented enhanced PSPS protocols and modeling.

We also improved our execution by implementing:

- The Lean Operating System, a rigorous process that provides visibility to our commitments, engages our coworkers in daily and weekly operating reviews, employs a set of problem solving tools that are used when metrics are not being

achieved and lastly standardizes our work so that our outcomes are visible, controllable and predictable; and,

- The Wildfire Risk Governance Steering Committee, which centralized oversight of our wildfire mitigation programs.

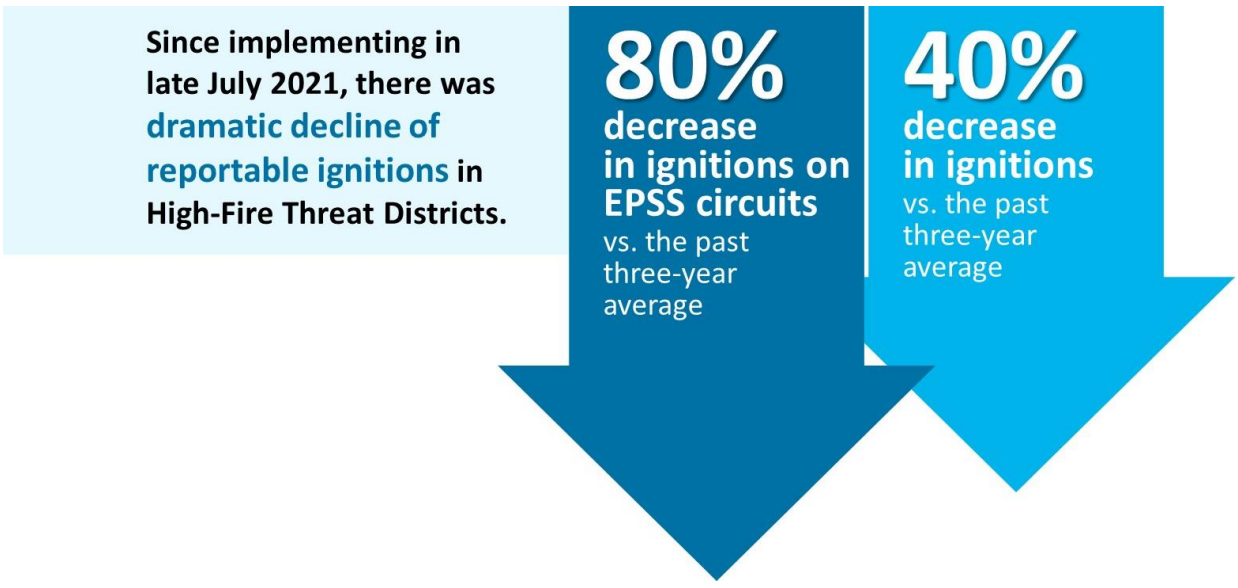
C. Additional Steps Taken During 2021

In July 2021, we also took two bold steps to implement programs that we believe will substantially reduce wildfire risks even further; one of which has already delivered dramatic results.

First, following an internal assessment and external benchmarking, we announced our 10,000-mile underground program to eliminate wildfire risk from overhead electric facilities. The undergrounding program is described in Section 7.3.3.16.

Second, we implemented EPSS on approximately 11,500 miles of distribution circuits, or 45 percent of the circuits in HFTD areas. Through EPSS, we addressed the evolving wildfire risk and dramatically decreased CPUC-reportable ignitions, as indicated in Figure PG&E-ES-3 below:

FIGURE PG&E-ES-3:
IGNITION REDUCTION ON EPSS ENABLED CIRCUITS AND OVERALL DECREASES IN HFTD AREA CPUC-REPORTABLE IGNITIONS AFTER EPSS ENABLED



Note: The reduction in CPUC-reportable ignitions occurred between July 28, 2021 and October 20, 2021.

While EPSS resulted in fewer fire ignitions, increased public safety, and reduced the risk of a catastrophic wildfire, impacted customers in high fire threat areas also experienced more outages. To address outages and customer impacts, we re-engineered the sensitivity of devices to continue to provide ignition risk reduction while reducing the likelihood of an outage.

In addition, we improved coordination between our devices to reduce the size of outages and coordination of patrol crews for faster restoration times. As a result, average customer outage duration on EPSS-enabled circuits decreased by 40 percent after these changes were implemented. Despite reductions in customer outages, we appreciate that we can certainly do more.

Given the significant ignition reduction and the criticality of reducing ignitions that could cause a catastrophic wildfire, we are expanding the EPSS program in 2022 to all 25,500 distribution line miles in HFTD and HFRA areas, as well as select non-HFTD areas in our service area. We recognize that EPSS may result in increased outages in 2022 and so we will be continuing our efforts to engineer the best technical solutions including taking additional operational actions to reduce outages and expanding customer support offerings. We will also be evaluating integrating EPSS and EVM, as well as other wildfire initiatives, so that these programs together most effectively mitigate wildfire risks and reduce customer outage impacts. The EPSS program is described in more detail below and in Section 7.3.6.8.

D. Overview of PG&E's 2022 WMP

Our 2022 WMP has three overarching goals, consistent with our established approach to wildfire risk reduction as shown in Figure PG&E-ES-4 below:

FIGURE PG&E-ES-4:
PG&E 2022 WMP GOALS



Each of our specific wildfire programs are in the service of these goals.[4] Below, we summarize these programs within each of the wildfire mitigation categories identified by Energy Safety.

1) **Risk Assessment and Mapping** – PG&E continues to advance our capabilities in wildfire risk modeling and the visualization of risk model outputs to enable better decision-making. Our 2021 and 2022 activities include:

[4] In the WMP, the terms initiative and program are used interchangeably. In this Executive Summary, we will use the term program for brevity and consistency rather than referring to "initiatives and programs."

TABLE PG&E-ES-1:
RISK ASSESSMENT AND MAPPING ACTIVITIES

2021	2022
In 2021, we enhanced our risk modeling to inform our wildfire mitigation activities by: • EXPANDING geographical coverage, adding input data sources, refining probability of ignition modules; • MODELING wildfire risk for transmission assets through the Wildfire Transmission Risk Model; • DEVELOPING an initial PSPS Consequence Model at a circuit level; and, • DEVELOPING spatial model views in our enterprise data management platform to inform EVM and System Hardening programs.	In 2022, we will continue building on this risk modeling foundation to effectively make risk-informed decisions in the planning and execution of wildfire risk reduction activities by: • DEVELOPING new modeling for ignition risk; • UTILIZING the PSPS Consequence Model; • INCORPORATING ingress/egress in risk modeling; and, • ACTIVELY PARTICIPATING in the risk modeling working group led by Energy Safety.

Additional details on our Risk Assessment and Mapping programs are provided in Section 7.3.1.

2) **Situational Awareness and Forecasting** – Our situational awareness and forecasting programs reduce the risk of wildfire by monitoring weather conditions and potential fire conditions through our network of weather stations, high-definition cameras and sensors, as well as state-of-the-art weather forecasting that is used by PG&E and other agencies. We will continue to make the information obtained from this technology available to CalFIRE, first responders, and the public. Our 2021 and 2022 activities include:

TABLE PG&E-ES-2:
SITUATIONAL AWARENESS AND FORECASTING ACTIVITIES

2021	2022
In 2021, we increased our situational awareness of potential wildfire ignitions and risk by: • INCREASING weather modeling inputs and outputs; • LAUNCHING two proof-of-concept pilots to evaluate the effectiveness of artificial intelligence and machine learning for high-definition cameras to detect wildfires; and, • INSTALLING an additional 308 weather stations and 153 high-definition cameras in our service area.	In 2022, we will continue to expand our situational awareness by: • REFINING the models that we use for situational awareness; • INSTALLING 100 additional weather stations and 98 high-definition cameras; and • DEPLOYING Distribution Fault Anticipation and Early Fault Detection technology and assessing Sensor IQ™ (SIQ) technology.

Additional details on our Situational Awareness and Forecasting programs are provided in Section 7.3.2.

3) **Grid Design and System Hardening** – PG&E's grid design and system hardening initiatives significantly reduce wildfire risks. Our comprehensive System Hardening program is a key strategy to mitigate wildfire risk caused by overhead assets. Our 2021 and 2022 activities include:

TABLE PG&E-ES-3:
GRID DESIGN AND SYSTEM HARDENING ACTIVITIES

2021	2022
In 2021, we advanced our system hardening and grid design efforts by: • COMPLETING 210 miles of distribution system hardening (which includes undergrounding, overhead hardening, microgrid and Remote Grid); • HARDENING or removing 104 miles of transmission lines; • SYSTEMATICALLY REPLACING equipment in HFTD areas that creates ignition risks, such as non-exempt fuses (more than 1,400) and surge arresters (more than 15,000); and, • LAUNCHING our plan to underground 10,000 miles of overhead distribution lines in HFTD areas.	In 2022, we are rapidly expanding our system hardening efforts by: • COMPLETING 470 circuit miles of system hardening work which includes overhead system hardening, undergrounding and removal of overhead lines in HFTD or buffer zone areas; • COMPLETING at least 175 circuit miles of undergrounding work, including Butte County Rebuild efforts and other distribution system hardening work; • REPLACING or removing 32 miles of transmission conductor to reduce ignition risk from those lines; • INSTALLING additional automated devices which allow us to sectionalize our grid and reduce the impact of PSPS events; and, • REPLACING equipment in HFTD areas that creates ignition risks, such as non-exempt fuses (3,000) and surge arresters (~4,500, all known, remaining in HFTD areas).

Additional details on our Grid Design and System Hardening programs are provided in Section 7.3.3.

4) **Asset Management and Inspections** – The asset information we obtain through inspection programs is essential to informing our operational risk models and "learn" over time to become more effective at predicting ignition risks. Inspection programs use multiple data gathering methods, including patrol, physical testing (e.g. intrusive pole), ground, aerial, infrared, and Light Detection and Ranging (LiDAR), among others. Our 2021 and 2022 activities include:

TABLE PG&E-ES-4:
ASSET MANAGEMENT AND INSPECTIONS ACTIVITIES

2021	2022
In 2021, we continued our enhanced inspection programs designed to reduce the potential for wildfire ignition from our electrical equipment by: • COMPLETING enhanced detailed inspections on all distribution poles and transmission structures in Tier 3 and Zone 1 HFTD areas and on approximately 33 percent of the Tier 2 HFTD and HFRA distribution poles and transmission structures; • COMPLETING supplemental ground and aerial inspections of 71 distribution substations, 33 transmission substations and 38 hydro substations; • USING infrared technology to identify potential risks not easily detectable, and LiDAR imaging to improve our knowledge about our assets; and, • UPGRADING our intrusive pole inspection Program's field hardware and software to enhance record keeping and data system integrations.	For 2022, our inspections and asset management programs will reduce wildfire ignition risk by: • CONTINUING our enhanced detailed inspection programs for distribution and transmission facilities; • COMPLETING supplemental ground and aerial inspections of 86 distribution substations, 43 transmission substations, and 52 hydroelectric substations to reduce potential ignition risks from these facilities located throughout HFTD areas; • CONTINUING to evolve the effectiveness of our inspection processes and procedures; • PERFORMING LiDAR data acquisition on distribution and transmission facilities; and, • CONTINUING to work down the ignition risk tags backlog.

Additional details on our Asset Management and Inspections programs are provided in Section 7.3.4.

5) **Vegetation Management and Inspections** – Our Vegetation Management program, components of which exceed regulatory requirements, is critical to mitigating wildfire risk. Our vegetation management team inspects and identifies needed vegetation maintenance on all distribution and transmission circuit miles in PG&E's service area on a recurring cycle through Routine and Tree Mortality Patrols, as well as Pole Clearing. Our EVM program goes above and beyond regulatory requirements for distribution lines by expanding minimum clearances and removing overhang in HFTD areas. Our 2021 and 2022 activities include:

TABLE PG&E-ES-5:
VEGETATION MANAGEMENT AND INSPECTIONS ACTIVITIES

2021	2022
In 2021, in addition to the work performed in our Routine, Tree Mortality and Pole Clearing programs, we were able to reduce the potential for vegetation caused ignitions by: • COMPLETING 1,983 miles of EVM work, 98 percent of which was focused on the highest 20 percent or risk-ranked Circuit Protection Zones; • EXPANDING 218 miles of transmission ROWs to reduce vegetation contact with our transmission facilities; and, • ENHANCING our vegetation management work verification and training to ensure the quality of work performed.	In 2022, we will continue to perform our vegetation management programs by: • PERFORMING 1,800 miles of EVM work; • COMPLETING detailed LiDAR inspections; • CONTINUING a pilot program to include an enhanced process to perform visual assessment of all sides of potential strike trees on routine vegetation management patrols in HFTDs. The pilot program will inform an implementation of this enhanced process on routine vegetation management patrols in HFTDs; and, • UNDERTAKING extensive work quality audits and reviews through our Quality Assurance Vegetation Management and Quality Verification Vegetation Management programs.

Additional details on our Vegetation Management and Inspections programs are provided in Section 7.3.5.

6) **Grid Operations and Protocols** – PG&E is focused on safely operating our electrical grid in a manner that reduces the risk of wildfire ignitions, including ongoing activities such as disabling reclosers and expanding programs, specifically EPSS. Our 2021 and 2022 activities include:

TABLE PG&E-ES-6:
GRID OPERATIONS AND PROTOCOLS ACTIVITIES

2021	2022
In 2021, we made our system safer through our grid operations by: • IMPLEMENTING EPSS on approximately 11,500 miles of distribution circuits in HFTD areas (45 percent of the circuits), which significantly reduced CPUC-reportable ignitions; • DISABLING automatic reclosers in HFTD areas prior to fire season and for the duration of the entire fire season; • UTILIZING our Safety and Infrastructure Protection Team (SIPT) to support fire prevention and mitigation activities, as well as "on call" status during the summer preparedness period and our Public Safety Specialists (PSS) to help inform our wildfire mitigation efforts; and, • IMPROVING the PSPS re-energization protocols by implementing "all clear zones" and refining external communications and customer notifications processes.	In 2022, we plan to expand our grid operations and protocols to reduce potential ignitions by: • EXPANDING EPSS to all HFTD and HFRA areas, as well as select non-HFTD areas adjacent to HFTD and HFRA to achieve significant ignition reduction we experienced in 2021; • ENGINEERING our equipment settings to reduce the reliability impacts of EPSS and providing support and extensive communication with impacted customers and communities; and, • CONTINUING other operational mitigations, such as disabling reclosing on all automatic devices within the HFTD and HFRA areas during fire season.

Additional details on our Grid Operations and Protocols programs are provided in Section 7.3.6.

7) **Data Governance** – Our data governance initiatives primarily support other WMP initiatives, which depend on access to accurate data for situational intelligence, analysis and insight, decision-making, and regulatory reporting. Our 2021 and 2022 activities include:

TABLE PG&E-ES-7:
DATA GOVERNANCE ACTIVITIES

2021	2022
In 2021, we continued to expand our data driven approach to wildfire mitigation by: • INCREASING our capacity to deliver new, high-quality data objects into Foundry; and, • DEVELOPING eight new wildfire-related analytic and situational intelligence products.	In 2022, we will be building on our data capabilities by: • EXPANDING the electric operations data available in our data platform; and, • DEVELOPING new analytic and situational intelligence products within the data platform, and maturing platform governance.

Additional details on our Data Governance programs are provided in Section 7.3.7.

8) **Resource Allocation and Methodology** – We have developed analytical tools to evaluate risk and risk mitigations and prioritize work to address our highest risks, particularly wildfires, more effectively. Our 2021 and 2022 activities include:

TABLE PG&E-ES-8:
RESOURCE ALLOCATION AND METHODOLOGY ACTIVITIES

2021	2022
In 2021, we developed a broader ability to analyze risk and use this analysis in our work planning by: • EXPANDING RSE scores to more risk mitigation and control programs; and, • ENGAGING with a third-party technical advising group to perform an assessment of RSE methodologies used in the 2021 WMP.	In 2022, we plan to continue expanding the use of our risk analyses by: • IMPLEMENTING the third-party technical advising group findings; • ESTABLISHING an RSE Governance Team; and, • ENHANCING our use of RSEs as an important tool to evaluate risk initiatives and key inputs into the overall decision-making process.

Additional details on our Resource Allocation and Methodology programs are provided in Section 7.3.8.

9) **Emergency Planning and Preparedness** – PG&E has developed an emergency response plan that is focused on protecting life and property and communicating information as quickly as possible to first responders, local and state authorities, and our communities and customers. Our highly-qualified workforce is trained on protocols to respond to any incident and restore power safely. In the event of a major emergency, we have a dedicated customer support team to assist impacted customers. Our 2021 and 2022 activities include:

TABLE PG&E-ES-9:
EMERGENCY PLANNING AND PREPAREDNESS ACTIVITIES

2021	2022
In 2021, we continued to enhance our emergency planning preparation by: • ADOPTING web-based training sessions for emergency support personnel training; • INCREASING the number of line workers to support service restoration; and, • INCREASING public awareness of emergency planning and preparedness information through our communications efforts.	In 2022, we intend to expand these capabilities by: • TRAINING all profiled employees on restoration protocols; • CONDUCTING field exercises for all impacted divisions; • DEVELOPING a communications and operations plan that engages external agencies for inclusion in after-action reviews; and, • CONDUCTING multi-channel awareness campaigns with a focus on customers impacted by PSPS and EPSS events and customers with access or functional needs.

Additional details on our Emergency Planning and Preparedness programs are provided in Section 7.3.9.

10) **Stakeholder Cooperation and Community Engagement** – Working with agencies and customers is an important part of our wildfire mitigation efforts. We recognize that a one-size-fits-all approach to engagement does not necessarily consider a community's specific priorities and needs. Our 2021 and 2022 activities include:

TABLE PG&E-ES-10:
STAKEHOLDER COOPERATION AND COMMUNITY ENGAGEMENT ACTIVITIES

2021	2022
In 2021, we worked effectively to communicate with our communities, customers, and local and state agencies by: • CONTINUING to focus on localized engagement; • INCREASING public awareness and support of utility wildfire mitigation activity by working closely with agencies and critical facilities to ensure they are informed of PG&E's emergency planning and preparedness resources and actions; and, • HOSTING over 390 meetings with agencies to share information related to PG&E's wildfire mitigation efforts.	In 2022, we will continue communicating critical wildfire and PSPS information and be better informed about customer and community needs by: • LISTENING to customers, community leaders, and community-based organizations to fully understand and respond to concerns and feedback about communications; • PARTICIPATING in various industry groups to benchmark and identify potential alternative solutions from industry leaders around the world; and • HOSTING events and meetings designed to inform and coordinate with local agencies and communities and our customers.

Additional details on our Stakeholder Cooperation and Community Engagement programs are provided in Section 7.3.10.

In addition to these mitigation categories, we will also continue to use our PSPS protocols as a final option when necessary to keep our customers and our communities safe. The more targeted, smaller, and shorter PSPS events in 2021 resulted from a combination of favorable weather conditions, enhancements to our electrical system, the incorporation of feedback from our customers and our communities, and continuous improvement based on lessons learned from past events. In 2021, these continuous improvements included enhancements to meteorology modeling that incorporated weather, tree overstrike, and equipment condition data into machine learning, PSPS Distribution Scoping Guidance Updates, Transmission PSPS Scoping Protocols, a PSPS Risk-Benefit Assessment, and our Re-energization Strategy and Protocols.

In 2022, we plan to continue to make progress to minimize customer impacts during PSPS events by focusing on three major areas: (1) customer support efforts; (2) restoration; and (3) mitigation initiatives. Additional details on our PSPS initiatives are provided in Section 8.

E. Challenges Ahead

We are working with tremendous urgency to reduce the risk of wildfires in our service area by implementing risk-informed and data-driven programs and mitigations. Looking ahead, the climate change challenges for California are significant and growing. As the United States Department of Agriculture (which includes the National Forest Service) Secretary Tom Vilsack recently noted in announcing a 10-year strategy to reduce wildfire risk in the Western United States:

> [O]ur experts expect the trend [of wildfires] will only worsen with the effects of a changing climate, so working together toward common goals across boundaries and jurisdictions is essential to the future of these landscapes and the people who live there.[5]

Changes in weather patterns combined with California's vegetation "debt" (i.e., the amount of burnable fuel on forest lands) further highlight the wildfire risk that California can expect will only increase for the foreseeable future.

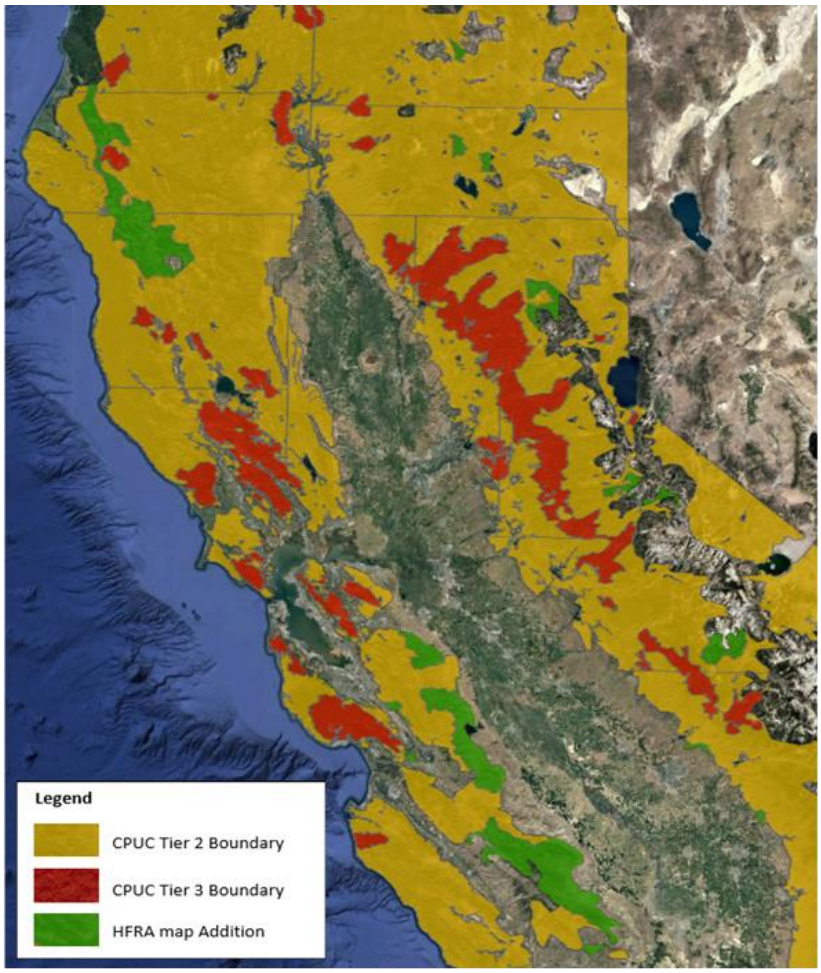
These concerns are particularly true for PG&E's service area. Over half of PG&E's service area lies in HFTD areas identified by the Commission in 2018.[6] Roughly one-third of PG&E's total overhead assets, or approximately 5,500 line-miles of electric transmission and 25,500 line-miles of distribution assets lie within these HFTDs. In addition, PG&E has identified HFRAs (areas outside Tier 2 and Tier 3 HFTD areas) that represent areas where there are risk factors for potential wildfires. PG&E's HFTD and HFRA areas are identified in Figure PG&E-ES-5 below.

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5 Available at: Secretary Vilsack Announces New 10-Year Strategy to Confront the Wildfire Crisis | USDA.

6 Available at: www.cpuc.ca.gov/firethreatmaps.

FIGURE PG&E-ES-5:
HFTD AND HFRA AREAS IN PG&E SERVICE AREA



The 2021 drought and wildfire season reinforced the importance of collaboration in wildfire mitigation. We appreciate the partnership with Energy Safety, the CPUC, local, state, and federal policymakers and legislators, stakeholders, our customers, and our communities to make every effort to reduce wildfire risk and end catastrophic wildfires.

F. Conclusion

The programs and initiatives described in this 2022 WMP provide a comprehensive, innovative and multi-faceted approach to wildfire risk reduction using the best tools, techniques, and technology available today and reflect the continuous evolution of our approach. The wildfire risk in our service area is changing rapidly, and we are moving boldly to address it. In such a rapidly changing environment we know we must be open to the ideas of others and feedback. We look forward to receiving more input from and working collaboratively with Energy Safety, the CPUC, local and state agencies, communities, and our customers and to achieve our stand that catastrophic wildfires shall stop.

PACIFIC GAS AND ELECTRIC COMPANY

2022 WILDFIRE MITIGATION PLAN

SECTION 1

PERSONS RESPONSIBLE FOR EXECUTING THE WILDFIRE MITIGATION PLAN

1. Persons Responsible for Executing the Wildfire Mitigation Plan

Provide an accounting of the responsibilities of the responsible person(s) executing the plan, including:

1. Executive level with overall responsibility

2. Program owners specific to each component of the plan

Title, credentials, and components of responsible person(s) must be released publicly, but other contact information may be provided in a redacted file attached to the Wildfire Mitigation Plan (WMP) submission.

The following individuals have responsibilities for oversight, governance and execution of Pacific Gas and Electric Company's (PG&E) 2022 Wildfire Mitigation Plan (WMP). While hundreds of leaders, and thousands of employees and contractors, contribute to the WMP activities or have ownership or accountability for individual initiatives or other portions of the WMP, we have identified below the leaders who have general responsibility for the referenced sections of the 2022 WMP.

Executive-Level Owner With Overall Responsibility:

Sumeet Singh, Executive Vice President, Chief Risk Officer and Chief Safety Officer

- E-mail – [redacted]
- Telephone number – [redacted]

Program Owners for Each Component of Plan:

TABLE PG&E-1-1:
PROGRAM OWNERS FOR EACH COMPONENT OF PLAN

Section	Name	Title	E-Mail	Phone Number	Component
Section 1: Persons Responsible for Executing the Plan	[redacted]	Executive Vice President, Chief Risk Officer and Chief Safety Officer	[redacted]	[redacted]	General Oversight and Management of WMP Activities
Section 2: Adherence to Statutory Requirements		Director, Community Wildfire Safety Program			All
Section 3: Actuals and Planned Spending		Director, Community Wildfire Safety Program			All
Section 4: Lessons Learned and Risk Trends		Director, Community Wildfire Safety Program			4.1 – Lessons Learned 4.6 – Progress Reporting
		Director, Electric Operations (EO) Risk Management and Analytics			4.2, 4.3, & 4.5 – Risk Understanding and Modeling
		Director, Data Management & Analytics			4.4 – Research
Section 5: Inputs to the Plan and Directional Vision		Director, Community Wildfire Safety Program			All Note: Operational teams support Section 5.4 on skilled resource details
Section 6: Metrics and Underlying Data		Director, Community Wildfire Safety Program			All Note: Various specific teams support data collection

TABLE PG&E-1-1:
PROGRAM OWNERS FOR EACH COMPONENT OF PLAN
(CONTINUED)

Section	Name	Title	E-Mail	Phone Number	Component
Section 7: Mitigation Initiatives	[redacted]	Director, Community Wildfire Safety Program	[redacted]	[redacted]	7.1.C & D – Wildfire Mitigation Strategy 7.2.A, B & D – WMP Implementation.
		Director, Data Management & Analytics			7.1.E – New or Emerging Technologies 7.3.7 – Data Governance
		Director, EO Risk Management and Analytics			7.1.A – PG&E's Approach to Managing Wildfire Risk 7.1.B – Risk Modeling Outcomes in Decision-Making and Mitigations 7.1.F – Risk 7.3.1 – Risk Assessment and Mapping
		VP, Emergency Preparedness & Response			7.3.2 – Situational Awareness and Forecasting 7.3.6 – Grid Operations and Protocols 7.3.9 – Emergency Planning and Preparedness

TABLE PG&E-1-1:
PROGRAM OWNERS FOR EACH COMPONENT OF PLAN
(CONTINUED)

Section	Name	Title	E-Mail	Phone Number	Component
	[redacted]	Director, Standards and Work Methods	[redacted]	[redacted]	7.1.G – Grid Design and System Hardening Mitigations 7.1.H – Grid Design and System Hardening High-Level Maps 7.1.I – Asset Management and Inspections Geographic Information System (GIS) Layer (Distribution) 7.3.3 – Grid Design and System Hardening 7.3.4 – Asset Management and Inspections 7.3.8 – Resource Allocation Methodology
		Director, Transmission, Substation & Storage Strategy			7.1.I – Asset Management and Inspections GIS Layer (Transmission/ Substation)
		Director, Engagement, Strategy and Programs			7.3.10 – Stakeholder Cooperation and Community Engagement
		Sr Director, Vegetation Management Ops			7.1.J – Enhanced Clearances GIS Layer 7.3.5 – Vegetation Management and Inspections
		System Inspections Quality Control			7.2.C – Monitor and Audit Inspection Effectiveness

TABLE PG&E-1-1:
PROGRAM OWNERS FOR EACH COMPONENT OF PLAN
(CONTINUED)

Section	Name	Title	E-Mail	Phone Number	Component
	[redacted]	Director, Business Finance Electric Operations & Engineering Strategy	[redacted]	[redacted]	7.3.a – Financial Data
Section 8: Public Safety Power Shutoff (PSPS)		Director, Public Safety Power Shut Off			8.1 – Directional Vision for PSPS 8.2 – Protocols on PSPS 8.3 – Projected Changes to PSPS Impact 8.5 – PSPS-Specific Metrics 8.6 – Identification of Frequently De-Energized Circuits
		Director, Emergency Field Operations			8.2.4 – Re-Energization Strategy
		Director, Engagement, Strategy and Programs			8.2.2 – Strategy to Minimize Public Safety Risk 8.2.5 – Customer, Agency, and External Communications 8.4 – Engaging Vulnerable Communities
Section 9: Appendix		Director, Community Wildfire Safety Program			All
		Director, EO Risk Management and Analytics			9.5 – PG&E Glossary of Models

1.1 Verification

Verification

Complete the following verification for the WMP submission:

(See Rule 1.11)

(Where Applicant is a Corporation)

I am an Officer of the applicant corporation herein and am authorized to make this verification on its behalf. The statements in the foregoing document are true of my own knowledge, except as to matters which are therein stated on information or belief, and as to those matters I believe them to be true.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on July 26, 2022 at San Ramon, California.

(Date) (Name of city)



_____

Sumeet Singh, Executive Vice President, Chief Risk Officer
and Interim Chief Safety Officer

1.2 Initial Explanatory Notes and Comments

This section provides some initial explanatory notes and comments that will assist readers when reviewing our 2022 WMP.

(a) Consistency with 2022 WMP Guidelines Template

On December 15, 2021, Energy Safety issued the final version of the 2022 WMP Guidelines Template (2022 WMP Guidelines). The 2022 WMP Guidelines provided an outline for the 2022 WMP and tables for the utilities to complete as part of their submission. We have attempted to the best of our ability to provide the information requested by Energy Safety in the time allotted and in the manner requested in the 2022 WMP Guidelines. Due to the relatively condensed period between the issuance of the Guidelines and the submission of the 2022 WMP, there may be some areas where PG&E is unable to provide the requested data. Where data is unavailable, we have noted this in our 2022 WMP.

(b) Narrative Subparts

Some sections in the 2022 WMP are quite lengthy. In order to assist the reader, PG&E has added lettered subparts in these sections (e.g., (a), (b), etc.).

(c) Formatting and Additional Tables and Figures

To provide context to help understand the tables and narrative, we have included the instructions from the 2022 WMP Guidelines in *italics* at the beginning of each section and table in the 2022 WMP.

We are also providing additional tables to explain various additional data or calculations that PG&E performed to complete tables required in the Guidelines. We have included only the required tables, not the PG&E specific tables, in the excel files that it is posting with the 2022 WMP. The additional PG&E specific tables are identified in the following format in the narrative:

TABLE PG&E-SECTION#-TABLE#.

Similarly, where PG&E has provided figures to supplement the narrative, these PG&E specific figures are identified in the same format:

FIGURE PG&E-SECTION#-FIGURE#.

(d) Definition of Terms and Glossaries

We have used the Glossary provided in the 2022 WMP Guidelines as a reference source for terminology and have included it as Section 9.3 in our 2022 WMP. Some terms used in PG&E's 2022 WMP are not defined in the Guidelines Glossary. To provide clarity for readers, we have also included in Section 9.4 a PG&E-specific glossary.

(e) Model Glossary

There are a number of models referred to and discussed throughout the 2022 WMP. In order to assist the reader, PG&E is including a glossary of models in Section 9.5 listing the primary and component models referred to in the 2022 WMP with a brief description of each.

(f) Initiative v. Program

The 2022 WMP uses the terms "initiative" and "program" interchangeably to describe specific efforts that PG&E is making to reduce wildfire risk. PG&E has used the initiatives defined by Energy Safety in the 2022 WMP, but also at points refers to programs, which may be one or more initiatives.

(g) Definition of Transmission and Distribution

PG&E defines transmission voltage as being 60 kilovolt (kV) or above and has used this delineation for many years. Distribution is, therefore, defined as below 60 kV. Therefore, any references in the 2022 WMP to transmission refers to voltages at 60kV or above. Note that in some of the Energy Safety-provided tables or definitions transmission has been defined as 65kV or above. PG&E is unable to re-orient our data systems to use 65kV as the delineation between distribution and transmission.

(h) Ignition Data

The fire ignition data provided in the 2022 WMP, particularly Tables 7.1 and 7.2, is based on fire incident reports filed with the CPUC annually in accordance with D.14-02-015. The ignition data provided in these tables reflects preliminary data. PG&E's final 2021 fire ignition report is due on April 1, 2022 and 2021 data will be further reviewed in advance of that filing.

(i) Distinguishing Climate and Weather

The 2022 WMP Guidelines and other 2022 WMP materials, such as the Maturity Survey, reference "climate" and "weather" and in some cases use the two terms interchangeably. Meteorology (weather) and climatology (climate) are unique disciplines concerned with very different geographic and temporal granularities of natural phenomena. "Weather" refers to short period variation in the atmosphere at a given location. "Climate" refers to the condition of the atmosphere over a long period of time over a large area. Climate projections can be an important planning tool that provide the expected bounds for future operating conditions on a decadal scale; however, the nature of statistical projections makes climate data unsuitable for precisely predicting specific future outcomes. PG&E's Climate Resilience Team continues to coordinate with the PG&E's Community Wildfire Safety Program to identify opportunities where application of long-term climate projections would result in safer and/or more affordable outcomes. In general, the programs and planning reviewed in the WMP have time horizons ranging from months to a few years and as such are not meaningfully informed by climate projections. Thus, in our 2022 WMP and Maturity Survey responses, references to "climate" and "weather" are generally understood to be referring to shorter term weather trends, rather than long-term climate trends, unless the context of the Guidelines or Maturity Survey instructions makes clear otherwise.

(j) Cross-Referencing

We are mindful of the 2022 WMP Guidelines direction to include cross-referencing and hyperlinks to "minimize duplication of narratives." Consistent with this direction, we have tried to include more cross-referencing of material to streamline the 2022 WMP.

(k) Referenced Documents

In the 2022 WMP Guidelines, Energy Safety requested electrical corporations post all documents referenced in their WMPs on a WMP-specific website. We have included on our WMP-specific website a document that lists the documents referenced in our WMP and provides links to where the materials can be obtained.

(l) Additional Initiative Sections

In response to Energy Safety's Revision Notice, we have included in Section 7.3.4 three Critical Issue responses that concern asset management and inspections because this was the most appropriate place in the 2022 WMP to include these responses. See Sections 7.3.4.17 to 7.3.4.19.

(m) Attachments

Throughout the 2022 WMP, there are references to attachments that are applicable to specific sections and provide additional materials. For ease of reference, we are including below a list of the attachments. In the text of the 2022 WMP, we refer to the attachment name and number. In the list below, we have also added the designation "CONF" which indicates whether an attachment is confidential or not. PG&E will provide on our website a public version of each attachment unless the attachment is confidential in its entirety, in which case the attachment will not be provided on our website:

List of Attachments:

- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.1_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.1_Atch02
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.2.1_Atch01_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.2.1_Atch02
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.2.1_Atch03
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.3_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.1_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.1_Atch02_CONF

List of Attachments (continued):

- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.2_Atch01_CONF

- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.2_Atch02_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Atch02
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 21-09_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 21-09_Atch02
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 21-14_Atch01_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 5.4.B_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 5.4.B_Atch02
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 5.4.B_Atch03
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 5.5.A_Atch01_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 5.5.C_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Remedy 5.5.D_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.1.E_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.1.F_Atch01_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.1.H_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.1.I_Atch01_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.1.J_Atch01_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.1.J_Atch02_R1_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.3_Atch01_CONF
- 2022-07-26_PGE_22_RNR_R1_Section 7.3.a_Atch01
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch02
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch03
- 2022-07-26_PGE_22_RNR_R1_Section 7.3.a_Atch04
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch05
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch06_R1

List of Attachments (continued):

- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch07

- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch08
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch09
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 7.3.a_Atch10
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 8.2.4_Atch01_CONF
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 8.6_Atch01_R1
- 2022-07-26_PGE_22-04_RNR_R3_Atch01CONF
- 2022-07-11_PGE_22-05_RNR_R2_Atch01
- 2022-07-11_PGE_22-05_RNR_R2_Atch02
- 2022-07-11_PGE_22-05_RNR_R2_Atch03
- 2022-07-11_PGE_22-05_RNR_R2_Atch04
- 2022-07-11_PGE_22-05_RNR_R2_Atch05
- 2022-07-11_PGE_22-05_RNR_R2_Atch06
- 2022-07-11_PGE_22-05_RNR_R2_Atch07
- 2022-06-27_PGE_22-07_RNR_R1_Atch01
- 2022-06-27_PGE_22-07_RNR_R1_Atch02
- 2022-07-11_PGE_22-12_RNR_R2_Atch01CONF
- 2022-07-11_PGE_22-12_RNR_R2_Atch02
- 2022-07-11_PGE_22-12_RNR_R2_Atch03CONF
- 2022-07-11_PGE_22-12_RNR_R2_Atch04
- 2022-07-11_PGE_22-12_RNR_R2_Atch05
- 2022-06-27_PGE_22-13_RNR_R1_Atch01
- 2022-06-27_PGE_22-13_RNR_R1_Atch02
- 2022-07-26_PGE_RNR_Change_Log

PACIFIC GAS AND ELECTRIC COMPANY

2022 WILDFIRE MITIGATION PLAN

SECTION 2

ADHERENCE TO STATUTORY REQUIREMENTS

2. Adherence to Statutory Requirements

Section 2 comprises a "check list" of the Public Utilities Code (Pub. Util. Code) § 8386(c) requirements and subparts. The utility is required to both affirm that the Wildfire Mitigation Plan (WMP) addresses each requirement AND cite the section and page number where statutory compliance is demonstrated fully. Citations are required to use cross-referencing with hyperlinks.

Note: Energy Safety reserves the right to automatically reject a WMP that does not provide substantiation for statutory compliance or does not provide citations to appropriate sections of the WMP.

Table 2-1 provides an exemplar for the minimum acceptable level of information and citation for the statutory check list.

TABLE 2-1:
ILLUSTRATIVE CHECK LIST

Requirement	Description	WMP Section and Page Number
2	The objectives of the plan	Section 4.1, p. 13
11	Protocols for the de-energization of the electrical corporation's transmission infrastructure, etc.	Section 5 Overview, pp. 30--31

Table 2-2 provides the full list of statutory requirements. A table similar to Table 2-2 is required with the appropriate citation for each requirement. If multiple WMP sections address a specific requirement, then references to all relevant sections with a brief indication of information provided in each section must be provided. The table must include each section reference separated by semi-colon (e.g., Section 5, pp. 30-32 (workforce); Section 7, p. 43 (mutual assistance)) where appropriate, and associated hyperlinks to the referenced section.

TABLE 2-2:
STATUTORY COMPLIANCE MATRIX

Requirement	Description	WMP Section and Page Number
1	An accounting of the responsibilities of person(s) responsible for executing the plan	Section 1, pp. 18-22
2	The objectives of the plan	Section 5.2, pp. 270-274 (the objectives of the plan); Section 5.3, pp. 275-314 (plan program targets)
3	A description of the preventive strategies and programs to be adopted by the electrical corporation to minimize the risk of its electrical lines and equipment causing catastrophic wildfires, including consideration of dynamic climate change risks	Section 4.2, pp. 73-83 (risk assessment); Section 4.2.B, pp. 85-89 (fuel condition assessment); Section 4.2.1, pp. 90-99 (evaluation of service territory risk); Section 4.3, pp. 100-116 (risk modeling regarding ignition risk); Section 4.5.1, pp. 134-226 (risk modeling generally); Section 7.1.A, pp. 337-340 (approaching to managing wildfire risk) Section 7.1.B, pp. 341-344 (use of risk modeling in decision-making and mitigation); Section 7.1.C, pp. 345-349 (major investments to mitigate wildfire risk); Section 7.1.F, pp. 357-358 (wildfire risk data); Sections 7.3.1 to 7.3.10, pp. 382-986 (initiative and program descriptions); Section 7.3.4.17, pp. 676-697 (initiative to address maintenance tags); Section 8.2, pp. 1011-1065 (PSPS strategy and protocols)

TABLE 2-2:
STATUTORY COMPLIANCE MATRIX
(CONTINUED)

Requirement	Description	WMP Section and Page Number
4	A description of the metrics the electrical corporation plans to use to evaluate the plan's performance and the assumptions that underlie the use of those metrics	Section 4.5.2, pp. 227-232 (calculation of key metrics); Section 6, pp. 330-335 and Attachment 2022-07-26_PGE_22_RNR_R1_Section 7.3.a_Atch01; Sections 8.1.1, pp. 990-995 and 8.1.4.1, pp. 1001-1005 (PSPS historical lookback and impact of mitigations) Section 8.5, p. 1097 and Quarterly Data Request, Table 11 (PSPS metrics)
5	A discussion of how the application of previously identified metrics to previous plan performances has informed the plan	Section 4.1, pp. 51-72 (lessons learned informing 2022 WMP); Section 4.6 Additional Remedy 5.4.B, pp. 233-269 (Asset Management and Inspections-Corrective notifications) Section 6, pp. 330-335 and Attachment 2022-07-26_PGE_22_RNR_R1_Section 7.3.a_Atch01, Tables 1-12 (WMP metrics and underlying data); Section 7.1.F, pp. 357-358 (wildfire risk data showing wildfire risk); Section 7.1.H, p. 364 (prioritization of grid design and system hardening); Section 7.1.I, p. 365 (asset management and inspection plan for 2022); Section 7.1.J, p. 366 (enhanced vegetation work 2020-2022);

TABLE 2-2:
STATUTORY COMPLIANCE MATRIX
(CONTINUED)

Requirement	Description	WMP Section and Page Number
		Section 7.3.6.8, pp. 840-871 (EPSS implementation informed by ignition metrics); Section 8.1.3, pp. 999-1000 (lessons learned for PSPS); Section 8.1.4, pp. 1001-1010 (future plans for PSPS based on lessons learned and metrics)
6	Protocols for disabling reclosers and de-energizing portions of the electrical distribution system that consider the associated impacts on public safety. As part of these protocols, each electrical corporation shall include protocols related to mitigating the public safety impacts of disabling reclosers and de-energizing portions of the electrical distribution system that consider the impacts on all of the aspects listed in Pub. Util. Code 8386c	Section 7.3.6.1, pp. 815-816 (automatic recloser operations); Section 7.3.6.8, pp. 840-871 (EPSS protocols); Sections 8.2.1 to 8.2.3, pp. 1012-1047 (decisions to de-energize for PSPS)
7	Appropriate and feasible procedures for notifying a customer who may be impacted by the de-energizing of electrical lines, including procedures for those customers receiving a medical baseline allowance as described in paragraph (6). The procedures shall direct notification to all public safety offices, critical first responders, health care facilities, and operators of telecommunications infrastructure with premises within the footprint of potential de-energization for a given event	Section 7.3.9.2 to 7.3.9.3, pp. 922-933 (community outreach, public awareness, and customer support before, during and after wildfires, and customer support during emergencies) Section 7.3.10.1, pp. 944-974 (community engagement including PSPS); Section 7.3.10.3, pp. 979-981 (coordination with suppression agencies) Section 8.2.5, pp. 1053-1064 (customer communications re PSPS); Sections 8.4.1, 8.4.3, and 8.4.4, pp. 1071-1096 (community outreach efforts before and during PSPS events)

TABLE 2-2:
STATUTORY COMPLIANCE MATRIX
(CONTINUED)

Requirement	Description	WMP Section and Page Number
8	Identification of circuits that have frequently been de-energized pursuant to a de-energization event to mitigate the risk of wildfire and the measures taken, or planned to be taken, by the electrical corporation to reduce the need for, and impact of, future de-energization of those circuits, including, but not limited to, the estimated annual decline in circuit de-energization and de-energization impact on customers, and replacing, hardening, or undergrounding any portion of the circuit or of upstream transmission or distribution lines	Section 7.3.3.11, pp. 499-526 (grid design efforts to mitigate PSPS impacts); Sections 7.3.3.16 to 7.3.3.17, pp. 553-613 (undergrounding and system hardening which can reduce de-energization events); Section 7.3.6.8, pp. 840-871 (EPSS implementation); Section 8.3, pp. 1066-1068 (projected impacts on PSPS from wildfire mitigations); Section 8.6, pp. 1098-1133 (identification of frequently de-energized circuits)
9	Plans for vegetation management	Section 7.1.J, p. 366 (enhanced vegetation work 2020-2022); Sections 7.3.5.1 to 7.3.5.21, pp. 721-815
10	Plans for inspections of the electrical corporation's electrical infrastructure	Sections 7.3.4.1 to 7.3.4.16, pp. 614-675 (asset inspections); Section 7.3.4.19, pp. 711-720 (actions taken to improve quality control and quality assurance of asset inspections); Sections 7.3.5.2 to 7.3.5.3, pp. 724-734 (distribution and transmission vegetation inspections); Sections 7.3.5.7 to 7.3.5.8, pp. 754-760 (remote sensing inspections); Section 7.3.5.17, pp. 789-798 (substation inspections);

TABLE 2-2:
STATUTORY COMPLIANCE MATRIX
(CONTINUED)

Requirement	Description	WMP Section and Page Number
		Section 7.3.5.21, pp. 811-814 (vegetation inspection guidelines).
11	Protocols for the de-energization of the electrical corporation's transmission infrastructure, for instances when the de-energization may impact customers who, or entities that, are dependent upon the infrastructure	Section 8.2.3.4, pp. 1036-1038 (PSPS protocols for transmission); Section 8.2.3.5, pp. 1039-1040 (outage impacts for transmission); Sections 8.2.3.6 and 8.2.3.7, pp. 1041-1047 (general timing for decisions and PSPS Risk-Benefit Tool)
12	A list that identifies, describes, and prioritizes all wildfire risks, and drivers for those risks, throughout the electrical corporation's service territory, including all relevant wildfire risk and risk mitigation information that is part of the Safety Model Assessment Proceeding and the Risk Assessment Mitigation Phase filings	Section 4.2, pp. 73-99 (risk drivers); Section 4.3, pp. 100-116 (ignition drivers); Section 4.5.1(a), pp. 138-148 (Enterprise Risk Model identifying risks and drivers)
13	A description of how the plan accounts for the wildfire risk identified in the electrical corporation's Risk Assessment Mitigation Phase filing	Section 4.2, pp. 73-99 (implementation of Safety Model Assessment Proceeding (S-MAP) settlement); Section 4.5.1(a), pp. 138-148 (S-MAP settlement and Enterprise Risk Model); Section 7.3.8.3, pp. 915-917 (Risk Spend Efficiency and RAMP proceeding)
14	A description of the actions the electrical corporation will take to ensure its system will achieve the highest level of safety, reliability, and resiliency, and to ensure that its system is prepared for a major event, including hardening and modernizing its infrastructure with improved engineering, system design, standards, equipment, and facilities, such as undergrounding, insulation of distribution wires, and pole replacement	Section 5.4.4, pp. 325-327 (training for grid hardening work); Section 7.1.H, pp. 363-364 (prioritization of grid design and system hardening); Sections 7.3.3.16 to 7.3.3.17, pp. 554-613

TABLE 2-2:
STATUTORY COMPLIANCE MATRIX
(CONTINUED)

Requirement	Description	WMP Section and Page Number
		(undergrounding and system hardening initiatives and programs)
15	A description of where and how the electrical corporation considered undergrounding electrical distribution lines within those areas of its service territory identified to have the highest wildfire risk in a California Public Utilities Commission (Commission) fire threat map	Section 7.1.H, p. 364 (prioritization of grid design and system hardening); Section 7.3.3.16, pp. 554-579 (undergrounding)
16	A showing that the electrical corporation has an adequately sized and trained workforce to promptly restore service after a major event, taking into account employees of other utilities pursuant to mutual aid agreements and employees of entities that have entered into contracts with the electrical corporation	Section 5.4, pp. 315-329 (workforce training and recruitment); Section 7.3.9.1, pp. 918-921 (workforce for service restoration and mutual assistance); Section 7.3.9.4, pp. 934-936 (emergency preparedness training); Section 8.2.4, pp. 1048-1052 (PSPS restoration strategy)
17	Identification of any geographic area in the electrical corporation's service territory that is a higher wildfire threat than is currently identified in a Commission fire threat map, and where the Commission must consider expanding the high fire threat district based on new information or changes in the environment	Section 4.2.1, pp. 90-99 (service territory threat evaluation)
18	A methodology for identifying and presenting enterprise-wide safety risk and wildfire-related risk that is consistent with the methodology used by other electrical corporations unless the Commission determines otherwise	Section 4.2, pp. 73-99 (implementation of Safety Model Assessment Proceeding (S-MAP) settlement); Section 4.5.1(a), pp. 138-148 (S-MAP settlement and Enterprise Risk Model); Section 7.3.8.3, pp. 915-917 (Risk Spend Efficiency and RAMP proceeding)

TABLE 2-2:
STATUTORY COMPLIANCE MATRIX
(CONTINUED)

Requirement	Description	WMP Section and Page Number
19	A description of how the plan is consistent with the electrical corporation's disaster and emergency preparedness plan prepared pursuant to Section 768.6, including plans to restore service and community outreach	Sections 7.3.9.2 to 7.3.9.3, pp. 922-933 (community outreach and customer support before, during and after wildfires and customer support during emergencies); Section 7.3.9.4, pp. 934-936 (emergency plan); Section 7.3.9.5, pp. 937-940 (preparedness and planning for service restoration after emergency); Section 7.3.10.1, pp. 944-974 (community engagement to prepare for wildfire seasons, PSPS and EPSS).
20	A statement of how the electrical corporation will restore service after a wildfire	Section 7.3.9.1, pp. 918-921 (training and personnel for service restoration); Section 7.3.9.5, pp. 937-940 (preparedness and planning for service restoration after emergency)
21	Protocols for compliance with requirements adopted by the Commission regarding activities to support customers during and after a wildfire, outage reporting, support for low-income customers, billing adjustments, deposit waivers, extended payment plans, suspension of disconnection and non-payment fees, repair processing and timing, access to electrical corporation representatives, and emergency communications	Section 7.3.9.2, pp. 922-926 (community engagement before, during and after wildfires) Section 7.3.9.3, pp. 927-933 (customer support during emergencies); Section 7.3.10.1, pp. 944-974 (customer engagement for wildfire mitigation)

TABLE 2-2:
STATUTORY COMPLIANCE MATRIX
(CONTINUED)

Requirement	Description	WMP Section and Page Number
22	A description of the processes and procedures the electrical corporation will use to do the following: Monitor and audit the implementation of the plan. Identify any deficiencies in the plan or the plan's implementation and correct those deficiencies. Monitor and audit the effectiveness of electrical line and equipment inspections, including inspections performed by contractors, carried out under the plan and other applicable statutes and Commission rules.	Section 4.1, pp. 51-72 (lessons learned); Section 4.6, pp. 233-269 (reporting on Remedies and Additional Issues identified by the Office of Energy Infrastructure Safety); Section 7.2.A, pp. 367-368 (monitor and audit WMP implementation); Section 7.2.B, pp. 369-371 (WMP deficiencies); Section 7.2.C, pp. 372-374 (monitor and audit inspection effectiveness) Section 7.3.4.14, pp. 664-668 (quality assurance and quality control (QA/QC) for inspections); Section 7.3.4.19, pp. 711-720 (actions taken to improve quality control and quality assurance of asset inspections); Section 7.3.5.13, pp. 769-779 (QA/QC for vegetation management) Section 7.3.9.6, pp. 941-942 (protocols to learn from wildfire events)

PACIFIC GAS AND ELECTRIC COMPANY

2022 WILDFIRE MITIGATION PLAN

SECTION 3

ACTUALS AND PLANNED SPENDING FOR MITIGATION PLAN

3. Actuals and Planned Spending for Mitigation Plan

3.1 Summary of Wildfire Mitigation Plan Initiative Expenditures

Table 3.1-1 summarizes the projected costs (thousands of dollars) per year over the 3-year Wildfire Mitigation Plan (WMP) cycle, including actual expenditures for past years. In Table 3.1-2, break out projected costs per category of mitigations, over the 3-year WMP plan cycle. In reporting "planned" expenditure, use data from the corresponding year's WMP or WMP Update (i.e., 2020 planned expenditure must use 2020 WMP data). The financials represented in the summary tables below equal the aggregate spending listed in the mitigations financial tables reported quarterly. Nothing in this document is required to be construed as a statement that costs listed are approved or deemed reasonable if the WMP is approved, denied, or otherwise acted upon.

TABLE 3.1-1:
SUMMARY OF WMP EXPENDITURES – TOTAL
(THOUSANDS OF DOLLARS)

Year	Spend in thousands of $USD
2020 Planned	$3,224,295
2020 Actual	$4,461,564
2020 Difference	$(1,237,269)
2021 Planned	$4,898,624
2021 Actual	$4,797,530
2021 Difference	$101,094
2022 Planned	$5,963,945
2020-22 Planned (With 2020 and 2021 Actual)	$15,223,039

TABLE 3.1-2:
SUMMARY OF WMP EXPENDITURES BY CATEGORY
(THOUSANDS OF DOLLARS)

WMP Category	2020			2021			2022	2020-2022 Planned (w/2020 and 2021 Actuals)
	Planned	Actual	Difference	Planned	Actual	Difference	Planned	
Risk and Mapping	$5,311	$5,865	$(553)	$6,841	$8,801	$(1,960)	$7,954	$22,620
Situational Awareness	42,191	83,719	(41,528)	49,789	80,932	(31,143)	82,929	247,580
Grid Design and System Hardening	1,695,179	2,359,486	(664,308)	2,641,561	2,381,682	259,879	3,134,808	7,875,976
Asset Management and Inspections	216,529	302,693	(86,164)	266,904	273,073	(6,169)	281,294	857,060
Vegetation Management (VM)	846,018	1,422,090	(576,073)	1,507,398	1,751,067	(243,668)	1,980,005	5,153,162
Grid Operations	244,065	112,819	131,245	192,059	87,173	104,885	258,000	457,993
Data Governance	90,975	58,094	32,881	147,362	95,272	52,090	97,822	251,187
Resource Allocation	2,148	7,091	(4,944)	7,121	10,001	(2,880)	9,774	26,866
Emergency Planning	44,619	53,936	(9,318)	26,341	54,401	(28,060)	56,693	165,030
Stakeholder Cooperation and Community Engagement	37,261	55,769	(18,509)	53,248	55,129	(1,880)	54,667	165,565
Total	$3,224,295	$4,461,564	$(1,237,269)	$4,898,624	$4,797,530	$101,094	$5,963,945	$15,223,039

PG&E is providing the following additional information regarding the financial expenditure information provided above in Tables 3.1-1 and 3.1-2:

- Tables 3.1-1 and 3.1-2 span multiple cost recovery mechanisms including the General Rate Case (GRC), Transmission Owner (TO) rate case at the Federal Energy Regulatory Commission (FERC), Catastrophic Event Memorandum Account (CEMA), Fire Risk Mitigation Memorandum Account (FRMMA), Wildfire Mitigation Plan Memorandum Account (WMPMA), Microgrid Memorandum Account (MGMA), Emergency Consumer Protection Memorandum Account (ECPMA), Electric Program Investment Charge (EPIC), and Wildfire Mitigation Balancing Account (WMBA). Some of these costs have already been approved for inclusion in customer rates and some of these costs are still pending review or approval through cost recovery proceedings.

- While the primary work performed for wildfire risk mitigation is in High Fire Threat District (HFTD) areas, some work and financial costs associated with Non-HFTD areas have been included in the WMP expenditure information.

- Information regarding 2020[7] and 2021[8] "Planned" are from prior WMPs, which has the prior assumptions on cost grouping by initiatives. This will result in some differences from the 2020 and 2021 "Actual," which is based on the current 2022 WMP view.

- 2022 "Planned" costs are PG&E's best estimate for the proposed programs as of February 25, 2022. Further changes to 2022 budgets and work plans are possible and actual costs may vary substantially from these plans depending on actual work completion, conditions, and requirements.

- For the 2020 and 2021 "Actual" information, the population of work included in these financial data sets is aligned to the 2022 WMP scope and list of initiatives.

- Given program changes and as cost tracking evolves over time, high level assumptions were made in some cases to recreate 2020 "Actual" in the 2022 WMP initiative view. For example, in some cases, where data is hard to identify or lack granularity, we used 2021 or 2022 as proxies to recast for 2020.

- The 2022 forecast, for the most part, is tied to the PG&E Budget, which could include additional dollars for more work or units.

  The total for Grid Design & System Hardening category in Table 3.1-2 differs from the aggregate total for Grid Design & System Hardening initiatives in Table 12. In our response to Critical Issue RN-PGE-22-13, Table 12 was updated to break out Capital costs for Undergrounding, Overhead and Remote Grid from the System Hardening initiative Section 7.3.3.17.1. The disaggregated costs are shown in Section 7.3.3.16 (Undergrounding), Section 7.3.3.3 (Overhead Conductor), and

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7 Numbers are derived from the 2020 WMP (First Quarterly Report submitted on September 9, 2020).

8 Numbers are derived from the 2021 WMP-Revised (June 3, 2021).

Section 7.3.3.17.5 (Remote Grid); however, the same costs are also still included in the initiative 7.3.3.17.1, and therefore should not be added to the Grid Design & System Hardening category totals.

3.2 Summary of Ratepayer Impact

For each of the years in Table 3.2-1, report the actual and projected cost increases to ratepayers due to utility related ignitions and wildfire mitigation activities engaged. For past years below, account for all expenditures incurred in that year due to utility related ignitions and wildfire mitigation activities. Below the table, describe the methodology behind the calculations.

Table 3.2-1 below provides the average portion of a customer's monthly bill related to utility-related ignitions (Row 1) and wildfire mitigation activities (Row 2) for a typical bundled residential non-CARE (California Alternate Rates for Energy) customer having an average monthly usage of 500 kWh (kilowatt-hours). Following Table 3.2-1, we provide an explanation concerning how the data in Table 3.2-1 was developed. Please note that the numbers in Table 3.2-1 reflect the year-over-year increase in the portion of a customer's monthly bill that is funding mitigation activities that reduce the risk of catastrophic wildfire risks or costs associated with utility-related ignitions.

TABLE 3.2-1:
WMP ELECTRICITY COST INCREASE TO RATEPAYERS

Outcome Metric Name	Annual Performance						Unit(s)
	Actual					Projected	
	2017	2018	2019	2020	2021	2022	
Increase in electric costs to ratepayer due to utility related ignitions (total)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.44 0.3%	Dollar value of average monthly rate increase attributable to utility-related ignitions per year (e.g., $0.44/month on average in 2022 across customers for utility-related ignitions occurring from 2017-in 2021)
Increase in electric costs to ratepayer due to wildfire mitigation activities (total)	$0.00	$0.00	$0.79 0.5%	$1.67 1.1%	$11.63 7.6%	$6.13 3.7%	Dollar value of average monthly rate increase attributable to WMPs per year

Note: PG&E understands that Table 3.2-1 should reflect year-over-year increases. Thus, the numbers included show the increase in the portion of a customer's monthly bill from one year to the next associated with utility-related ignitions or wildfire mitigation activities.

3.2.(a) Ratepayer Impact Due to Utility-Related Ignitions

This section addresses the first row in Table 3.2-1 regarding impacts from utility-related ignitions. For the 5-year period from 2017-2021 included in Table 3.2-1, PG&E reviewed wildfire response and recovery efforts where costs have been incurred and identified. We also reviewed advice letters related to the wildfire events that are added to the Wildfire Expense Memorandum Account (WEMA).[9]

For purposes of Table 3.2-1, PG&E is defining "utility-related ignitions" to be California Public Utilities Commission (CPUC or Commission)-reportable utility-related fire ignitions. This review resulted in the identification of 12 CPUC-reportable utility-related fire ignitions:

- 2017 – Railroad Fire, Atlas Fire, Cascade Fire, Redwood Fire, and Nuns Fire
- 2018 – Camp Fire
- 2019 – Camino Fire, Bethel Island Fire, and Kincade Fire
- 2020 – Zogg Fire
- 2021 – Dixie Fire and Fly Fire.[10]

PG&E interprets the category of "increase in electric costs to ratepayers due to utility-related ignitions" to include CEMA costs incurred for restoration activities during these catastrophic events.[11] These costs include repairing the damaged utility facilities and replacing equipment to restore service to customers.

For the period of 2017-2021, PG&E incurred approximately $1.3 billion in expenditures associated with these twelve utility-related ignitions. Excluding non-incremental overheads and amounts disallowed as a result of the CPUC's decision (Decision (D.) 20-05-019) in the Order Instituting Investigation (OII) into the 2017 Northern California wildfires and the 2018 Camp fire, the recorded adjusted amount associated with these twelve utility-related ignitions is $404 million for 2017-2021. None of these costs are or have been reflected in CPUC-jurisdictional rates to date.

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9 In accordance with D.18-06-029 issued by the CPUC, PG&E notifies the Commission via Tier 1 advice letter whenever a new event is added to the WEMA.

10 PG&E's investigation of the Kincade, Zogg, Dixie, and Fly Fires is ongoing. PG&E has included these fires for completeness because California Department of Forestry and Fire Protection (CAL FIRE) has either announced its determination that PG&E's facilities caused the fire or CAL FIRE is still investigating the cause.

11 We have not included liability insurance costs for purposes of the ratepayer impact estimate because we cannot quantify how much of these costs are due to utility-related ignitions. In addition, we are not including third-party claims costs that would be recovered through CPUC-jurisdictional rates as these costs may not be borne by customers. For example, customer rates did not include any third-party claims costs related to the 2017 fires and the 2018 Camp Fire. The recovery of third-party claims costs related to other wildfires is still uncertain and thus these costs are not included.

For CPUC-jurisdictional rates, PG&E is currently seeking recovery of recorded costs incurred through 2019 for the Camino Fire and Bethel Island Fire in the Wildfire Mitigation and Catastrophic Events (WMCE) Application (A.) 20-09-019. A proposed settlement agreement was filed in that proceeding in December 2021, which is pending CPUC approval.

For FERC-jurisdictional rates, PG&E included external legal fees and third-party claims costs for the Kincade Fire and the Zogg Fire in our Formula Rate Annual Update submitted to FERC on December 1, 2021 for Rate Year 2022. PG&E began collecting these costs in transmission rates on January 1, 2022.[12]

To calculate the ratepayer impact due to utility-related ignitions, we have included the associated revenue requirement amounts described below.

1) Revenue requirement of $0.011 million related to the 2019 Camino Fire and Bethel Island Fire included in the 2020 WMCE settlement described above. This revenue requirement is assumed to impact customer rates beginning in June 2022 through May 2024, consistent with the 2020 WMCE settlement agreement.

2) External legal fees and third-party claims costs of $44.5 million for the Kincade Fire and the Zogg Fire in the FERC rate. Beginning on January 1, 2022, these costs are being collected in electric transmission rates through the Formula Rate mechanism.

Table PG&E-3.2-1 summarizes the revenue requirement due to utility-related ignitions occurring in 2017-2021.

TABLE PG&E-3.2-1:
REVENUE REQUIREMENT – UTILITY RELATED IGNITIONS
(MILLIONS OF DOLLARS)

	2017	2018	2019	2020	2021	2022
Revenue Requirement	$0.0	$0.0	$0.0	$0.0	$0.0	$45.0

As a result, PG&E has estimated that the average monthly bill impact from utility-related ignitions costs occurring from 2017 through 2021 will be $0.44 in 2022. The bill impacts reflected in Table 3.2-1 (Row 1) are not representative of the bill increases customers will experience when these costs are implemented in rates. Rather, these bill impacts represent the portion of the total bill that would be associated with utility-related ignitions. The actual change to bills in any future period will depend on the changes in the total authorized revenue requirement and electric sales at the time of implementation.

[12] PG&E's inclusion of Zogg and Kincade fire related costs in the Annual Update has been protested by parties and those protests are currently pending before FERC.

3.2.(b) Ratepayer Impact Due to Wildfire Mitigation Activities

This section addresses the second row in Table 3.2-1 above regarding impacts from wildfire mitigation activities. PG&E incurred approximately $13.4 billion in expenditures associated with utility Wildfire Mitigation Plan (WMP) activities for the period of 2017-2021. These expenditures can be broadly categorized in five ways.

1) Costs totaling approximately $4.7 billion related to the wildfire mitigation activities approved in the 2017 GRC and the 2020 GRC, which include Enhanced Vegetation Management, system hardening program, situational awareness and public safety shut off program.

2) Costs totaling $3.9 billion recorded to the wildfire mitigation memorandum accounts (WMP Memorandum Account and Fire Risk Mitigation Memorandum Account). These costs include enhanced wildfire inspections, repair and replace, as well as microgrid programs.

3) Costs totaling approximately $2.9 billion related to transmission facilities including inspections of electric transmission facilities, system hardening, and enhanced controls.

4) Costs totaling approximately $1.8 billion related to distribution base programs. These costs are not included in the ratepayer impact calculations as these programs are related to non-mitigation activities.

5) Costs totaling approximately $0.1 billion related to Butte Rebuild, Emergency Consumer Protection Memorandum Account (ECPMA), and Electric Program Investment Charge (EPIC), which will be collected in future rates pending Commission approval of these programs through cost recovery proceedings.

Excluding non-incremental overheads and amounts disallowed as a result of the Wildfire OII D.20-05-019, the recorded adjusted amount for wildfire mitigation activities is approximately $12.3 billion for the period of 2017-2021. The specific wildfire mitigation activities reflected in existing rates are summarized below.

1) 2017 GRC Decision (D.17-05-013) – Approved $13.8 million of capital expenditures for electric distribution equipment replacement in 2019 for Tier 2 and 3 High Fire-Threat Districts. This amount was collected in rates in 2019.

2) 2020 GRC Decision (D.20-12-005) – Authorized PG&E to establish vegetation management (VM) and wildfire mitigation balancing accounts. PG&E is authorized to recover incurred costs up to the annual authorized cost cap of 120 percent for VM and up to 115 percent for wildfire mitigation through a Tier 2 advice letter filing. The following authorized amounts are included in existing rates or will be collected in rates:

    - 2020 – $657.6 million in expense for VM; $61.4 million in expense and $603.3 million in capital expenditures for wildfire mitigation. These amounts are amortized in customer rates beginning March 2021 until 2023.

- 2021 – $723.4 million in expense for VM; $63.6 million in expense and $930.9 million in capital expenditures for wildfire mitigation. These amounts are collected in customer rates in 2021-2023.

- 2022 – $795.7 million in expense for VM; $57.4 million in expense and $1,151.1 million in capital expenditures for wildfire mitigation. These amounts are collected in customer rates in 2022 through 2023/2024.

3) 2020 WMCE Application (A.20-09-019) – PG&E sought recovery of incremental recorded costs for wildfire mitigation activities incurred through December 2019 totaling $1.603 billion in the 2020 WMCE Application. A proposed settlement agreement was filed in that proceeding in December 2021 seeking approval of $1.038 billion in revenue requirement and a proposed decision on the settlement agreement is expected in the first quarter of 2022. For the bill impact calculation, PG&E has reflected the Commission's decision which granted an interim rate relief of $447 million of revenue requirement, to be collected over a 17-month period from January 2021 to May 2022. PG&E assumes the remaining revenue requirement associated with these costs, once approved, will be collected in rates over a 24-month period from June 2022 to May 2024, consistent with the settlement agreement.

4) PSPS Resiliency Strategies and Microgrid Order Instituting Rulemaking (Rulemaking 19-09-009) – PG&E incurred approximately $137 million in expense and $20 million in capital incremental costs in 2020 and approximately $127 million in expense and $17 million in capital incremental costs in 2021 associated with the Microgrids program tracked in the Microgrids Memorandum Account. These costs are related to the make-ready program, temporary generation program, and community microgrid enablement program. PG&E sought recovery of the 2020 recorded costs in the 2021 WMCE Application (A.21-09-008), which was filed in September 2021. None of these costs are or have been reflected in rates to date.

5) 2018 CEMA Application (A.18-03-015) – PG&E recorded $541 million of tree mortality and fire risk reduction expense incurred for the period of 2016 through 2019. PG&E sought recovery of 2016-2019 tree mortality expense in A.18-03-015. A proposed settlement agreement was filed in that proceeding in November 2021. The interim 2018 CEMA revenue requirement of $373 million authorized in D.19-04-039 associated with the 2016 and 2017 CEMA costs was fully collected in rates in 2019 and 2020. Of this interim rate relief amount, we assume $257 million is related to the recovery of the tree mortality and fire risk reduction expense. The remaining revenue requirement amount, following a final decision in that proceeding, is assumed to go into rates in 2022 and 2023.

6) FERC Formula Rate – PG&E incurred approximately $2.9 billion of expenditures for the period of 2017-2021, net of Wildfire OII disallowances (D.20-05-019), related to electric transmission wildfire mitigation activities. These costs will be recovered under the FERC Formula Rate mechanism. Our FERC rates are established through a Formula Rate annually (i.e., for a Rate Year) using actual costs data from the period two years prior to the Rate Year (i.e., 2017 actual costs are used for Rate Year 2019). For Operations and Maintenance expenses, the following amounts were included in rates:

- Rate Year 2019 – $0
- Rate Year 2020 – $16.6 million
- Rate Year 2021– $594.1 million
- Rate Year 2022 – $396.1 million

For capital costs, PG&E has included:

- Rate Year 2019 – $0
- Rate Year 2020 – $20.3 million
- Rate Year 2021 – $232.5 million
- Rate Year 2022 – $649.0 million

To develop an estimate of the ratepayer impact due to utility wildfire mitigation activities, PG&E converted the expenditures to revenue requirement from various decisions and applications discussed above. We have factored in cost of capital, depreciation, Assembly Bill 1054 equity rate base exclusion and other parameters in the revenue requirement calculation through 2022. We estimate a total revenue requirement of approximately $3.9 billion through 2022 associated with the $11.6 wildfire mitigation expenditures described above.

Table PG&E-3.2-2 below summarizes the revenue requirement by year for 2017 through 2022 due to wildfire mitigation activities.

TABLE PG&E-3.2-2:
REVENUE REQUIREMENT – WILDFIRE MITIGATION ACTIVITIES
(MILLIONS OF DOLLARS)

	2017	2018	2019	2020	2021	2022
Revenue Requirement	$0.0	$0.0	$51.4	$223.0	$1,467.3	$2,129.1

As described above, PG&E has made certain assumptions on the cost recovery periods in order to calculate monthly bill impacts through 2022 associated with wildfire mitigation activities. For costs that have been approved to go into rates, PG&E has reflected the recovery period as outlined in the decision. For costs contained in applications that have already been filed, PG&E has reflected the cost recovery periods proposed in those applications or subsequent settlement agreements. As a result, PG&E has estimated that the year over year increase in the portion of a customer's monthly bill that is funding wildfire mitigation activities occurring from 2017 through 2021 was $0.00 in 2017, $0.00 in 2018, $0.79 in 2019, $1.67 in 2020, $11.63 in 2021, and $6.13 in 2022. The actual change to bills in any future period will depend on the changes in the total authorized revenue requirement and electric sales at the time of implementation.

PACIFIC GAS AND ELECTRIC COMPANY

2022 WILDFIRE MITIGATION PLAN

SECTION 4

LESSONS LEARNED AND RISK TRENDS

4. Lessons Learned and Risk Trends

4.1 Lessons Learned – How Tracking Metrics on the 2020 and 2021 Plans Informed the 2022 Plan Update

Describe how the utility's plan has evolved since the 2020 Wildfire Mitigation Plan (WMP) and 2021 WMP Update submissions. Outline any major themes and lessons learned from the 2020 and 2021 plans, and subsequent implementation of the initiatives. In particular, focus on how utility performance against the metrics used has informed the 2022 WMP Update. Include an overview map of the utility's service territory. If any of the lessons learned are derived from data, include visual/graphical representations of this/these lesson(s) learned.

At a high level, the lessons learned in 2021 from implementation of the 2021 WMP involve three key themes:

- Continued safety focus – We are continuing to reinforce and expand our situational awareness, customer outreach and support, and refine operational practices to both reduce wildfire potential and the customer impacts of our mitigation programs.

- Coordination and knowledge sharing – We are enhancing our risk modeling, fire consequence modeling, operational practices, and reporting (e.g., remediations for tracking and reporting identified by the California Public Utilities Commission (CPUC or Commission)), and working in coordination with our peer California utilities, academic community, industry experts, regulators, and other external partners.

- Refine focus areas to most effective core programs – We are continuing to evaluate the anchors of our Wildfire Mitigation work from system hardening and Enhanced Vegetation Management (EVM) and new programs such as Enhanced Powerline Safety Settings (EPSS) and undergrounding, driven by our analysis of risk reduction and the balance towards faster implementation and more permanent mitigation considering continuing challenges with climate change.

In addition to these high-level lessons learned, there were also a number of specific situations that resulted in lessons learned and actions taken to address those lessons. In our 2021 Revised WMP, we described lessons learned for five areas and our approach in 2021 for addressing these lessons learned.[13]

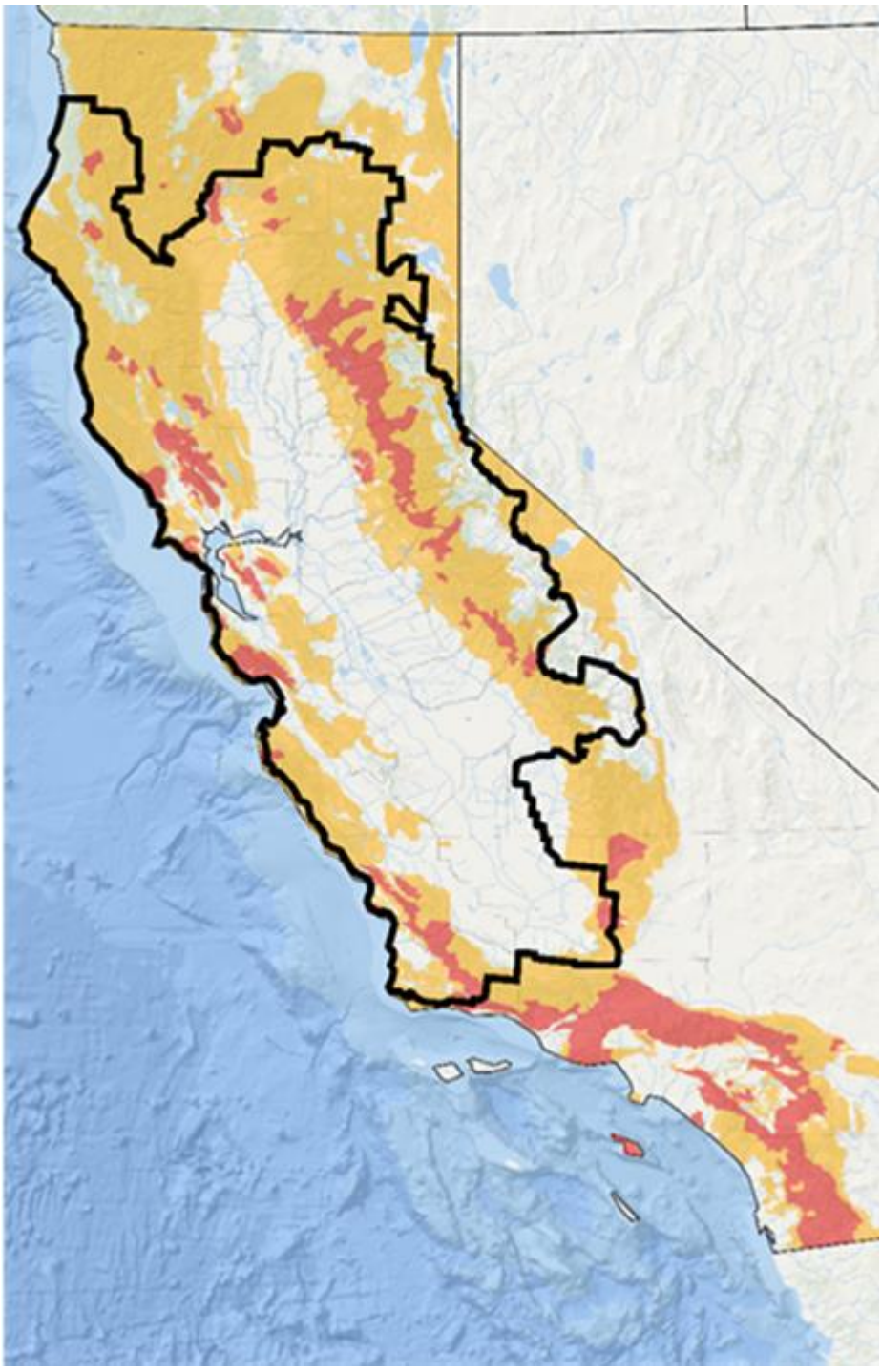
Below, we summarize our progress in 2021 on these 2020 lessons learned. We are also providing a summary of lessons learned in 2021 in a number of different areas and on a number of different issues, and how these lessons have informed our 2022 WMP.

Finally, in response to the request for an overview map of PG&E's service territory, we are providing Figure PG&E-4.1-1 below, which outlines PG&E's service territory, as well as the High Fire Threat District (HFTD) Tier 2 (orange) and Tier 3 (red) areas.

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13 2021 Revised WMP, pp. 46-50.

FIGURE PG&E-4.1-1:
PG&E SERVICE TERRITORY AND TIER 2 AND TIER 3 HFTD AREAS



The remainder of this section includes:

Subsection 4.1(a): 2020 Lessons Learned and 2021 Progress;

Subsection 4.1(b): Lessons Learned from Enhanced Oversight and Enforcement Process (EOEP);

Subsection 4.1(c): Lessons Learned from Self-Identified Issues;

Subsection 4.1(d): Lessons Learned from the 2020 WMP Independent Evaluator (IE) Report;

Subsection 4.1(e): Lessons Learned from EPSS Implementation;

Subsection 4.1(f): Lessons Learned Regarding Environmental Remediation;

Subsection 4.1(g): Lessons Learned from Streamlining the 2022 WMP and Initiative Targets; and

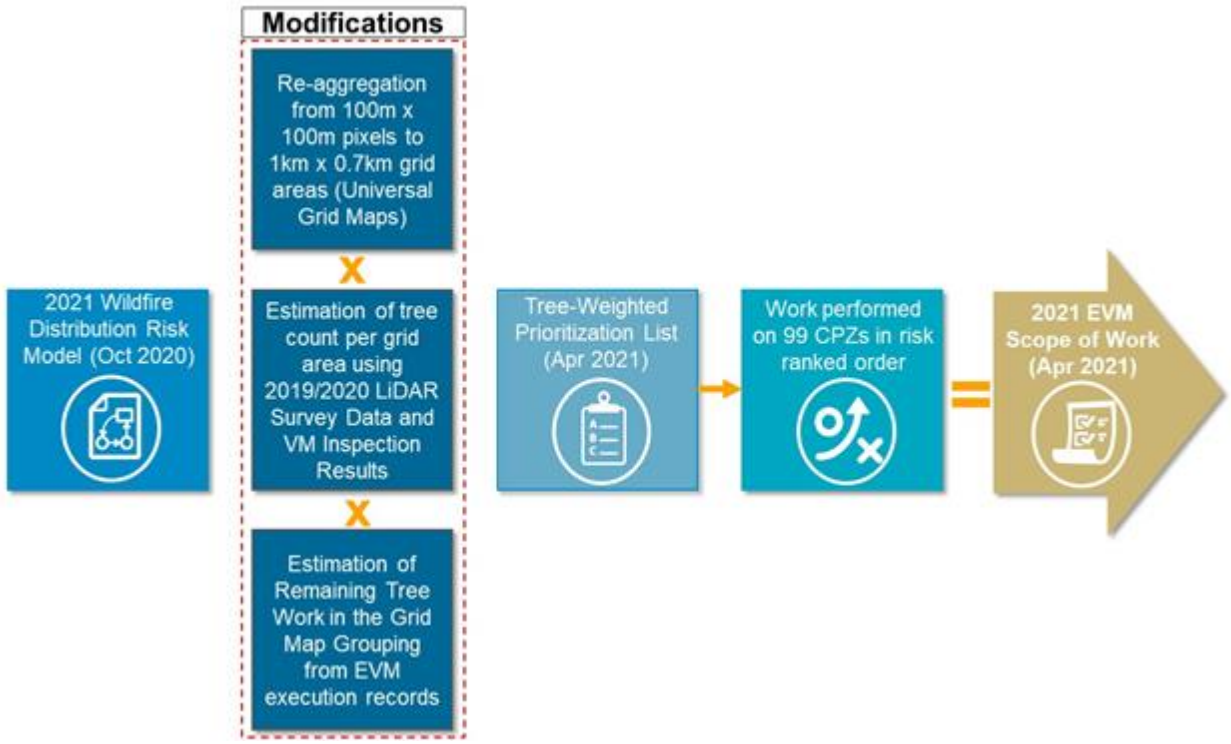
Subsection 4.1(h): Response to Critical Issue RN-PG&E-22-01.

4.1(a) 2020 Lessons Learned and 2021 Progress

The 2021 WMP identified five areas for lessons learned in 2020: (1) EVM risk prioritization; (2) system inspection prioritization and execution; (3) vegetation management quality improvements; (4) risk modeling improvements; and (5) Public Safety Power Shutoff (PSPS) improvements. We made substantial progress on each of these areas in 2021 and plan to continue that progress in 2022. A brief description of the progress in each area is provided below:

- EVM Risk Prioritization – In 2021, we used the 2021 Wildfire Distribution Risk Model (WDRM) v2 and supplemented it with the most up-to-date LiDAR and inspection data and developed the 2021 EVM Scope of Work to prioritize the highest risk circuit segments (also referred to as circuit protection zones or CPZs). At a high level, the risk prioritization process for EVM in 2021 is reflected in Figure PG&E-4.1-2 below.

FIGURE PG&E-4.1-2:
DEVELOPMENT OF RISK PRIORITIZED 2021 EVM SCOPE OF WORK



As a result of this prioritization, PG&E performed almost 98 percent of our EVM work in 2021 on the top 20 percent of the highest risk circuit segments. For more information on our EVM Program see subsection (b) below and Section 7.3.5.2.

- System Inspection Prioritization and Execution – In 2021, PG&E's Asset Strategy groups developed playbooks to perform a full review of assets to validate that system inspections in the highest risk areas were prioritized for inspection before late summer peak of wildfire season. We also updated our asset records in our Asset Registry, including the work down of our as-built and mapping corrections backlog, to ensure that they are being assigned to prioritized maintenance plans. For more information on our System Inspection program improvements, see Section 7.3.4.3. PG&E continues to improve our timeliness of technology updates to align with training schedules and the start of inspection schedules.

- Vegetation Management Quality Improvements – In 2021, we significantly increased resources to validate the quality of vegetation management work, including adding contract resources and internal Work Verifiers, the creation of the Quality Control group to focus on active field observations, and an increase in Senior Vegetation Management Inspectors to provide additional real-time safety and compliance support in the field. For more information on our Vegetation Management Quality improvements, see Section 7.3.5.6.

- Risk Modeling Improvements – PG&E continued to improve our risk modeling capabilities, including implementing automated data intake, improved code execution and model spatial views, and post-model steps to workplan development.

These improvements now provide a repeatable and more transparent set of tools with which to use and review model results. Finally, improved data has refined the predictive power of the wildfire risk models. To improve the predictive power of the wildfire risk models, we have updated asset failure and 'risk events' data sets with another year of training data and improved data sets that characterize asset and climate conditions such as LiDAR, inspection data, meteorology, fuels, and soils. For more information on our risk modeling improvements, see Section 4.5.1.

- PSPS Improvements – In 2021, we implemented new PSPS protocols and processes that impacted the scoping of PSPS events and continued to implement programs that reduce the customer impacts of these events. These improvements resulted in better balancing the benefits of mitigating wildfire risks against the customer impacts from a PSPS event. Our improvements focused on the following areas: (1) meteorology modeling and distribution scoping improvements; (2) transmission scoping protocols; (3) risk-benefit tool; (4) mitigation initiatives; (5) re-energization strategy and protocols; and (6) programmatic improvements in communication, resources, and assistance to impacted customers and communities. For more information on our PSPS program improvements, see Section 8.1.

4.1(b) Lessons Learned From EOEP

In Resolution (Res.) M-4852, the CPUC placed PG&E in Step 1 of its EOEP process because of "insufficient progress with risk driven mitigation efforts", specifically with regards to EVM.[14] On May 6, 2021, in response to CPUC direction, we submitted our EVM Corrective Action Plan (CAP).[15] The EVM CAP specifically addressed shortcomings the CPUC identified in our EVM Program regarding risk prioritization of work. The EVM CAP included a detailed discussion of how PG&E will prioritize the highest risk circuit segments for work in 2021.[16] PG&E has provided three 90-Day Update reports to the CPUC regarding our progress on EVM work in 2021, as well as our 2022 EVM workplan.[17] PG&E has also participated in two CPUC-sponsored workshops regarding the EVM CAP.

Relevant to this section of the 2022 WMP, the EVM CAP included four lessons learned from 2020 regarding the EVM Program and specific actions that PG&E had implemented in 2021 to address these issues.[18] In summary, in our EVM CAP we identified lessons learned and remedies for each lesson learned concerning: (1) risk

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14 Res.M-4852 at p. 1.

15 *Enhanced Oversight and Enforcement Process Corrective Action Plan*, submitted May 6, 2021 (EVM CAP).

16 EVM CAP, pp. 11-15.

17 See 90-Day Reports submitted by PG&E on August 4, 2021, pdfa_planofreorganizationoii-2019_report-pge_20210804-public.pdf (ca.gov), November 4, 2021 (Attachment 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.1_Atch01), and February 2, 2022 (Attachment 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.1_Atch02).

18 EVM CAP, p. 7.

prioritization of EVM work; (2) consistency and clarity as to risk modeling used to inform EVM work; (3) goals focused on performing the highest risk work; and (4) centralized decision making and oversight regarding EVM work through the Wildfire Risk Governance Steering Committee (WRGSC). The EVM CAP provides more detail about each of these four lessons learned and changes that we implemented in 2021 to address these lessons learned.[19]

4.1(c) Lessons Learned From Self-Identified Issues

During 2021, PG&E submitted several notices to the CPUC regarding issues that we had self-identified. Some of these self-identification notices included lessons learned and PG&E's plans to address those lessons learned. In this section of the 2022 WMP, we are providing a summary of the lessons learned in the self-identification notices and references to materials that have more detailed discussions of the lessons learned and corrective actions taken.

On March 4, March 12, and May 20, 2021, PG&E identified issues related to enhanced inspections of hydroelectric substations in 2020. In our May 20, 2021 letter, we described corrective actions regarding our substation inspection process going forward including clear roles and responsibilities, a comprehensive inventory with programmatic oversight, a comprehensive and auditable maintenance and inspection program, and issues related to our ongoing CAP Program. PG&E's implementation of these corrective actions is described in more detail in the May 20, 2021 letter.[20]

On May 7, 2021, PG&E identified issues related to General Order (GO) 165 and WMP enhanced inspections for electric distribution poles. We indicated that certain GO 165 inspections had not occurred within the required compliance time and that certain poles in Tier 3 areas had not been inspected consistent with our 2020 WMP. In our self-identification letter, we provided a gap analysis and CAP including performing the required inspections, implementing controls for our inspection program, and strengthening our asset registry. PG&E's implementation of these corrective actions is described in more detail in the May 7, 2021 letter.[21]

On June 1, 2021, we self-identified issues related to accounting for the number of weather stations and high-definition cameras in prior WMPs. We indicated that some of the numbers in our WMP needed to be corrected and provided updated numbers. In our November 1, 2021 Progress Report, for Remedy PG&E-21-08, we indicated that as a result of lessons learned from this self-identified issue we have instituted "standardized counting procedures and the development of detailed WMP reporting and

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19 *Id.*

20 See Letter from Debbie Powell to Caroline Thomas Jacobs and Leslie Palmer dated May 20, 2021, pp. 3-4.

21 See Letter from Debbie Powell to Caroline Thomas Jacobs and Leslie Palmer dated May 7, 2021, pp. 4-5.

confirmation requirements across the entire Community Wildfire Safety Program portfolio to eliminate any future reporting ambiguity."[22]

4.1(d) Lessons Learned From the 2020 WMP IE Report

On June 30, 2021, Bureau Veritas North America (BV) issued its *Final Independent Evaluator Annual Report on Compliance* for the 2020 WMP (2020 WMP IE Report). PG&E provided our response to the 2020 WMP IE Report on August 16, 2021 (PG&E IE Report Response). The 2020 WMP IE Report described audits of PG&E and recommended areas of improvement in areas such as EVM, VM tag procedures, pole inspections, weather stations, High Definition cameras, fuse replacement installations, and sectionalizing devices. PG&E addressed these audit findings and provided our comments regarding areas for improvement in the PG&E IE Report Response.[23] For example, we addressed locations that BV indicated vegetation management work was not in compliance with our standards, corrected field records with prepopulated data for pole inspections, and performed field verifications of conditions identified in the 2020 WMP IE Report. These lessons learned and improvements that PG&E is planning to make are described in more detail in the PG&E IE Report Response.

4.1(e) Lessons Learned From EPSS Implementation

We implemented our EPSS program in 2021 by setting devices with faster trip settings and higher impedance fault detection. This allowed our equipment to automatically turn off more quickly if the system detected a problem, such as an object striking an overhead line. The EPSS program had significant benefits including an 80 percent reduction in CPUC-reportable ignitions on EPSS-enabled circuits as compared to a 3-year average. However, while EPSS significantly reduced ignition risk, it also adversely impacted customer service as a result of increased outages. We received feedback from customers and communities regarding the impact of EPSS. Some of the lessons learned from the initial EPSS program implementation include:

- Better defining and managing risk-informed criteria for where and when to enable EPSS and establishing more localized thresholds for activation and shut-off of EPSS devices;
- Developing more optimized circuit settings;
- Improving outage response times;
- Centralizing data and reporting across enabled processes, systems, and tools;
- Proactive customer engagement and outreach regarding EPSS; and
- Ongoing and regular reporting regarding EPSS impacts.

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22 *Pacific Gas and Electric Company's Submission of 2021 Wildfire Mitigation Progress Report*, dated November 1, 2021, p. 22 (Progress Report).

23 PG&E IE Report Response, pp. 4-8.

4.1(f) Lessons Learned Regarding Environmental Remediation

In our Progress Report, we described lessons learned regarding environmental remediation.[24] With regards to working with agencies and local and state governments, we are continuing our work to obtain additional programmatic permits/agreements due to the success we have seen with our current agreements. This programmatic approach has provided a clear strategy for agencies, local and tribal governments, and PG&E to process the substantial amount of work around wildfire mitigation and system hardening. Through the development of these agreements, we have created standardization around work notification packages and nomenclature to describe the work. These agreements have also allowed us to help address the resource shortfall with many of these agencies and governments, by creating reimbursable agreements. The reimbursable agreements allow for the agencies and governments to hire additional staff to address PG&E's workload. These agreements have also created a more constructive and collaborative relationship between our agency and government partners and PG&E as there is more engagement between PG&E and our agency and government partners' leadership. This enables us to work through challenges when they arise due to the stronger lines of communication that have been built in the development and rollout of these agreements.

4.1(g) Lessons Learned From Streamlining the 2022 WMP and Initiative Targets

Since the WMP process began, the complexity and scope of the WMPs has expanded significantly. We are mindful of Energy Safety's direction to streamline WMP reporting and so, in the 2022 WMP we developed a template for each initiative in Section 7.3 so similar information is provided for each Initiative.

In addition, in preparing our 2022 WMP, we also benchmarked against Southern California Edison Company's (SCE) and San Diego Gas & Electric Company's (SDG&E) 2021 WMPs. Specifically, we reviewed the number of initiative targets that SCE and SDG&E adopted and reported on in their 2021 WMPs, as well as the overall length and structure of their WMPs. This was helpful to better align with the utilities on our approach to initiative targets.

As a result of these efforts, we have reduced the number of our initiative targets. We have identified our quantitative and qualitative Initiative Targets for 2022 in Tables 5.3-1(a) and 5.3-1(b), respectively. The Initiative Targets are also repeated in the specific initiative descriptions in Section 7.3. We believe that these changes are consistent with Energy Safety's direction regarding streamlining the 2022 WMP.

4.1(h) Response to Critical Issue RN-PG&E-22-01:

Critical Issue Title: PG&E has not adequately documented the causes of, or direct lessons learned from, PG&E-ignited catastrophic wildfires.

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[24] Progress Report, p. 74.

Required Remedies: *For each PG&E-ignited catastrophic wildfire (greater than 500 acres) since 2017,*[25] *PG&E must:*

a. List the cause(s) of each catastrophic wildfire and any associated lessons learned, and

Detail the specific measures PG&E is taking to i) directly mitigate the causes of past PG&E-ignited catastrophic wildfires, and ii) integrate lessons learned from past PG&E-ignited wildfires into its wildfire mitigation strategy

Response to Critical Issue RN-PG&E-22-01:

In response to this Critical Issue, we are providing a description of each fire that: (1) occurred since 2017; (2) was greater than 500 acres; and (3) was determined by the California Department of Forestry and Fire Protection (CAL FIRE), a local fire suppression agency, the Safety and Enforcement Division, or the United States Forest Service (USFS) to have been caused by Pacific Gas and Electric Company (PG&E) or its assets.[26] We appreciate the feedback from the Office of Energy Infrastructure Safety (Energy Safety) regarding the need to provide lessons learned that are specifically related to the fire at issue. In this response and going forward in future Wildfire Mitigation Plans (WMP), we will identify lessons learned and specific mitigations related to the causes of specific fires.

For each fire below, in addition to the date of ignition and cause, we are describing the lessons learned, measures to mitigate the cause, and how the lessons learned have been integrated into our wildfire strategy. We note that:

- The cause indicated is based on available PG&E information and evaluations and/or reports or information provided by external parties. There may have been additional causes and/or contributing factors that were not evident based on the information available and/or identified in the reports received. In addition, for some of the fires below, PG&E was not able to confirm, based on available evidence, an external party's determination regarding the cause of the fire.

- For the integration of lessons learned into our wildfire strategy, we identify programs in our 2022 WMP that integrate lessons learned. For brevity, we are not providing a lengthy description of each program identified but are instead providing a reference to where in the 2022 WMP a description of the program is provided.

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25 Where CAL FIRE, USFS, or local fire suppression agencies determined PG&E or its assets caused the fire or the CPUC's Safety and Enforcement Division found PG&E in violation. Nothing in this response should be taken as an admission of causation, which is not essential to a lessons learned approach.

26 We are not including the Wolf Fire which occurred on January 19, 2021. The Wolf Fire could have been contained at approximately 100 acres but was allowed to burn by fire authorities as part of a 'firing out' operation to remove fuels, ultimately reaching 685 acres.

- We are continuing evolve and strengthen our mitigations based on ongoing learnings. For example, although not implemented in response to the 2017 fires, the EPSS implemented in 2020 has substantially reduced ignitions.

Finally, PG&E is in the process of significantly enhancing our ignition investigation process. The enhanced ignition investigation process will impact lessons learned from ignitions and wildfires going forward. The Enhanced Ignition Analysis program is described in more detail in our response to Critical Issue RN-PG&E-22-06.

Fire Name: Railroad Fire	
Date of Ignition	August 29, 2017
Cause Based on Available Information	PG&E tree contractor inadvertently dropped dead Cedar tree that the contractor was working on into a PG&E distribution line.
Lessons Learned	PG&E did not perform a specific lessons learned analysis for the Railroad Fire. However, we have significantly improved PG&E employee and contractor training with regard to vegetation management.
Measures to mitigate cause	Not applicable.
Integration of Lessons Learned into Wildfire Strategy	While we did not implement specific mitigations related to the Railroad Fire, we have significantly improved the training of and minimum qualifications for vegetation management employees and contractors. These efforts include working with seven community colleges to develop and implement an extensive five-week training program for tree crews and workers. (2022 WMP, Section 7.3.5.14). PG&E has also implemented training programs for vegetation management employees and contractors who are responsible for vegetation management projects. (2022 WMP, Section 5.4.2)

Fire Name: October 2017 Wildfires	
Date of Ignition	Various (see details below for each fire)
Cause Based on Available Information	Vegetation contact and equipment failures in high winds (see details below for each fire)
Lessons Learned	The October 2017 wildfires occurred during high wind events that resulted in: (1) vegetation contact with electrical facilities; and/or (2) equipment failure. Our lessons learned focused on vegetation management, equipment failure, and high wind weather events.[(a)]
Measures to mitigate cause	Vegetation Contact: Initiated Enhanced Vegetation Management (EVM) program in High Fire Threat District (HFTD) areas to go above and beyond regulatory requirements and address the highest risk Circuit Protection Zones (CPZ). Increased vegetation inspection capabilities by employing enhanced technologies such as Light Detection and Ranging (LiDAR). By 2019, we had captured LiDAR and imagery data on almost all Tier 2 and Tier 3 HFTD distribution lines. Implemented a digital record system for EVM data to better track vegetation and identify potential risks. Disabled automatic reclosers in Tier 2 and Tier 3 HFTD areas to prevent potential ignitions from vegetation contact in high wind and weather events during fire season. Implemented system hardening program to mitigate risks associated with vegetation contact. Equipment Failures: Developed modeling and analytics to evaluate conductor to conductor contact (Cascade Fire). Evaluated the types of materials used for distribution poles for strength and resiliency to mitigate pole failures (Sulphur Fire). High Winds and Weather Leading to Potential Ignitions: Developed and began implementation of Public Safety Power Shutoff (PSPS) program in 2018 for distribution lines that traverse Tier 3 areas to mitigate potential ignitions from vegetation contact or equipment failure that could occur during high wind and other weather events. In 2019, PSPS was expanded to all distribution and transmission lines that traverse Tier 2 and Tier 3 HFTD areas. Installed weather stations to be more aware of local weather and wind conditions.

(a) PG&E notes that the California Public Utilities Commission (CPUC) is currently conducting a Root Cause Evaluation (RCE) of the October 2017 Wildfires. The results of the RCE may result in additional lessons learned.

Fire Name: October 2017 Wildfires			
Integration of Lessons Learned into Wildfire Strategy	Vegetation Contact: EVM has been integrated into our vegetation management program and for the 2022 WMP is being performed on 1,800 of the highest risk ranked circuit miles. (2022 WMP, Section 7.3.5.2) We have incorporated LiDAR vegetation inspections for both distribution and transmission facilities and have plans to continue to capture and update our LiDAR datasets. (2022 WMP, Sections 7.3.5.7 and 7.3.5.8) We have continued to enhance and are developing our One Vegetation Management platform, which will allow for digital work packages, tracking, and records for vegetation management. (2022 WMP, p. 773) We have SCADA-enabled many reclosers and for reclosers that are automatic, we are continuing to disable them in HFTDs during fire season. (2022 WMP, Section 7.3.6.1) We have significantly expanded our system hardening program, including undergrounding, which is intended to mitigate the potential for vegetation caused ignitions. (2022 WMP, Section 7.3.3.17) Equipment Failure: We are focusing our pole loading and replacement program on Tier 2 and Tier 3 HFTD areas to address potential pole failures that may lead to an ignition, such as the pole failure related to the Sulphur Fire. In 2021, we performed a pole loading analysis on 61,000 of the highest risk poles. (2022 WMP, Section 7.3.3.13). In addition, as a part of our system hardening program, we are evaluating and where needed replacing poles with stronger composite poles that reduce the risk of failure during wildfires. (2022 WMP, p. 539) Our PSPS program addresses weather conditions including high wind events. Because conductor to conductor contact typically occurs during high wind events, the PSPS program can mitigate the wire-to-wire contact that occurred in the Cascade Fire. (2022 WMP, Section 8.) High Winds and Weather: We have continued to evaluate and refine our PSPS program which is intended to prevent ignitions during high wind and other weather conditions, such as Red Flag Warnings. (2022 WMP, Section 8.2.3) We are continuing to install weather stations and high definition cameras for situational awareness of high winds and weather events. (2022 WMP, Sections 7.3.2.1.3 and 7.3.2.1.4)		
October 2017 Wildfire Details	Fire Name	Ignition Date	Cause
	CHEROKEE	10/8/2017	Vegetation Contact
	ADOBE	10/8/2017	Vegetation Contact
	NUNS	10/8/2017	Vegetation Contact
	SULPHUR	10/8/2017	Pole Failure
	LA PORTE	10/8/2017	Conductor Failure
	PRESSLEY	10/8/2017	Vegetation Contact
	NORRBOM	10/8/2017	Vegetation Contact
	REDWOOD VALLEY	10/8/2017	Vegetation Contact

Fire Name: October 2017 Wildfires			
	CASCADE	10/8/2017	Wire-Wire Contact in High Wind
	PARTRICK	10/8/2017	Vegetation Contact
	ATLAS	10/8/2017	Vegetation Contact
	LOBO	10/9/2017	Vegetation Contact
	PYTHIAN/OAKMONT	10/17/2017	Vegetation Contact
	POCKET	10/21/2017	Vegetation Contact

Fire Name: Airline Fire	
Date of Ignition	June 4, 2018
Cause Based on Available Information	The Eastern and Airline Fires started at two different points and had two different apparent causes but are related: (1) the Eastern Fire resulted from a healthy tree branch that leaned into a distribution pole in high winds breaking one of three conductors (CAL FIRE determined that tree-trim activities were sufficient); and (2) the Airline Fire was a result of the Eastern Fire vegetation contact which caused a fault current resulting in a conductor failure on a long span and a wire down. The long span did not have vibration dampers which may have weakened the conductor that failed.
Lessons Learned	The tree which caused the initial ignition (Eastern Fire) was healthy and CAL FIRE determined that tree-trim activities were sufficient. However, a contributing cause leading to the second ignition (Airline Fire) may have been missing vibration dampers which were not identified in previous inspections and maintenance.
Measures to mitigate cause	We are currently in the process of reviewing our existing maintenance tags for tags that identify missing vibration dampers and are also reviewing our guidance to inspectors so that they properly identify missing vibration dampers during inspections.
Integration of Lessons Learned into Wildfire Strategy	As described above, we are currently reviewing existing maintenance tags for missing vibration dampers and reviewing guidance that we give to inspectors with regard to vibration dampers. More generally, we have improved the scope and quality of our inspection processes to identify and create maintenance tags for equipment issues. Our detailed inspection processes are described generally in Sections 7.3.4.1 and 7.3.4.2 of the 2022 WMP. Improvements that we are making to the quality of our inspections are described in the response to Critical Issue RN-PG&E-22-08.

Fire Name: Camp Fire	
Date of Ignition	November 8, 2018
Cause Based on Available Information	Connection Device (C-Hook) Failure on overhead transmission line. Red Flag Warning (RFW) the day of ignition.
Lessons Learned	The Camp Fire resulted from a connection device (C-Hook) failure that caused an ignition. The lessons learned from the Camp Fire include: (1) the need for rigorous equipment inspections and maintenance; and (2) using risk modeling to prioritize inspection and maintenance work so that maintenance is performed in the highest risk area for wildfires. In the enhanced inspection process, wear on C-Hooks and other equipment was specifically addressed.
Measures to mitigate cause	Enhanced Asset Inspections: Initiated Wildfire Safety Inspection Program (WSIP) in 2019 to perform enhanced inspections of all PG&E overhead transmission and distribution equipment and facilities in HFTD areas. This program, which became the foundation of our current enhanced inspection program, was informed by a Failure Modes and Effects Analysis (FMEA) that PG&E conducted after the Camp Fire. The FMEA identified multiple potential points of failure on transmission assets that could cause ignitions, including wear on C-hooks and other insulator attachment hardware, and the failure points capable of visual observation were incorporated into WSIP inspection forms. A similar approach was utilized for WSIP inspections of distribution facilities. PG&E's enhanced WSIP inspections differed from our prior routine inspections in various ways, including, for transmission towers in elevated and extreme high fire-threat areas, the use of climbing and drones equipped with high-resolution cameras; inspection forms that specifically required inspectors to check for certain potential failure modes (including worn cold-end hardware) and document the condition of various components (including cold-end hardware), regardless of whether they required repair; review of drone photographs by members of the Drone Inspection Review Team; and review and prioritization of inspection findings by Centralized Inspection Review Team (CIRT), composed of qualified personnel with collective experience in engineering, inspections and maintenance. Risk Modeling and Prioritized Inspections and Maintenance: Develop risk models that specifically evaluate the potential for asset or equipment failure, including failure associated with asset age, environmental factors such as wind speed and direction, corrosion and other relevant risk drivers where such a failure may result in a wildfire ignition. Use risk models to inform prioritization of highest risk maintenance tag work Expanded PSPS Program: In 2019, PSPS was expanded to all distribution and transmission lines that traverse Tier 2 and Tier 3 HFTD areas.

Fire Name: Camp Fire	
Integration of Lessons Learned into Wildfire Strategy	Enhanced Asset Inspections: We have implemented detailed asset inspections which are now a part of wildfire strategy for both distribution and transmission facilities in HFTD and High Fire Risk Areas (HFRA). (2022 WMP, Sections 7.3.4.1 and 7.3.4.2) Risk Modeling and Prioritized Inspections and Maintenance: We are developing sub-models for our risk modeling that specifically evaluate the potential for equipment failure. (2022 WMP, Sections 4.5.1 and 7.3.1.3, as well as Initiative Targets A.01 and A.02) We have also used risk modeling to prioritize inspections for transmission facilities. For example, the annualized Operability Assessment Model which was used in conjunction with the Wildfire Consequence Model to develop transmission wildfire risk scores. (2022 WMP, Section 7.3.4.2) In 2021, PG&E began to utilize risk modeling to proactively reduce risk from the current backlog of maintenance tags by prioritizing the highest risk tags. (2022 WMP, pp. 316-317)

Fire Name: Lonoak Fire	
Date of Ignition	June 25, 2019
Cause Based on Available Information	Bird strike mid-span resulted in fault stress on wire and caused #2 gauge Aluminum Conductor Steel Reinforced (ACSR) wire to fail. In addition, the Alcoa Stockbridge vibration dampers may have contributed to the failure of the conductor wire.
Lessons Learned	Periodic inspection and maintenance of the equipment was not adequate for the wires or the vibration damper. In addition, vibration damper may have accelerated crack propagation in wires.
Measures to mitigate cause	Corrective Action Program (CAP) event assigned to determine ongoing risk from vibration dampers in the field and deployed on #2 ACSR and #4 ACSR conductor wires. Specifically, the team evaluated extent of risk between two ACSR and Alcoa Stockbridge dampers. PG&E Procedure TD-2305-JA02 (job aid) was updated with photographs from this incident to demonstrate what to look for in inspections with regard to broken wire stands at the vibration damper.
Integration of Lessons Learned into Wildfire Strategy	We have updated our job with regard to inspections for broken wire near vibration dampers. More generally, we have implemented detail inspections and are working to improve inspection quality. Our detailed inspection processes are described generally in Sections 7.3.4.1 and 7.3.4.2 of the 2022 WMP. Improvements that we are making to the quality of our inspections are described in the response to Critical Issue RN-PG&E-22-08.

Fire Name: Kincade Fire	
Date of Ignition	October 23, 2019
Cause Based on Available Information	One of the open jumpers on a transmission tower located along the Sonoma and Lake County border broke due to wear induced by wind and caused an ignition near the base of the tower.
Lessons Learned	The Kincade Fire resulted from an electrical line that was not being used at the time but that was still energized and the jumpers were electrically connected. Lessons learned involved: (1) evaluating whether idle facilities should remain energized and/or be removed; and (2) equipment failure resulting from weather conditions.
Measures to mitigate cause	Removal of Idle Facilities and Jumpers: Immediately after the Kincade Fire, PG&E reviewed all transmission lines to determine if other energized spans not serving customer load remained. Based on the review, one line in an HFTD area was identified and de-energized. Revised guidance issued for employees and contractors regarding idle facilities and open jumpers and issued guidance on open jumpers to be cut as short as practical, typically 2-3 feet in length. Surveyed transmission system to identify and remediate open jumpers not in compliance with new guidance. Revised inspection forms so that inspectors are required to report facilities that are not serving customer load. Removed remaining idle facilities in the area where the Kincade Fire was initiated. Implemented plan to remove conductor and structures (where applicable) associated with approximately 70 permanently abandoned transmission lines or portions of transmission lines. Risk Modeling: Developed risk modeling intended to focus on the probability of asset failure to prioritize asset management work. Enhanced Asset Inspections and Maintenance: Implemented enhanced inspections and risk prioritized maintenance programs to address items identified during inspection.
Integration of Lessons Learned into Wildfire Strategy	Idle Facilities: We have included the removal of idle distribution and transmission facilities as a part of our overall system hardening program. (2022 WMP, Sections 7.3.3.17.1 and 7.3.3.17.2) Risk Modeling: We have developed the Wildfire Transmission Risk Model (WTRM) to assess risk based on the probability of equipment or an asset failure. (2022 WMP, Sections 4.5.1 and 7.3.1.3, as well as Initiative Target A.02). Enhanced Asset Inspections and Maintenance: We have been implementing enhanced inspections in HFTD and HFRA areas and prioritizing maintenance. These programs are described in more detail above in the discussion of the Camp Fire.

Fire Name: Grizzly Fire	
Date of Ignition	October 27, 2019
Cause Based on Available Information	Grass fire occurred in a wildlife area utilized for bird and elk hunting. PG&E did not evaluate or collect physical evidence at the time because none of the authorities or media reports suggested that PG&E's facilities were implicated. The fire could have resulted from overhead electrical equipment, but we are unable to determine the precipitating event(s) which may have caused an equipment failure. There was a RFW the day of ignition.
Lessons Learned	Although PG&E was unable to determine the apparent and/or contributing causes, three mitigation measures were implemented.
Measures to mitigate cause	Special Patrol of Circuit: Following investigation of the incident, and out of an abundance of caution, an additional patrol was initiated downstream from a line recloser source-side of the fire's suspected area of origin to: Verify raptor construction. Identify any spans where the conductor may be too close together, where spreader brackets could be installed, if needed. Identification of any poles that were leaning and causing too much slack on the conductors. Identification of splice counts on each span (pole to pole). Use of Wooden Pole Elk Guards: Elk guards utilized to add additional protection to wooden poles near the suspected area of origin. Evaluation of Line Spreader Devices: Assessment to determine if the use of line spreader devices or other protective devices could be effective in reducing the likelihood of a potential line-to-line fault at the Incident Location (Tier 1 Non-HFTD).
Integration of Lessons Learned into Wildfire Strategy	Because the cause of the fire was not definitively determined, we have not been able to include specific lessons learned into our wildfire strategy, but we performed mitigations related to the specific incident location. However, our enhanced inspection program, described above in the discussion of the Camp Fire, identifies asset conditions that may result in ignitions and prioritizes high risk maintenance work to mitigate the potential for ignitions.

Fire Name: Drum/Lompoc Fire	
Date of Ignition	June 14, 2020
Cause Based on Available Information	Electrical conductor between two poles failed midspan and contacted the ground igniting vegetation. The specific cause of the failure could not be determined.
Lessons Learned	We were not able to determine the specific cause of the conductor failure. There was no vegetation in the area and although there is bird activity, no bird carcass was found afterwards. We are improving our ignition investigation capability to be able to do more extensive analyses of these types of ignitions in the future. In addition, to the extent the fire was the result of equipment failure, our enhanced inspection program is intended to review all of our equipment and identify equipment that may fail and cause a wildfire ignition.
Measures to mitigate cause	See Camp Wildfire (describing enhanced inspection measures).
Integration of Lessons Learned into Wildfire Strategy	See Camp Wildfire (describing enhanced inspection measures). In early 2021, PG&E established the Enhanced Ignition Analysis (EIA) program, uniting experts in different departments, including equipment failure experts in Applied Technology Services (ATS) and Asset Failure Analysis (newly-established to support this process), to better understand the causes of PG&E facility ignitions and recommend targeted corrective actions to reduce the risk of wildfires. In regard to ignitions where equipment failure is the suspected cause, the EIA team will coordinate the collection of failed assets for testing and analysis then analyze remaining risk (Extent of Condition) to inform wildfire mitigation strategies.

Fire Name: Zogg Fire	
Date of Ignition	September 27, 2020
Cause Based on Available Information	Vegetation Contact. RFW the day of ignition.
Lessons Learned	Our analysis of the Zogg Fire led us to further evaluate the propensity for tree-related outages and overstrike tree potential, specifically during certain weather conditions such as RFW days, and to pilot programs to perform more detailed inspections of potential strike trees on routine vegetation management patrols.
Measures to mitigate cause	Vegetation Contact: See October 2017 Fires for discussion of mitigations implemented regarding vegetation contact. Public Safety Power Shutoff (PSPS): We modified our PSPS Protocols to include locations with tree over-strike potential in the 70th percentile or above. This was described in more detail in our 2021 WMP. (2021 WMP, p. 980)
Integration of Lessons Learned into Wildfire Strategy	Vegetation Contact: EVM has been integrated into our vegetation management program and for the 2022 WMP is being performed on 1,800 of the highest risk ranked circuit miles. (2022 WMP, Section 7.3.5.2) We are continuing a pilot program in 2022 to perform a visual inspection of all sides of a potential strike tree on routine vegetation management patrols in HFTD areas. We have incorporated LiDAR vegetation inspections for both distribution and transmission facilities and have plans to continue to capture and update our LiDAR datasets. (2022 WMP, Sections 7.3.5.7 and 7.3.5.8) We have SCADA-enabled many reclosers and for reclosers that are automatic, we are continuing to disable them in HFTD Tier 2 and 3 areas during fire season. (2022 WMP, Section 7.3.6.1) We have significantly expanded our system hardening program, including undergrounding, which is intended to mitigate the potential for vegetation caused ignitions. (2022 WMP, Section 7.3.3.17) PSPS: We have continued to evaluate and evolve our PSPS protocols. We have incorporated tree-overstrike potential as a key attribute in our PSPS models that are based on artificial intelligence and machine learning. (2022 WMP, Section 8.2.3.2) We have incorporated high-risk vegetation and asset tags into our PSPS protocols so that we can inform the scope of PSPS events, appropriately, to address this potential risk. (2022 WMP, Section 8.2.3.2)

Fire Name: Dixie Fire	
Date of Ignition	July 13, 2021
Cause Based on Available Information	Ignited when a tree fell onto an overhead distribution line and two of three conductors opened but the third conductor remained energized because the fuse remained closed.
Lessons Learned	Even on non-RFW days and/or days with no weather or wind events, an ignition can occur when vegetation or other objects contact an energized powerline.
Measures to mitigate cause	Enhanced Powerline Safety Settings (EPSS): The EPSS program has been implemented to reduce the potential for vegetation contact resulting in an ignition on non-RFW and/or high wind days. PSPS is weather dependent. However, EPSS will be enabled on all HFTD and HFRA distribution circuits in our service territory based on Fire Potential Index (FPI) conditions and criteria approved by our Wildfire Risk Governance Steering Committee. Outage Response Times: We have revised our response time standard to respond to outages in HFTD areas, where we can safely do so, within 60 minutes as compared to the prior standard which required a response within 24 hours to a low level outage such as the one experienced on the circuit associated with the Dixie Fire.
Integration of Lessons Learned into Wildfire Strategy	EPSS: EPSS has been integrated into our wildfire strategy in 2021 (pilot on approx. 170 HFTD circuits) and 2022 (all HFTD/HFRA circuits). (2022 WMP, Section 7.3.6.8) Outage Response Times: We have revised our response time to outages in HFTD areas to within 60 minutes. (2022 WMP, p. 774)

4.2 Understanding Major Trends Impacting Ignition Probability and Wildfire Consequence

Describe how the utility assesses wildfire risk in terms of ignition probability and estimated wildfire consequence, including use of Multi-Attribute Risk Score (MARS) and Multi-Attribute Value Function (MAVF) as in the Safety Model and Assessment Proceeding (S-MAP)[27] and Risk Assessment Mitigation Phase (RAMP), highlighting changes since the 2020 WMP and 2021 Update. Include description of how the utility distinguishes between these risks and the risks to safety and reliability. List and describe each "known local condition" that the utility monitors per GO 95, Rule 31.1, including how the condition is monitored and evaluated.

We substantially updated our wildfire risk modeling and risk assessment tools in for the 2021 WMP and intend to continue to make improvements in 2022. Section 4.5.1 provides an overview of the updated risk models that we will be using in 2022, as well as our process for evaluating and validating these models. This Section 4.2 explains the use of established risk modeling tools (i.e., MAVF and MARS), explains PG&E's Bow Tie analysis, describes how PG&E distinguishes between wildfire risks and other safety and reliability risks, and describes known local conditions.

(a) Use of MAVF and MARS

Pursuant to Decision (D.) 18-12-014, PG&E implemented the S-MAP Settlement Agreement in 2019, including the development of an MAVF and Risk Bow Tie for Wildfire analysis. PG&E employs an MAVF to combine all potential consequences of the occurrence of a risk event and create a single measurement of value known internally as MARS.[28] An MAVF consists of the following components:

- Attributes;
- Ranges;
- Natural Units;
- Weights; and
- Scaling Function.

D.18-12-014 also provides six principles to use in determining the MAVF components: Attribute Hierarchies, Measured Observations, Comparison, Risk Assessment, Scaled Units, and Relative Importance.

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27 Updates to S-MAP are currently being considered in Rulemaking (R.) 20-07-013 – Order Instituting Rulemaking to Further Develop a Risk-based Decision-making Framework for Electric and Gas Utilities.

28 D.18-12-014, p. 17, 2018 S-MAP Revised Lexicon: *MAVF*.

The key components of the MAVF that PG&E used for assessing wildfire related risks, and how we adhere to the principles, are shown in Table PG&E-4-2.1 below and are described in the discussion following the table.

TABLE PG&E-4.2-1:
KEY COMPONENTS OF MAVF

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

(a) Pursuant to D.18-12-014 and D.16-08-018, utility shareholders' financial interests are to be excluded from the General Rate Case (GRC) and RAMP risk evaluation and risk mitigation considerations.

- Ranges – Pursuant to D.18-12-014, the smallest observable value of an Attribute is the low end of the range, and the largest observable value is the high end of the range. PG&E interprets the largest observable value to be a reasonable value informed by historical events and plausible large consequence scenarios. In our analysis and risk framework, event consequences are not capped at the high end of the range, but rather, the range is a specification required in setting the MAVF weights.
  - The high end of the Safety Attribute Range, set to 100, is an order of magnitude value informed by recent events.
  - The high end of the Electric Reliability Range (4 Billion CMI) was based on the most severe reliability impact from a single event of 3.6 billion CMI from the October 26, 2019 PSPS event.
  - The Gas Reliability high end is based on a scenario of an outage at a critical gas facility.
  - The Financial Attribute's high end represents a financial loss commensurate with an Energy Crisis - type event.
- Natural Units – EF is defined as the sum of Public, Employee and Contractor Fatalities and Serious Injuries per event occurrence. Serious Injuries are defined as situations that require hospitalization of an individual pursuant to existing Federal

and State reporting guidelines.[29] Fatalities and Serious Injuries are converted to EFs using the multiplicative factors 1.00 and 0.25, respectively. The conversion rate from Serious Injury to EF is based on information available from Federal sources.[30]

- Weights – Attribute Weights were assigned to reflect a relative importance of moving each Attribute from its least desired level (i.e., Upper Bound) to its most desirable level (i.e., zero), following the MAVF Principle 6 – Relative Importance.[31] For example, the Attribute Weights reflect PG&E's view that it is twice as valuable to move the Safety Attribute from 100 to 0 EFs as it is to move the Financial Attribute from $5 billion to $0. Assigning 50 percent weight to the Safety Attribute is in line with PG&E's emphasis on safety and is also consistent with the S-MAP Settlement Decision's requirement for a minimum 40 percent weighting for Safety.[32]

- Scaling Function – The Non-Linear Scaling Function is used to convert each Attribute from its Natural Unit to Scaled Units.[33] It consists of the following segments, with each segment intended to represent events that are either operational (i.e., encountered in the course of regular operations), critical or catastrophic.

  - For natural units from 0 to 1 percent of the Range (operational/moderate events): Linear function from 0 to 0.1 Scaled Units.

  - For natural units from 1 percent to 10 percent of the Range (critical events): Quadratic function from 0.1 to 5 Scaled Units.

  - For natural units from 10 percent to 100+ percent of the Range (catastrophic events): Linear function from 5 to 100+ Scaled Units.

For the 2022 WMP, PG&E has changed the MAVF Scaling Function by removing the cap on Scaled Units.

D.18-12-014 directs utilities to use Expected Value when calculating the Consequence of Risk Event (CoRE) and use the scaling function to capture aversion to extreme

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29 Pipeline and Hazardous Materials Safety Administration §191.3 Definitions: Incident (see also: 49 CFR § 191.3 - Definitions. | CFR | US Law | LII/Legal Information Institute (cornell.edu).

30 See "Treatment of the Values of Life and Injury in Economic Analysis," Table 2-3, Federal Aviation Administration (FAA) Office of Aviation Policy and Plans, Updated September 2016, (available at: https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/econ-value-section-2-tx-values.pdf.

31 D.18-12-014, Attachment A, Step 1A, No 7. MAVF Principle 6 –Relative Importance. p. A-6.

32 D.18-12-014, p. 66.

33 D.18-12-014, pp. 17-18; 2018-S-MAP Revised Lexicon: Scaled Unit of an Attribute: a value that varies from 0 to 100.

outcomes or indifference over a range of outcomes. Under PG&E's Non-Linear Scaling Function, the risk score, as measured by Scaled Units, will be low for operational events, but increases quadratically as critical events approach catastrophic (but low probability) levels. Once catastrophic levels are attained the function assigns 10 times higher score for each potential increase in Natural Units when compared to operational events. This captures aversion to critical and catastrophic outcomes and gives higher priority to controls and mitigations that affect them.

In PG&E's risk modeling, Attribute levels (e.g., the financial consequence of a risk event) are assumed to be uncertain and are represented by well-defined probability distributions. PG&E uses Monte Carlo simulations of risk events based on these probability distributions to generate consequence levels in Natural Units, convert Natural Units into Scaled Units using the Range and Scaling Function. The Expected Value of Scaled Units are then used to compute Attribute CoRE by applying the Attribute Weights and Scaler of 1000. Then Attribute CoRE values for each Attribute are summed together to derive CoRE. CoRE values are then multiplied to Frequency of a Risk Event to get Risk Scores, consistent with the Risk Assessment principle.

Overall, the S-MAP conforming risk assessment methodology has not changed substantially since the 2021 WMP. However, there have been a few important changes to the Wildfire Bow Tie analysis including:

- HFTD Distribution tranches were updated to incorporate the circuit segment and HFTD Tier level results of the 2021 WDRM v2 to provide more granularity in the risk assessment,

- The impact of climate change was assumed to amplify the consequence of all ignitions rather than increase the percentage of ignitions occurring when a Red Flag Warning (RFW) is in place.

These changes are described in more detail in Subsection (b) below.

(b) Wildfire Risk Assessment and Bow Tie Analysis

Consistent with D.18-12-014, PG&E assesses wildfire risk and estimated wildfire consequences in a Bow Tie analysis. The updated Bow Tie analysis provides the risk scores by drivers for 2022 which are reflected in Table PG&E-4.2.2.

TABLE PG&E-4.2-2:
WILDFIRE RISK DRIVERS

Wildfire Risk Score for 2022									
	HFTD				Non-HFTD				
Drivers	Distribution	Transmission	Substation	HFTD Total	Distribution	Transmission	Substation	Non-HFTD Total	Grand Total
Vegetation Contact	14,019	130	0	14,148	95		0	95	14,243
Equipment / facility failure	7,452	296	14	7,762	112	2	0	114	7,876
Contact from object	668	299		967	40	3		43	1,010
Wire-to-wire contact	322			322	1			1	322
Unknown	187	25		212	4	0		4	216
Other	127	8		135	1			1	136
Utility work / Operation	23			23	0			0	23
Vandalism / Theft	6	8		15	1	0		1	15
Contamination	14			14	1	0		1	15
CC - Seismic Scenario	10			10	0			0	10
Grand Total	**22,827**	**766**	**14**	**23,608**	**255**	**5**	**0**	**260**	**23,868**

% Risk									
	HFTD				Non-HFTD				
Drivers	Distribution	Transmission	Substation	HFTD Total	Distribution	Transmission	Substation	Non-HFTD Total	Grand Total
Vegetation Contact	58.7%	0.5%	0.0%	59.3%	0.4%	0.0%	0.0%	0.4%	59.7%
Equipment / facility failure	31.2%	1.2%	0.1%	32.5%	0.5%	0.0%	0.0%	0.5%	33.0%
Contact from object	2.8%	1.3%	0.0%	4.1%	0.2%	0.0%	0.0%	0.2%	4.2%
Wire-to-wire contact	1.3%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	1.4%
Unknown	0.8%	0.1%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.9%
Other	0.5%	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.6%
Utility work / Operation	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
Vandalism / Theft	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
Contamination	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
CC - Seismic Scenario	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Grand Total	**95.6%**	**3.2%**	**0.1%**	**98.9%**	**1.1%**	**0.0%**	**0.0%**	**1.1%**	**100.0%**

Baseline Frequency for 2022									
	HFTD				Non-HFTD				
Drivers	Distribution	Transmission	Substation	HFTD Total	Distribution	Transmission	Substation	Non-HFTD Total	Grand Total
Equipment / facility failure	28	3	0	32	139	2	0	141	173
Contact from object	22	6		28	101	7		108	136
Vegetation Contact	74	1	0	74	61		0	61	135
Unknown	6	0		6	10	1		11	17
Wire-to-wire contact	9			9	1			1	10
Other	3	0		3	4			4	7
Vandalism / Theft	0	0		0	2	0		2	2
Contamination	0			0	1	0		2	2
Utility work / Operation	1			1	0			0	1
CC - Seismic Scenario	0			0	0			0	0
Grand Total	**143**	**10**	**0**	**153**	**319**	**11**	**0**	**330**	**483**

% Frequency									
	HFTD				Non-HFTD				
Drivers	Distribution	Transmission	Substation	HFTD Total	Distribution	Transmission	Substation	Non-HFTD Total	Grand Total
Equipment / facility failure	5.8%	0.7%	0.0%	6.6%	28.7%	0.4%	0.1%	29.2%	35.8%
Contact from object	4.5%	1.2%	0.0%	5.7%	20.9%	1.5%	0.0%	22.4%	28.1%
Vegetation Contact	15.2%	0.1%	0.0%	15.3%	12.6%	0.0%	0.0%	12.6%	27.9%
Unknown	1.2%	0.1%	0.0%	1.3%	2.1%	0.1%	0.0%	2.2%	3.6%
Wire-to-wire contact	1.8%	0.0%	0.0%	1.8%	0.3%	0.0%	0.0%	0.3%	2.0%
Other	0.6%	0.0%	0.0%	0.7%	0.7%	0.0%	0.0%	0.7%	1.4%
Vandalism / Theft	0.1%	0.0%	0.0%	0.1%	0.4%	0.0%	0.0%	0.4%	0.5%
Contamination	0.1%	0.0%	0.0%	0.1%	0.3%	0.1%	0.0%	0.4%	0.5%
Utility work / Operation	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.2%
CC - Seismic Scenario	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Grand Total	**29.5%**	**2.2%**	**0.0%**	**31.7%**	**66.0%**	**2.2%**	**0.1%**	**68.3%**	**100.0%**

Table PG&E-4.2-2 shows that:

- 95.6 percent of Wildfire Risk comes from HFTD distribution;
- 3.2 percent of the Wildfire Risk comes from HFTD transmission;
- 59.7 percent of the risk is from vegetation contact; and
- 33.0 percent of the risk is from equipment/facility failure.

It also shows that the vegetation contact driver is the highest contributor for the risk for HFTD distribution but equipment/facility failure driver is higher contributor for transmission and non-HFTD distribution. Figures PG&E-4.2-1, PG&E-4.2-2, and PG&E-4.2-3 show associated Bow Tie visuals for the PG&E electric service territory, HFTD distribution, and HFTD transmission, to show breakdown of risk score as multiplication of frequency and consequence for different driver and outcome.

FIGURE PG&E-4.2-1:
WILDFIRE RISK BOW TIE ANALYSIS
(PG&E SERVICE TERRITORY; OVERHEAD CIRCUITS ALL VOLTAGE CLASSES)

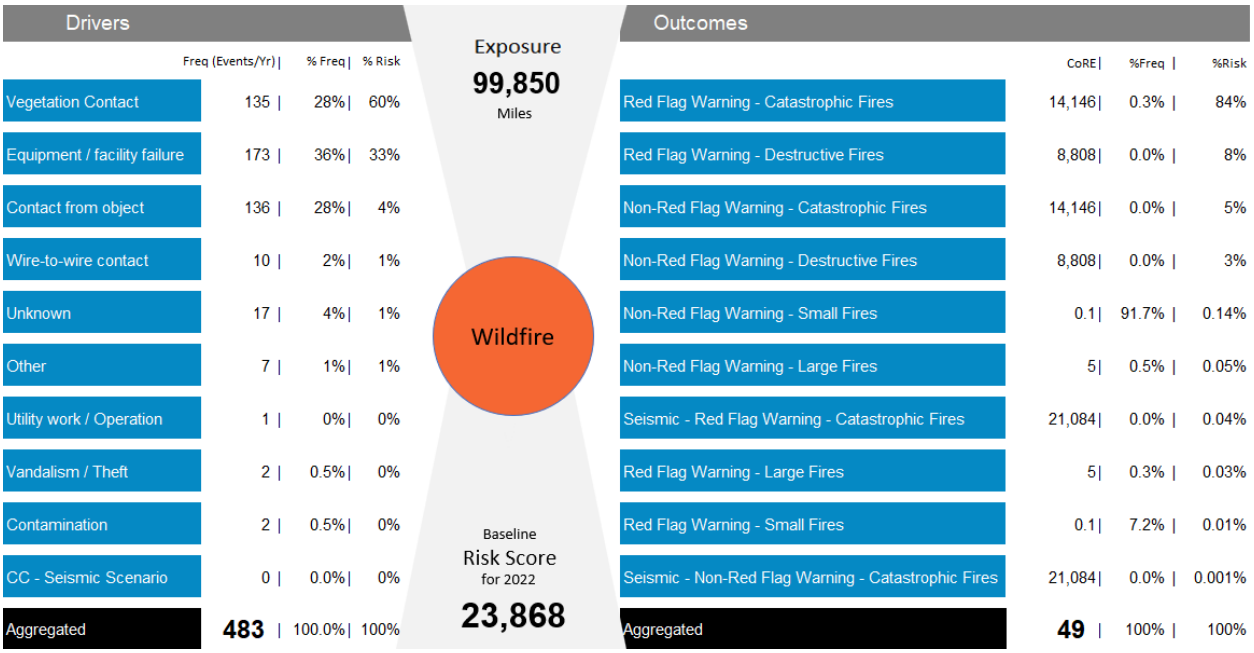


FIGURE PG&E-4.2-2:
WILDFIRE RISK BOW TIE ANALYSIS
(PG&E HFTD ONLY; DISTRIBUTION VOLTAGE OVERHEAD CIRCUITS)

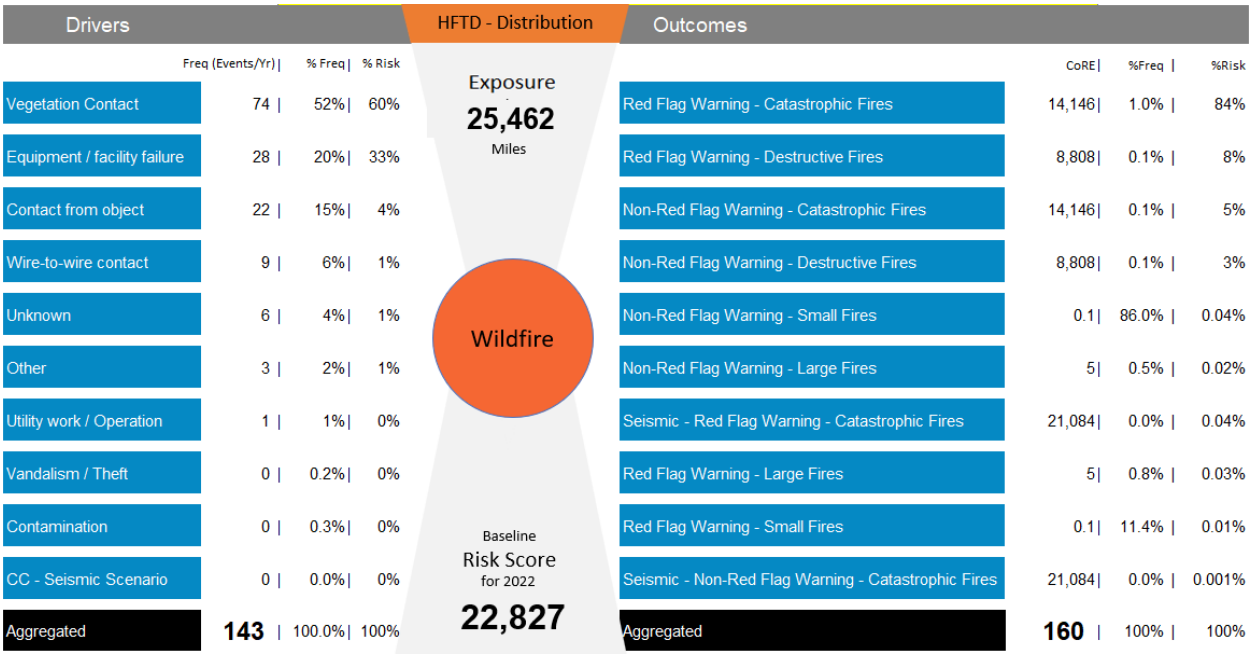
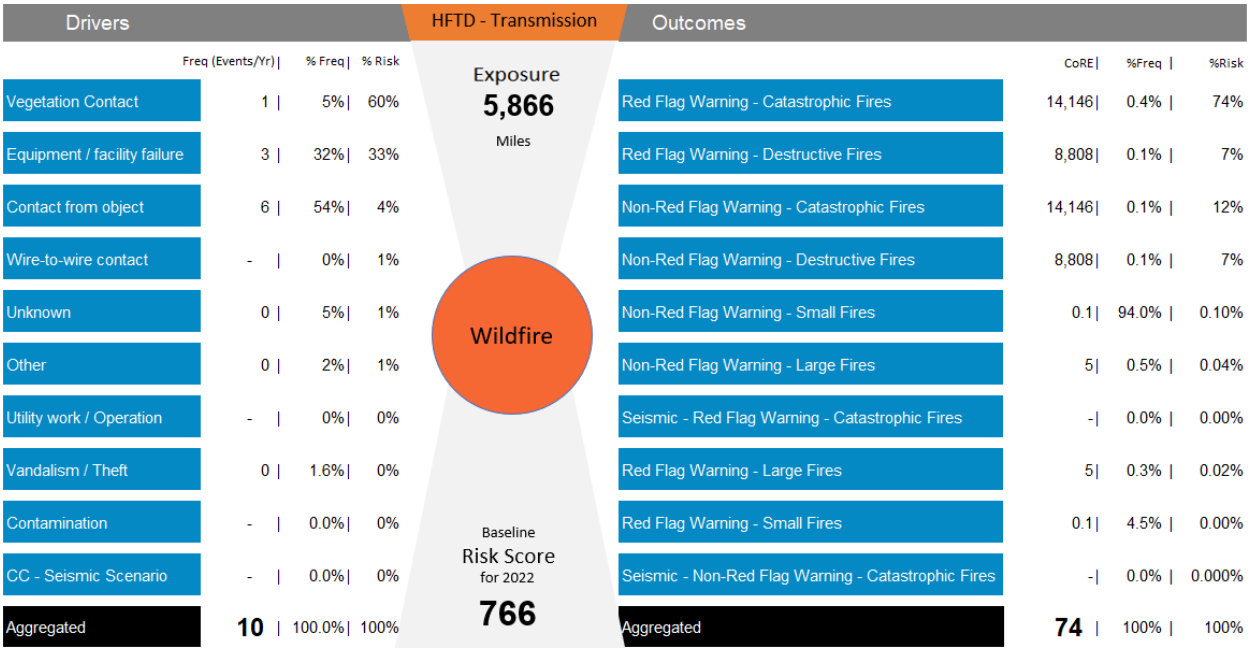


FIGURE PG&E-4.2-3:
WILDFIRE RISK BOW TIE ANALYSIS
(PG&E HFTD ONLY; TRANSMISSION VOLTAGE OVERHEAD CIRCUITS)



PG&E provides a summary below of the elements of the Bow Tie analyses as shown in Figures PG&E-4.2-1, PG&E-4.2-2, and PG&E-4.2-3 above:

1. Drivers-Ignition Frequencies – Shown on the left of the visuals above, the current S-MAP conforming Bow Tie is derived from normalizing the ignitions by Transmission and Distribution overhead line miles of exposure reported annually to the CPUC. In accordance with D.14-02-015, PG&E annually reports to the CPUC fire incidents that may be associated with PG&E facilities and that meet the following conditions: (a) a self-propagating fire of material other than electrical and/or communication facilities; (b) the resulting fire traveled greater than one linear meter from the ignition point; and (c) PG&E has knowledge that the fire occurred. The S-MAP conforming model discussed in detail in PG&E's 2023 GRC Testimony used ignitions reported to the CPUC for years 2015 through 2020.[34] PG&E is still finalizing the 2021 reportable ignition data in preparation for our annual report, thus data from 2015 through 2020 was used in the model. However, the frequencies in the above analysis reflect the estimated impact of mitigations implemented in 2021

2. Total Exposure – Shown in the center of the visuals above across all Tranches: 99,850 circuit miles of overhead Transmission and Distribution voltage conductor covering PG&E's service territory. Since the 2020 RAMP Report, PG&E has received feedback from Energy Safety, Safety Policy Division (SPD), and various stakeholders that the level of tranching was not adequate to represent the risk profiles of PG&E's system. In response to this feedback, for the Wildfire Risk Bow Tie Analysis used in the 2022 WMP, PG&E has incorporated the results of the 2021 WDRM v2 to further delineate wildfire risk across PG&E's distribution system in HFTD at a more granular level summarizing into 25 tranches (compared to three tranches used in 2020 RAMP Report and 2021 WMP). PG&E also further differentiated transmission tranches by voltage levels.

3. Outcomes-Wildfire Consequences – There is a wide range of potential public safety risks resulting from a fire ignition associated with PG&E assets. In the overwhelming majority of cases, fire ignitions do not end up a large wildfire because they are extinguished quickly and/or do not propagate far. However, in some cases, ignitions can result in larger wildfires. PG&E uses fire incidents from the California Department of Forestry and Fire Protection (CAL FIRE) database to estimate the safety and financial consequences of wildfire. For each fire incident, the CAL FIRE dataset provides the location, size, number of destroyed/damaged structures, and the number of fatalities/injuries. Reliability consequences are estimated by using distribution customer minutes for outages that were associated with CPUC-reportable ignitions and known fires associated with those outages. PG&E is providing a more granular outcomes of consequences, as shown on the right side of the Bow Tie, on ignitions in terms of three variables:

    a. The size/destructiveness of the fire that resulted from the ignition. PG&E's categorization of fire size is based on the following definitions:

        - Catastrophic – A fire that destroys 100 or more structures, and results in a serious injury and/or fatality.

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34 PG&E 2023 GRC Exhibit (PG&E-4) pp. 3-14 through 3-23.

- Destructive – A fire that destroys 100 or more structures but does not result in a serious injury or fatality.

- Large – A fire that burns 300 or more acres but does not meet the definition of a Destructive or Catastrophic fire.

- Small – A fire that burns fewer than 300 acres.

b. Whether the ignition took place on a day and in an area in which a RFW was in place or not. RFW is a forecast warning issued by the National Weather Service (NWS) in the United States to inform the public, firefighters, and land management agencies that conditions are ideal for wildland fire combustion and rapid spread.[35] The potential consequences of ignitions are higher when an RFW is in effect.[36]

c. For catastrophic fires, only, whether the catastrophic fire is associated with a seismic event.

The wildfire risk of the entire system is the sum of the risk scores over all tranches. The risk score for each tranche is the sum of risk scores for each combination of driver and outcome for the tranche based on the product of the frequency of a risk event associated with the driver and outcome, and consequence of that outcome. In the Bow Tie Analysis used in 2022 WMP, PG&E incorporated lessons learned from analyzing ignition data that indicated a different likelihood of an ignition resulting in a RFW outcomes for a different driver. Based on PG&E's 2015-2020 CPUC-reportable ignitions, the percentage of ignitions occurring when a RFW is in effect is the highest for vegetation contact driver, followed by equipment/facility failure, and then all other drivers. CoRE values for RFW is higher than CoRE values for non-RFW due to higher chance of resulting in large, destructive and catastrophic outcomes. Thus, this change resulted in higher CoRE value for vegetation contact driver compared to one for equipment failure driver, and higher CoRE value for equipment failure driver compared to one for the rest of the drivers.

(c) How PG&E distinguishes between wildfire risks and other safety and reliability risks

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35 Precise temporal and spatial mapping analysis of RFW conditions is conducted by utilizing RFW GIS shapefiles from: https://mesonet.agron.iastate.edu/request/gis/watchwarn.phtml. (as of June 16, 2020).

In a February 19, 2020 letter to PG&E providing feedback on information that PG&E provided in workshops held on January 13, 2020 and February 4, 2020, TURN recommended that "for clarity" PG&E use "Fire Weather *Conditions* instead of *Warning*" when classifying outcomes. At the time of the workshop, PG&E used the term "Fire Weather Warning" to refer to elements of the NWS RFW. PG&E's use of RFWs to categorize outcomes is appropriate because it is a simple, objective metric from a trusted third-party (NWS) that serves as a reasonable proxy for fire weather conditions.

36 PG&E's WDRM assumes that starting in 2023 the probability that an ignition occurs at a location and day that RFW is in effect will increase in 5-year increments based on the Cal-Adapt Wildfire Data.

Wildfire risk is one of the risks in the PG&E's Corporate Risk Register. All risks in the PG&E's Corporate Risk Register have associated safety, reliability, and/or financial consequences. The safety, reliability and financial consequences of each risk are modeled separately and combined into a risk score using the MAVF.

We have defined Wildfire Risk as PG&E assets or activities that may initiate a fire that is not easily contained, endangers the public, private property, sensitive lands or environment. In the Wildfire Risk Bow Tie Analysis, PG&E currently defines the risk event as the CPUC-reportable ignition from PG&E's electric transmission, distribution, and substation assets, and safety, reliability and financial consequence resulting from a CPUC-reportable ignition is captured.

We also include non-wildfire consequences from a failure of electric assets such as:

- Failure of Electric Distribution Overhead Assets;
- Failure of Electric Distribution Underground Assets;
- Failure of Electric Distribution Network Assets;
- Failure of Electric Transmission Overhead Assets;
- Failure of Electric Transmission Underground Assets;
- Failure of Electric Transmission Substation Assets;
- Failure of Electric Distribution Substation Assets; and
- Third Party Safety Incident risk.

The asset failure risks define a risk event as a failure of assets not caused by third parties and captures the non-wildfire safety, reliability, and financial consequence from failure of assets. For example, a failure of asset resulting in a CPUC-reportable ignition is included in the frequency of asset failure risk events, but the consequences for those events are set to zero in the asset failure risks because those are captured in the wildfire risk. Asset failure risks also do not consider failures caused by wildfire from PG&E's CPUC-reportable ignitions, since the consequences from those failures are captured through wildfire risk consequences from the associated CPUC-reportable ignition.

PG&E includes failure of assets caused by third parties in the Third-Party Safety Incident risk. Thus, non-wildfire safety, reliability and financial consequence of a failure of assets caused by third-party vehicular contact with PG&E's pole or guy wire, and third-party contact with intact electric assets are classified to Third-Party Safety Incident risk, not in the asset failure risks. On the other hand, wildfire risk includes an CPUC-reportable ignition caused by third party drivers.

(d) List and Description of "Known Local Conditions" as That Term is Used in GO 95, Rule 31.1

GO 95, Rule 31.1 directs PG&E to design, construct and maintain a facility in accordance with accepted good practice for the intended use and known local conditions. PG&E's Overhead Design Manual contains the standards and methodologies for designing and assessing facilities according to the known local conditions such as mechanical loading, geographic location, and HFTD and non-HFTD areas. As such, PG&E has specific design standards as it relates to HFTD areas. Additionally, our inspection and maintenance procedures and practices are adjusted for Tier 2 and Tier 3 areas within HFTD. PG&E developed our S-MAP conforming Bow Tie for the wildfire risk by creating separate tranches for HFTD and non-HFTD areas. The higher risk scores and Risk Spend Efficiency (RSE) values for mitigations in the HFTD areas enables prioritization of wildfire mitigation initiatives in HFTD areas. For additional information on PG&E's evaluation of HFTD areas, including the development of our HFRA Map identifying risk areas beyond HFTDs, please see Section 4.2.1.

4.2.A. Contribution of Weather to Ignition Probability and Estimated Wildfire Consequences

A) Describe how the utility monitors and accounts for the contribution of weather to ignition probability and estimated wildfire consequence in its decision -making, including describing any utility--generated Fire Potential Index or other measure (including input variables, equations, the scale or rating system, an explanation of how uncertainties are accounted for, an explanation of how this index is used to inform operational decisions, and an explanation of how trends in index ratings impact medium--term decisions such as maintenance and longer--term decisions such as capital investments, etc.).

To understand the real-time to short-term weather and fire risk (hour to week ahead), PG&E's Meteorology and Fire Science department utilizes real-time weather station data and weather model data from multiple models. These weather model data are utilized to drive dead fuel moisture (DFM) and live fuel moisture (LFM) models, which together with other data, feed into PG&E's Fire Potential Index (Utility FPI or FPI) Model and Ignition Probability Weather (IPW) Model. The weather, LFM, and DFM data are also used in our fire spread model application, to dynamically simulate the potential spread and consequences of fire. For longer-term decisions and work planning, such as for System Hardening and EVM, we utilize climatological weather datasets and fire spread simulations across a range of historical fire weather days to inform investment decisions where the risk is highest over the long term. Additional details on the numerous elements of PG&E's weather, fuels, outage and fire potential index forecasting can be found in Sections 4.2.B, 4.5.1(f), 4.5.1(g), 7.3.1.5, 7.3.2.1.1, 7.3.2.1.2, and 8 of the 2022 WMP.

4.2.B. Contribution of Fuel Conditions

B) Describe how the utility monitors and accounts for the contribution of fuel conditions to ignition probability and estimated wildfire consequence in its decision-making, including describing any proprietary fuel condition index (or other measures tracked), the outputs of said index or other measures, and the methodology used for projecting future fuel conditions. Include discussion of measurements and units for live fuel moisture content, dead fuel moisture content, density of each fuel type, and any other variables tracked. Describe the measures and thresholds the utility uses to determine extreme fuel conditions, including what fuel moisture measurements and threshold values the utility considers "extreme" and its strategy for how fuel conditions inform operational decision--making.

PG&E has deployed methods to predict DFM and LFM on the PG&E-AWS cloud. The DFM method is capable of predicting the moisture content of multiple DFM fuel classes (i.e., DFM 1hr, DFM 10hr, DFM 100hr, DFM 1,000hr) at 2 × 2 km spatial resolution, hourly temporal resolution, out 129 hours. PG&E has also deployed a method to predict LFM at a resolution of 2 × 2 km, for Chamise and Manzanita plant species. These are machine learning methods developed using National Fuel Moisture Database observations. In 2020 and 2021, PG&E partnered with Atmospheric Data Solutions and Technosylva to develop the next generation of LFM and DFM Models. In 2021, these models were extended to provide 129 hours of forecast data, providing a longer lead time than previously available. The DFM Model PG&E deployed is a customized version of the DFM model utilized in the NFDRS 2016 model version.

Figure PG&E-4.2-4 below is an example hour output from the DFM 10hr fuel class.

FIGURE PG&E-4.2-4:
HOUR OUTPUT FOR 10 HOUR DFM MODEL

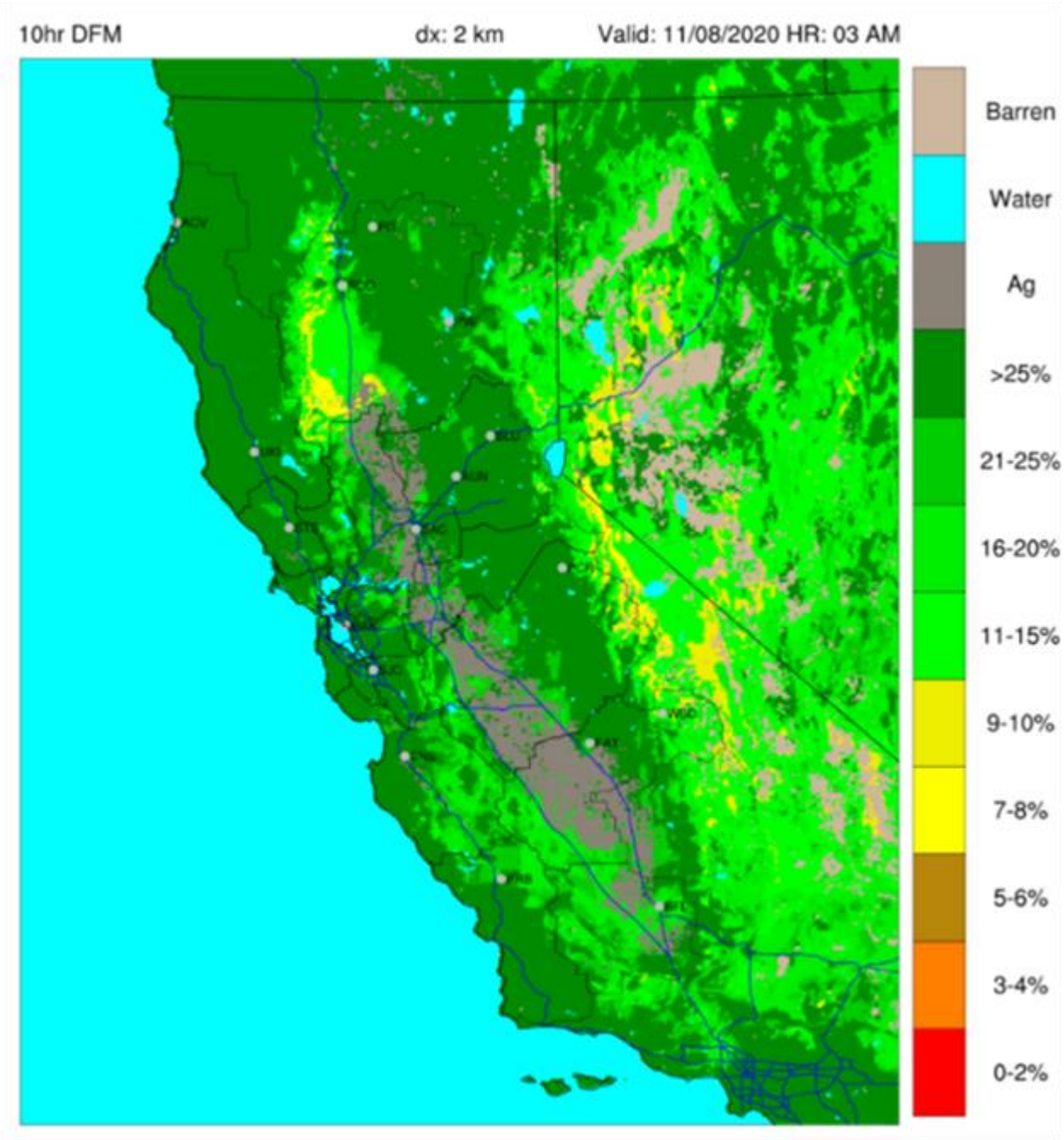
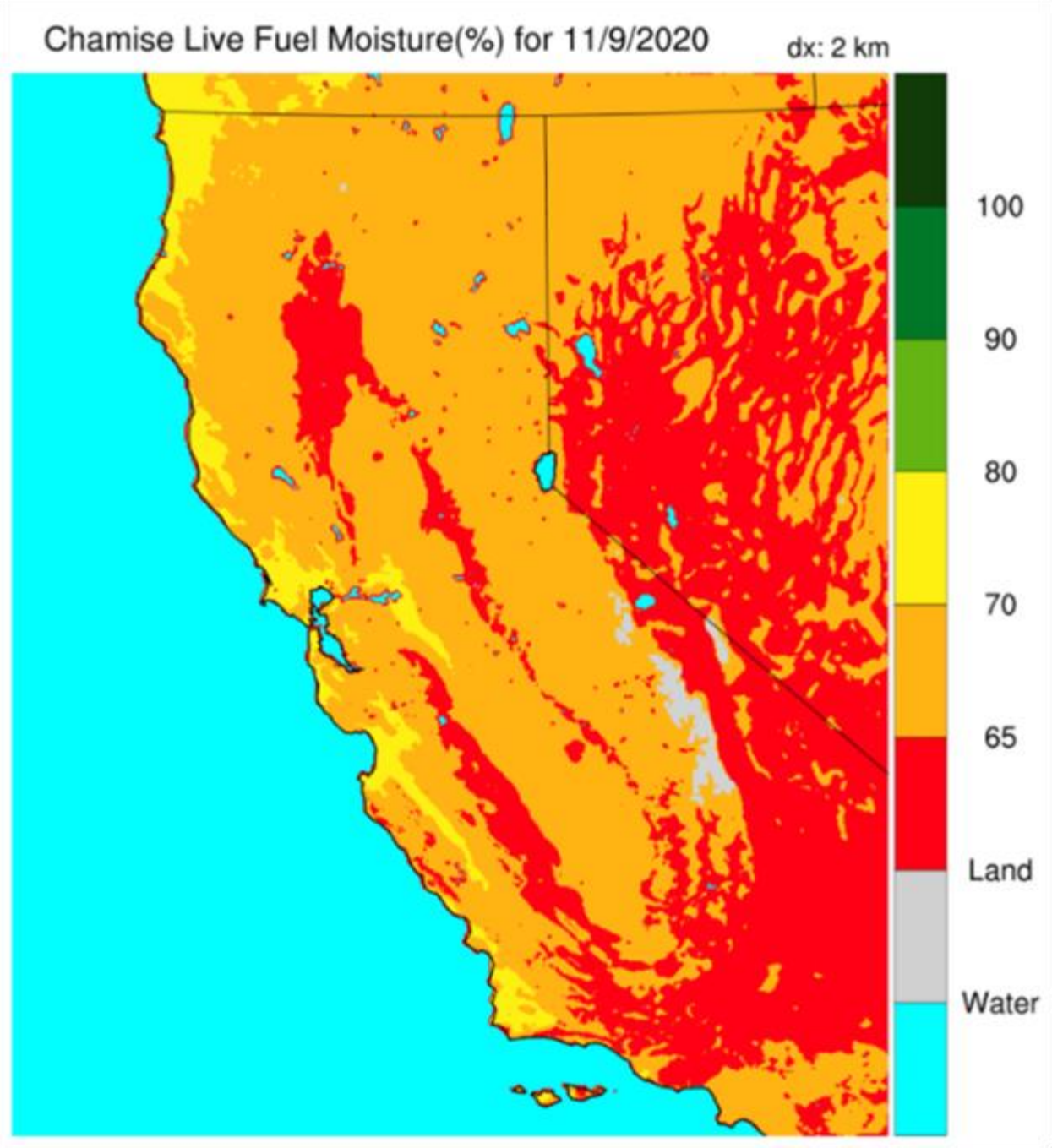


Figure PG&E-4.2-5 below is an example hour output from the LFM Model for chamise.

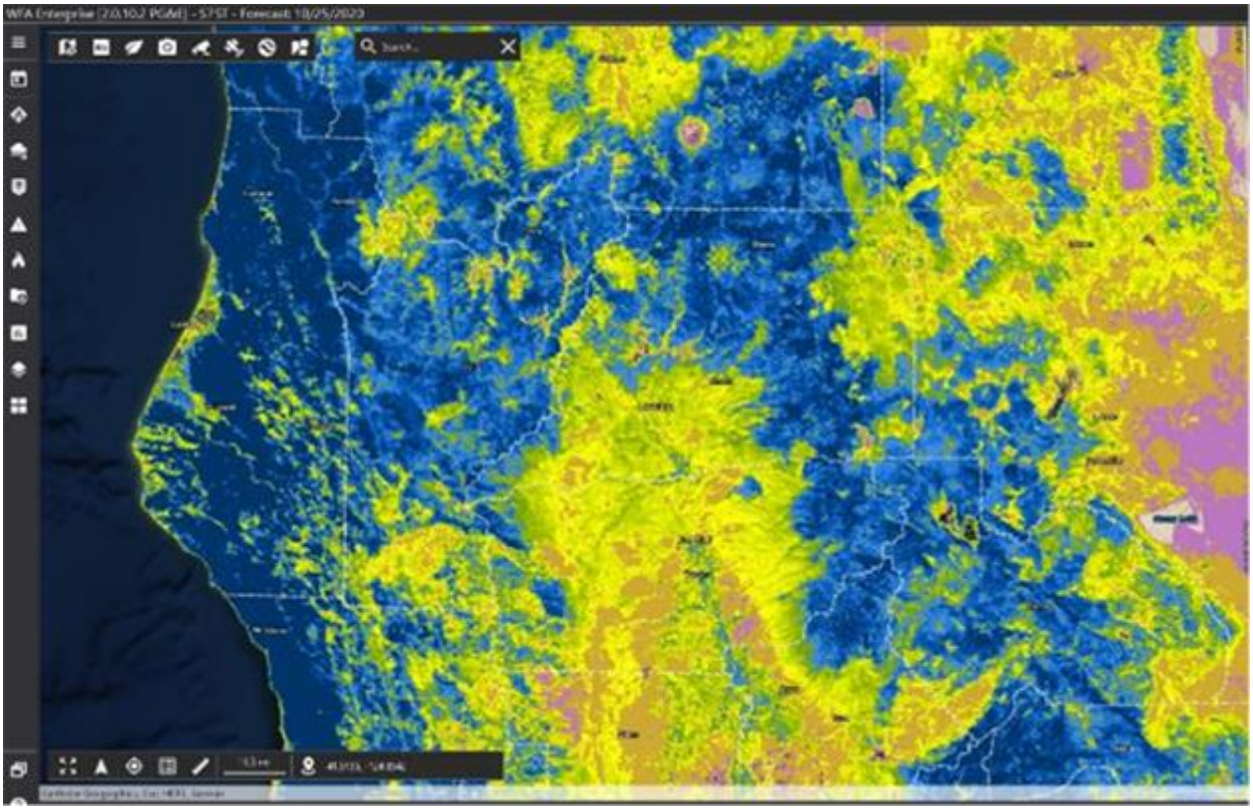
FIGURE PG&E-4.2-5:
HOUR OUTPUT FROM LFM MODEL



In addition to creating new forecast models, PG&E created a 30+ year climatology of DFM and LFM Model output at hourly, 2 x 2 km resolution as well. These robust historical datasets allow PG&E meteorologists and data scientists to evaluate the DFM and LFM conditions present during historical fires.

PG&E also sought to create new LFM Models using remotely sensed satellite data. We partnered with Technosylva to deploy LFM woody and LFM herbaceous fuel models that take advantage of recent Moderate Resolution Imaging Spectroradiometer (MODIS) satellite measurements and indices such as the Normalized Difference Vegetation Index (NDVI). Figure PG&E-4.2-6 below is an example NDVI output is presented. These models were built using machine learning techniques and were trained against National Fuel Moisture Database observations.

FIGURE PG&E-4.2-6:
EXAMPLE OF NORMALIZED DIFFERENCE VEGETATION INDEX OUTPUT



LFM models developed and deployed are trained on field observations. PG&E is taking steps to bolster these observations and provide them to the public. These observations can help validate existing models and enable more accurate models to be developed in the future as they can take advantage of many more observations. In 2020 and 2021, for example, PG&E established an internal LFM sampling program to complement samples collected by state and federal agencies across Northern and Central California. This network consists of 30 locations where plant species, such as Chamise and Manzanita, are sampled to measure the amount of fuel moisture in these plants throughout the seasonal cycle. Site locations were selected and scouted by PG&E meteorologists as well as PG&E Safety and Infrastructure Protection Teams (SIPT) personnel. Samples are collected in the field and shipped to a laboratory for processing. The results of all measurements are uploaded and made publicly available via the National Fuel Moisture Database. These observations are critical to train and

validate high-resolution LFM models and satellite-derived LFM products and will be helpful for PG&E and others to train the next generation of LFM models.

4.2.1 Service Territory Fire-Threat Evaluation and Ignition Risk Trends

Present a map of the highest risk areas identified within the current HFTD tiers of the utility's service territory as a figure in the WMP. Discuss fire threat evaluation of the service territory to determine whether a modification to the HFTD is warranted (i.e., expansion beyond existing Tier 2 and Tier 3 areas). If the utility believes there are areas in its service territory that are not currently included in the HFTD but require prioritization for mitigation efforts, then the utility is required to provide a process outlining the formal steps necessary to have those areas considered for recognition in the CPUC-defined HFTD. Include a discussion of any fire threat assessment of its service territory performed by the electrical corporation, highlighting any changes since prior WMP submissions. In the event that the utility's assessment determines the fire threat rating for any part of its service territory is insufficient (i.e., the actual fire threat is greater than what is indicated by the CPUC's Fire Threat Map and High Fire Threat District designations), the utility is required to identify those areas for potential HFTD modification, based on the new information or environmental changes, showing the differences on a map in the WMP. To the extent this identification relies upon a meteorological or climatological study, a thorough explanation and copy of the study must be included as an Appendix to the WMP.

List, describe, and map geospatially (where geospatial mapping is applicable) any macro trends impacting ignition probability and estimated wildfire consequence within utility service territory, highlighting any changes since the 2021 WMP Update:

1. *Change in ignition probability and estimated wildfire consequence due to climate change.*

2. *Change in ignition probability and estimated wildfire consequence due to relevant invasive species, such as bark beetles.*

3. *Change in ignition probability and estimated wildfire consequence due to other drivers of change in fuel density and moisture.*

4. *Population changes (including Access and Functional Needs population) that could be impacted by utility ignition.*

5. *Population changes in HFTD that could be impacted by utility ignition.*

6. *Population changes in Wildland Urban Interface (WUI) that could be impacted by utility ignition.*

7. *Utility infrastructure location in HFTD vs non-HFTD.*

8. *Utility infrastructure location in urban vs rural vs highly rural areas.*

This section is divided into two subsections. Subsection (a) describes service territory fire-threat evaluation, and subsection (b) describes trends impacting ignition probability and estimated wildfire consequence within our service territory.

(a) Service Territory Fire-Threat Evaluation

To inform the scope of PSPS events, PG&E has performed, and continues to perform, a fire threat assessment of our service territory focused on identifying areas where an ignition during an offshore wind event could lead to a catastrophic wildfire.[37] The culmination of this assessment is referred to as PG&E's High Fire Risk Area (HFRA) map. The HFRA map serves as an initial filter in the PSPS scoping process, upon which additional event-specific spatial information is overlaid and analyzed to arrive at final PSPS scope. The HFRA map may be used for other purposes as well, such as informing workplans and risk assessment.

PG&E began development of our HFRA map in 2020, by using the Tier 2 and Tier 3 portions of the CPUC's HFTD map as a starting point and adding areas where we believe an ignition, during an offshore wind event, could lead to a catastrophic wildfire. At the end of 2020, PG&E's HFRA map included all areas in the Tier 2 and Tier 3 portions of the CPUC's HFTD map, as well as PG&E's additions. Those additions, the process used to identify them, and the resulting HFRA map were described in PG&E's 2021 WMP.[38]

In 2021, PG&E continued to develop our HFRA map. This was done by removing areas from the HFRA map where we concluded that an ignition during an offshore wind event either would not occur or otherwise would not lead to a catastrophic wildfire. The process used to identify areas for removal largely followed the process used to identify areas for addition, with two exceptions. First, a step was added for field validation, described in Step 3, below. Second, a step was added for wildfire exposure analysis, using wildfire simulation software, described in Step 4, below.

The steps of the process used in 2021 to identify areas for removal from the HFRA map are listed below.[39] In each step of the process, the candidate area was assessed to determine the potential that an ignition during an offshore wind event would lead to a catastrophic wildfire. If, at any step of the process, a candidate area was determined to have this potential, it was not considered any further for removal from PG&E's HFRA map. Only those areas that satisfied all five steps of the process were ultimately removed from the HFRA map. The five steps include:

1. Candidate areas were initially identified for potential removal from the HFRA map by subject matter experts familiar with the local area and fire history.

2. A core team, composed of PG&E subject matter experts in wildfire analysis, meteorology, electrical engineering, and PSPS operations, jointly assessed each of

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37 PG&E's HFRA focuses on offshore wind-event conditions because offshore wind events are essential features of the strong and episodic increases in catastrophic wildfire risk that PSPS is intended to mitigate.

38 2021 Revised WMP, pp. 85-89.

39 The HFRA modification process was implemented in three rounds in 2021, resulting in three HFRA map updates. The same steps were implemented in each round, but the order of the steps was changed between the first and second rounds to improve efficiency. The list presented here reflects the order used in the latter two rounds.

the candidate areas identified in Step 1, using geospatial software and datasets (e.g., aerial imagery, vegetation maps, topographic maps).

3. Each of the candidate areas remaining after Step 2 were assessed in the field by one or more of PG&E's Public Safety Specialists, each with extensive, local wildfire management experience.

4. Each of the candidate areas remaining after Step 3 were subjected to wildfire exposure analysis. Specifically, this analysis leveraged PG&E's 30-year, 2-km resolution climatology and Technosylva's wildfire simulation software to estimate fire behaviors and numbers of impacted structures resulting from simulated ignitions in each candidate area, under each candidate area's most extreme fire weather and dead fuel moisture scenarios of the last 20 years. Extreme scenarios included a mixture of worst-case days, as well as offshore wind-event days, PSPS days, days of catastrophic wildfire occurrence, and some typical hot and dry summer days.

5. Each of the candidate areas remaining after Step 4 were assessed by the UCLA B. John Garrick Institute for Risk Sciences, using geospatial software and datasets (e.g., aerial imagery, vegetation maps, topographic maps).[40]

Application of this process in 2021 resulted in the removal of 218 discrete areas from PG&E's HFRA map. At the end of 2021, PG&E's revised HFRA map represents the spatial net result of the CPUC's HFTD map, plus PG&E's 2020 additions, minus PG&E's 2021 removals. Table PG&E-4.2-3 below summarizes the results of HFRA modifications in 2020 and 2021, for transmission and distribution miles in HFRA areas in 2020 and 2021, and the number of customers that would be within PSPS scope. Figure PG&E-4.2-7 provides a map of HFTD Tier 2 and Tier 3 areas and HFRA areas in PG&E's service territory as of December 2021. In 2022, we plan to continue to evaluate our HFRA map to further improve alignment with our objective.

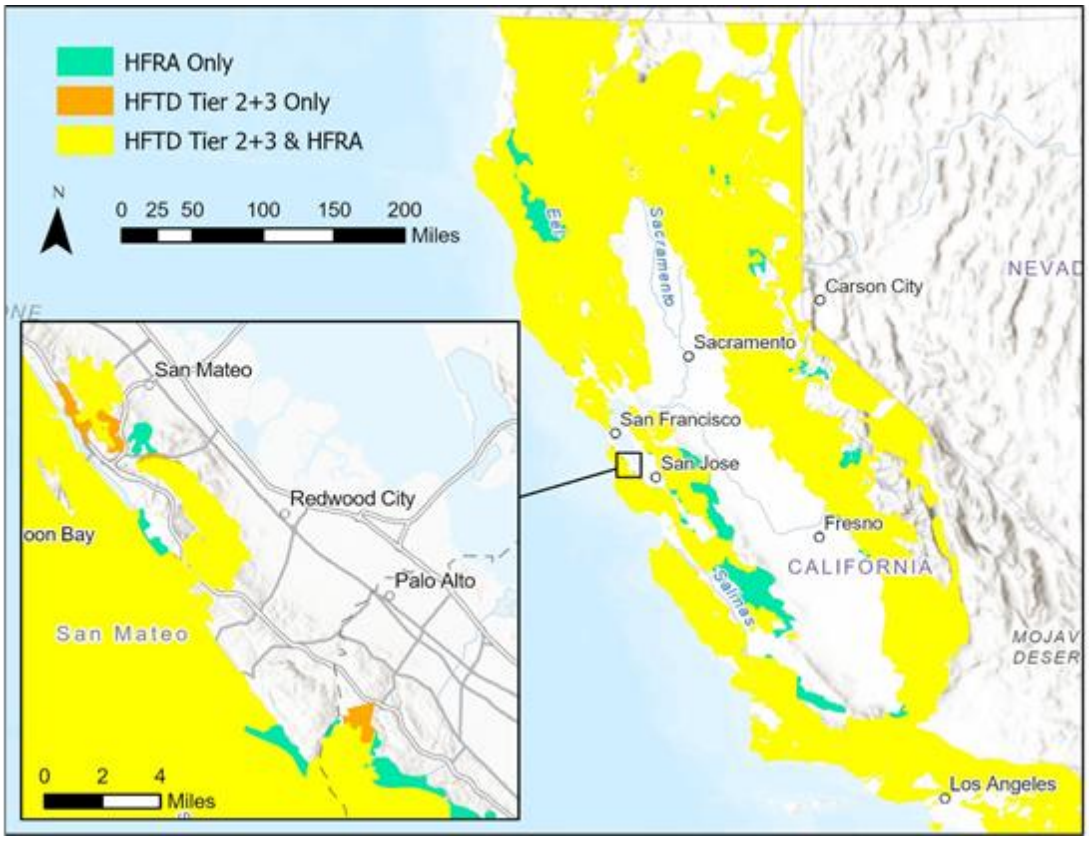
TABLE PG&E-4.2-3:
SUMMARY OF PG&E HFRA MODIFICATIONS IN 2021

	2020 Modifications	2021 Modifications
Area (square miles)	+3,280	-30
Overhead Transmission Circuit Miles	+230	-30
Overhead Distribution Circuit Miles	+610	-170
Customers in PSPS Scope	+3,000	-36,000

[40] Results of assessments by B. John Garrick Institute for Risk Sciences are summarized in reports. The three assessment reports pertaining to those areas considered for removal from HFRA in 2021, are included as attachments:

- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.2.1_Atch01;
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.2.1_Atch02; and
- 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.2.1_Atch03.

FIGURE PG&E-4.2-7:
CPUC HFTD MAP TIER 2 AND TIER 3, AND PG&E HFRA MAP, DECEMBER 2021



PG&E believes that many, but likely not all, of the past modifications to our HFRA map should also be applicable to the CPUC's HFTD map. This is based on the understanding that the CPUC's HFTD map and PG&E's HFRA map are designed to achieve related objectives. Tier 2 and Tier 3 of the CPUC's HFTD map are intended to identify areas where stricter fire-safety regulations are to be applied, which the CPUC did by identifying areas with elevated risk and extreme risk, respectively, (including likelihood and potential impacts on people and property) from wildfires associated with overhead utility power lines and overhead utility power-line facilities.[41] PG&E's HFRA map is intended to inform the geographic scope of PSPS events, which it attempts to do by identifying areas of PG&E's service territory where it believes an ignition, during an offshore wind event, could lead to a catastrophic wildfire, as well as informing in some cases work plans and risk assessments.

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41 CPUC D.17-01-009 (2017, p. 25) broadly defines Tier 2 and Tier 3 of the CPUC's HFTD map as "Areas with elevated wildfire risk" and "Areas with extreme wildfire risk", respectively. A set of more explicit definitions is given in the Independent Review Team Final Report on the Production of the California Public Utility Commission's Statewide Fire Map 2 (CPUC, 2017, p. 12), and reiterated in CPUC Decision 20-12-030 (2020, p. 2), and on the CPUC's Fire-Threat Maps and Fire-Safety Rulemaking webpage (https://www.cpuc.ca.gov/industries-and-topics/wildfires/fire-threat-maps-and-fire-safety-rulemaking).

All areas added to the HFRA map (i.e., areas currently within PG&E's HFRA map, but currently outside of Tier 2 and Tier 3 of the CPUC's HFTD map) should be candidates for inclusion in Tier 2 or Tier 3 of the CPUC's HFTD map based on the idea that stricter fire safety regulations should be applied in any area where an ignition could lead to a catastrophic wildfire. However, it is unclear how such additions should be allocated between Tier 2 and Tier 3, given existing Tier 2 and Tier 3 definitions. We also believe that some of the areas removed from the HFRA map (i.e., areas currently outside PG&E's HFRA map, but currently inside Tier 2 or Tier 3 of the CPUC's HFTD map) may warrant removal from Tier 2 or Tier 3 of CPUC's HFTD map. These areas were removed from the HFRA because they were determined to lack catastrophic wildfire risk, given an ignition, and under offshore wind event conditions. To determine their candidacy for removal from the CPUC's HFTD maps, these areas would need to be re-assessed with respect to wildfire risk generally, per Tier 2 and Tier 3 definitions (i.e., wildfire risk associated with all levels of wildfire consequence including but not limited to catastrophic wildfire, not conditional on an ignition, and not conditional on offshore-wind-event conditions).

For future modifications to the CPUC's HFTD map, PG&E envisions a CPUC-led process modeled on the one used to initially develop the CPUC's HFTD map, in which: (a) operational guidance and methodology were collaboratively developed; and (b) an Independent Review Team (IRT) conducted a technical review of the changes proposed by the Territory Leads, and made inquiries about, modified, and ultimately accepted or rejected the proposed modifications based on that technical review.

(b) Ignition Risk trends

Macro Trends Impacting Ignition Probability and/or Wildfire Consequence:

PG&E has identified the following macro-trends that may impact wildfire ignition probability and/or wildfire consequences:

TABLE PG&E-4.2-4:
MACRO TREND THAT MAY IMPACT WILDFIRE IGNITION PROBABILITY AND/OR WILDFIRE CONSEQUENCES

Rank	Macro Trends	Comments
1	Change in ignition probability and estimated wildfire consequences due to climate change	Several key climate change trends are influencing variable periods of extreme wildfire risks in Northern California. These trends significantly increase wildfire ignition risks around utility networks. Warmer winters are causing increases in rainfall rather snow, resulting in a decrease to the snowpack. This reduces available water resources earlier in summer months, stressing vegetation and increasing available fuels. Compounding the shift from snow to rain are extended dry periods following summer months deeper into fall and early winter. Northeast winds are more common in fall and winter months in Northern California and if not accompanied by rainfall or other atmospheric moisture wildfire risks continue to increase despite the presence of lower temperatures. Ignitions that occur under these conditions can result in large conflagrating wildfires that can further promote risk associated with Northern California's abundant fuel and extreme terrain resulting in fires that develop their own devastating weather. *Reference*: OEHHA: https://oehha.ca.gov/epic/changes-climate/precipitation. "Extremely dry and extremely wet years have become more common in California. On average, the state receives 75 percent of its annual precipitation from November through March, with 50 percent occurring from December through February. As the winter months have become warmer in recent years, more precipitation has been falling as rain instead of snow over the watersheds that provide most of the state's water supplies." "The last decade also includes the driest consecutive four-year period, from 2012 to 2015." "Warming temperatures, declining snowpack, and earlier spring snowmelt runoff can create stresses on vegetation" *Reference:* National Geographic: https://www.nationalgeographic.com/science/2019/10/climate-change-california-power-outage/ "Increasing heat, changing rain and snow patterns, shifts in plant communities, and other climate-related changes have vastly increased the likelihood that fires will start more often and burn more intensely and widely than they have in the past." "The changes in climate have created the perfect conditions for fire. Lower precipitation and warmer air temperatures dry the forests and other vegetation. Add strong winds and decades of fire suppression into the mix and you have a dangerous recipe for wildfire." *Reference*: National Geographic: https://www.nationalgeographic.com/science/article/climate-change-increases-risk-fires-western-us "In recent years, the area burned by wildfires has increased in parallel with increasing air temperatures (OEHHA, 2018.)" Diablo events that carry warm and dry air to the coast, play a key role in amplifying "fire weather" conditions. The combination of Diablo events and the later onset of winter precipitation can create an environment of dry vegetation, which is primed for explosive wildfire conditions. *Reference*: CA State Gov https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-013_Statewide_Summary_Report_ADA.pdf

TABLE PG&E 4.2-4:
MACRO TREND THAT MAY IMPACT WILDFIRE IGNITION PROBABILITY AND/OR WILDFIRE CONSEQUENCES
(CONTINUED)

Rank	Macro Trends	Comments
2	Change in ignition probability and estimated wildfire consequence due to relevant invasive species, such as bark beetles	Invasive species create landscape level concerns that have significant potential to impact areas within and adjacent to utility rights of way (ROW). Effects can extend well beyond the ROW making effective mitigation challenging for utilities without more holistic engagement and support from surrounding landowners and stakeholders. Of concern to utilities are both invasive plant and insect species. Invasive insect species, such as bark beetles, can exacerbate forest health concerns and result in hazardous tree conditions that require repetitious monitoring and mitigation by utilities. Native insect species, under stressed environmental conditions – like drought, can impose the same impacts and challenges. Invasive plant species in California tend to thrive in disturbed environments, often displacing native species. There is evidence that these invasions can change and intensify fire regimes. Landscape disturbance can be presented following fires, as well as during ROW maintenance and enhancements. Regardless of disturbance origin utilities are continually compelled to perform additional monitoring and mitigation to identify and control detrimental impacts associated with invasive species. Bark beetle outbreaks can make wildfire outbreaks much worse. During the window of time after beetles have killed the tree and its needles turn from green to red, the wood is more susceptible to ignition. *Reference*: Earth Island https://www.earthisland.org/journal/index.php/articles/entry/are-bark-beetles-are-further-aggravating-wildfires-in-california/ The invasive cheatgrass has changed much of the West's fire cycle, especially across the sagebrush sea, this has been damaging to the habitat that supports more than 350 species of plant and animals. The most pervasive impact of cheatgrass domination has been its influence on the size, intensity, and natural cycles of wildfire. Cheatgrass dies just in time for a typical fire season to start and is an extremely flashy fuel. Today's fires are becoming hotter and more frequent in part because of the dominance of cheatgrass. *Reference*: Theodore Roosevelt Conservation Partnership https://www.trcp.org/2020/08/28/invasive-species-fueling-western-wildfires/

TABLE PG&E 4.2-4:
MACRO TREND THAT MAY IMPACT WILDFIRE IGNITION PROBABILITY AND/OR WILDFIRE CONSEQUENCES
(CONTINUED)

Rank	Macro Trends	Comments
3	Changes in ignition probability and estimated wildfire consequence due to other drivers of change in fuel density and moisture	There have been notable changes to PG&E's service territory, in both fuel density and moisture over the last several decades. These changes significantly increase wildfire ignition risks around utility lines. Contributing factors to these changes cover a wide range of influences, including but not limited to; climate change, land use patterns, fire suppression and variable forest management practices. Fuel density is increasing while available moisture in critical wildfire risk periods is decreasing. This has been accompanied by increases in large tree mortality (partially due to bark beetles) and overall changes in forest structure. Bark beetles have always been present in periodic outbreaks, and normally cold winter weather keeps their population somewhat in check, preventing large tree die-offs. However, as winter temperatures rise, and in conjunction with the recent drought, their populations have burgeoned to create unprecedented tree die-offs. The lack of surviving seed trees is likely to cause failure of pine regeneration and result in forest conversion to shrubland. Extreme fire weather, particularly in the form of hot and dry winds, can have a strong influence on shrubland fire regimes, and contributes to conversion of shrublands to grasslands. *Reference*: CA State Gov https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-013_Statewide_Summary_Report_ADA.pdf The combination of more fires and drier conditions may expand deserts and otherwise change parts of California's landscape. Livestock grazing may also accelerate the conversion of grassland to desert in response to a changing climate. The 2012-2016 drought led to the most severe moisture deficits in the last 1,200 years and a 1-in-500 year low in Sierra snowpack. Future increases in temperature, regardless of whether total precipitation goes up or down, will likely cause longer and deeper California droughts, posing major problems for water supplies, natural ecosystems, and agriculture. *Reference*: EPA https://www.epa.gov/sites/default/files/2016-09/documents/climate-change-ca.pdf Forests are becoming denser with decreased presence of large trees and significant tree mortality over the last decade. Lands that are left unmanaged are subject to increases in accumulated dead and downed fuels that can be annually influenced by surrounding finer, flashier fuels following periods of rain or snowfall. *Reference:* PNAS: https://www.pnas.org/content/112/5/1458. *Reference:* California Energy Commission: https://www.energy.ca.gov/sites/default/files/2019-11/Projections_CCCA4-CEC-2018-014_ADA.pdf
4	Population changes (including Access and	Population in California and PG&E's territory has seen consistent growth over time, though population of California decreased slightly in 2020 (due to a variety of factors related to the pandemic) (Cal Matters). Much of this population growth continues in lands previously undeveloped and bordering, or in, fire prone wildland areas. "San

TABLE PG&E 4.2-4:
MACRO TREND THAT MAY IMPACT WILDFIRE IGNITION PROBABILITY AND/OR WILDFIRE CONSEQUENCES
(CONTINUED)

Rank	Macro Trends	Comments
	Functional Needs population) that could be impacted by utility ignition	Francisco is experiencing a unique and dramatic exodus, which is causing 50 percent or 100 percent increases in Bay Area in-migration for some counties in the Sierras" (LA Times). The lack of affordable housing near the coast, has also driven utility customers further south, north, and inland (CA Climate Change Assessment). *Reference:* CA Gov Climate Change Assessment https://barc.ca.gov/sites/default/files/20190116-sanfranciscobayarea.pdf *Reference*: Cal Matters https://calmatters.org/politics/2021/05/california-population-shrink-exodus/ *Reference*: LA Times https://www.latimes.com/california/story/2021-03-04/california-exodus-san-francisco-migration *Reference*: HBI http://www.homebuyinginstitute.com/news/california-forecast-cooling-trend-2022/ Current estimates suggest that at least 25 percent of California's residents already reside in areas subject to significant wildfire risk. With projection of upward population trends continuing, it is likely that populations in the WUI and/or the HFTD areas will relatedly increase. These trends may be compounded by the societal impacts of Covid-19. Housing trends in 2020 indicated a shift associated with stay-a-home orders and increased capability to telecommute. These emerging trends have indicated a desire to relocate from urban communities to more rural communities, many within the HFTD areas. The lack of availability and affordability of housing in lower wildfire risk urban areas within the PG&E territory are also factors that many residents evaluate and that all stakeholders, including policymakers, must consider as we all move forward. A significant, but variable and uncertain, portion of the population increases in higher wildfire risk areas will include customer with supplemental access or other functional needs. Utilities (and other stakeholders) will need to continue to engage in programs and education campaigns that inform and prepare all customers to mitigate these growing risks. *References:* LCAU: https://lcau.mit.edu/project/cataloguing- interface-wildfire-and-urban-development-California. PPIC: https://www.ppic.org/content/pubs/report/R_116HJ3R.pdf. CNBC: Warming climate, population sprawl threaten California's future with more destructive wildfires, https://www.cnbc.com/2019/11/09/why-californias-wildfires-are-going-to-get-worse.html.

TABLE PG&E 4.2-4:
MACRO TREND THAT MAY IMPACT WILDFIRE IGNITION PROBABILITY AND/OR WILDFIRE CONSEQUENCES
(CONTINUED)

Rank	Macro Trends	Comments
5	Population changes in HFTD that could be impacted by utility ignition	See PG&E's response to Item #4. Given the overall area of the HFTD areas as a percentage of PG&E's service territory (over 50 percent), it is likely that population growth in the HFTD areas will not be an exception to anticipated trends. In fact, population growth in HFTD areas may exceed, at least in some areas, population growth in non-HFTD areas.
6	Population changes in WUI that could be impacted by utility ignition	See PG&E's response to Item #4. Given the overall area of the WUI as a percentage of PG&E's service territory, it is likely that population growth in WUI will not be an exception to anticipated trends. The HFTD map was informed by WUI data and tremendous overlap between the two categories exists within PG&E service territory.
7	Utility infrastructure location in HFTD vs non-HFTD	PG&E anticipates limited net-addition of utility assets in the near future. Therefore, the overall breakdown of assets between HFTD and non-HFTD areas is not expected to significantly evolve going forward. Nonetheless, the volume and location of utility infrastructure already in HFTD areas (~1/3rd of PG&E's overhead electric assets) presents a risk to be mitigated, which is the focus of this plan. When adding or replacing utility infrastructure, particularly in or near HFTD, siting decisions should complement other resiliency and hardening programs continually over the decades to come. Given the increased focus on upgrading, strengthening or replacing assets in HFTD, the location and characteristics of infrastructure in HFTD areas will see more significant changes as compared to Non-HFTD areas.
8	Utility infrastructure location in urban vs rural vs highly rural areas	See PG&E's response to Item #7. There is high correlation between the HFTD areas and rural/highly rural areas within PG&E's service territory. There is similar correlation between urban areas and non-HFTD areas. Therefore, the trends impacting urban vs. rural are largely similar to those impacting HFTD vs. non-HFTD.

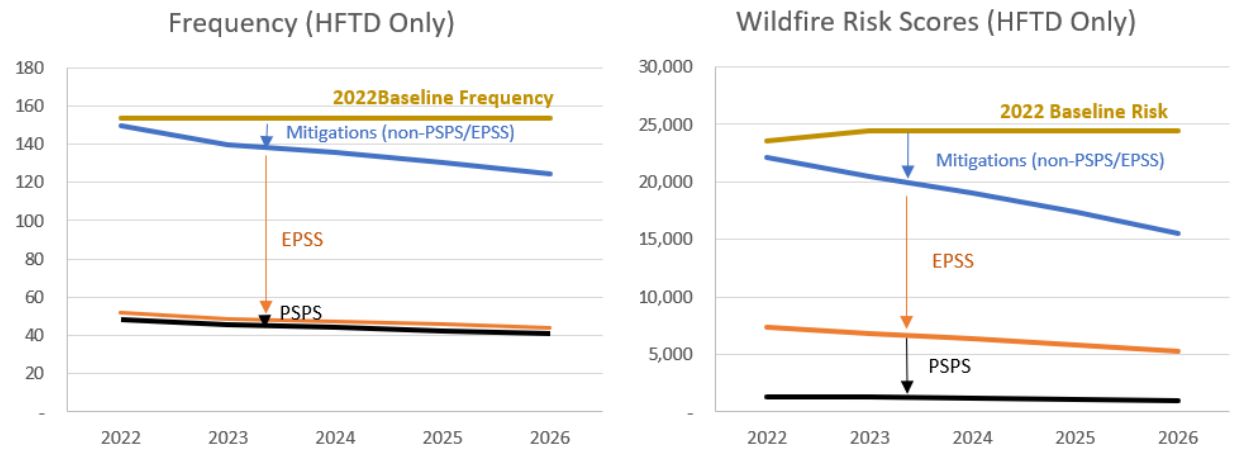
4.3 Change in Ignition Probability Drivers

Based on the implementation of the above wildfire mitigation initiatives, explain how the utility sees its ignition probability drivers evolving over the 3-year term of the WMP, highlighting any changes since the 2021 WMP Update. Focus on ignition probability and estimated wildfire consequence reduction by ignition probability driver, detailed risk driver, and include a description of how the utility expects to see incidents evolve over the same period, both in total number (of occurrence of a given incident type, whether resulting in an ignition or not) and in likelihood of causing an ignition by type. Outline methodology for determining ignition probability from events, including data used to determine likelihood of ignition probability, such as past ignition events, number of risk events, and description of events (including vegetation and equipment condition).

Based on our implementation of wildfire mitigation initiatives, PG&E has seen an overall decrease in the ignition probability, corresponding to changes in estimated wildfire frequency and risk scores.

In addition, PSPS and EPSS have had a significant impact on ignition probabilities, reflected in estimated wildfire frequency and risk scores. The impacts of PSPS and EPSS in HFTD are represented in Figure PG&E-4.3-1 below showing the impacts of ignition frequency and risk through the use of the 2022 Enterprise Risk Model.

FIGURE PG&E-4.3-1:
IMPACTS OF EPSS, PSPS AND MITIGATION ON IGNITION FREQUENCY AND IGNITION PROBABILITY (HFTD ONLY)



In the remainder of this section, we describe our :

(a) 2022 Enterprise Risk Model for Wildfire Risk;

(b) Methodology for Determining Ignition Probability From Events For WDRM;

(c) Equipment Probability of Ignition Model; and,

(d) Vegetation Probability of Ignition Model.

(a) 2022 Enterprise Risk Model for Wildfire Risk

In 2021, PG&E built the 2022 Enterprise Risk Model for Wildfire Risk, or 2022 ERM, to provide a consistent enterprise-wide risk assessment and modeling framework using PG&E's MAVF in alignment with the S-MAP Settlement Agreement.[42] This model is used to calculate pre-mitigated (or baseline) risk scores and post-mitigation risk scores, to compare them across different risks in PG&E's Corporate Risk Register and produce the RSE scores at a program level for the WMP and GRC (see Section 4.5.1(a) – 2022 Enterprise Risk Model for Wildfire Risk).

This section provides an overview of the 2022 ERM and, more specifically, ignition drivers considered in the model[43] used to evaluate wildfire risk. Exposure to the wildfire risk is modeled based on the approximately 99,000 total overhead circuit miles in PG&E's electric distribution and transmission systems. Of the total overhead circuit miles, approximately 25,500 distribution circuit miles are within the CPUC designated HFTD areas. The risk drivers used for this model are:

1) Vegetation Contact;
2) Equipment/Facility Failure;
3) Contact from Object;
4) Wire-to-Wire Contact;
5) Unknown;
6) Other;
7) Vandalism/Theft;
8) Utility Work/Operation;
9) Contamination; and
10) Seismic.

The risk drivers for this risk event have been modified since PG&E filed our 2020 RAMP Report to align with the Cause categories outlined in the 2021 WMP Guidelines[44] for Table 7.1 and Table 7.2. The one exception is that in the 2021 WMP, Vegetation Contact is a sub-driver of the Contact from Object driver, whereas in the 2022 ERM,

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42 For a detailed description, see PG&E's Enterprise Risk Model Documentation and User Guide, available in 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.3_Atch01.pdf.

43 A more detailed discussion of the 2023 GRC Enterprise Risk Model was provided in PG&E's testimony in the 2023 GRC. See Exhibit (PG&E-4), Chapter 3.

44 Attachment 2.2: 2021 Wildfire Mitigation Plan (WMP) Guidelines Template (ca.gov)

Vegetation Contact is a stand-alone risk driver. This change in risk driver was made to reflect the vegetation contact driver's contribution to the risk.

Wildfire baseline risk includes approximately 483 risk events (ignitions)[45] systemwide and 153 (32 percent) risk events in HFTD areas for 2022. Risk events in HFTD areas accounted for 99 percent of the overall risk. The Equipment/facility failure risk driver accounts for 36 percent of ignitions systemwide and 21 percent of ignitions in HFTD areas.[46] Conductor and connector failures account for most of these equipment failure incidents. The Vegetation Contact risk driver accounts for 28 percent of ignitions systemwide and 18 percent of ignitions in HFTD areas.[47] The number of events and percentages for each driver are provided in Figures PG&E-4.2-1, PG&E-4.2-2, and PG&E-4.2-3 in Section 4.2 above.

PG&E updated our 2020 ERM to support the 2020 RAMP filing and our 2021 WMP. Since we our 2020 RAMP Report, we have made changes to our 2020 ERM as discussed below. Certain changes were made in response to feedback from SPD and parties, as noted below, while other changes were made by PG&E as we continue to update and refine our enterprise risk models. PG&E also made many changes to align to the 2021 Wildfire Distribution Risk Model v2 (2021 WDRM v2) by using the outputs in the 2022 ERM discussed in the 2021 WMP.

SPD and parties (intervenors) recommended that PG&E's risk models incorporate more granular tranching. For example, SPD stated that given the diverse environments and conditions covered by PG&E's electric distribution system it was unreasonable to assume a homogeneous risk profile as PG&E did in the 2020 RAMP Report.[48]

PG&E agreed that the tranches included in the 2020 ERM could be improved. In response to SPD and parties' feedback, PG&E revised the tranches in the 2022 ERM. PG&E expanded the number of tranches from 8 to 40 systemwide.[49] Transmission tranches were further refined by voltage class and HFTD areas, expanding from 2 to 12. HFTD distribution tranches were further refined, expanding from 3 to 25. The 25 distribution tranches represent the combination of 5 quintiles of the Likelihood of a Risk

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45 Based on the CPUC's reportable fire ignition definition, fire ignition is defined as an ignition resulting a fire that traveled more than one meter from the ignition point and burnt something other than PG&E facilities. (D.14-02-015, Appendix C, p. C-2, Section 1.A.4.) PG&E's current 2023 GRC Risk Model uses all reportable ignitions systemwide; previous versions of the model were limited to high fire risk areas (Fire Index Area's in the 2017 RAMP and HFTD areas in the 2020 GRC). PG&E's baseline forecast of 2022 ignitions is 483, which is based on historical ignitions with certain adjustments.

46 The Equipment Failure risk driver accounts for 21 percent of ignitions in HFTD areas, 20 percent of ignitions in HFTD Distribution, and 32 percent of ignitions in HFTD Transmission.

47 The Vegetation risk driver accounts for 48 percent of ignitions in HFTD areas, 52 percent for HFTD Distribution, and 5 percent of ignitions in HFTD Transmission.

48 SPD Staff Report, p. 5.

49 There are two substation tranches and one non-HFTD distribution tranche that have not changed since the 2020 RAMP Report.

Event and the CoRE. An important aspect of the refinement in HFTD distribution tranching is the alignment of the 2022 ERM to the 2021 WDRM v2.

The 2021 WDRM v2 provides a risk ranking for the prioritization of EVM and System Hardening work. The 2022 ERM assesses enterprise risks, including wildfire, using a common framework and develops RSEs using the MAVF scoring approach agreed to in the 2020 S-MAP Settlement Agreement. PG&E aligned the two models by using the outputs from the 2021 WDRM v2 in the 2022 ERM. For equipment/facility failure (conductor damage or failure) and vegetation contact risk drivers the 2021 WDRM v2 informs the 2022 ERM to the probability of ignition at the distribution circuit segment level within the HFTD areas. Additionally, Technosylva simulation results in the 2021 WDRM v2 inform the wildfire consequence at the distribution circuit segment level.

PG&E also made four key changes to our risk drivers since the 2020 RAMP Report:

1) In its evaluation of PG&E's 2020 RAMP Report, TURN, a party to the proceeding, stated that:

> ...[a] correct portrait of PG&E's wildfire risk requires that the considerable risk resulting from PG&E's operational failures be recognized and that the risk reduction benefits from fixing those problems be quantified.[50]

SPD agreed that this was a valid comment and that operational failures should be modeled as a risk driver.[51] To capture this, the 2022 ERM includes ignitions associated with PG&E workforce-caused outages as a 'Utility work/Operation' driver. PG&E will continue to explore other ways to represent operational failures in the risk model.[52]

2) In the process of providing feedback to PG&E's 2020 RAMP Report, the Mussey Grade Road Alliance, a party to the proceeding, requested an analysis of ignitions by different drivers by local wind speed. From the analysis, it was concluded that ignitions resulting from both vegetation-related and equipment-related root causes are more likely to occur under higher wind speed conditions, and there is a strong correlation between high winds and RFW, during which destructive or catastrophic fires are more likely to occur.

In the 2022 ERM, PG&E incorporated lessons learned from analyzing ignition data that indicated the likelihood of an ignition occurring during an RFW varies by ignition driver. Based on PG&E's 2015–2020 CPUC-reportable ignitions report, the percentage of ignitions occurring when an RFW is in effect is the highest for vegetation contact, followed by equipment/facility failure, and then all other drivers. Also, since there is a higher likelihood for an ignition to develop into a large, destructive, or catastrophic fire when an RFW is in effect than when an RFW is not

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50 TURN's Opening Comments on PG&E's RAMP Report and the SPD's November 25, 2020 Evaluation Report, A.20-06-012 (Jan. 15, 2021) (TURN Opening Comments), p. 7.

51 SPD Staff Report, p. 71.

52 For example, PG&E has introduced a new data entry field as part of our Corrective Action Program to identify and track ignitions that are submitted by PG&E workforce.

in effect, this results in a higher CoRE value for the vegetation-contact driver than the CoRE value for other drivers.

3) PG&E updated the 2022 ERM risk drivers and sub-drivers, used to inform our 2023 GRC, to align with those presented in the 2021 WMP so that the information is consistent between the two regulatory filings.

4) PG&E updated the risk drivers and sub-drivers for substation tranches. Even if there were no ignitions in the 2015-2020 dataset from specific drivers, substation outages that could cause an ignition were incorporated into the model to capture the potential substation failures that could lead to an ignition.

PG&E has also made three additional changes to the 2022 ERM since filing our 2023 GRC Application.

1) For certain risk driver/subdriver combinations, not covered by outputs from the 2021 WDRM v2, the 2022 ERM was updated to improve the allocation of system-wide ignition frequency among tranches.

2) In the 2022 ERM, the climate change cross-cutting factor (multiplier) is now applied to amplify the consequence of ignitions instead of the frequency of ignitions occurring during an RFW.

3) In the 2022 ERM, HFTD distribution tranches and associated risk scores were refreshed by incorporating the impact of mitigations implemented in 2021.

(b) Methodology for Determining Ignition Probability From Events For WDRM

In support of risk-based Electric Operations planning, PG&E has developed distribution[53] asset risk models designed to quantify wildfire risks from the distribution system at planning and situational awareness timescales, support risk-based decision making, and enable reporting of risk reduction activities to regulators and the public. To do this, PG&E characterizes wildfire risk as:

Risk = Ignition Probability x Wildfire Consequence.

Both the probability (also referred to as likelihood) and the consequence of an ignition are conditioned, to a degree, on the environmental factors (i.e., sustained wind speeds and gusts, temperature, vegetation, structures, and topography) experienced by distribution assets which utilizes the age of the asset, location of the asset, and other physical characteristics.

To answer the question of *where* ignition events are likely to occur, we have estimated fire season ignition probabilities using maximum entropy models (MaxEnt) pioneered in the modeling of ecological ranges of species. These models are trained on ignition (outage or initiating event) locations and gridded spatial (raster) environmental and asset attribute data. The data can draw from a specific time period, but the model itself

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53 PG&E defines voltages below 60 kV as distribution and voltages 60 kV and above as transmission.

is dedicated to spatial, not temporal, patterns. The MaxEnt Model provides relative scores or, probabilities for fire-season ignitions per “pixel” of input data.

In order to more accurately assess and define risks, in 2020 PG&E:

1) Replaced the regression equipment ignition likelihood from prior models with the Equipment Probability of Ignition Model

2) Replaced the regression vegetation ignition likelihood from prior models with the Vegetation Probability of Ignition Model

By incorporating these models into the WDRM, PG&E was able to:

- Incorporate additional variables in the models, increasing accuracy (tree types, wind scores, ground cover);
- Model ignitions directly by utilizing the MaxEnt algorithm as compared to modeling proxies in prior models; and,
- Reduce overfitting by developing training and testing datasets for model development.

A wide range of input data sets were used in developing both the Vegetation Probability of Ignition and the Equipment Probability of Ignition Models. Table PG&E-4.3-1 summarizes the data developed to date for use in these models. A more detailed description of the Vegetation Probability of Ignition and the Equipment Probability of Ignition Models is provided after Table PG&E-4.3-1.

TABLE PG&E-4.3-1:
DATA USED TO DEVELOP PROBABILITY OF IGNITION MODELS

Data Set	Category	Source	Spatial resolution	Units	Descriptions
100-hour fuels	Meteorological data	gridMET	~4km	%	Unless otherwise noted, all gridMET data aggregated from 2014 to 2016. The dead fuel moisture data were obtained from gridMET, and the "100-hour-fuels" feature was included in the model. The exact gridMET variable use is known as fm-100, and is a standard fire modeling metric of fuel dryness for fuels about 1-3" in diameter - intermediate sized fuels.
1000-hour fuels	Meteorological data	gridMET	~4km	%	fm-1000, as defined above, but for 3-8" in diameter.
burn index	Meteorological data	gridMET	~4km		The US National Fire Danger Rating System (USNFDRS) Burning Index (BI)
energy release	Meteorological data	gridMET	~4km		USNFDRS Energy Release Component (ERC)
precipitation average	Meteorological data	gridMET	~4km	Mm	Daily precipitation average
specific humidity	Meteorological data	gridMET	~4km	kg/kg	Specific humidity
vapor pressure deficit avg	Meteorological data	gridMET	~4km	kPa	Measure how much water is in the air compared to how much it could hold at the given temperature. Vapor Pressure Deficit drives evapotranspiration and is the mechanism for fuels drying out during fire season.
temperature max average	Meteorological data	gridMET	~4km	K	Average of daily maximum temperature in Kelvin (recall that it is sensed via satellite)
wind avg	Meteorological data	RTMA	~2.5km	m/s	Hourly average wind speed at 10m, averaged from 2016 to 2018
wind max	Meteorological data	RTMA	~2.5km	m/s	Annual 99th percentile hourly wind speed at 10m assessed over 2016 to 2018

TABLE PG&E-4.3-1:
DATA USED TO DEVELOP PROBABILITY OF IGNITION MODELS
(CONTINUED)

Data Set	Category	Source	Spatial resolution	Units	Descriptions
windy summer day pct	Meteorological data	RTMA	~2.5km		The percentage of days with sustained hourly wind speeds over 15 mph
gusty summer day pct	Meteorological data	RTMA	~2.5km		The percentage of days with sustained hourly wind speeds over 20 mph
tree height max	Tree data	Salo Sciences	100m		Tree height data were obtained from a third-party vendor, Salo, and the "tree-height-max" feature was developed by calculating the maximum tree height, in meters, for each 100m x 100m pixel area along the distribution grid, according to the processed satellite data provided by Salo. The satellite imagery was collected in November 2019.
tree height average	Tree data	Salo Sciences	100m		Same as above but taking the average tree height for each pixel.
Impervious	Surface condition	National Land Cover Database (NLCD)	100m	%	NLCD imperviousness products represent urban impervious surfaces as a percentage of developed surface over every 30-meter pixel in the United States, scaled to 100m.

TABLE PG&E-4.3-1:
DATA USED TO DEVELOP PROBABILITY OF IGNITION MODELS
(CONTINUED)

Data Set	Category	Source	Spatial resolution	Units	Descriptions
Unburnable	Surface condition	LANDFIRE 2016 Surface Fuels Model	100m	%	The "un-burnable" feature is a land surface descriptor similar to imperviousness that includes surfaces that typically don't ignite when a spark occurs. The feature was derived from several land use types within the 2016 LANDFIRE surface fuel model (USGS, 2016) and is the percentage of the 100m x 100m pixel identified as un-burnable. The land use types considered "un-burnable" in the composite spatial layer include: urban, snow/ice, agriculture, water, and barren.
local topography	Surface condition	National Elevation Database (NED)	100m		The relative topography of the area was also used as a feature in the model. The topographic position index (TPI) was extracted from a USGS NED at 100-meter resolution. The TPI compares the cell elevation to the mean elevation for the local neighboring area (positive values are above the mean and negative values are below the mean) (The Nature Conservancy).
HFTD	HFTD	CPUC	100m		Categorical variable that is 1 for non-HFTD locations, 2 for Tier 2 and 3 for Tier 3.
Age	Asset data	Electric Distribution Geographic Information System (EDGIS) Conductors	100m		The estimated conductor age (the "estimated-age") was calculated as the number of years since the installation year, as listed in EDGIS. If the installation date was missing or invalid, then the estimated age in the STAR model dataset was used

TABLE PG&E-4.3-1:
DATA USED TO DEVELOP PROBABILITY OF IGNITION MODELS
(CONTINUED)

Data Set	Category	Source	Spatial resolution	Units	Descriptions
Materials	Asset data	EDGIS Conductors	100m		The type of conductor material was split into one-hot encoded dummy variables, which identified conductor materials aluminum (Al), copper (Cu), and ACSR ("conductor-material-al," "conductor-material-cu," and "conductor-material-acsr," respectively) as binary model features.
Size	Asset data	EDGIS Conductors	100m		The conductor size dataset was split into one-hot encoded dummy variables, which identified conductor size #2, #4, and #6 ("conductor-size-2," "conductor-size-4," and "conductor-size-6," respectively) as binary model features. Lower numbers correspond with larger diameters.
Splice count	Asset data	EDGIS Conductors	100m		Splices were identified from the splices database table (Emili Scaief, 2020). In order to prevent splice locations from introducing bias to the model, only the Reliability Program splice records were used, which only included spans with more than three splices per phase/span.
Coastal indicator	Asset data	EDGIS Conductors	100m		Coastal areas were identified using a binary feature in the model. Coastal areas within PG&E service territory were mapped internally in PG&E and conductors are tagged with a coastal indicator field in EDGIS.

(c) Equipment Probability of Ignition Model

Ignition likelihood for equipment was determined based on a probability analysis predicting ignitions in 100m x 100m pixels. The Equipment Probability of Ignition Model was trained on conductor failure related ignitions limited to fire season events and CPUC-reportable ignitions from 2015 to 2018 and tested using the 2019 ignitions. The modeling technique used was a maximum entropy (MaxEnt) algorithm. MaxEnt algorithm provides a way of estimating the relative occurrence rate given a fairly modest number of ignition locations. The principle of maximum entropy states that the

probability distribution which best represents the current state of knowledge is the one with the largest entropy, in the context of precisely stated prior data.

A range of variables were included in the initial modeling. These included meteorology data, PG&E asset data, and remote sensing data from government and private third parties. The most important variables for the Equipment Probability of Ignition Model are identified below in Table PG&E-4.3-2.

TABLE PG&E-4.3-2:
VARIABLES IN EQUIPMENT PROBABILITY OF IGNITION MODEL

Variable	Permutation Importance
Non-burnable area	30.8
Daily precipitation, mean	29.8
Conductor material: ACSR	9.7
Estimated conductor age	8.9
Max tree height	4.3
Reliability Program splice	4.3
Vapor pressure deficit, mean	4.0
Conductor size: 2	3.4
Conductor size: 4	1.6
100-hour fuels, mean	1.1
Max temperature, mean	1.0
Wind speed, mean	0.9
Local topography	0.2
Conductor size: 6	0.1
Conductor material: Al	~0
Conductor material: Cu	~0

Using these variables, a probability of ignition was assigned for each 100m x 100m grid. These probabilities were indexed and calibrated to the total expected ignition frequency.

Updates to this model are planned on an annual basis as additional equipment types are modeled. In 2021, Electric Corrective tag data and asset data was used in the Equipment Probability of Ignition Model and, additional equipment failure models for poles and transformers. These additional equipment models will combine with an update to the conductor failure model in the 2022 WDRM v3 to improve the predictive power of equipment caused ignition probabilities to further enhance the model to better inform mitigation programs.

(d) Vegetation Probability of Ignition Model

Ignition likelihood for vegetation was determined based on a probability analysis predicting ignitions in 100m x 100m pixels. As part of the 2021 WDRM v2, the Vegetation Probability of Ignition Model was trained on CPUC-reportable ignitions during fire seasons from 2015 to 2018 and tested using the 2019 ignitions. This data set includes all vegetation related outages that resulted in an ignition. The modeling technique used was a MaxEnt algorithm. The MaxEnt algorithm provides a way of estimating the relative occurrence rate given a fairly modest number of ignition locations. The principle of MaxEnt states that the probability distribution which best

represents the current state of knowledge is the one with the largest entropy, in the context of precisely stated prior data.

Variables in the initial model included meteorology data, PG&E asset data, and remote sensing data from government and private third parties. The most important variables for the Vegetation Probability of Ignition Model are included below in Table PG&E-4.3-3.

TABLE PG&E-4.3-3:
VARIABLES IN VEGETATION PROBABILITY OF IGNITION MODEL

Variable	Permutation Importance
tree-height-max	26.1
100-hour-fuels-avg	24.1
vapor-pressure-deficit-avg	21.6
gusty-summer-day-pct	6
HFTD	4.2
precipitation-avg	3.1
Impervious	2.8
specific-humidity-avg	2.4
burn-index-avg	2.3
wind-max	1.9
temperature-avg	1.6
windy-summer-day-pct	1
local-topography	0.8
tree-height-avg	0.8
1000-hour-fuels-avg	0.6
energy-release-avg	0.4

Using these variables, a probability of ignition was assigned for each 100m x 100m grid. These probabilities were indexed and calibrated to the total expected ignition frequency.

Response to Critical Issue RN-PG&E-22-07:

Critical Issue Title: PG&E's ignition projections do not account for its ignition mitigation measures

Remedy # 1:

1. *PG&E must revise and resubmit Table 7.2 from PG&E's 2022 Update to project 2022 and 2023 ignitions factoring in risk reduction benefits of mitigation measures, including (but not limited to) EPSS, undergrounding, and covered conductor.*

Response to Critical Issue RN-PG&E-22-07 Remedy # 1:

We have revised Table 7.2 to include projections for 2022 and 2023 ignitions across all circuits (both HFTD and non-HFTD), factoring in risk reduction benefits of traditional wildfire mitigation measures. These mitigation measures include efforts such as undergrounding and covered conductor, as well as new mitigation programs such as EPSS. Overall, across PG&E's system territory, 2022 ignitions are expected to

decrease by 9 percent and 2023 ignitions are expected to decrease by an additional 6 percent, as compared to the previous year.

The new projections in Table 7.2 were calculated by:

1) Adjusting recent annual average Distribution HFTD ignition counts based on expected mitigation effectiveness for traditional mitigations;

2) Factoring for the additional reduction impact from EPSS; and

3) Accounting for variation in the year 2022 data from that of previous years, based on observed data from the beginning of this calendar year.

A summary is provided in Table RN-PG&E-22-07-01 below broken down by HFTD and non-HFTD areas and by voltage class. We are also providing a system-wide total of observed and forecasted ignitions.

TABLE RN-PG&E-22-07-01:
IGNITIONS ANNUAL OBSERVED AND FORECAST

	Voltage Class	2015-2020 Average Observed	2021 Observed	2022 Forecast	2023 Forecast
HFTD	Distribution	144	129	97	71
HFTD	Transmission	11	4	10	10
HFTD	Subtotal T&D	155	133	107	81
Non-HFTD	Distribution	321	337	319	319
Non-HFTD	Transmission	11	10	11	11
Non-HFTD	Subtotal T&D	332	347	329	329
System	Total T&D	487	480	436	410
% Change			-1%	-9%	-6%

Note: Differences due to rounding.

Each of the steps to calculate the forecasted HFTD 2022 and 2023 ignitions is described in the response to Remedy # 2 below. Forecasted 2022 and 2023 ignitions for non-HFTD areas are calculated using the same methodology as HFTD, based on the proposed set of mitigations that apply to non-HFTD areas set forth in the GRC application, as described in Exhibit 4 Chapter 3. For example, since EPSS is not enabled in non-HFTD areas, this mitigation is not factored into non-HFTD ignition forecasts. PG&E can provide workpapers supporting the GRC application if Energy Safety requests.

The revised Table 7.2 is provided with this response as Attachment 2022-06-27_PGE_22-07_RNR_R1_Atch01.

Remedy # 2:

2. *PG&E must also provide a narrative description for what factors are considered when calculating ignition projections, inclusive of WMP mitigation measure implementation, the weights of such factors and effects on projected ignitions.*

Response to Critical Issue RN-PG&E-22-07 Remedy # 2:

Given that the most frequent ignitions are associated with Distribution facilities, our mitigation work is heavily focused on reducing the number of Distribution ignitions in the HFTD and HFRA areas. Below we provide a narrative description of the factors considered when calculating our ignition projections, including the weights of factors and the effects on projected ignitions.

1) Adjusting recent annual average HFTD ignition counts based on expected mitigation effectiveness for traditional mitigations:

The annual average historical Distribution HFTD ignition counts, for the years 2015-2020, is 143 ignitions per year,[54] which was used as an initial projected baseline for the year 2022. 2021 ignitions were intentionally excluded from the baseline calculations so as not to introduce variability as a result of EPSS being implemented for only a portion of the year and only in a select number of HFTD circuits. Recognizing that there is year-to-year variability in ignition counts, we calculated a 95 percent confidence interval, based on plus or minus two standard deviations—in line with standard statistical practice—so as to account for variations in ignition rates. Thus, with 95 percent confidence, our 2022 baseline numbers, excluding all mitigation measures, would range between 110 and 176 ignitions.

Based on the portfolio of mitigations presented in the 2022 WMP and GRC,[55] PG&E expects its mitigation plan, excluding EPSS, to reduce HFTD Distribution ignitions by approximately 3.0 percent from 2021 to 2022, and by approximately 7.4 percent from 2022 to 2023.[56] As a result, the projected ignitions for 2022 and 2023 in HFTD Distribution are expected to drop from a historical annual average of 143 in 2021 to 139 in 2022 and 128 in 2023. However, as observed in actual 2021 performance, the impacts of EPSS had not been fully considered in this forecast.

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54 The 6-year historic average was used for defining the ignitions baseline as it accounts for variation in weather conditions and other environmental factors. Numbers have been rounded to whole numbers.

55 The mitigations include, but are not limited to, the implementation of covered conductor, undergrounding, and various vegetation management initiatives.

56 Based on the standard framework established by CPUC's SMAP of calculating risk reduction from portfolio effectiveness of mitigations as described in Section 4.2 of the WMP and the GRC.

A similar approach for calculating ignition reduction is used for Transmission ignitions. However, there are certain limitations to our ability to estimate Transmission ignition reductions resulting from EPSS, which are described in more detail below.

2) Factoring for additional impact from EPSS:

In 2021, we deployed EPSS on a portion of Distribution HFTD circuits during the second half of the year. Based on the latest EPSS risk-informed decision criteria as of June 2022, greater deployment of EPSS is expected to occur over the course of the year. However, this deployment will also be primarily targeted to occur during periods when the forecasted fire conditions are anticipated to be at level R3 or above.[57] As such, we estimate EPSS's overall effectiveness across the year to be 45 percent. This number accounts for EPSS's overall 80 percent effectiveness, when applicable to 88 percent of primary circuit ignitions, with fire conditions at level R3 above, representing approximately 64 percent of previous ignitions. With these estimates, when EPSS is included as a mitigation in the HFTD ignition forecast, this reduces our 2022 estimate to 76 ignitions, and our 2023 estimate to 71 ignitions.[58]

As a result of low ignition count data for Transmission HFTD and insufficient observed run time, we were not able to establish effectiveness of EPSS on specific Transmission voltage classes (*i.e.,* 60 kV, 70 kV, and 115 kV) in a statistically valid manner at this time. Therefore, PG&E has not incorporated an EPSS-based reduction into the projected ignitions for Transmission for 2022 and 2023. While we believe EPSS will have a positive impact on mitigating Transmission-associated ignitions, this more conservative approach to forecasting is purposefully being employed until the impact of EPSS on ignitions from these Transmission voltage classes can be more accurately assessed.

3) Accounting for variation in the year 2022 data from that of previous years, based on observed data from the beginning of the year:

Since we have already observed ignition data from January to May in 2022, we have adjusted the 2022 year-end projections to include these observed ignitions. On average, from 2015 to 2021, January through May makes up approximately 15 percent of the annual ignitions, with the traditional fire season of June through November comprising 80 percent of annual ignitions, and the final 5 percent of ignitions occurring in December. Thus, for 2022, we subtracted the amount of ignitions forecasted to occur in January through May (*i.e.,* 76 x 15 percent = 12) from the expected annual total of 76, and then added back the actual observed ignitions during this time period (32 ignitions) for the January through May period, as indicated in Table RN-PG&E-22-07-02 below:

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57 R3 is a Fire Rating Index for when fire danger is high; in R4, fire danger is critical; and in R5, fire danger is extreme.

58 139 x (1-45%) = 76 for 2022 and 128 x (1-45%) = 71 for 2023.

TABLE RN-PG&E-22-07-02:
2022 HFTD DISTRIBUTION IGNITIONS YEAR TO DATE AND YEAR END FORECAST

Month	Historical Average Ignitions w/o EPSS	Historical Average Ignitions w/ Projected EPSS (45% effectiveness)	Revised Forecast to Include 2022 YTD Observed Ignitions
January	2	1	2
February	4	2	5
March	3	2	4
April	4	2	10
May	8	5	11
Year to Date Subtotal	21	12	32
Traditional Fire Season Estimate (Jun to Nov)	111	61	61
December Estimate	7	4	4
Year End Forecast	139	76	97

Note: Differences due to rounding.

While observed ignition data from January to May 2022 was higher than expected, this is largely the result of unpredictable external factors that are expected to revert to historical levels in future months. Specifically, from January through May 2022, we observed:

- An increase in third party-caused ignitions (11 ignitions in 2022 compared to 2015 to 2021 averages of 3 ignitions for the same time period); and
- Animal contact ignitions (5 ignitions associated with animal activity in 2022 compared to 2015 to 2021 averages of 1 ignition for the same time period).

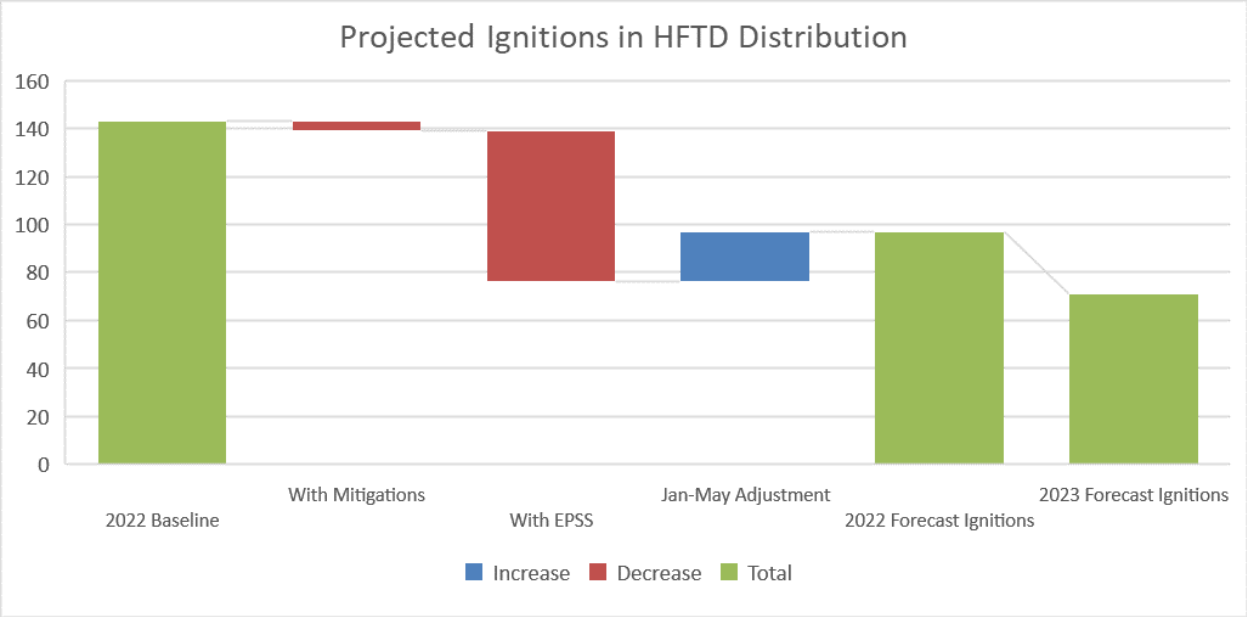
During this same period in 2022, equipment failure and vegetation contact caused ignitions have been below average. PG&E believes the inclusion of the January to May 2022 actual figures is an appropriate adjustment to better reflect our ignition projections for 2022. We expect the remainder of the year to adhere closer to historical averages.

When these values are combined (observed 2022 year to date, and expected forecast), we computed a new projected 2022 year-end value of 97 HFTD distribution ignitions, but highlight that the range for this number, with a 95 percent confidence interval, is from 79 to 114 ignitions.

For 2023 year-end value, we project HFTD distribution 71 ignitions, after accounting for our continued mitigations, with a 95 percent confidence interval, and a range of 54 to 87 ignitions. This figure could also substantially change as we continue to evaluate the impacts of EPSS settings on our system. This represents our best available information as of June 2022 and will continue to provide adjustments and updated data as part of our quarterly and annual WMP reporting.

Figure RN-PG&E-22-07-01 below summarizes the changes to the HFTD ignition projections described above.

FIGURE RN-PG&E-22-07-01:
HFTD DISTRIBUTION IGNITIONS FORECAST WATERFALL



4) Resulting Revised Table 7.2:

A revised Table 7.2 has been provided, with expected ignition figures. The outputs can be seen in Table 12 of Attachment 2022-06-27_PGE_22-13_RNR_R1_Atch01 with the adjustment due to EPSS shown in Attachment 2022-06-27_PGE_22-07_RNR_R1_Atch02.

4.4 Research Proposals and Findings

Report all utility-sponsored research proposals, findings from ongoing studies and findings from studies completed in 2020 and 2021 relevant to wildfire and PSPS mitigations.

4.4.1 Research Proposals

Report proposals for future utility-sponsored studies relevant to wildfire and PSPS mitigation. Organize proposals under the following structure:

1. *Purpose of research – Brief summary of context and goals of research*

2. *Relevant terms – Definitions of relevant terms (e.g., defining "enhanced vegetation management" for research on EVM)*

3. *Data elements – Details of data elements used for analysis, including scope and granularity of data in time and location (i.e., date range, reporting frequency and spatial granularity for each data element, see example table below).*

EXAMPLE TABLE REPORTING DATA ELEMENTS

Data Element	*Collection Period*	*Collection Frequency*	*Spatial Granularity*	*Temporal Granularity*	*Comments*
Ignitions from contact with vegetation in non-enhanced vegetation areas	*2014 – 2021+ (ongoing)*	*Per ignition*	*Lat/long per ignition*	*Date, hour of ignition (estimated)*	*–*
Ignitions from contact with vegetation in enhanced vegetation areas	*2019 – 2021+ (ongoing)*	*Per ignition*	*Lat/long per ignition*	*Date, hour of ignition (estimated)*	*–*

4. *Methodology – Methodology for analysis, including list of analyses to perform; section must include statistical models, equations, etc. behind analyses.*

5. *Timeline – Project timeline and reporting frequency to Office of Energy Infrastructure Safety.*

California Polytechnic State University, San Luis Obispo (Cal Poly) WUI Fire Information, Research, and Education (FIRE) Institute

1. Purpose of Research

The purpose of the Cal Poly FIRE Institute is to make significant contributions to solving the WUI fire problem through integrated and applied research and education that innovates, informs policy, disseminates information, and educates students and professionals.

In 2021, PG&E partnered with, and advised on the direction of research, and associated activities by, the FIRE Institute as it works toward the development of solutions for sustainable fire-resilient communities and safer and more effective fire-preparedness and response operations through applied research and incorporation of technology.

2. Relevant Terms

No terms used herein require additional definition.

3. Data Elements

There are no specific data elements related to this effort as the initial research proposals have not been concluded at this time.

4. Methodology

None currently, as this research partnership is in its beginning phase.

5. Timeline

Activities in 2021 included an open introductory seminar to engage stakeholders (e.g., private sector, utilities, government, regulatory bodies, academia), definition of areas of mutual research interest, discussion of initial research proposals, and planning for the in-person symposium in 2022 (postponed from 2021 due to COVID-19 restrictions).

As work progresses, we will continue to report on our advisory role to the FIRE Institute, PG&E-relevant research direction and initiatives, as well as PG&E WMP-relevant results from this research collaboration.

4.4.2 Research Findings

Report findings from ongoing and completed studies relevant to wildfire and PSPS mitigation. Organize findings reports under the following structure:

1. *Purpose of research – Brief summary of context and goals of research*

2. *Relevant terms – Definitions of relevant terms (e.g., defining "enhanced vegetation management" for research on EVM)*

3. *Data elements – Details of data elements used for analysis, including scope and granularity of data in time and location (i.e., date range, reporting frequency and spatial granularity for each data element, see example table above)*

4. *Methodology – Methodology for analysis, including list of analyses to perform; section must include statistical models, equations, etc. behind analyses*

5. *Timeline – Project timeline and reporting frequency to the Office of Energy Infrastructure Safety. Include any changes to timeline since last update*

6. *Results and discussion – Findings and discussion based on findings, highlighting new results and changes to conclusions since last update*

7. *Follow-up planned – Follow up research or action planned as a result of the research*

San Jose State University (SJSU) – Climatological Analysis

1. Purpose of Research

The purpose of the research is to better understand wildland fire behavior by studying fire-atmospheric interactions through partnership with the SJSU Fire Weather Research Lab. SJSU has established the largest academic Wildfire Interdisciplinary Research Center in the United States with five new tenure-track faculty members. SJSU will help PG&E analyze our 30-year 2 km × 2 km WRF model climatology to better understand the fire weather conditions associated with extreme wildfire and PSPS events. The analyses will be conducted by two tenure-track faculty, one post-doctoral scholar, and two graduate students.

2. Relevant Terms

No terms require additional definition.

3. Data Elements

TABLE PG&E-4.4-1:
DATA ELEMENTS
(SAN JOSE STATE UNIVERSITY – CLIMATOLOGICAL ANALYSIS)

Data Element	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Comments
PG&E 30-year downscaled climatology	1990-2020 (modeled)	Modeled hourly weather data	2km × 2km grid	Hourly Data through the climatology	
PG&E Fire Occurrence Dataset	2003-2020	N/A	N/A	N/A	Dataset of fire ignitions in PG&E territory gathered from multiple sources.

4. Methodology

a) Conduct analyses using PG&E's new 30-year climatology of 2 kilometer, hourly, WRF model output.

- This data shall allow for robust analyses on critical fire weather conditions using a combination of high spatiotemporal resolution and long duration data to investigate the following combined with fire occurrence datasets:
  - Climatology and decadal trends in fire weather and Diablo Wind events, or other Foehn wind events (type, intensity, duration, etc.);
  - A Diablo Wind metric shall be created and used to understand the climatology of events;
  - This metric shall be used to rank all Diablo Wind Events across the 30-year history based on strength, geographic extent, and duration; and
  - Using PG&E's proprietary and public fire occurrence datasets to evaluate numerous fire weather indices to help determine which index is best correlated to daily fire growth.

b) Generation of grid point distributions, percentile data maps from the climatology data.

- Map visualizations to be generated: 90th, 95th, 99th and Maximum (minimum) maps of:
  - Wind Speed;
  - Wind Gust;
  - Temperature;

- Relative humidity (minimum);
- Dewpoint depression (minimum);
- Precipitation; and
- Diablo Fire Weather Index.

- Grid point specific distributions shall be used by PG&E to put the forecast in perspective with the historical data.

c) Covariation of fire weather mesoscale circulation patterns with the synoptic patterns and known modes of climate variability.

d) High-resolution trends in existing fire-weather indices and local fire season duration to help determine annual average start and end time of fire season.

e) SJSU will interact regularly with the PG&E Meteorological staff and will provide regular online meetings on research progress.

f) SJSU shall conduct the proposed analyses and publish the results in peer-reviewed journals.

5. Timeline

The research project is ongoing. Timeline for preliminary results is scheduled for 2022.

6. Results and discussion

There are no results at this time, as the research is ongoing.

7. Follow-up planned

Any follow-up would be planned after review of the research results.

Review of Dynamically Downscaled Climate Projections for the Pacific Gas and Electric Service Area

1. Purpose of Research

Climate model projections can help quantify future impacts from climate change. However, some modeling approaches are limited in their ability to resolve the small spatial and time scales over which climate impacts occur. To address this, high spatial and temporal resolution dynamically downscaled WRF simulations were developed for the PG&E service area using boundary conditions from three Global Climate Models. These dynamically downscaled simulations resolved projected changes through mid-century for a suite of climate variables relevant to operational planning and risk-based decision-making, including extreme windspeeds, 925 hectopascal (hPa) winds, the frequency of diablo wind events, soil moisture, and the frequency of precipitation days.

2. Relevant Terms

- Hectopascal – The international unit for measuring atmospheric or barometric pressure.
- Relative Concentration Pathway (RCP) – A greenhouse gas concentration pathway adopted by the Intergovernmental Panel on Climate Change to describe different climate futures.

3. Data Elements

TABLE PG&E-4.4-2:
DATA ELEMENTS
(REVIEW OF DYNAMICALLY DOWNSCALED CLIMATE PROJECTIONS FOR THE PACIFIC GAS AND ELECTRIC SERVICE AREA)

Data Element	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Comments
Extreme windspeeds	1995-2004, 2045-2054	N/A	12km	10 years	
925 hPa winds					
Frequency and location of Diablo wind events					
Soil moisture					
Precipitation Days					

4. Methodology

To develop high space and time resolution dynamically downscaled climate model simulations for a suite of climate variables relevant to PG&E's operational planning and risk-based decision-making, Argonne used 12-km, dynamically downscaled WRF simulations (WRF, Model V3.3.1) to develop projections for several climate variables of interest. Projections focus on the ten-year period surrounding mid-century (i.e., 2045-2054) relative to a ten-year historical baseline period (i.e., 1995-2004), and consider RCP 8.5, which assumes global greenhouse gas concentrations continue to rise largely unabated throughout the 21st century. The projected climate variables include (1) extreme surface wind speeds; (2) 925 hPa wind directions; (3) frequency of Diablo wind events; (4) 500 hPa heights; (5) root zone soil moisture; and (6) annual precipitation days.

5. Timeline

The research was completed in 2021.

6. Results and discussion

Results show large variabilities for future environmental and atmospheric variables, implying high uncertainty regarding the specifics of future wildfire-relevant

conditions. As such it is difficult to reach overarching conclusions concerning projected changes in Diablo wind events and wildfire risk. We therefore currently do not recommend the results of this research be quantitatively incorporated into risk modeling or other planning efforts.

7. Follow-up planned

No direct follow-up is planned at this time given the lack of conclusive agreement between projections generated by the study models. PG&E may revisit this topic in coming years once the next generation of Coupled Model Intercomparison Projections data becomes widely available.

Electrical Assets Probabilistic Risk Assessment Model

1. Purpose of Research

PG&E has partnered with the B. John Garrick Institute for the Risk Sciences at the University of California Los Angeles (UCLA) to leverage the rigorous modeling used in the nuclear industry to perform thorough and complex wildfire risk assessments and management planning. At the Diablo Canyon Nuclear Power Plant, PG&E has used a probabilistic risk assessment model for over 30 years. The model is constantly updated with current plant design and state-of-the-art analysis methodologies, where data from 30 years of industry and plant specific experience is used to model component reliability and unavailability. The model can perform quantitative assessment of risks from a multitude of complex factors, including internal plant failures, seismic events, fire, and flooding. Each model element has been independently reviewed by industry peer review teams and the results have been audited on numerous occasions by the Nuclear Regulatory Commission, and the model is capable of quantitatively risk-ranking over 3,000 individual system components including the transmission lines that supply Diablo Canyon with offsite power. Using the know-how with this model used at the Diablo Canyon Nuclear Power Plant, PG&E is working with risk experts at UCLA to develop a similar model for wildfire risks for our electrical assets within HFTD areas. This risk model is in an exploratory phase at this point and could potentially in the future have value to each of the initiatives directed at reducing potential ignitions, reducing ignition consequence, reducing the frequency of outages, reducing the duration of outages, and reducing the impact of outages.

2. Relevant Terms

No terms require additional definition.

3. Data Elements

The Probabilistic Risk Assessment model is a decision framework that utilizes the Data Elements of the models described in Section 4.5.1.

4. Methodology

The model performs a quantitative assessment of risks from a multitude of complex factors related to wildfire risks for our electrical assets within HFTD areas and is based

upon the know-how developed for modeling risk factors at the Diablo Canyon Nuclear Power Plant.

5. Timeline

The draft Probabilistic Risk Assessment reference planning model was completed in 2021, and the model was compared to other risk models that were used for decision making during the 2021 fire season. In 2022 the model will continue to be tested and calibrated. As this is exploratory research it is too early to determine a precise timeline as testing and calibration is ongoing.

Wildfire Mitigation Open Innovation Challenge

1. Purpose of Research

PG&E initiated an "Open Innovation Challenge" to identify novel technologies that could potentially reduce PG&E-caused wildfire risk. The search for innovations was global in reach and went beyond the electric utility industry technology sector. PG&E aimed to identify one or more promising innovative technologies for use in a pilot project.

2. Relevant Terms

No terms require additional definition.

3. Data Elements

No specific data elements for analysis are available.

4. Methodology

The open innovation challenge process started with a definition of problem statements, instead of pre-supposing potential solutions. These problem statements were created following a series of interviews conducted with internal and external subject matter experts on areas where innovations could potentially provide the greatest ignition risk reduction. The set of problem statements described the problem areas that PG&E would like solved or improved upon, without specifying any technology or techniques to solve the problems. As a result of this process, PG&E narrowed our focus for this challenge to the following four areas:

A. Advancement of the state-of-the-art for "monitor & mitigate" technologies for real-time detection of faults and prevention of arcing, sparking, and other ignition events along transmission and distribution infrastructure;

B. Alternatives to current undergrounding methods, including level-grounding;

C. Reducing labor required for vegetation management; and

D. Innovative heat-resistant materials.

Using these problem statements, PG&E solicited innovators, entrepreneurs, and startups to request that they apply if they have solutions for the defined problems.

The solicitation was made through two methods: a research community network-driven effort and an automated computer programmed Internet search method. For the research community network-driven method, PG&E reached out through known innovation networks, academic research partners, and other technology knowledge experts. For the automated computer method, a programmed Internet search parsed technical journals, professional sites, startups sites, patent databases, and other publications across industries and disciplines to identify authors, institutes, and companies with relevant ideas or expertise. After compiling the potentially relevant resources, PG&E created a ranked list of the top innovators in each challenge area for further solicitation including for referrals and submission of an application to this challenge. The resulting proposals were then vetted, and finalists selected.

5. Timeline

In December 2020, PG&E announced this open innovation challenge, published the problem statements described in the Methodology section above, and set a submission deadline in early 2021. The solicitation and innovator communication phase followed, concluding with the ranking and final selection phase for each of the challenge areas. For the remaining two finalists, the process has been ongoing throughout 2021.

6. Results and discussion

Below is a description of the seven finalists, the first two of which PG&E continues to pursue for pilots:

a. Smart Conductor

PG&E continues to pursue a pilot with this finalist for both distribution and transmission applications and continues to perform due diligence inside of PG&E as well as to benchmark with other North American electric utilities. The reasons for the continued interest include the potential for: (a) a distribution system hardening speed improvement by avoiding a rebuild as may be required with conventional re-conductoring practices; and (b) the ability to monitor the condition of the conductor for incipient fault or failure conditions end-to-end via an embedded fiber optic core.

b. Pole-mounted Multi-Sensor for Predictive and Real-Time Failure Reporting

PG&E continues to pursue a pilot with this finalist for its novel ability to provide both predictive failure analysis as well as real-time reporting of various of pole and pole-adjacent equipment (crossarms, guys, transformers, capacitor banks, conductors, etc.) failures that can lead to ignition.

c. Aerial and Fixed-Sensor Based Asset Predictive Maintenance, Vegetation Grow-in, and Dynamic Line Rating System

Upon further evaluation, this finalist was eliminated due to significant overlap of the proposed set of capabilities with other PG&E initiatives.

d. 3D Printing of Level-Grounding or Underground Assets

Upon further evaluation, this finalist was eliminated due to the immaturity and capability gaps of the proposed technology set as well as the acknowledgment that solving other problems that hinder improvement of undergrounding speed and cost would be of greater benefit. However, PG&E continues to communicate with this startup and is supportive of this startup's innovation as it may apply to undergrounding initiatives.

e. Protection Sensitivity Enhancer for Four-Wire Distribution

After the original analysis, the use case was refined to focus on enabling increased sensitivity of existing protection equipment on four wire distribution systems in HFTDs. Following a series of discussions with the company and third-party electrical engineering consultants, it was determined that the technology, and the operational integration of it, was not on a path to being able to allow meaningfully higher levels of circuit protection on four-wire distribution systems using the scheme consistently throughout the distribution system.

f. Ultrafast Breaker

The primary reason that PG&E ended the evaluation of this early-stage technology was that reducing breaker time will reduce fault current energy but will not change the relay time (which is more significant than breaker time) so the effectiveness at lowering the ignition risk potential was limited after further consideration of the operational context.

g. Satellite-Based Vegetation Analytics

This finalist is not being pursued further at this time as PG&E is evaluating the efficacy of satellite-based vegetation analytics through a different vendor and initiative.

7. Follow-up planned

For the two remaining finalists, an update will be provided in this section in the 2023 WMP.

Targeted Tree Species Study

1. Purpose of Research

The purpose of PG&E's Targeted Tree Species Study is to identify species that are more likely to fail near PG&E facilities, thereby creating potential wildfire ignitions. PG&E will use the information obtained through the study to evaluate the performance of the species risk rating component of our Tree Assessment Tool (TAT). The study involves an analysis of tree mortality rates related to precipitation. PG&E will also use the information obtained through the study to evaluate our scheduling for patrol cycles as part of our vegetation management responsibilities.

2. Relevant Terms

- Species Risk – What a particular tree species (in isolation of everything else) tells you about the likelihood of the tree failing or the likelihood of its failure relative to its frequency in the population.
- Tree Assessment Tool or TAT – Tool that evaluates an individual tree's likelihood of failing and supplies instruction of whether to abate or not abate the tree.
- Patrol Cycle – The span of time between inspections.

3. Data Elements

TABLE PG&E-4.4-3:
DATA ELEMENTS
(TARGETED TREE SPECIES STUDY)

Data Element	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Comments
Ignitions from contact with vegetation	2008-2020+ (ongoing)	Per ignition	Circuit and/or Regional level	Date	
Outages from contact with vegetation	2008-2020+ (ongoing)	Per outage	Circuit and/or Regional level	Date	
Trees assessed by TAT	March 2020+ (ongoing)	Per tree basis	Lat/Long per tree	Date	
Routine tree records	2013-2020+ (ongoing)	Per tree basis	Lat/Long per tree (where available)	Date	
Windspeed data	2006-2008	Average of daily maximum		Date	
Evapotranspiration Data provided by Vendor	January 2007 – June 2021			Date	

4. Methodology

A. The vendor will identify the appropriate external data sources to study in conjunction with internal data provided by PG&E to develop and execute a targeted tree species study to quantify failure risk by species and region.

B. The vendor will study tree mortality rates in conjunction with precipitation levels to evaluate patrol cycles within our service territory.

C. The vendor will develop a working knowledge of the TAT and the species risk rating component currently in use.

D. The vendor will evaluate the species risk component of the TAT currently in use for effectiveness, using available external data sources and data provided by PG&E.

E. The vendor will evaluate the weighting of the risk component of the TAT using data provided by PG&E.

F. The vendor will help set up a system for continuous monitoring of TAT for ongoing evaluation.

5. Timeline

The research is planned to be complete in Q2 2022. PG&E plans to report on the status of this research in the next annual update.

6. Results and discussion

The vendor was onboarded in April 2021 and initial data acquisition was completed June 2021. Dataset summary statistics were delivered by the vendor in September 2021, with reports, quantifiable and environmental analyses, peer reviews, and a final analysis and report expected to complete in Q1 2022.

7. Follow-up planned

Any follow-up would be planned after review of the research results.

Independent, External Review of 2021 Proposed Modifications to PG&E's HFRA Map by the B. John Garrick Institute for Risk Sciences at UCLA (GIRSRT)

1. Purpose of Research

The GIRSRT provided an independent, external review of 2021 proposed modifications to PG&E's HFRA Map. The HFRA map makes incremental changes to the HFTD map by adding regions where the risk of utility triggered catastrophic wildfire from an offshore wind event is high and removing regions where it is not.

2. Relevant Terms

- High Fire Risk Area – Mapping terminology that aligns with other California utilities' use of maps supplemental to the HFTD Map. While the HFTD is a foundational tool to identify areas of elevated or extreme wildfire risk for utilities, it was not developed at the electric asset level and is not operationally informed for PSPS program scoping and execution. HFRA refinements may also serve to inform future adjustments or recommendations to improve the HFTD map.

- Aspect – The direction the slope faces (north, east, south, west). The aspect determines the effect of solar heating, air temperature, and moisture. In the Northern Hemisphere, south facing slopes receive more solar heating which results in lower humidity, rapid moisture loss, and lighter fuels such as grasses. Seasonal directions of solar heating should be taken into consideration when analyzing a slope's aspect.

- Slope – A ratio of rise over run. Another way to think of slope is height over distance expressed as a percentage. Slopes can range from slight to steep but the influence on wildland fire is substantial. The steeper the slope the faster a fire moves uphill. Flames are closer to the fuel source, radiation heat increases the dehydration and preheats the vegetation, resulting in ignition sooner than on a slight slope or level ground.

- Land Use – Evaluation of modification and maintenance activities to the natural wildland landscape. Land use can change probability of fire ignition and fire behavior.

- Fuel Loading – Fuel loading is reported in tons of fuel available per acre. The higher the fuel loading, the more heat that will be produced during a fire.

- Fuel Position – Fuel position is based on relation to the ground. It can be defined by three types of fuels: subsurface fuels, surface fuels, and aerial fuels.

- Fuel Continuity – The horizontal and vertical spacing of fuels. These are often referred to as continuous fuels or patchy fuels. The rate and direction of the fire is predictable with continuous fuels. Patchy fuels are difficult to calculate because the radiant heat may not be able to ignite the source.

3. Data Elements

TABLE PG&E-4.4-4:
DATA ELEMENTS
FOR EXTERNAL REVIEW OF THE PROPOSED 2021 HFRA MAP

Data Element	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Comments
Aerial imagery	Varied	Varied	Varied	Varied	Utilization of readily available and current satellite imagery from Google Earth and ESRI to inform land use, fuels, and terrain at variable scale to inform wildfire ignition risks and potential fire behavior.
Topographic map layers	Varied	Varied	Varied	N/A	Utilized to evaluate the slope of the terrain in and adjacent to areas of the HFRA to inform potential for fire spread.
Fire perimeter history	Annual Ongoing MTBS and GeoMAC	Ongoing	Varied	Varied	Utilization of fire perimeter data to evaluate fire frequency/regimes, fire spread patterns and effectiveness of historical suppression efforts.
Fire spread modeling	N/A	Varied	N/A	Varied	The use of computational fire spread modeling to inform or support recommendations based on qualitative local knowledge and other analysis.
Qualitative historical local knowledge	N/A	N/A	N/A	N/A	Experience-based inputs and recommendations from PG&E Public Safety Specialists with fire response and experience in specific regions of PG&E service territory.

TABLE PG&E 4.4-4:
DATA ELEMENTS
FOR EXTERNAL REVIEW OF THE PROPOSED 2021 HFRA MAP
(CONTINUED)

Data Element	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Comments
Field visits	N/A	N/A	N/A	N/A	As needed field verification for supplemental evaluation of actual current conditions.
Meteorology outputs	1989-2020 * modeled	N/A	2km x 2km grid	Hourly	Utilization of 30-year climatological re-analysis to inform anticipated exposures to electric assets and surrounding wildland fuels and terrain.
Historical outage datasets	2009-2017	On-going	N/A	N/A	Datasets of outages that occurred during offshore wind events were used to inform polygon creation and by highlighting areas that typically experience outages during offshore wind events.

4. Methodology

After internal draft development of proposed modifications to the HFRA Map, PG&E commissioned the GIRSRT to review the proposed modifications. During this review, the GIRSRT evaluated the criteria used to add or remove the areas to or from the HFTD Map. To supplement these criteria, the GIRSRT accessed additional data sets to enable complementary, objective assessments for land use, fuel load and slope. The GIRSRT also utilized fire history and perimeter data to check alignment of candidate regions with recent fires.

5. Timeline

GIRSRT's review of all 2021 proposed modifications to the HFRA map was completed by September 2021.

6. Results and Discussion

GIRSRT reviewed the proposed modifications to the HFRA Map, as well as the rationale used to make the case for each modification. GIRSRT agreed with PG&E's methodology and concurred with the majority of the proposed modifications. GIRSRT also recommended that some areas proposed for addition or removal be expanded or contracted based on their analysis.

7. Follow-up Planned

PG&E intends to continue utilizing GIRSRT for external review of additional proposed HFRA map modifications in 2022.

Lab Testing to Understand Ignition Behaviors Associated with Electric and Magnetic Field Induction

1. Purpose of Research

To understand potential ignition risks associated with deenergized power lines with induced voltages and currents, a thorough literature search was performed both internally and with the help of a third party, the Electric Power Research Institute, and no technical publications were found related to this scenario. To further explore this potential risk, lab testing was conducted to determine the fire ignition potential of induced voltages and currents at relatively low energy level associated with deenergized power lines in close proximity to other energized lines. Various scenarios were created in internal PG&E and external vendor labs to mimic the induction level currents and voltages and potential ignitions of a down conductor, with recognition of the varying factors in field conditions (i.e., ground resistivity).

2. Relevant Terms

No terms require additional definition.

3. Data Elements

TABLE PG&E-4.4-5:
DATA ELEMENTS
(LAB TESTING TO UNDERSTAND IGNITION BEHAVIORS ASSOCIATED WITH ELECTRIC AND MAGNETIC FIELD INDUCTION)

Data Element	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Comments
Lab Testing to understand Induction driven Ignition	2020	N/A	N/A	August-September 2020	Lab data collected via testing.

4. Methodology

Two types of current injection methodologies were used to perform the testing:

A. Current injection via a ground rod.

B. Current injection via a conductor resting on the surface of the ground.

Two types of fuel beds were used to represent flammable vegetation. The first type is a CAL FIRE specified fuel bed per page 23 of the California Power Line Fire Prevention Field Guide used to qualify electrical equipment devices for exemption from Public

Resource Code Section 4292. This fuel bed is an erosion control blanket consisting of 12 mm (1/2 inch) thick layer of agriculture straw material. Four layers of the blanket were laid over the 44″ × 44″ area of compacted topsoil. The required moisture of the fuel bed is less than 5 percent, and this was achieved by using an environmental chamber to dry the blanket for at least 48 hours prior to testing. The temperature of the environmental chamber was kept at approximately 100°F.

The second type of fuel bed consisted of sod purchased at the local hardware store and naturally dried outdoors for five days.

PG&E Internal Lab Test Circuit – For internal testing, energizing the ground rod/conductor using a high potential test unit with a max current output of 70mA, a current was injected through the fuel bed and soil to the ground plane, which created a ground potential rise and voltage gradient around the electrode.

External Lab's High Power Lab Test Circuit – For external testing, a high-power lab set was used, which was connected to BC Hydro's (British Columbia, Canada) largest substation via a 230kV transmission line. A stepdown transformer can provide voltages up to 44 kV. The lab capacitor bank had a selection of capacitors to adjust the current within the desired range of 0.1 – 5 A to match as closely as possible the large source impedance of the real system in an induced voltage scenario.

5. Timeline

The testing was conducted in August and September 2020.

6. Results and Discussion

Empirical data collected through a total of 150 tests provided us with better insight into ignition behaviors at low power levels, with different voltage and current combinations. However, the testing did not provide clear thresholds of ignition. The research found that the cases where the conductor was on the ground (representing a fallen conductor due to high wind or tree impact), the conditions of the ground and contact material were the most influential factors for ignition. We also witnessed reduced probability of ignition at lower voltage and current combinations, as well as increased ground impedance. Additionally, it was observed that current was less likely to be established and sustained in dry hay with lower voltages due to high impedance.

7. Follow-up Planned

Based on the findings from the testing, it was determined that grounding and sectionalizing the deenergized lines, where feasible, to reduce induced voltages and currents may be the best way to minimize ignition risk. PG&E is working on determining the feasibility and PSPS procedural impact of this requirement and establishing revised guidance.

4.5 Model and Metric Calculation Methodologies

4.5.1 Additional Models for Ignition Probability, Wildfire and PSPS Risk

Each utility is required to report details on the models and methodologies used to determine ignition probability, wildfire risk, and PSPS risk. This must include the following for each model—a list of all inputs, details of data elements used in the analysis, modeling assumptions and methodologies, input from Subject Matter Experts (SME), model verification and validation (e.g., equation(s), functions, algorithms or other validation studies), model uncertainty and accuracy, output (e.g., windspeed model) and applications of model in WMP (e.g., in selection of mitigations, decision-making).

The narrative for each model must be organized using the headings described below. A concise summary of the model(s) must be provided in the main body of the WMP in this section, with additional detail provided for each model in an appendix.

1. *Purpose of model – Brief summary of context and goals of model*

2. *Relevant terms – Definitions of relevant terms (e.g., defining "enhanced vegetation management" for a model on vegetation-related ignitions)*

3. *Data elements – Details of data elements used for analysis. Including at minimum the following:*

    a. *Scope and granularity (or, resolution) of data in time and location (i.e., date range, spatial granularity for each data element, see example table above).*

    b. *Explain the frequency of data updates.*

    c. *Sources of data. Explain in detail measurement approaches.*

    d. *Explain in detail approaches used to verify data quality.*

    e. *Characteristics of the data (field definitions/schema, uncertainties, acquisition frequency).*

    f. *Describe any processes used to modify the data (such as adjusting vegetative fuel models for wildfire spread based on prior history and vegetation growth).*

4. *Modeling assumptions and limitations – Details of each modeling assumption, its technical basis, and the resulting limitations of the model*

5. *Modeling methodology – Details of the modeling methodology. Including at minimum the following:*

    a. *Model equations and functions*

    b. *Any additional input from Subject Matter Experts (SME) input*

    c. *Any statistical analysis or additional algorithms used to obtain input*

    d. *Details on the automation process for automated models*

6. *Model uncertainty – Details of the uncertainty associated with the model. This must include uncertainty related to the fundamental formulation of the model as well as due to uncertainty in model input parameters*

7. *Model verification and validation – Details of the efforts undertaken to verify and validate the model performance. Including at minimum the following:*

    a. *Documentation describing the verification basis of the model, demonstrating that the software is correctly solving the equations described in the technical approach.*

    b. *Documentation describing the validation basis of the model, demonstrating the extent to which model predictions agree with real-world observations.*

8. *Modeling frequency – Details on how often the model is run (for example, quarterly to support risk planning versus daily to support on-going risk assessments).*

9. *Timeline for model development – Model initiation and development progress over time. If updated in last WMP, provide update to changes since prior report*

10. *Application and results – Explain where the model has been applied, how it has informed decisions, and any metrics or information on model accuracy and effectiveness collected in the prior year.*

11. *Key improvements from working group – For each model, describe changes which have been implemented as a result of wildfire risk modeling working group discussions. Provide a high-level summary of recommendations from the wildfire risk modeling working group.*[59]

[59] For purposes of brevity, in the description of each model below, we will use the title for each of the eleven items requested by Energy Safety, but will not include the full description of each item.

In this section, we are providing detailed information regarding our primary risk and operational models used for wildfire mitigation and situational awareness. We have tried to provide information for each of the 11 categories, and sub-categories, of information requested by Energy Safety. In some cases, we group the sub-categories into a response for a single category. We have tried to be as responsive as possible in providing the information requested by Energy Safety but are happy to provide additional information or detail regarding any of these models.

We are starting this section with Table PG&E-4.5.1-1 which lists the risk and operational models that will be discussed in this section. The models discussed in Section 4.5.1 can be thought of as "primary" models, meaning they may utilize information that was created from "component" models (also referred to as modules). The primary models are also included in Section 9.5, Table PG&E-9.5-1 which is our glossary of models. In addition, in Section 9.5, we are providing a list of component models or modules that provide information for our primary models. The component models are listed in Table PG&E-9.5-2.

Each primary risk and operational model has its own section within Section 4.5.1 and uses the headings (a) through (i). Because the component models feed into the primary models, they are not discussed in detail.

TABLE PG&E-4.5.1-1:
OVERVIEW OF PRIMARY PG&E RISK AND OPERATIONAL MODELS

4.5.1 Subsection	Model Name	Abbreviated Name	Brief Description	Use Case (Planning or Operational)
4.5.1(a)	2022 Enterprise Risk Model for Wildfire Risk	2022 ERM	Bow Tie-based wildfire risk model for distribution and transmission system	Planning
4.5.1(b)	2021 Wildfire Distribution Risk Model (Version 2)	2021 WDRM v2	Wildfire risk-based model for overhead (OH) Distribution system	Planning
4.5.1(b)	2022 Wildfire Distribution Risk Model (Version 3)	2022 WDRM v3	Wildfire risk-based model for OH Distribution system	Planning
4.5.1(c)	Wildfire Transmission Risk Model	WTRM	Wildfire risk-based model for OH Transmission system. This model is also known as the Transmission Composite Model (TCM)	Planning
4.5.1(d)	Wildfire Consequence Model	WFC Model	Wildland fire simulation model to estimate propagation and consequences of ignitions	Planning
4.5.1(e)	Enhanced Vegetation Management Tree Weighted Prioritization Model	EVM Tree Weighted Prioritization	Wildfire risk-based model incorporating tree density for OH Distribution circuit segments for the purpose of EVM scoping and prioritization	Planning
4.5.1(f)	Fire Potential Index Model	FPI Model	Provides estimates of the probability of large or catastrophic fire growth. Used to identify real-time and near-term forecasted risk due to various weather and fuel components.	Operational
4.5.1(g)	Ignition Probability Weather Model	IPW Model	Provides estimates of the probability of an ignition given an outage on an hourly basis.	Operational
4.5.1(h)	Transmission Operability Assessment Model	OA Model	Used to assess physical condition of Transmission facilities for operational and planning decisions	Operational/ Planning
4.5.1(i)	Public Safety Power Shutoff Consequence Model	PSPS Consequence Model	Projects the impacts and benefits of performing PSPS activities at the circuit or circuit segment level (formerly known as Circuit Protection Zones or CPZs)	Planning

4.5.1(a) 2022 Enterprise Risk Model for Wildfire Risk

The 2022 Enterprise Risk Model (2022 ERM) was developed for the Risk Assessment Mitigation Phase (RAMP) and General Rate Case (GRC) proceedings to evaluate enterprise risks that have potential safety consequences.[60] This model provides a consistent enterprise-wide risk assessment and modeling framework using PG&E's Multi Attribute Value Function (MAVF) in alignment with the Safety Model Assessment Proceeding (S-MAP) Settlement Agreement (S-MAP Settlement).[61] This model is used to calculate pre-mitigated (or baseline) risk scores and post-mitigation risk scores, to compare them across different risks in PG&E's Corporate Risk Register, and produce the Risk Spend Efficiency (RSE) scores at a program level for the WMP and GRC. The 2022 ERM enables the calculation of a risk score at the system level and can determine changes to the risk score based on planned mitigations. Enterprise risk modelling capabilities are focused on a "whole risk view" covering all risk drivers and consequences for the entire system (including transmission and distribution) and an evaluation of mitigations at the program level.

1. Purpose of model

The purpose of the 2022 ERM is to assess enterprise risks (including wildfire) using a common framework (i.e., Risk Bow Tie and MAVF) and to compare baseline and post-mitigation risk using the MAVF scoring approach in the S-MAP Settlement and ultimately to develop RSEs at a portfolio/program level.

2. Relevant terms

- Attribute – An observable aspect of an event that involves risk or reflects a utility objective such as safety or reliability. Changes in the levels of attributes are used to determine the consequences of a Risk Event. The attributes in an MAVF should cover the reasons that a utility should consider risk mitigation activities. PG&E uses safety, reliability, and financial as Attributes.

- Bow Tie (or Risk Bow Tie) – A tool that visually represents the Risk Event in the center, a listing of drivers on the left side that potentially lead to the Risk Event occurring, and a listing of Consequences on the right side that show the potential outcomes if the Risk Event occurs.

- Consequence of Risk Event (CoRE) – The weighted sum of scaled values of the consequence levels of the individual Attributes using PG&E's full MAVF.

- Likelihood of Risk Event (LoRE) – The probability that a given Risk Event will occur with respect to a single element (unit of exposure) of a specified Tranche over a year in the planning period. PG&E computes LoRE based on the Frequency divided by total exposure units in a Tranche.

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60 For a detailed description, see PG&E's Enterprise Risk Model Documentation and User Guide, available in 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.3_Atch01.pdf.

61 The S-MAP Settlement was approved in D.18-12-014.

- Mitigation – a measure or activity proposed or in process that is designed to reduce the impact/consequences and/or the likelihood/probability of a risk event.[62]

- Multi-Attribute Value Function (MAVF) – Risk calculation methodology introduced during CPUC's S-MAP and RAMP proceedings.

- Natural Unit – The way the level of an attribute is measured or expressed. For example, the natural unit of a financial attribute may be dollars.

- Outcomes – The final resolution or end result.

- Range (of the Natural Unit) – Part of the specification of an Attribute. For an Attribute with a numerical natural unit, such as dollars, the smallest observable value of the Attribute is the low end of the range and the largest observable value is the high end of the range. Therefore, any Attribute level that results as a consequence of an event, or a risk mitigation action, or of doing nothing should be found within the range.

- Risk Driver – A factor that could influence the likelihood of occurrence of a Risk Event. A driver may include external events or characteristics inherent to the asset or system.

- Risk Event – An event with probability of ignition, including wires down, contacts with objects, line slap, events with evidence of heat generation, and other events that cause sparking or have the potential to cause ignition.

- Scaled Unit – The scaled unit is set to 0 for the most desirable level of natural unit in the range of natural units. The scaled unit is set to 100 for the least desirable level of natural unit in the range of natural units. For any level of attribute between the most desirable and the least desirable levels, the scale unit is between 0 and 100. The benefit achieved by changing the level of an Attribute in natural units is measured by the corresponding difference in scaled units.

- Sub-Driver – A further, more detailed categorization of a Risk Driver.

- Technosylva – Vendor of fire simulation software whose outcomes are based on available fuels, topography, and weather; and structure and population data. Technosylva simulation outputs are used as the source of spatially resolved fire severity data that is the primary input into the spatial wildfire consequence calculations.

- Tranche – A logical disaggregation of a group of assets (physical or human) or systems into subgroups with like characteristics for purposes of risk assessment.

3. Data elements

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62 D.18-12-014, p.17 (See 2018 S-MAP Revised Lexicon, pp. 16-19).

a. Scope and granularity (or, resolution) of data in time and location (i.e., date range, spatial granularity for each data element, see example table above).

Table PG&E-4.5.1-2 provides the data elements for the 2022 ERM:

TABLE PG&E-4.5.1-2:
2022 ERM DATA ELEMENTS

Data Element	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Source
CPUC-reportable Ignitions	2015-2020	Per Ignition	Lat/long, where known	Date and Time of estimated ignition start	PG&E Internal
Outage data	2015-2020	Per Outage	Lat/long, where known	Date and Time of outage start	PG&E Internal
Large fires in PG&E's service territory	2015-2020	Annually, when reports become available	Lat/long, where known	Date and Time of estimated ignition start	CALFIRE website
PSPS damages and hazards	2019-2020	Per each PSPS event	Lat/long, where known	Date	PG&E Internal
2021 Wildfire Distribution Risk Model	N/A	N/A	Pixel/Circuit segment	One year	PG&E Internal
PG&E Overhead Asset Line miles	N/A	N/A	Generally Lat/long	N/A	PG&E Internal
Mitigation data	N/A	As needed	N/A	N/A	PG&E Internal

b. Explain the frequency of data updates.

While datasets described above in Table PG&E-4.5.1-2 are updated on their own update cycles, for the ERM Model we have been updating the datasets for the past complete year at the time of each model update.

c. Sources of data. Explain in detail measurement approaches.

Data associated with CPUC-reportable ignitions, outage, and PSPS damages and hazards are measured in a variety of ways, including automated data collection, field inspections that may precede or follow the event, and desktop review of event records.

d. Explain in detail approaches used to verify data quality.

- CPUC-reportable ignitions are verified through a process undertaken by our Electric Incident Investigation (EII) team.

- Outage data is verified and quality checked by dedicated teams. Reviews are aligned to documented guidance documents. Input from SMEs—such as asset management, vegetation, incident investigations—is used to update the guidance document.

- Large fires in PG&E's service territory are based on data is gathered from external sources.

- PSPS damage and hazard data is collected for each event via the Inspect App and then reviewed for accuracy by the Intelligence & Investigation team within PG&E's Emergency Operations Center (EOC).

- The verification of data quality for the 2021 WDRM v2 is described below in Section 4.5.1(b).

- Mitigation data representing the exposure, effectiveness, and benefit length of a mitigation is verified through a quality control process undertaken by SMEs who review the data and perform validations of it.

e. Characteristics of the data (field definitions/schema, uncertainties, acquisition frequency).

The characteristics of the event data for the elements listed above are historical records of events with supporting data fields such as date/time, location, drivers, sub-drivers, asset type, etc.

f. Describe any processes used to modify the data (such as adjusting vegetative fuel models for wildfire spread based on prior history and vegetation growth).

Ignition data from 2015-2020 was modified by adding estimated avoided ignitions from system hardening, enhanced vegetation management, and PSPS during 2019 to 2020, to derive 2021 baseline risk score from historical data. PG&E also adds any known fires that are not included in the CPUC-reportable ignition dataset due to investigation status.

Data from the Conductor and Vegetation modules were used to inform the Likelihood of Risk Event (LoRE) for each circuit segment by HFTD Tiers 2 and 3 for conductor-involved ignitions and vegetation driver. (Please see Section 4.5.1(b) below for more information on these risk modules). Adjustments were made to account for: (1) the overlap between the Conductor module and Vegetation module so that there is no double counting of vegetation-driver conductor-involved ignitions; (2) 2015-2020 ignition counts because the Conductor module and Vegetation module were calibrated using 2015-2018 ignition data; and (3) mitigation impacts from System Hardening and Enhanced Vegetation Management programs implemented in 2019 and 2020. Non-vegetation conductor involved ignition frequency and vegetation driver frequency were then further allocated to applicable drivers and sub-drivers using outage data. Note that likelihood of ignitions that are not vegetation driver and not conductor-involved are unavailable from the 2021 WDRM v2. Thus, LoRE values for drivers and sub-drivers associated with those ignitions were added by LoRE calculated at the circuit

and tier level (i.e., circuit split by HFTD Tiers) using 2015-2020 ignition data for the applicable drivers and sub-drivers.

The Wildfire Consequence Model of the 2021 WDRM v2 was used to inform CoRE values of circuit segment by HFTD Tiers. Specifically, the Wildfire Consequence Model provided the probability of Large Fire given an ignition and probability of Destructive Fire given an ignition based on the Technosylva simulation of 8-hour fire spread, aggregated to each circuit segment by HFTD Tiers. These probabilities were further calibrated based on probabilities of Large and Destructive Fires given an ignition in PG&E's HFTD, which were calculated using PG&E's 2015-2020 CPUC-reportable ignitions and CALFIRE large fire dataset in PG&E territory during 2015-2020.

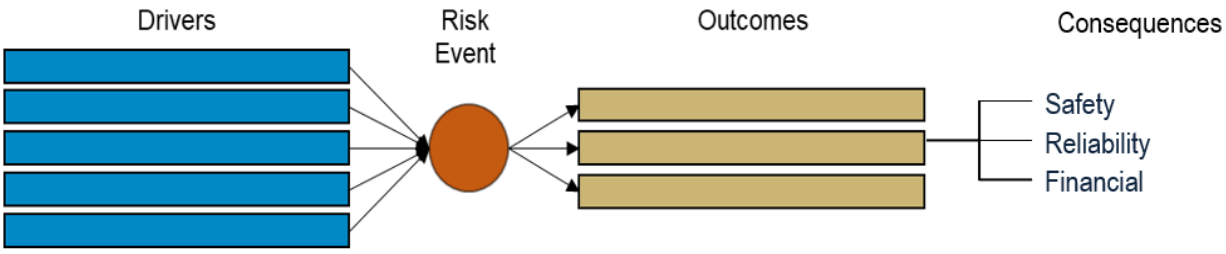
4. Modeling assumptions and limitations

The 2022 ERM follows the requirements set forth in the S-MAP Settlement, as described in more detail below in (5).

5. Modeling methodology

The 2022 ERM is built on a Bow Tie framework with the MAVF and Risk Score methodology required by S-MAP Settlement. The center of the Bow Tie represents a Risk Event, the left-hand side represents risk drivers, and the right-hand side represents risk outcomes. Outcomes are used to differentiate severity of consequences resulting from a risk event. This is illustrated in Figure PG&E-4.5.1-1.

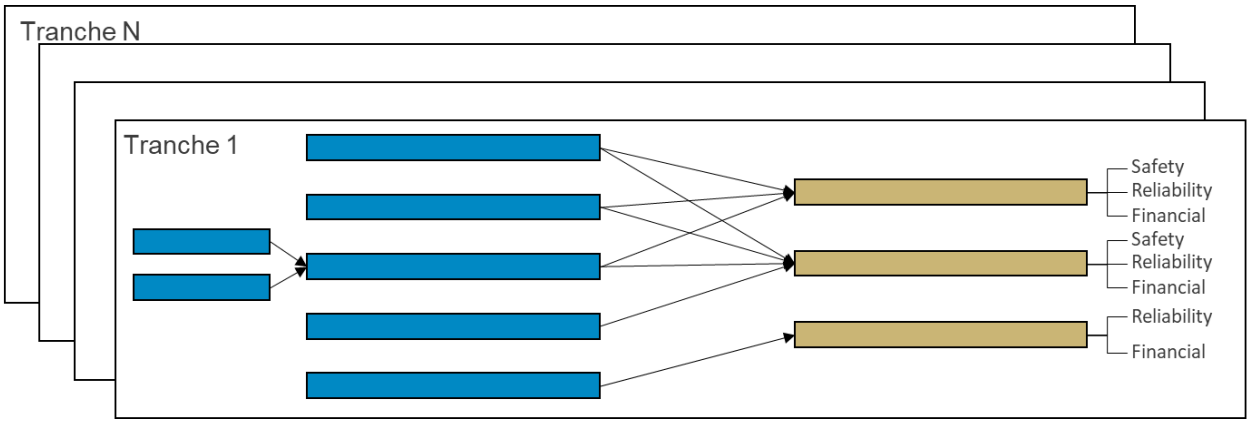
FIGURE PG&E-4.5.1-1:
CONCEPTUAL MODEL OF THE BOW TIE FRAMEWORK, WITH DRIVERS ON THE LEFT, THE RISK EVENT IN THE CENTER, OUTCOMES, AND CONSEQUENCES ON THE RIGHT



Note: The left-hand side of the Bow Tie is quantified using likelihood of a risk event for each driver; and the right-hand side of the Bow Tie is quantified using consequences of a risk event for each outcome.

The quantification is calculated at the Tranche level. A Tranche represents a logical disaggregation of a group of assets (physical or human) or systems into subgroups with similar risk profiles for the purpose of risk quantification. Thus, the final risk event Bow Tie is constructed from a series of tranche level Bow Ties that are ultimately combined and presented as a single Bow Tie. Figure PG&E-4.5.1-2 below shows the individual tranche level Bow Ties.

FIGURE PG&E-4.5.1-2:
ILLUSTRATION OF RELATIONSHIP BETWEEN DRIVERS (LEFT) AND OUTCOMES (RIGHT) WITH CONSEQUENCE ATTRIBUTES PER TRANCHE



Note: Even though Bow Tie graphics show an arrow from drivers (five blue boxes) to outcomes for visualization purposes, Bow Tie implemented in the Risk Model Input File and Enterprise Risk Model is more correctly represented by having arrows to come from sub-drivers (two blue boxes on the left) to outcomes directly without being aggregated into drivers.

Risk drivers, which can be further broken down into sub-drivers, are factors that contribute to the occurrence of a risk event. Sub-driver inputs represent the expected LoRE per unit of exposure. Sub-driver likelihood values (the probability of a risk outcome per unit of exposure per year from that sub-driver) are characterized at the Tranche × Sub-Driver × Outcome level.

The 2022 ERM Wildfire Risk Bow Tie has 65 tranches, 37 sub-drivers, and 10 outcomes, the number of likelihoods that are required by the Model as an input is 65 × 37 × 10 = 24,050.

The event frequency is the product of the exposure and expected annual likelihood of a risk event per unit exposure. The LoRE and event frequency are aggregated across sub-drivers, drivers, outcomes and/or tranches to show different levels of aggregated LoRE and event frequency.

Outcomes are characterized by statistical distributions of the potential levels of impact from a risk event across four different attributes, which are listed in Table PG&E-4.5.1-3 Consequences are sampled from their respective distributions for each set of tranche, outcome, and attribute and for each year of the analysis period.

TABLE PG&E-4.5.1-3:
CONSEQUENCE ATTRIBUTES AND THEIR NATURAL UNITS

Attribute	Natural Unit
Safety	Equivalent Fatality
Electric Reliability	Customer-Minutes Interrupted
Gas Reliability	Customers Affected
Financial	Dollars

a. Model equations and functions

Baseline Risk Score:

For each year *y* in the WMP period, the Baseline Risk Score can be expressed formulaically as:

$$R_{y,prbase} = \sum_{\tau \epsilon T} X_{y,\tau} \left(\sum_{o \epsilon O} \left(\underbrace{\sum_{d \epsilon D} \underbrace{\left(\sum_{\sigma \epsilon S_d} p_{y,\tau,d,\sigma}(d,\sigma) \times p_{y,\tau}(o|\sigma) \right)}_{p_{y,\tau,d}}}_{p_{y,\tau,o}} \right) \times C_{y,\tau}(\boldsymbol{c_a}|o) \right)$$

Where:

$T \equiv \{\tau$: Tranches per D.18-12-014. e.g. for Wildfire, there are 65 tranches$\}$
$D \equiv \{d$: $Known$ Risk Event drivers$\}$
$S_{d \epsilon D} \equiv \{\sigma$: Sub-drivers of Driver $d\}$
$O \equiv \{o$: Outcomes (e.g., Catastrophic, Destructive, etc.)$\}$
A $\equiv \{a$: Attributes - Safety, Electric Reliability, Gas Reliability, Financial$\}$
$X_{y,\tau}$: Exposure units (e.g. miles) in Tranche τ for year y
$p_{y,\tau,d,\sigma}(d,\sigma)$: $Year\ y$ probability of Risk Event due to driver d/sub-driver σ in Tranche τ
$p_{y,\tau,d}$: $Year\ y$ probability of Risk Event due to driver d in Tranche τ
$p_{y,\tau}(o|d)$: $Year\ y$ conditional probability in Tranche τ of Outcome o given driver d
$p_{y,\tau,o}$: $Year\ y$ probability of Outcome o in Tranche τ

Additionally, $C_{y,\tau}(\boldsymbol{c_a}|o)$above, the conditional Consequence of Risk Event (CoRE) for tranche τ, given Outcome *o*, is defined as

$$C_{y,\tau}(\boldsymbol{c_a}|o) \equiv 1000 \times \sum_{a \epsilon A} \omega_a \mathrm{E}_{y,a,\tau,o}[\mathrm{f}(\boldsymbol{c_a}/r_a)]$$

Where:

$\boldsymbol{c_a}$: A Random Variable for the levels for Attribute a, measured in natural units, pursuant to D.18-12-014
ω_a: Weight of Attribute a, pursuant to D.18-12-014
r_a: Range of Attribute a, pursant to D.18-12-014
$\mathrm{E}_{y,a,\tau}[.]$: Expected value under the probability distribution for Year y, Attribute a, Tranche τ,Outcome o
$f(.)$: PG&E Scaling Function, pursuant to D.18-12-014

Post-mitigation Risk Scores:

ERM also produces post-mitigation risk scores for each year in the horizon. The post-mitigation risk score is the level of risk assuming that a set of mitigation programs are implemented at specific levels with an assumed level of effectiveness in each tranche.

For each year in the horizon, the post-mitigation risk score is then calculated as follows:

$$R_{y,post} = \sum_{\tau \epsilon T} X_\tau \left(\sum_{o \epsilon O} \left(\sum_{d \epsilon D} \left(\sum_{\sigma \epsilon S_d} p'_{y,\tau,d,\sigma}(d,\sigma) \right) \times p_{y,\tau,o}(o|d) \right) \times C'_y(\boldsymbol{c_a}|o) \right)$$

Where:

$$p'_{y,\tau,d,\sigma}(d,\sigma) = p_{y,\tau,d,\sigma}(d,\sigma) \times \left[1 - \prod_{m \in M_\tau^L} \left(1 - \frac{X_{y,\tau,d,\sigma,m}}{X_{y,\tau}} \epsilon^L_{\tau,d,\sigma,m} \right) \right]$$

$$C'_y(\boldsymbol{c_a}|o) = 1000 \times \sum_{a \epsilon A} \omega_a \mathrm{E}_{y,a,o} \left[\mathrm{f} \left(\frac{\boldsymbol{c_a}}{r_a} \times \left[1 - \prod_{m \in M_o^C} \left(1 - \epsilon^C_{o,m} \right) \right] \right) \right]$$

And

$$M_\tau^L \equiv \{m\text{: Proposed mitigations that reduce probability/Likelihood for Tranche } \tau\}$$

$$M_o^C \equiv \{m\text{: Proposed mitigations that reduce Consequences of Outcome } o\}$$

$X_{y,\tau,d,\sigma,m}$: $Year\ y$ units (e.g. miles) in scope of mitigation *m*, for tranche τ, driver *d*, sub-driver σ
$\epsilon^L_{\tau,d,\sigma,m}$: Effectiveness (in %) of mitigation m that reduces likelihood/probability for tranche τ, driver *d*, sub-driver σ
$\epsilon^C_{o,m}$: Effectiveness (in %) of mitigation m that reduces consequences for tranche τ, outcome *o*

b. Any additional input from Subject Matter Experts (SME)

Consistent with the S-MAP Settlement, the 2022 ERM utilizes SMEs throughout the process. SMEs identify which data sets to use, provide the overall logic to use for calculating LoRE and CoRE, provide guidance on how to utilize tranches and scope risks, and review quantitative work to reduce potential errors in data and calculations. For example, SME inputs are used to determine the multipliers for CoRE and the probability of ignition developing into more severe fires for seismic scenarios. Also, SME input is used to in estimating the number of ignitions reduced from mitigations in 2019 and 2020 such as system hardening, EVM and PSPS, used to adjust historical ignition data to derive 2021 baseline frequency.

c. Any statistical analysis or additional algorithms used to obtain input

The 2022 ERM takes a probability distribution of a consequence in different attributes for each outcome severity (catastrophic, destructive, large and small) as an input. Calibration analysis using the fire dataset is done to find the reasonable probability distribution and its parameters.

d. Details on the automation process for automated models

Input preparation for the Bow Tie model is not automated but the 2022 ERM itself is automated using Python. Data is prepared manually, and inputs are prepared in combination of the Python code and manual calculation. Once input is prepared in the Risk Input File, which is standardized template for running 2022 ERM for any risk characterized using the Bow Tie framework, the Python code is executed to generate the output files that includes risk score and Bow Tie data.

6. Model uncertainty

There is uncertainty associated with the model formulation as well as model input parameters. Consistent with the S-MAP Settlement, the risk score formula is represented as the multiplication of the Frequency and CoRE. The Frequency is uncertain in nature but the S-MAP risk score formula uses the expected value of the frequency. The uncertainty in the frequency thus is not captured. In particular, the model estimates the baseline frequency for 2022 based on the historical event data from 2015-2020 adjusted for the estimated impact from major mitigations implemented in 2019 and 2020. There is variability and uncertainty around the external factors that impact risk event occurrence itself at different locations in PG&E's service territory and also around internal factors such as the impact of varying levels of mitigations in each year, and degradation of asset health.

The parameters for probability distribution used to represent the CoRE for each outcome severity are also uncertain. Probability distributions associated with financial consequence for a destructive fire and safety consequence for a catastrophic fire are calibrated using historical fires data in PG&E's service territory during 2015-2020 but the number of data points for such fires are limited, which leads to high uncertainty of distribution parameters.

Effectiveness percentages used to model mitigations are also subject to uncertainty, due to data variability, and/or use of SME judgement.

There is also uncertainty associated with the climate change multipliers which the 2022 ERM uses to adjust the probability distribution calibrated using historical fire consequence data to obtain the consequences of a risk event for future years. However, currently such uncertainty is not reflected and translated into the CoRE values.

7. Model verification and validation

a. Documentation describing the verification basis of the model, demonstrating that the software is correctly solving the equations described in the technical approach.

The risk score calculation performed using Python was implemented in Microsoft Excel to verify the results are the same between Excel implementation and Python calculation. The Excel implementation of the risk score calculation was shared with parties in PG&E's 2020 RAMP Report[63] and 2023 GRC proceeding[64] along with ERM User Guide and Documentation.

In certain cases, the ERM uses closed-form formulas for calculating the CoRE values, which involves taking expected value of Scaled Units, when consequences in the natural unit is represented by a probability distribution. PG&E verified closed form formulas by performing the equivalent calculation using the Monte Carlo Simulations.

The MAVF calculation function of the 2022 ERM is verified through unit tests.

b. Documentation describing the validation basis of the model, demonstrating the extent to which model predictions agree with real-world observations.

The 2022 ERM is used to calculate risk scores for baseline and post-mitigation scenarios. The model itself is not validated versus real-world observations.

8. Modeling frequency

Since 2019, the ERM has been updated annually to support WMP, RAMP and GRC submissions.

9. Timeline for model development

Since the 2021 WMP filing, the ERM has been updated to support the 2022 WMP and the 2023 GRC application.

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63 PG&E's 2020 Risk Assessment Mitigation Phase Report filed on June 30, 2020 in CPUC Application (A.) 20-06-012 (2020 RAMP Report).

64 PG&E's General Rate Case for rate years 2023-2026 filed at the CPUC in A.21-06-021 (2023 GRC).

10. Application and results

The 2022 ERM was used to compute the RSE values in the 2022 WMP and the 2023 GRC.[65] RSE is one, but not the only, factor that PG&E uses to assess projects and programs. In determining which projects to select, PG&E must consider factors such as risk reduction, cost, efficiencies, overall authorized GRC funding, the availability of PG&E and contractor resources, synergies with other work, and dependencies and requirements such as permitting and the different rules for working with California's counties and cities.

The model is also used to inform the trajectory of risk and components of the risk (such as contribution of each driver, sub-driver, outcome and tranche) to the risk.

11. Key improvements from working group

No specific recommendations have been provided from the Wildfire Risk Modeling Working Group to date for the ERM for Wildfire Risk.

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65 PG&E used the RSE Lite Tool, a model that uses outputs from the 2022 ERM to calculate RSEs. For a detailed description of the RSE Lite Tool, see PG&E's RSE Lite Tool Documentation and User Guide, available in 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.1_Atch01.pdf.

4.5.1(b) Wildfire Distribution Risk Model

This section addresses the Wildfire Distribution Risk Model or WDRM. Since the 2021 WMP, we have had two versions of this model. The 2021 Wildfire Distribution Risk Model (Version 2), also known as 2021 WDRM v2, was developed in 2020 and was used to inform work planning in 2021 and 2022. The 2021 WDRM v2 leveraged the Wildfire Risk Bow Tie and MAVF risk scoring methodology discussed in Section 4.5.1(a) above. The 2021 WDRM v2 is consistent with the application of wildfire risk being the product of the probability or likelihood of an ignition event multiplied by the consequence of the event. The 2021 WDRM v2 estimates wildfire risk values for circuit segments of the overhead distribution system in PG&E's HFTDs to provide insights into the locations with high wildfire risk by risk driver to inform the development of mitigation programs such as System Hardening and EVM. For a detailed description of the 2021 WDRM v2, please see our 2021 Revised WMP, starting on page 133, or see attachment 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.1_Atch02.

The 2022 Wildfire Distribution Risk Model (Version 3), also known as 2022 WDRM v3, was developed by PG&E as a natural evolution of the 2021 WDRM v2. It is used to quantify the wildfire risk posed by PG&E's overhead distribution facilities (also known as assets or equipment), which includes conductors, transformers, support structures (or poles, which includes related equipment such as cross arms and guy wires). The 2022 WDRM v3 quantifies risk for additional risk drivers over the 2021 WDRM v2.

The 2022 WDRM v3 provides predictions of the where, why, and how much wildfire risk occurs during a typical wildfire season (defined as June 1st through November 30th). The model differentiates risk by location and/or individual assets, providing information on where the likelihood of ignitions and the consequences of ignitions are elevated (and by how much), so that PG&E can prioritize higher-risk areas for applying potential mitigation efforts. Through modeled relationships between risk and a wide array of environmental (i.e., wind, temperature, fuels) and asset characteristics, it also helps PG&E understand the factors contributing to risk. Finally, the 2022 WDRM v3 estimates whether specific mitigations (i.e., EVM, System Hardening, pole replacement, and transformer replacement) may be most effective for which asset types in which locations by estimating the wildfire risk reduction achieved by performing a given mitigation at a given location or on a given asset.

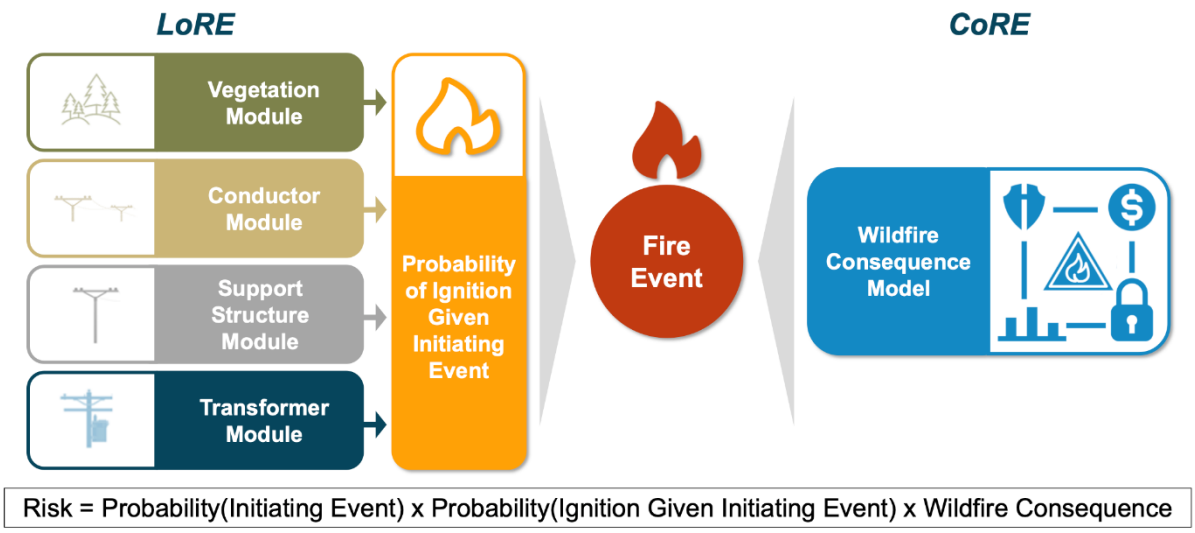
While there are temporal elements, like weather, within the 2022 WDRM v3, the predictions are defined as annual wildfire season-wide estimates of risk. The model does not determine when within the season (i.e., what month, day, or time) wildfires may occur in the future. The 2022 WDRM v3 is a "Planning" model whose outputs must be relevant over single to multi-year planning timeframes. To support planning work, the modeling time horizon is a single fire season. Other models, which are categorized as "Operational", such as PG&E's FPI and IPW Models, focus on informing day-to-day risk mitigation operations based on hourly weather forecasts, but only for a few days into the future.

The 2022 WDRM v3 introduces the composite model architecture. The output of the 2022 WDRM v3 is a spatial map with numerous layers—each characterizing risk from different causes and/or associated with different assets. These layers of risk, or modules, can be examined and compared individually, or they can be composited

together in various configurations to understand groups of risk, or total risk, from the overhead distribution system, at a particular location or for one or more asset types.

Figure PG&E-4.5.1-3 below summarizes the relationship of the 2022 WDRM v3 model to its risk modules.

FIGURE PG&E-4.5.1-3:
2022 WDRM V3 COMPOSITE MODEL ARCHITECTURE



Because the 2021 WDRM v2 was described in detail in our 2021 WMP, we will not repeat the same discussion here. In the remainder of this section, we address the 2022 WDRM v3.

Finally, it is important to note that in this 2022 WMP, the model that is used for the development of workplans for the distribution system is the 2021 WDRM v2 which is described above and in the 2021 WMP. As described in (9) below, the 2022 WDRM v3 is still being reviewed prior to approval. Since workplans for the 2022 WMP needed to be developed prior to the beginning of the year, the 2021 WDRM v2 was used to inform these workplans.

1. Purpose of model

The purpose of the 2022 WDRM v3 is to: (1) provide understanding of the potential wildfire risk associated with PG&E's electric distribution assets, (2) enable risk-informed decision making, and (3) give PG&E visibility into risk reductions from wildfire risk mitigation initiatives

The 2022 WDRM v3 is our primary wildfire risk model. Thus, an additional purpose of the model is to serve as the aggregation of various risk analysis, so the analysis is used consistently across all the various wildfire mitigation programs and projects on the electric distribution system.

2. Relevant terms[66]

- Area Under the Receiver Operating Characteristic (ROC AUC) – ROC AUC is a performance metric designed to test a model's ability to discriminate between cases that were correctly classified (true positive examples) versus non-cases (false positive examples) and is widely used to evaluate classification models.

- Consequence – The effect of the occurrence of a Risk Event. Consequences affect Attributes of an MAVF.

- Fire Behavior Index (FBI) – A scale of 1 to 5 that captures fire severity as a function of flame length (intensity of burn) and rate of spread. FBI of 3 or greater is expected to require aggressive suppression.

- Maximum Entropy (MaxEnt) – The name given to a family of algorithms that seek to differentiate between the characteristics of locations that have hosted grid events and those that have not.

- Mitigation – A measure or activity proposed or in process that is designed to reduce the impact/consequences and/or the likelihood/probability of a risk event.

3. Data elements

Because the 2022 WDRM v3 is a collection of multiple modules, each focused on a specific combination of cause and asset type, the response to each of the sections below may refer to the overall WDRM, or to elements within one or more of the modules.

a. Scope and granularity (or, resolution) of data in time and location (i.e., date range, spatial granularity for each data element, see example table above).

The 2022 WDRM v3 utilizes a large array of data, gathered from such sources as Asset Management, Outage Reports, Inspection Records, PG&E and public Meteorology, Vegetation Management, etc.

Table PG&E-4.5.1-4 below provides information regarding the relevant data sets used in the 2022 WDRM v3.

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66 For purposes of brevity, PG&E will not repeat definitions of relevant terms that were defined for earlier models in this section.

TABLE PG&E-4.5.1-4:
2022 WDRM V3 DATA SETS

Source	Provides	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Availability and URL
PG&E events - outages, ignition, PSPS, inspections, and other PG&E events	Event type, cause, equipment type, voltage, and other characteristics	2015-2021	Daily	Generally lat/long	Point-in-time events	PG&E internal
PG&E asset attributes	Asset types, locations, characteristics, for poles, conductors, transformers, etc.	2015-2021	NA	Generally lat/long	NA	PG&E internal
National Land Cover Database (NLCD) - produced by USGS	Land cover types, including vegetation and "impervious"	NA	NA	30m	NA	Public - https://developers.google.com/earth-engine/datasets/catalog/USGS_NLCD_RELEASES_2016_REL
GAP/LANDFIRE National Terrestrial Ecosystems data - produced by USGS	Detailed vegetation and land cover classification	2011	NA	30m	NA	Public - https://developers.google.com/earth-engine/datasets/catalog/USGS_GAP_CONUS_2011?hl=en
LANDFIRE surface fuels model - produced by USGS	"nonburnable" land cover	2016	NA	100m	NA	Public - https://www.nwcg.gov/publications/pms437/fuels/surface-fuel-model-descriptions
National Elevation Database (NED) - produced by USGS	Elevation, slope	NA	NA	100m	NA	Public - https://gee.stac.cloud/87CgnARxhwvgHXTnJH
High Fire Threat Districts - produced by CPUC	HFTD assignment	2018	NA	100m	NA	Public - https://www.cpuc.ca.gov/industries-and-topics/wildfires/fire-threat-maps-and-fire-safety-rulemaking
WorldPop	Population density	2010 and 2015	NA	100m	NA	Public - https://developers.google.com/earth-engine/datasets/catalog/WorldPop_GP_100m_pop
Salo Sciences	Satellite derived tree height, count, etc.	2019	NA	100m	NA	PG&E - licensed from Salo Sciences - https://salo.ai/
PG&E LiDAR Survey	LiDAR derived tree height, count, etc.	2019	NA	100m	NA	PG&E - Vegetation Management

TABLE PG&E-4.5.1-4:
2022 WDRM V3 DATA SETS
(CONTINUED)

Source	Provides	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Availability and URL
Fire Potential Index (FPI) - produced by PG&E Meteorology	Dead Fuel Moisture (DFM), wind speed and direction, temperature, precipitation, etc.	2020 and 2021	NA	2km	See documentation in Section 4.5.1(f)	PG&E - Meteorology - See documentation in Section 4.5.1(f)
gridMET - University of Idaho Gridded Surface Meteorological Database	Vapor Pressure Deficit, specific humidity, burn index, energy release component	2015-2019	NA	4km	Daily	Public - https://developers.google.com/earth-engine/datasets/catalog/IDAHO_EPSCOR_GRIDMET
Real-Time Mesoscale Analysis (RTMA) is a high-spatial and temporal resolution analysis for near-surface weather conditions, produced by NOAA/NWS	Wind gust data	2016-2018	NA	2.5km	Hourly	Public - https://developers.google.com/earth-engine/datasets/catalog/NOAA_NWS_RTMA
TreeMap	Prevailing tree species	2014	NA	30m	NA	Public - https://www.nature.com/articles/s41597-020-00782-x
California Wildlife Habitat Relationships (CWHR) –- California Department of Fish and Wildlife. California Interagency Wildlife Task Group. 2014. CWHR version 9.0	Habitat type/prevailing vegetation species or type	2014	NA	100m	NA	Public - https://wildlife.ca.gov/Data/CWHR
Gridded National Soil Survey Geographics Database (gNATSGO).	Local soil type/composition and characteristics	2019	NA	10m	NA	Public - https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcseprd1464625

b. Explain the frequency of data updates.

While the 2022 WDRM v3 will be formally updated once per year, the datasets described above in (3)(a) above each have different update cycles. For example, asset data is updated continuously, whereas a dataset like soils may be updated only once every decade. Leading up to the date when the final 2022 WDRM v3 is run, the data components used for the model are typically the most up-to-date elements available at that time.

c. Sources of data. Explain in detail measurement approaches.

Table PG&E-4.5.1-5 below identifies the measurement approach for data elements.

TABLE PG&E-4.5.1-5:
2022 WDRM V3 DATA SOURCES WITH MEASUREMENT APPROACH

ID	Source	Measurement
1	PG&E events - outages, ignition, PSPS, inspections, and other PG&E events	Events are measured in a variety of ways, including automated data collection, field inspections that may precede or follow the event, desktop review of event records, etc.
2	PG&E asset attributes	Asset attributes are measured in a variety of ways, including capture of attributes during asset installation or repair, transcription of paper to digital records, desktop review of records, LiDAR and other "bulk" survey methods, etc.
3	National Land Cover Database (NLCD) - produced by USGS	Measurement details can be found at the URL for this Source - see (3)(a) above
4	GAP/LANDFIRE National Terrestrial Ecosystems data - produced by USGS	Measurement details can be found at the URL for this Source - see (3)(a) above
5	LANDFIRE surface fuels model - produced by USGS	Measurement details can be found at the URL for this Source - see (3)(a) above
6	National Elevation Database (NED) - produced by USGS	Measurement details can be found at the URL for this Source - see (3)(a) above
7	High Fire Threat Districts - produced by CPUC	Measurement details can be found at the URL for this Source - see (3)(a) above
8	WorldPop	Measurement details can be found at the URL for this Source - see (3)(a) above
9	Salo Sciences	Measurement details can be found at the URL for this Source - see (3)(a) above
10	PG&E LiDAR Survey	A vendor to PG&E (SharperShape) collected LiDAR data via helicopters surveying assets and trees in primarily the HFTD portion of PG&E's service territory during 2019
11	Fire Potential Index (FPI) - produced by PG&E Meteorology	See documentation in Section 4.5.1(f)
12	gridMET - University of Idaho Gridded Surface Meteorological Dataset	Measurement details can be found at the URL for this Source - see (3)(a) above
13	Real-Time Mesoscale Analysis (RTMA) is a high-spatial and temporal resolution analysis for near-surface weather conditions, produced by NOAA/NWS	Measurement details can be found at the URL for this Source - see (3)(a) above
14	TreeMap	Measurement details can be found at the URL for this Source - see (3)(a) above
15	California Wildlife Habitat Relationships (CWHR) - California Department of Fish and Wildlife. California Interagency Wildlife Task Group. 2014. CWHR version 9.0	Measurement details can be found at the URL for this Source - see (3)(a) above
16	Gridded National Soil Survey Geographics Database (gNATSGO).	Measurement details can be found at the URL for this Source - see (3)(a) above

d. Explain in detail approaches used to verify data quality.

Table PG&E-4.5.1-6 below identifies the quality verification for data elements.

TABLE PG&E-4.5.1-6:
2022 WDRM V3 DATA QUALITY VERIFICATION

ID	Source	Data Quality Verification
1	PG&E events - outages, ignition, PSPS, inspections, and other PG&E events	PG&E's Risk and Data Analytics (RaDA) team performs extensive data cleansing and enhancement to improve the locations and characteristics of these events
2	PG&E asset attributes	RaDA team performs extensive data cleansing and enhancement to improve asset characteristics.
3	National Land Cover Database (NLCD) - produced by USGS	The data provider performs verification as this data is produced.
4	GAP/LANDFIRE National Terrestrial Ecosystems data - produced by USGS	The data provider performs verification as this data is produced.
5	LANDFIRE surface fuels model - produced by USGS	The data provider performs verification as this data is produced.
6	National Elevation Database (NED) - produced by USGS	The data provider performs verification as this data is produced.
7	High Fire Threat Districts - produced by CPUC	The data provider performs verification as this data is produced.
8	WorldPop	The data provider performs verification as this data is produced.
9	Salo Sciences	The data provider performs verification as this data is produced.
10	PG&E LiDAR Survey	The data provider performs verification as this data is produced.
11	Fire Potential Index (FPI) - produced by PG&E Meteorology	The data provider performs verification as this data is produced. See documentation in Section 4.5.1(f).
12	gridMET - University of Idaho Gridded Surface Meteorological Dataset	The data provider performs verification as this data is produced.
13	Real-Time Mesoscale Analysis (RTMA) is a high-spatial and temporal resolution analysis for near-surface weather conditions, produced by NOAA/NWS	The data provider performs verification as this data is produced.
14	TreeMap	The data provider performs verification as this data is produced.
15	California Wildlife Habitat Relationships (CWHR) - California Department of Fish and Wildlife. California Interagency Wildlife Task Group. 2014. CWHR version 9.0	The data provider performs verification as this data is produced.
16	Gridded National Soil Survey Geographics Database (gNATSGO).	The data provider performs verification as this data is produced.

e. Characteristics of the data (field definitions/schema, uncertainties, acquisition frequency).

Table PG&E-4.5.1-7 below identifies the characteristics of the data elements.:

TABLE PG&E-4.5.1-7:
2022 WDRM V3 DATA ELEMENTS AND CHARACTERISTICS

ID	Source	Field Definitions/Schema	Uncertainties	Acquisition Frequency
1	PG&E events - outages, ignition, PSPS, inspections, and other PG&E events	There are many fields in this dataset - the most relevant for WDRM include: location, time/date, event type (outage, ignition, etc.), cause, equipment involved	Much of this data is collected in the field by PG&E staff, which can lead to various uncertainties. Some of these events (especially ignitions) go through a desktop review process that can reduce uncertainty.	Preliminary data is typically available within minutes to days of the event occurring. Events that are reviewed and improved may take a few months to get updated.
2	PG&E asset attributes	There are many fields in this dataset - the most relevant for WDRM include: location, asset type, asset characteristics	Spatial uncertainties are present, but are being reduced by a long-term “conflation” project to update asset locations from LiDAR survey data. Asset attributes maybe be incorrect, and are sometimes absent.	Newly-installed assets are typically updated in PG&E's data systems within weeks to months. Various existing asset records may be updated by various data quality improvement projects at various times.
3	National Land Cover Database (NLCD) - produced by USGS	There are many fields in this dataset - those in use by WDRM include: impervious, rangeland components (e.g. shrubland, sagebrush, bare ground, etc.)	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.
4	GAP/LANDFIRE National Terrestrial Ecosystems data - produced by USGS	Single field with 584 numerical values, indicating different landcover descriptions	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.
5	LANDFIRE surface fuels model - produced by USGS	While this dataset may have many fields, only one is used in WDRM - the “unburnable” feature, which is a percentage of the 100m considered unburnable, because it is of land types not considered to have combustible fuel (agricultural land, snow and ice, water, and barren/rocky areas)	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.

TABLE PG&E 4.5.1 7:
2022 WDRM V3 DATA ELEMENTS AND CHARACTERISTICS
(CONTINUED)

ID	Source	Field Definitions/Schema	Uncertainties	Acquisition Frequency
6	National Elevation Database (NED) - produced by USGS	While this dataset may have many fields, only one is used in WDRM -elevation.	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.
7	High Fire Threat Districts - produced by CPUC	Single field with numerical values, indicating HFTD tier (1, 2, 3)	NA - this dataset is the canonical source of HFTD tier locations.	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.
8	WorldPop	Single field with numerical value - estimated number of people residing in each grid cell	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.
9	Salo Sciences	A few fields characterizing various tree attributes, such as height, coverage, etc.	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM. Future PG&E licensing of refreshed data may result in updates to this source for future WDRM versions.
10	PG&E LiDAR Survey	While this dataset has many fields, processing performed by Salo Sciences to merge this data with their data results in just a few fields characterizing various tree attributes, such as height, coverage, strike trees, etc.	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in v3 WDRM. Future PG&E LiDAR surveys may result in updates to this source for future WDRM versions.
11	Fire Potential Index (FPI) - produced by PG&E Meteorology	See documentation in Section 4.5.1(f)	See documentation in Section 4.5.1(f)	See documentation in Section 4.5.1(f)
12	gridMET - University of Idaho Gridded Surface Meteorological Dataset	While this dataset has many fields, only a few are used in WDRM: vapor pressure deficit, specific humidity, burn index, and energy release	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.
13	Real-Time Mesoscale Analysis (RTMA) is a high-spatial and temporal resolution analysis for near-surface weather conditions, produced by NOAA/NWS	While this dataset has many fields, only one is used in WDRM: wind gust speed.	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.

TABLE PG&E 4.5.1 7:
2022 WDRM V3 DATA ELEMENTS AND CHARACTERISTICS
(CONTINUED)

ID	Source	Field Definitions/Schema	Uncertainties	Acquisition Frequency
6	National Elevation Database (NED) - produced by USGS	While this dataset may have many fields, only one is used in WDRM -elevation.	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in both v2 and v3 of the WDRM.
14	TreeMap	While this dataset has many fields, only one is used in WDRM: a numerical descriptor of tree species	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in v3 WDRM.
15	California Wildlife Habitat Relationships (CWHR) - California Department of Fish and Wildlife. California Interagency Wildlife Task Group. 2014. CWHR version 9.0	While this dataset has many fields, only one is used in WDRM: a numerical descriptor of habitat type/prevailing vegetation species or type	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in v3 WDRM.
16	Gridded National Soil Survey Geographics Database (gNATSGO).	A few fields characterizing various soil attributes, such as thickness, drainage, slope, water content, flood frequency, etc.	Uncertainty details can be found at the URL for this Source - see (3)(a) above	None - this dataset was acquired once and utilized in v3 WDRM.

f. Describe any processes used to modify the data (such as adjusting vegetative fuel models for wildfire spread based on prior history and vegetation growth).

Of the data listed in the tables above, most are utilized in 2022 WDRM v3 without modification. The few elements that are modified are described below:

- PG&E Events
  - PG&E events often have more than one location field, and the locations of a given event do not always align with one another. A heuristic is applied to pick the most likely accurate location available for each PG&E event.
  - Prior to re-energizing the circuit/circuit segment after a PSPS event, PG&E performs inspections of the assets located in the de-energized areas. These inspections produce reports of locations where outages and ignitions might have occurred had the lines remained energized. In the 2022 WDRM v3, virtual outage and ignition indicators (the attributes used to model outages and ignitions) are assigned to PSPS events to account for the risks they would pose if the power were on. These are calibrated with weights that reflect the expected number of outages and ignitions that would have occurred had the PSPS events not occurred (PSPS inspections uncover more defects than the outages/ignitions observed under similar energized conditions historically).

- PG&E Asset Attributes
  - The following missing values are imputed for support structure attributes so that the machine learning model predicting likelihood of failure can make predictions for each modeled pole:
    - Missing “pole age” data is imputed using a decision tree regressor machine learning model that predicts a pole’s installation year given a set of pole attributes as model covariates.
    - Poles that can’t be linked to an open tag or notification are assumed to have zero open tags.
    - Missing “height” values are imputed using the median height given the pole’s class.
    - Missing “pole original circumference” values are imputed using the median circumference given the pole’s class and height.
    - Missing values for the “number of years since the last pole test and treat inspection” are replaced with the age of the pole (i.e. it is assumed that these poles have not been inspected since installation).
    - Missing “is private property” values are assumed to be False, or zero.
    - Missing “pole material values” are labeled as “unknown.”
    - Missing “pole original treatment type” values are labeled as “unknown.”
- Gridded National Soil Survey Geographics Database (gNATSGO).
  - Missing values (NA) in the fields utilized by the Support Structure module are imputed by choosing the median values for each field.
- WorldPop
  - Population Density values that are missing (NA) are replaced with zero.
- Salo Sciences and PG&E LiDAR Survey
  - Missing values (NA) are replaced with zero.

4. Modeling assumptions and limitations

Assumptions:

- It is assumed that events from June-November, the typical timing of fire seasons, are representative of all events capable of producing wildfire risk. If the training data for the WDRM were to include events caused by winter storms, icing, and other causal processes not compatible with ignition and wildfire spread, the pattern of model predictions would be influenced by events that contribute little or no

wildfire risk. To avoid exposing the model to misleading data, the training events are restricted to June through November. This does not require the assumption that no wildfires are possible in other months, but only that any ignitions and wildfires that do occur would have the same relationship with the model covariates as the ones the model is already trained on.

- The 2022 WDRM v3 is an "observational model" that uses the pattern of past outages and ignitions to predict their future. The core assumption of such an approach is that the correlations and causal processes that have governed past outages and ignitions will continue to govern them in the future.

- Machine learning tools, like feature generation, model regularization, and the preferential use of out of sample performance metrics, are well suited to the prediction of ignition probability and risk, which is the primary output required of the 2022 WDRM v3.

- Where there is limited or no empirical record of pursuing the proposed mitigations for wildfire risk mitigations are defined as characterized by their applicability to reducing ignitions from one or more subset of ignitions with an expected efficacy determined by SMEs.

Limitations:

- Systematic collection of non-CPUC-reportable ignitions was not in place prior to 2018.

- The 2022 WDRM v3 draws upon four separate sources of location data and applies a heuristic to find the best estimates of event locations, but its estimates must be robust to locational uncertainty. Please note that for Support Structure module and Transformer module, only the events that can be traced to specific assets have been used.

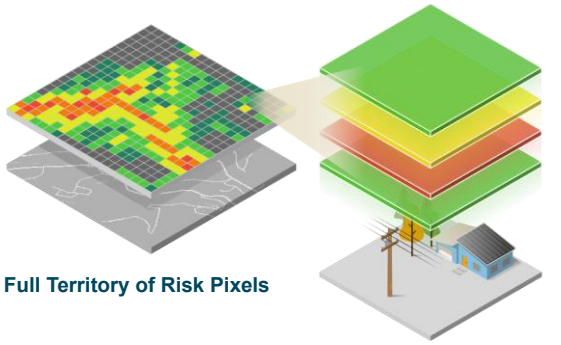
As described in the model development schedule in (9) below, the 2022 WDRM v3 does not make estimates for all risk drivers.

5. Modeling methodology

The 2022 WDRM v3 is a composite model, meaning the model includes numerous underlying risk modules, and the risk predictions of these modules may be composited together in various ways to serve various needs. Figure PG&E-4.5.1-4 below provides a graphic representation of composited modules.

FIGURE PG&E-4.5.1-4:
COMPOSITE MODEL ARCHITECTURE

The total risk (or probability) at a specific location (or specific asset) is the sum across each module in the composite.



Full Territory of Risk Pixels

Single Pixel with Four Modules to be Composited

	LoRE x CoRE = Risk		
	p(ignition)	Wildfire Consequence	Risk
Transformers	0.1%	17	0.017
Support Structures	0.5%		0.085
Primary Conductors	0.2%		0.034
Secondary Conductors	0.05%		0.0085
Composite (sum)	**0.85%**		**0.1445**

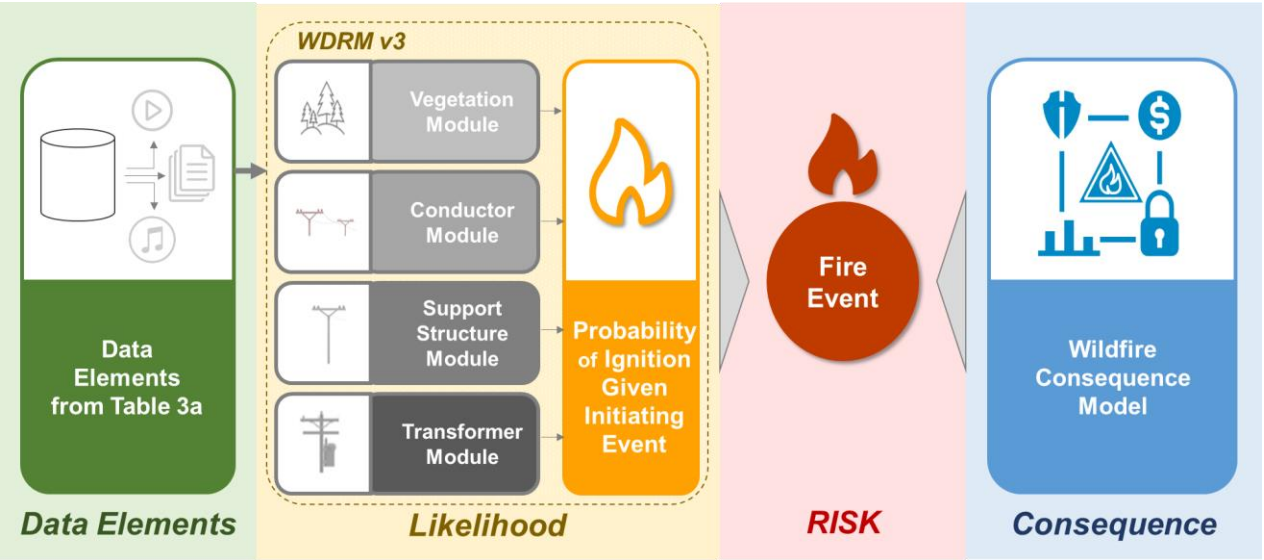
Compositing

The Composite model architecture allows identification of *specific* risk drivers, while also predicting *overall* risk

(Illustrative example only – 2022 WDRM v3 has slightly different modules and composites configuration)

Data elements (or datasets), such as environmental factors, meteorological factors, asset data, and other elements that could lead to an initiating event (outage), plus details of ignition events, and other failure and near-failure events, are inputs to the risk modules that are used by the 2022 WDRM v3.

FIGURE PG&E-4.5.1-5:
2022 WDRM V3 COMPOSITE MODEL ARCHITECTURE WITH DATA ELEMENTS



The output of the 2022 WDRM v3 are “pixel-based”, for evaluating risk scores within 100m x 100m grid cells across the PG&E service territory for the Vegetation and Conductor modules, and “asset-based” for the Support Structure and Transformer modules – risk scores are predicted per support structure and per transformer.

The 2022 WDRM v3 contains five risk modules that were developed for risk analysis. They are:

- Vegetation module, associated with vegetation in proximity to PG&E distribution assets;
- Conductor module, associated with six specific equipment types: primary and secondary conductor, primary and secondary interrupters, and primary and secondary other equipment (which includes all asset types other than conductors, interrupters, support structures, and transformers);
- Support Structure module, associated with support structures (e.g., poles, cross arms, guy wires);
- Transformer module, associated with overhead distribution transformers; and,
- Probability of Ignition Given Initiating Events module.

These five modules are aggregated to estimate the likelihood of a wildfire risk event (ignition) on the overhead distribution system for a grid location (pixel) or asset. This likelihood is then multiplied by Wildfire Consequence from the WFC Model to produce estimates of Wildfire Risk.

a. Model equations and functions

The key equation for the 2022 WDRM v3 is the risk equation defined as follows:

Wildfire Risk = Probability of Initiating Event x Probability of Ignition Given Initiation Event x Wildfire Consequence.

The following table lists the algorithm and method used for each risk module in the 2022 WDRM v3:

TABLE PG&E-4.5.1-8:
2022 WDRM V3 ALGORITHM/METHOD USED FOR RISK MODULES

Risk Analysis/Module	Algorithm/Method
Vegetation module	MaxEnt
Conductor module	MaxEnt
Support Structure module	Random Forest Classifier
Transformer module	Random Forest Classifier
Probability of Ignition (Given an Outage)	Logistic Regression
Wildfire Consequence Model	See Section 4.5.1(d)

Among the various algorithms in use in 2022 WDRM v3, the most prominent one is known as MaxEnt, which is short for “maximum entropy.” Below is a brief explanation of how MaxEnt is used along with assumptions and limitations.

For the spatially-explicit portions of the 2022 WDRM v3 (which are the probability (outage) portions of the Vegetation and Conductor modules), the objective is to identify which locale/site characteristics, patterns of weather and precipitation, and attributes of the grid assets, collectively termed the ‘model covariates’ are more correlated with outage locations than with random grid locations. For example, tall trees are more common among vegetation-caused outage locations than they are among typical distribution grid locations.

Metrics of dryness, HFTD tier assignments, conductor materials and size, and all the other data sources in these modules can all be checked for such patterns. The ratio of covariate value prevalence at outage locations to their prevalence across all grid locations is called the relative occurrence rate. MaxEnt provides a way of estimating the relative occurrence rate given a fairly modest number of outage locations. The way it does this is to fit a statistical distribution of covariate values for outage locations that is consistent with the values at known outage locations, but otherwise as similar as possible to the distribution of values found everywhere else along the distribution grid.

The similarity criteria described above is enforced using a metric called the relative information entropy between the outage locations and the Distribution grid locations, where the larger that metric is, the more similar the two distributions are. For this reason, the overall approach is referred to as a maximum entropy or MaxEnt estimation of the relative occurrence rate.

When multiplied by the fraction of all grid locations that experience fire-season outages annually, the relative occurrence rate is normalized into a distribution that provides the annual fire-season probability an outage will occur for all combinations of values of the covariates. This distribution can be used to or predict annual outage probabilities based on the covariate values found at each Distribution grid location.

b. Any additional input from Subject Matter Experts (SME) input

SMEs provided expertise on the types of inputs to be included for each risk module. Within the SME-identified inputs, and for some others recommended by data scientists, SMEs provided guidance as to the meaning of various codes, abbreviations, and terminology. SMEs shared knowledge with the data science team on various characteristics of the data that were helpful in preparing data sources for use in the modules.

After the initial running of the model, the SMEs were presented with draft model output. SMEs were asked to observe the output of the model, and comment on how the model predictions of wildfire risk aligned with their expertise. When SMEs provided feedback that WDRM predictions do not align with their expert opinions, WDRM team Analysts and Data Scientists examine the model predictions and related model input data—and findings are used to improve current and/or future versions of WDRM.

Estimates of mitigation effectiveness were provided by SMEs – these estimates were either used directly to calculate post-mitigation risk predictions (for Vegetation,

Conductor, and Transformer modules), or were used to inform empirical estimation of mitigation effectiveness (for Support Structure module).

c. Any statistical analysis or additional algorithms used to obtain input

Many of the data inputs used in the 2022 WDRM v3 are the output of precursor models. In some cases, the models are used to process and summarize remote-sensed data (e.g. land cover). In other cases, the models are used to process and summarize multiple and diverse data inputs into a singular output (e.g. population density).

An analysis of records of pole assets and support structure-related failures was performed to provide empirical estimates of the effectiveness, in terms of the reduction of probability (failure), and thus the reduction in wildfire risk, from pole replacement. These estimates were used to calculate post-mitigation risk values for the Support Structure module.

d. Details on the automation process for reproducibility of models

The 2022 WDRM v3 is highly automated using the Python computer language. When the model is run on an annual basis, it automatically grabs all datasets to be used, and locks them down. The model then continues with its automation to perform the step-by-step process of the modeling routines. When the model is finished running, it has a post-action state that can be audited to view each developed variable (such as covariates).

6. Model uncertainty

There is uncertainty in the location of events, especially outages and ignitions (due to different causes). The 2022 WDRM v3 has selected model methods (i.e. the maximum entropy model form) that are robust to location uncertainties, primarily because raster data is available at scales with values that are already assigned with appropriate resolutions and spatially correlated, but also because the expected error in locations is random in direction and thus a bias in the results is unlikely.

There is uncertainty in the numerical and categorical values of all 2022 WDRM v3 inputs, for reasons including:

- Uncertainty in the instrumentation that captured the data;
- Human fallibility in implementing and utilizing systems to record the data (i.e., cause options that are not available in the data collection interface, or incorrect options selected at time of data collection); and
- Lack of detail in the data structures used to capture the data (i.e., while it is ideal that only one outage should be associated with each ignition, there are sometimes multiple outages related to a single ignition event).

The goal of classification is to accurately separate events (ignitions, outages) from non-events by discovering or knowing the relationship between the event and the covariates. If the model is correctly specified and the variables accurately measured, then the remaining uncertainty is fundamental or irreducible uncertainty that cannot be

known. PG&E's strategy is to use a model structure that is flexible enough to take the shape of an unknown, true model. Both maximum entropy and the random forest classifier are very flexible. By taking an approach that includes covariates and using cross-validation to control for overfitting, the 2022 WDRM v3 structure seeks to minimize the fundamental uncertainty around the prediction of outage and ignition.

All models are subject to biases/variance errors that occur from incorrectly labeled events or inaccurately measured covariates. In WDRM, maximum entropy models the event data, and all spatial covariates are rasterized to 100m-scale resolutions. This down-resolution of the location data from latitude and longitude (lat-lon) to sub-kilometer scale grid location effectively eliminates problems introduced from small (< 100m) errors in measured location.

The potential for a non-event (normal operation) to be mislabeled as an event (ignition or outage) is very low. Similarly, events mislabeled as non-events are also unlikely, though more likely in the case of non-CPUC-reportable ignitions prior to 2018. However, this type of error will likely not bias results because, by definition, none of these ignitions caused significant damage.

Likewise, covariates come from many sources and are expected to contain error but systematic bias in that error is rejected by PG&E based on qualitative assessment of each source.

In addition to the bias assessment, a sensitivity analysis for each covariate is conducted in the form of 'knife importance' or 'permutation importance' metrics. These values quantify the impact of leaving a variable entirely out of the module (jackknifing) or the effect of permuting (scrambling) the data for that variable. While there are significant non-linearities in the model structure, these metrics capture the relative importance of error in a covariate propagating through the model: the variables with the largest importance likely have the largest impact on overall uncertainty when they are mismeasured.

7. Model verification and validation

a. Documentation describing the verification basis of the model, demonstrating that the software is correctly solving the equations described in the technical approach.

In early 2021, a detailed review of 2021 WDRM v2 was performed by Energy and Environmental Economics, Inc. (E3), an industry-leading source of expert guidance and technical analysis. That review produced numerous recommendations that influenced the development priorities for the 2022 WDRM v3.

In late 2021, E3 commenced another detailed review, this time of the 2022 WDRM v3. This review is considering all aspects of the 2022 WDRM v3 as well as the WFC Model, and some aspects of the larger risk and mitigation frameworks for which 2022 WDRM v3 is used. E3 is reviewing the technical approaches in use in WDRM, and the resulting model performance metrics. As of the state of the 2022 WMP submission, E3's review of 2022 WDRM v3 and WFC Model has not been completed. However, preliminary results are positive, and E3's assessment confirms that 2022 WDRM v3 is a substantial improvement over 2021 WDRM v2. E3's review process includes:

- Reviewing all relevant data, applications and documentation of results and approach as well as any internal efforts at validation and testing;

- Taking a critical look at the wildfire consequence data produced and how it is being incorporated into WDRM; and

- Building the 2022 WDRM v3 evaluation report in reference to and incremental to E3's review of 2021 WDRM v2.

The project is co-managed by E3's founding and managing partners who have prior experience working directly for PG&E with wildfire consequence data and the risks associated with climate change. They are assisted by a team of experts from E3 with backgrounds in the areas of risk modelling, grid planning, and short-term forecasting and machine learning.

b. Documentation describing the validation basis of the model, demonstrating the extent to which model predictions agree with real-world observations.

The 2022 WDRM v3 estimates of outage probabilities were validated statistically by reviewing results for past outage events. Spatial (MaxEnt) model results (Vegetation and Conductor modules) were tested using a train-test split ratio of 80 percent-20 percent and asset (Random Forest) model results (Transformer Outage, and Support Structure modules) were tested using a train-test ratio of 75 percent-25 percent. In all cases, this means that 20-25 percent of event data was withheld from the model training step and instead used to test the accuracy of model predictions against data it had never observed. This produces "out of sample" performance metrics that are indicative of how well a model will predict rather than how well it explains the data it was trained on.

The primary performance metric utilized was the Area Under the Receiver Operating Characteristic (ROC AUC – typically referred to simply as AUC), which is widely used to evaluate classification models. AUC is a performance metric designed to test the model's ability to discriminate between cases that were correctly classified (positive examples) and versus non-cases (negative examples).

Generally, an AUC score of 1 is a perfect model, while scores near and above 0.70 are considered to have good performance. AUC scores above 0.8 are considered to have excellent performance. A model with no skill has an AUC of less than 0.5.

Outage probability modules yielded AUC scores mainly ranging from 0.7-0.8. At the low end, the Transformer module, at the time of this writing, has an AUC score of ~0.55. At the high end, three modules predicting vegetation caused outages have AUCs in the 0.85 – 0.87 range.

A similar approach (withholding 20 percent of the data at random for testing) was taken to assessing the performance of the "probability of ignition given outage" module, yielding an out-of-sample AUC score of 0.77.

When outage probabilities are converted to the ignition probabilities necessary for computing wildfire risk (by utilizing the aforementioned "probability of ignition given

outage" model), AUC scores typically decrease slightly – most are in the 0.68 – 0.78 range, with the transformer module having the lowest AUC of 0.60, and the Vegetation Module having the highest AUC of 0.84.

When all module probability(ignition) predictions are composited together to produce a 2022 WDRM v3-wide prediction of probability(ignition), the AUC score is 0.73.

8. Modeling frequency

PG&E currently intends to update the WDRM on an annual basis. The 2022 WDRM v3 is a planning model, and therefore is used for longer term initiatives, such as System Hardening. These types of initiatives are typically budgeted at an annual rate, so the model's update frequency coincides with that.

9. Timeline for model development

Figure PG&E-4.5.1-6 below provides an overview of the 2022 WDRM v3 development schedule and Figure PG&E-4.5.1-7 provides a more detailed development schedule including model components.

FIGURE PG&E-4.5.1-6:
2022 WDRM V3 DEVELOPMENT SCHEDULE

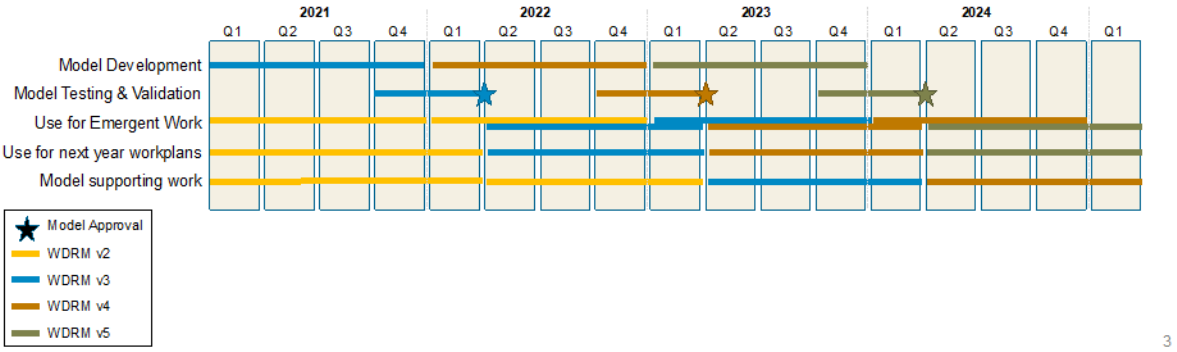
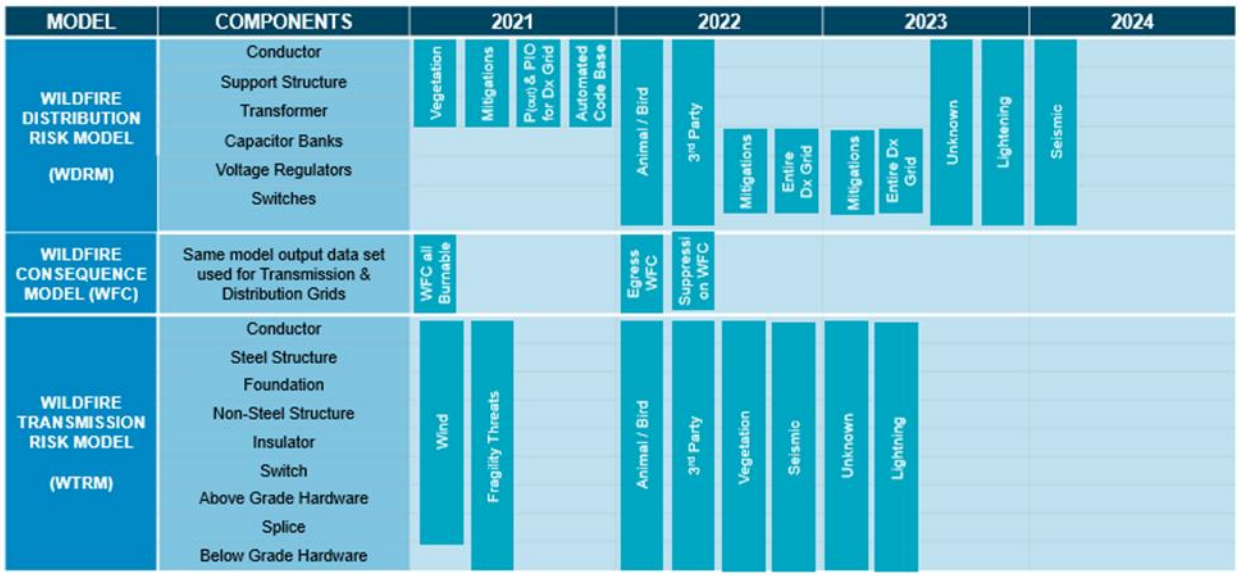


FIGURE PG&E-4.5.1-7:
WDRM RISK DRIVER DEVELOPMENT SCHEDULE



PG&E is currently reviewing the 2022 WDRM v3 for approval. The 2022 WDRM v3 review is scheduled to be completed and declared "final" by PG&E's Wildfire Governance Steering Committee in Q1 2022. The 2022 WDRM v3 will be used for the 2023 WMP. However, due to many notable improvements from 2021 WDRM v2 to the 2022 WDRM v3, PG&E has chosen to discuss the 2022 WDRM v3 in the 2022 WMP to describe these improvements. Importantly, the risk model used for the 2022 WMP workplan is the current 2021 WDRM v2.

The development of the 2022 WDRM v3 was the result of feedback from interested parties and through a review process by an independent third party (described in (7) above) which provided recommendations. Key improvements from the 2021 WDRM v2 to the 2022 WDRM v3 are more advanced machine learning techniques, incorporating newly available data, adding predictions of wildfire risk reduction when mitigating various sources of risk, and expansion of understanding of ignition sources and drivers.

10. Application and results

The 2022 WDRM v3 has not been applied in any capacity at this time. It will be applied to several initiatives after the internal process of review has been achieved and the model receives approval to replace 2021 WDRM v2. Once approved, the 2022 WDRM v3 will be used to develop 2023 workplans.

11. Key improvements from working group

The working group has not yet provided any recommendations that are directly related to the 2022 WDRM v3.

4.5.1(c) Wildfire Transmission Risk Model

The Wildfire Transmission Risk Model (WTRM) was developed by PG&E to quantify the wildfire risk related to PG&E's overhead transmission equipment. Like the 2022 WDRM v3, the goal of the WTRM is to assess risk based on the probability of an asset failure leading to an ignition occurring, and the consequence of a wildfire if it were to occur. The WTRM implements many of the same concepts as the 2022 WDRM v3, for example, by considering the situations in which wildfires could occur given the location and condition of assets. As will be discussed in more detail below, considerations for wind, vegetation, third-party damage, and contact from animals (including birds) are all considered to estimate the likelihood of an asset failure that could lead to an ignition. Like the 2022 WDRM v3, the consequence of a wildfire is estimated through the WFC Model.

The WTRM is a composite model. The probability of failure for a particular component is estimated based on a compositing of risk drivers (threats and hazards) that are specific to that component, herein referred to as a "module." Results for these modules are then combined with a consequence value to compute a risk value. These modules are supported through a combination of numerical analyses and quantitative modeling. The probability of ignition portion of this model has previously been referred to as the Transmission Composite Model (TCM).

1. Purpose of Model

The WTRM quantifies asset risk to enable prioritization of projects based on a common, interchangeable metric. It is analogous in purpose to the 2022 WDRM v3 except that the WTRM is for the Transmission system. To date, the output from the WTRM has been used to plan discretionary inspection work. Future plans include using results from the model to inform enhanced inspection and maintenance prioritization for the next year once the model has reached a stable state of maturity.

2. Relevant terms

- Failure Mode and Effects Analysis (FMEA) – A step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service.
- Fragility Curve – Represents the probability of failure for any value of a demand parameter.
- Hazard – Event that causes the ultimate failure of an asset (i.e., wind, ice, seismic, landslide, vandalism, vehicle impact, etc.).
- Threat – Degradation mechanism that weakens an asset and decreases the magnitude of a hazard needed to cause ultimate failure (i.e., corrosion, wear, contamination, erosion, etc.).

3. Data elements

Because the WTRM is a composite model of various analyses (or modules), the response to each of the sections below may refer to the overall model, or to elements within risk modules.

a. Scope and granularity (or, resolution) of data in time and location (i.e., date range, spatial granularity for each data element, see example table above).

The datasets curated for and used by the WTRM are grouped as follows:

- Asset-specific data – This includes, but is not limited to, asset type, unique identifier, material type, and location (latitude and longitude). Examples of asset type include a steel lattice tower, ceramic insulator, or aluminum conductor steel reinforced (ACSR) conductor. The unique identifier is typically the equipment number, although other asset-specific identifiers are used. Material type includes steel, wood, concrete, ceramic, and polymer, depending on the type of asset being modeled. This asset registry data is updated daily and is available at the asset-specific location (latitude and longitude).

- Environmental data – This includes, but is not limited to, the corrosivity of the environment (atmospheric and soil, for example), site-specific hazards (such as wind speeds, seismic accelerations, and landslide potential), and proximity to water. This data is updated annually and is available at various resolutions from 3 km x 3 km to 2 km x 2 km and point-specific (latitude and longitude), depending on the dataset.

- Condition data – This includes inspection data, such as enhanced visual inspection data (for example, from ground, drone, climbing, and aerial inspections), material-specific inspection data (for example, the Osmose Pole Test and Treat inspection program), and capacity computations. This data is refreshed on a daily basis and is available at the asset-specific location (latitude and longitude). While the datasets are refreshed daily, the inspection data is collected on different cadences that can be monthly, annually, or longer.

- Maintenance/repair/modification data – This includes records of any repair, maintenance, or modification work that would influence the WTRM's forecast of the annual failure rate (or annual probability of failure) for the asset under evaluation. This data is refreshed on a daily basis and is available at the asset-specific location (latitude and longitude).

- Prior incident data – This includes the history of unplanned events, such as wind-driven outages and third-party damage. This data is typically refreshed annually and is available at either the asset-specific (latitude and longitude), 3 km x 3 km or 2 km by 2 km grid size, or at the circuit-level.

b. Explain the frequency of data updates.

Input data for the WTRM is refreshed on a daily basis, with the exception of datasets that have longer refresh cadences, for example, outage data. The model itself is refreshed on-demand and, at a minimum, on an annual basis.

c. Sources of data. Explain in detail measurement approaches.

The sources of data for the WTRM include:

- Asset-specific data – Systems of record include Electric Transmission Geographic Information System (ETGIS), Transmission Support Structure (TSS), the Asset Feature List (AFL) dataset, and third-party vendor sites. Attributes collected include age, location, structure type, and voltage class. The data curation process measures and tracks the number of structures missing a particular attribute and whether or not a conservative assumption had to be made to populate the value.

- Environmental data – Systems of record include Land Base Geographic Information System (LBGIS) and the United States Department of Agriculture. Attributes collected include corrosion (atmospheric and soil) potential, wear likelihood, and the expected frequency of site-specific hazards such as wind. Measurements on the curated data include the number of assets for which environmental attributes are unable to be located. Efforts are then made to resolve these issues so that a fully representative dataset is available for the model.

- Condition data – Systems of record include Sherlock (for enhanced visual inspection data), and third-party vendor sites (for example, for the Osmose Pole Test and Treat data). Attributes collected include the current condition and post-repair conditions. Measurements on this data include matching maintenance and repair data with condition scores so that assets that have been repaired or replaced have their condition score updated to reflect the latest site condition.

- Maintenance/repair/modification data – SAP is the system of record for this data. Attributes collected include notification records alerting the model to maintenance such as a repair or replacement to an asset. These notifications are used to update the WTRM's interpretation of the asset's condition.

- Prior incident data – Systems of record include the historical outages spreadsheet, climatological dataset, and SAP. Attributes collected include the incident location and its classification. Each prior incident is checked against available meteorological data to verify its classification prior to incorporation into the model.

d. Explain in detail approaches used to verify data quality.

Each risk module of the WTRM uses input data from a variety of sources. There are two types of data quality issues that are flagged by quality checks that run when source data is curated for the WTRM for (1) missing data and (2) inconsistent data. Where data is missing, conservative assumptions are applied, where possible, to supplement. For example, when age data is unavailable from the system of record, conservative age logic enables the model to infer a reasonably conservative age. Instances where conservative age logic is used, as well as where data is missing, are flagged

accordingly so that the team can work with the Asset Knowledge Management (AKM) team to resolve these flagged data quality issues. Regarding instances of inconsistent data, for example, where two different systems of record report a different value for the same asset, this is flagged and presented for correction through either a corrective action, remapping request, or in collaboration with the AKM team.

e. Characteristics of the data (field definitions/schema, uncertainties, acquisition frequency).

In general, the characteristics of the data elements for these risk modules include:

- Age – This is the age of the specific component group and is pulled from ETGIS and the AFL dataset. Conservative age logic is employed to ensure the published age value is as accurate as possible while also reasonably conservative where assumptions must be made. Data quality issues are flagged so that follow-ups can be done to improve the source data.

- Location – The location of the asset (its latitude and longitude) and position within a geospatial reference layer (for example, a POMMS grid ID for wind-specific data) are both useful to determine which environmental exposures apply to the asset. These environmental exposures include, but are not limited to, corrosion characteristics, site wind hazard, landslide susceptibility, and seismic parameters. Using spatial joins ensures that the correct location-specific data is applied to the asset.

- Load capacity – This is estimated from the Power Line Systems - Computer Aided Design and Draft (PLS-CADD)[67] modeling effort. Data quality verification starts with the source data, where a rigorous QA/QC process is maintained to ensure only validated data is pushed to a production system of records, and also includes checks at the system of record level to ensure the load capacity data is applied to the correct structure.

- Maintenance and repair history – Notification data are used to ensure that maintenance and repairs are reflected in the annual failure rate output from the Model.

- Outage or prior incidents – This dataset is curated by multiple SMEs who research each outage prior to its inclusion for the WTRM. Research includes records analysis from systems of record, meteorological analysis using historical climatological datasets, and interview with field personnel to ascertain the true cause and accurate location of an outage or other incident.

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67 According to https://www.powerlinesystems.com/plscadd – PLS-CADD is the most powerful overhead power line design program on the market. PLS-CADD runs under Microsoft Windows and features an easy to use graphical user interface. It integrates all aspects of line design into a single stand-alone program with a simple, logical, consistent interface.

f. Describe any processes used to modify the data (such as adjusting vegetative fuel models for wildfire spread based on prior history and vegetation growth).

Input data for the WTRM are modified through:

- Bayesian Updating – This is a statistical tool employed to adjust the median and uncertainty parameters for the fragility curve based on prior outage data.
- Inspection code modification – Condition scores (3, 4, or 5 values) are updated when it is confirmed that a component has been replaced.
- PLS-CADD data – This is used to influence the median parameter for the fragility curve.

4. Modeling assumptions and limitations

The WTRM builds on assumptions that have been employed by the Transmission Operability Assessment (OA) Model, discussed in Section 4.5.1(h). These include:

- The identification of 47 components from a FMEA analysis, a failure of any one of which could result a wildfire ignition. These 47 components were subsequently collected into 9 asset group types to which asset-specific datasets are assigned. While the scope of the WTRM exceeds that of the OA Model to incorporate other hazards, the asset group types remain a proxy for a collection of components that share similar (i) life cycles, (ii) sensitivities to threats and hazards, and (iii) Asset Management strategies.
- The prioritization of threat and hazard models for development and deployment to production systems. This prioritization is driven by SMEs who ranked the criticality of a failure resulting from a threat-hazard pairing to prioritize the order of work.
- Age data is required for each component in order for the WTRM to compute an annual failure rate. Where direct age data is unavailable, conservative age logic assumptions are employed to produce age values that result in reasonably conservative outputs from the model.

The WTRM considers 47 components, which were placed in a component grouping based on the following considerations:

- Similar asset lifecycle
- Sensitivity to similar threats and hazards
- Similar Asset Management strategy

The resulting nine component groups are:

- Group A Conductor – The conductor grouping includes conductor, jumpers, shield wires, optical ground wire (OPGW), armor rod, aviation marker balls, and smart grid

devices. All the components in the group are subject to the same threats and hazards, or a subset of the threats and hazards.

- Group B Insulator – The insulator grouping includes insulators, flying bells and grading rings. All the components in the group are subject to the same threats and hazards, or a subset of the threats and hazards component.

- Group C Non-steel structures (i.e., wood poles) – The non-steel structure grouping includes treated wood poles, wood crossarms and bird and animal guards. All the components in the group are subject to the same threats and hazards, or a subset of the threats and hazards.

- Group D Steel structures (including steel poles and lattice steel structures) – The steel structure grouping includes steel structures as the primary component. The other components in the group are leg members, non-leg members, crossarm members and bird and animal guards. There are also small populations of composite (fiberglass) poles, concrete poles, and hybrid poles. Hybrid poles are those poles that have a concrete pole base and tubular steel pole top. While all the components in the group are subject to the same threats and hazards, composite poles may also be subject to ultraviolet (UV) degradation. They also have the same or similar life cycle.

- Group E Foundations – The foundation grouping includes foundations, stub angles and anchor bolts. All the components in the group are subject to the same threats and hazards, or a subset of the threats and hazards, as the primary component.

- Group F Switches – The switch grouping includes switches as the primary component. Other components in the group are distribution equipment, switch insulator, potential transformer (PT), contact-live part, quick break attachment, interrupter, battery, and operating assembly.

- Group G Above grade hardware – The component grouping for above grade hardware consists of two sub-groupings.

  – Sub-group 1 consists of components where the life cycle closely aligns with that of the structure. These include the hanger plate and bolts.

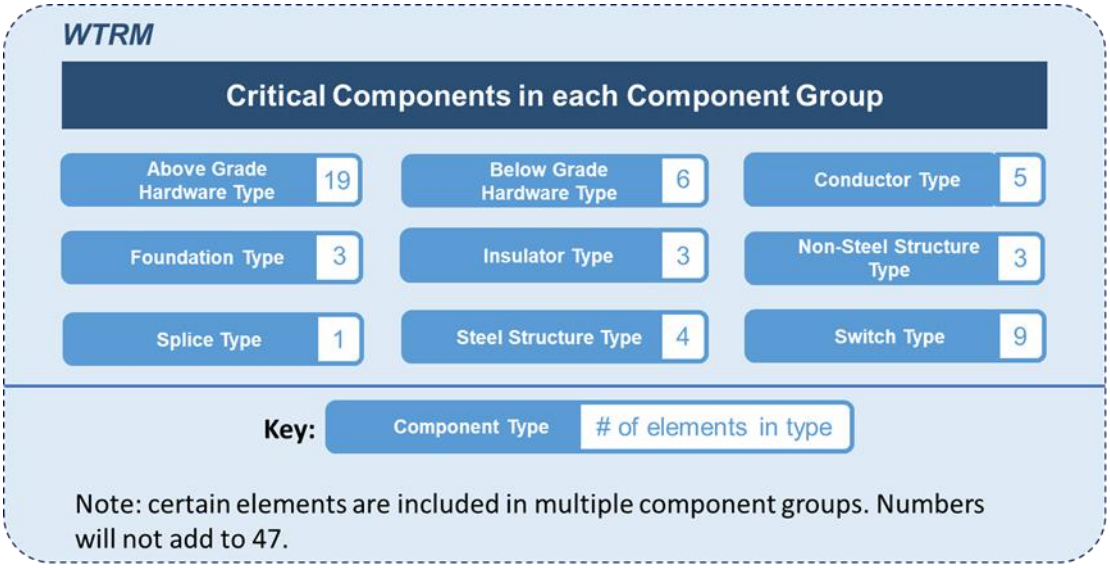
  – Sub-group 2 consists of components whose life cycle more closely aligns with that of conductor.

- Group H Below grade hardware – The below grade hardware grouping includes the anchor system, ground wire, and guy system.

- Group I Splice Type – The splice type component group captures threats and hazards that are specific to conductor splices. The prevalence of conductor splices are treated as uncertainty metrics for the WTRM. While invariably linked to conductors, their performance from an annual probability of failure perspective is computed separately and then combined with the conductor component group for the composite risk value.

The 47 components included in the WTRM, separated into the nine critical component groups described above, are reflected in Figure PG&E-4.5.1-8 below.

FIGURE PG&E-4.5.1-8:
WTRM COMPONENT GROUPS



The WTRM models all nine component groupings and considers only the hazard associated with wind, as well as the key threats associated with the group of components. As a starting point, the model assumes that all components have been designed to the minimum design wind loads and are equally susceptible to the threats affecting the component group. Therefore, the model results would be similar for all the components in a group.

As data is collected on individual components, the model framework will be used to select the most vulnerable component attributes for a given hazard. For example, if thicker hanger plates than required by minimum design wind loads have been installed on a structure, it may be determined that another component in the above grade hardware grouping has a higher probability of failure during high winds. In that case, the most vulnerable component attributes would be used to represent the component grouping probability of failure.

To ensure that the WTRM addresses the most conservative component attributes in a group, the model will consider multiple characteristics of components that make them more vulnerable to threats and hazards, such as age, damage identified by inspections, material properties most vulnerable to threats, and lower mechanical strength. As data is collected on individual components, the model framework can be used to identify one or more components of a grouping that exhibit different vulnerability to a particular hazard. In these cases, it may be desirable to form additional groupings of such components so that targeted asset management strategies can be developed accordingly.

Components of a given grouping will be modelled to ensure that the approach to hazard mitigation is conservative. For a few components with small populations and a limited deployment history, a probability of failure model will not be developed. In these cases, a deterministic approach will assign a conservative life cycle from the manufacturers' recommendations and industry best practices.

5. Modeling methodology

a. Model equations and functions

The WTRM is a first principles engineering model. Its model equations are rooted in established engineering and physics-based theories and does not explicitly employ machine learning algorithms because the underlying physics are amenable to mathematical modeling. However, various inputs to the model are derived from statistical approaches, such as the adjustments to the median and uncertainty terms of the fragility curve (through Bayesian Updating) and third-party damage forecasts (derived from a machine learning routine).

Formula used in the WTRM include:

- $R_f = C_f \cdot \sum P_f$;
- R_f = Risk of asset failure;
- Failure can be defined as ignition, or more broadly as outages;
- Dx defining "failure" as ignition and subsequently evaluate risk of ignition;
- P_f = Annual probability of failure;
- Specific to asset categories and hazards but are additive;
- Probability of failure by hazard can be influenced by degradation (fragility curve) of component driving by threat models; and
- C_f = Consequence of failure model, defined geospatially (i.e., Technosylva wildfire spread model).

b. Any additional input from Subject Matter Experts (SME) input

SMEs helped to:

- Prioritize the model development schedule by identifying which threats and hazards should be developed and deployed to production first.
- Interpret various datasets to make them usable as inputs for the WTRM.
- Provide feedback on the user interface design to ensure that outputs from the Model will support decision-making requirements.

On July 21, 2021, a cross-functional team of SMEs met at PG&E's Applied Technology Services (ATS) facility in San Ramon and on the phone to discuss grouping the 47 individual critical components into component groupings as described above in (4).

c. Any statistical analysis or additional algorithms used to obtain input

Bayesian Updating, mentioned previously, was used to adjust input parameters for the fragility computation based on historical outage data.

d. Details on the automation process for automated models

The WTRM is undergoing developments that will allow for automation. The model is being deployed to a Python code base. Input datasets are automatically prepared at the refresh cadences mentioned previously. These inputs are also backed up so that at any point in the future the WTRM can be run again.

6. Model uncertainty

Model uncertainty is measured and reported through dispersion terms applicable to key input parameters. The fragility curve, which represents the probability of failure for any value of a demand parameters, has the uncertainty (or dispersion) value as an input. The factors that influence this uncertainty term include the age of the asset or component, as well as environmental-specific factors referred to as "design life reduction factors."

7. Model verification and validation

a. Documentation describing the verification basis of the model, demonstrating that the software is correctly solving the equations described in the technical approach.

The model code is verified with full-scale functionality testing where the inputs and outputs from the software are checked against the inputs and outputs of a separate instance of the model. Both outputs must match for the model code to be considered verified.

b. Documentation describing the validation basis of the model, demonstrating the extent to which model predictions agree with real-world observations.

The WTRM will have its forecasts validated against on-the-ground inspection data. Variations between ground truth and model forecasts will then be studied to identify if the model's forecasting is consistent with observations. Since the WTRM is probabilistic, a statistically significant amount of field data must be collected and evaluated prior to any decision to tune the model to field observations.

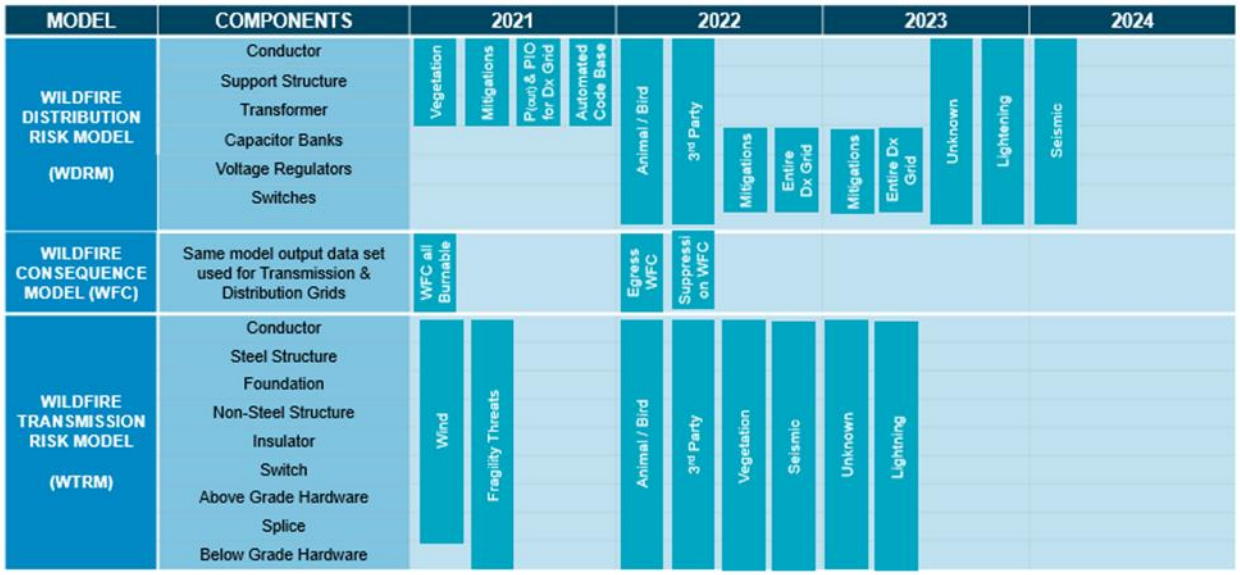
8. Modeling frequency

The WTRM will be run at least annually though it is also designed to run on-demand. The refresh cadence can be tuned to the requirements of Asset Strategy.

9. Timeline for model development

The timeline for development and release of the WTRM is provided in Figure PG&E-4.5.1-9 below. The multi-year schedule for the WTRM is shown along with the WDRM and WFC schedules in Figure PG&E-4.5.1-9.

FIGURE PG&E-4.5.1-9:
WTRM DEVELOPMENT SCHEDULE



10. Application and results

The WTRM has been used for discretionary inspections as referenced in the Section 7.3.4.10, Other Discretionary Inspection of Transmission Electric Lines and Equipment, Beyond Inspections Mandated by Rules and Regulations.

11. Key improvements from working group

No recommendations have been provided from the Wildfire Risk Modeling Working Group to date for the WTRM.

4.5.1(d) Wildfire Consequence Model

1. Purpose of model

The Wildfire Consequence Model (WFC Model) is a historically calibrated estimate of the impact (i.e., consequence of an ignition) measured in MAVF units and estimated at relevant PG&E infrastructure locations. When an ignition occurs at a location, the WFC Model estimates the impacts. The model relies on historical fire damage, simulations of fire propagation from Technosylva, and the Fire Potential Index (FPI) Model. By combining the FPI and Technosylva fire spread simulations in the WFC Model, we leverage the strengths of both models such that a more complete and applicable estimate of consequences can be produced.[68]

2. Relevant Terms

- Cal Fire Redbook – Cal Fire's historical recordings of fire damage: acres burned, buildings destroyed, fatalities
- Consequence – The effect of the occurrence of a Risk Event.
- Fire Potential Index (FPI) Rating (R) Score – The FPI Rating (R) from R1 (lowest) to R5 (highest). Ref: 4.5.1(f).2f
- Flame Length (FL) – Flame length is the distance between the flame tip and the midpoint of the flame depth at the base of the flame measured in feet. Flame length is an observable, measurable indicator of fireline intensity.
- Multi-Attribute Value Function (MAVF) – Risk calculation methodology introduced during CPUC's S-MAP and RAMP proceedings.
- Rate of Spread (ROS) – ROS is a Technosylva simulation output measuring the speed with which the fire is moving away from the site of origin measured in chains (66 feet) per hour.
- Technosylva – Vendor of wildfire simulations based on inputs such as available fuels, topography, weather, structure, and population data. Technosylva simulation outputs are used as an input into the PG&E Wildfire Consequences Model.
- Technosylva Simulation – Computerized simulations of wildfire behavior given an ignition at a location on a particular date. Currently, PG&E uses Technosylva's 8-hour simulation product.
- Visible Infrared Imaging Radiometer Suite (VIIRS) – Earth observation satellite data from NOAA, in the visible and infrared bands

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68 The WFC Model provides estimates of consequence when Technosylva simulations are unavailable. The Technosylva simulation outputs are generated only for certain dates associated with high wildfire risk and limited to HFTD areas

3. Data elements

a. Scope and granularity (or, resolution) of data in time and location (i.e., date range, spatial granularity for each data element, see example table above).

Table PG&E-4.5.1-9 below identifies the data elements in the WFC Model.

TABLE PG&E-4.5.1-9:
WFC MODEL DATA ELEMENTS

ID	Source	Provides	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Availability and URL
1	Wildfire simulation results	Acres burned, rate of spread, flame length, and other predicted fire impacts, for 8-hour wildfire simulations, performed under historically hazardous weather conditions, for points spaced 200m along PG&E's electrical asset network	2000-2020	NA	200m	NA	PG&E - licensed from Technosylva
2	Extended Fire Dataset with Agency Data	See documentation in Section 4.5.1(f).5	See documentation in Section 4.5.1(f)	See documentation in Section 4.5.1(f)	See documentation in Section 4.5.1(f)	See documentation in Section 4.5.1(f)	PG&E - licensed from Sonoma Technologies
3	Fire Potential Index (FPI) - produced by PG&E Meteorology	Dead Fuel Moisture (DFM), wind speed and direction, temperature, precipitation, etc.	2004-2020	NA	2km	Hourly	PG&E - Meteorology - See documentation in Section 4.5.1(f)

b. Explain the frequency of data updates.

Please see Table PG&E-4.5.1-9 above.

c. Sources of data. Explain in detail measurement approaches.

Table PG&E-4.5.1-10 below provides the measurement approach for the WFC Model.

TABLE PG&E-4.5.1-10:
WFC MODEL DATA SOURCES WITH MEASUREMENT APPROACH

ID	Source	Measurement
1	Wildfire simulation results	NA - The outputs of the wildfire simulations are used as-is - there is no "measurement" per se
2	Extended Fire Dataset with Agency Data	See documentation in Section 4.5.1(f).5
3	Fire Potential Index (FPI) - produced by PG&E Meteorology	See documentation in Section 4.5.1(f)

d. Explain in detail approaches used to verify data quality.

All input data sources are checked for gross errors, and erroneous rows and columns are corrected or discarded before further utilization. Individual data sources are checked as described in Table PG&E-4.5.1-11 below:

TABLE PG&E-4.5.1-11:
WFC MODEL DATA QUALITY VERIFICATION

ID	Source	Data Quality Verification
1	Wildfire simulation results	Check for spatial completeness via mapping and visual inspection. The data provider performs verification as this data is produced.
2	Extended Fire Dataset with Agency Data	See documentation in Section 4.5.1(f)
3	Fire Potential Index (FPI) - produced by PG&E Meteorology	The data provider performs verification as this data is produced. See documentation in Section 4.5.1(f)

e. Characteristics of the data (field definitions/schema, uncertainties, acquisition frequency).

Table PG&E-4.5.1-12 below provides the data characteristics for the WFC Model.

TABLE PG&E-4.5.1-12:
WFC MODEL DATA CHARACTERISTICS

ID	Source	Field Definitions/Schema	Uncertainties	Acquisition Frequency
1	Wildfire simulation results	A few fields summarizing the behavior and impact of each simulated wildfire, including: acres burnt, rate of spread, flame length, structures impacted, etc.	Unknown	A prior version of this dataset was acquired for v2 WDRM. An updated version was acquired for v3 WDRM.
2	Extended Fire Dataset with Agency Data	See documentation in Section 4.5.1(f).5	See documentation in Section 4.5.1(f).5	See documentation in Section 4.5.1(f).5
3	Fire Potential Index (FPI) - produced by PG&E Meteorology	See documentation in Section 4.5.1(f)	See documentation in Section 4.5.1(f)	See documentation in Section 4.5.1(f)

f. Describe any processes used to modify the data (such as adjusting vegetative fuel models for wildfire spread based on prior history and vegetation growth).

For long term risk assessment, PG&E utilized a projected fuel layer for the year 2030 that was provided by Technosylva. The intent is that the planning model is used to make longer-term decisions to reduce risk and we wanted to capture the potential future state of the fuels. Technosylva utilized their expertise in vegetative re-growth after fire disturbances (fire scars) to project the state of the fuels in 2030. This work leverages historical data on vegetation regrowth after fires based on satellite data and burn severity maps.

4. Modeling assumptions and limitations

The WFC Model is a partition that answers the question: What values of fire simulation variables FL and ROS, as well as FPI, allow PG&E to best capture historically destructive fires? The WFC Model includes two major assumptions.

First, the choice to identify the conditions leading to the most historically destructive fires is fundamental to PG&E's risk reduction goals. The historically destructive fires contribute disproportionally to the cost of all fires. The downside of this requirement is that the source data inherently limited; there are not very many highly destructive historical fires. This is both a model assumption and a data problem discussed below in (6). The more broadly PG&E tries to capture the destructiveness of fire conditions (the covariates), the more historical fires (data points) exist to estimate the consequences of an ignition. That is the consequences of ignition become the same regardless of fire conditions or mostly the same. The better PG&E captures the resolution in cost between different fire conditions the fewer data points to work with.

The second major assumption of the model is that the past relationship between historical fire destructiveness and the covariates FL, ROS, and FPI R score does not change over time.

5. Modeling methodology

a. Model equations and functions

In April 2021, Technosylva simulated 571 historically-dangerous weather conditions (from 2000 to 2020) across all burnable locations within PG&E's service territory, with simulated ignition points spaced in a 200 meter grid around all PG&E transmission and distribution assets.[69] The simulations assumed that the fuels present would be those as of 2030—which thus includes vegetation regrowth within historical wildfire burn scars.

For each ignition point, Technosylva provided the 8-hour fire simulation outputs (acres burned, buildings impacted, populations impacted, ROS and FL) for the 571 weather day simulations.

The PG&E Meteorology team produced an estimate for FPI on an hourly basis for 2 km pixels, from 2004 to 2020. FPI Fire Danger Rating is assigned based on probability of large or catastrophic fire. We then applied the following steps to this data:

1. We calculate the consequence at each of the Technosylva 326,431 ignition points and create a 200m radius buffer around each ignition point for the consequence value.

2. For each ignition point we get FPI and Technosylva simulations daily data for summer months (May to November) from 2004-2020. Since, FPI is hourly data we aggregate hourly data using maximum value in that day.

3. Develop a methodology for Destructive Fire Classification:

    a) For each satellite detect fire temporally and spatially match Technosylva simulation results and FPI fire rating values and use these as a guidance to come up with the threshold values.

    b) From the above analysis boundaries are drawn at Flame Length (FL) >=5 and Rate of Spread (ROS) >=12, or FPI Fire Rating of R4 or above.

4. Calculate the Destructive Fire Probability for each of the Technosylva ignition points.

    a) Classify whether each day falls into destructive or non-destructive using both the Technosylva simulation attributes (ROS & FL) and FPI Fire Danger Rating Attribute.

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69 This 200m grid around PG&E assets results in 326,431 ignition points.

1) Destructive Fire: (FPI Fire Danger Rating R4 or above) or Technosylva Criteria: Flame Length >= 5 ft & ROS >= 12 ch/hr

2) Non-Destructive Fire: not (Destructive Fire Condition)

3) Probability is the ratio of number of days it met the above condition over all the summer days in the time period (2014-2020)

5. Calculate the Expected MAVF CoRE values for destructive fire and non-destructive fire.

   a) For each of the satellite detect fires classify whether the fire meets necessary condition defined above for classifying as destructive fire.

   b) Using CalFire red books data, for each of the large fires we manually added buildings destroyed, and fatalities data. We assumed zero for the fires where we could not find the data.

   c) For each fire we calculated the MAVF CoRE values by converting the financial damage using acres and buildings destroyed. For Safety we used the actual fatalities data and ignored the reliability component.

      1) FINANCIAL_COST_PER_STRUCTURE = $1,000,000

      2) FINANCIAL_COST_PER_ACRE = $1,175

6. We took the mean value of fires in each class for the expected CoRE value aggregated by High Fire Risk Areas.

FIGURE PG&E-4.5.1-10:
WFC MODEL MAVF/CORE

:

	hfra_v4_1	destructive_class	mavf_core	lat
0	False	N	0.061373	2381
1	False	Y	0.182643	464
2	True	N	0.391632	3650
3	True	Y	240.180982	1109

7. Calculate the CoRE value for each ignition point by taking the weighted sum of the destructive fire probability and the CoRE value.

8. Create a 100m raster file using 200m Radius Buffer around each ignition point.

b. Any additional input from Subject Matter Experts (SME) input

The PG&E Public Safety Specialist (PSS) team performed a qualitative review of the WFC Model outputs. This review included exploration of consequence estimates in the Sierra Foothills, and in the vicinity of recent significant fires.

c. Any statistical analysis or additional algorithms used to obtain input

We classified historical satellite fire detects according to 2022 ERM fire size definitions and evaluated the model destructive fire criteria to determine the Accuracy and True and False Positive rate.

d. Details on the automation process for automated models

The WFC Model is partially automated. The output from Technosylva is automated as is the development of the FPI values. Future refinement of integration of these values will automate the production of the WFC Model values.

6. Model uncertainty

The historical fires are a record of real damage. Only a few dozen historical fires contribute significantly to the overall cost of fire. This is a source of uncertainty in the modeling process.

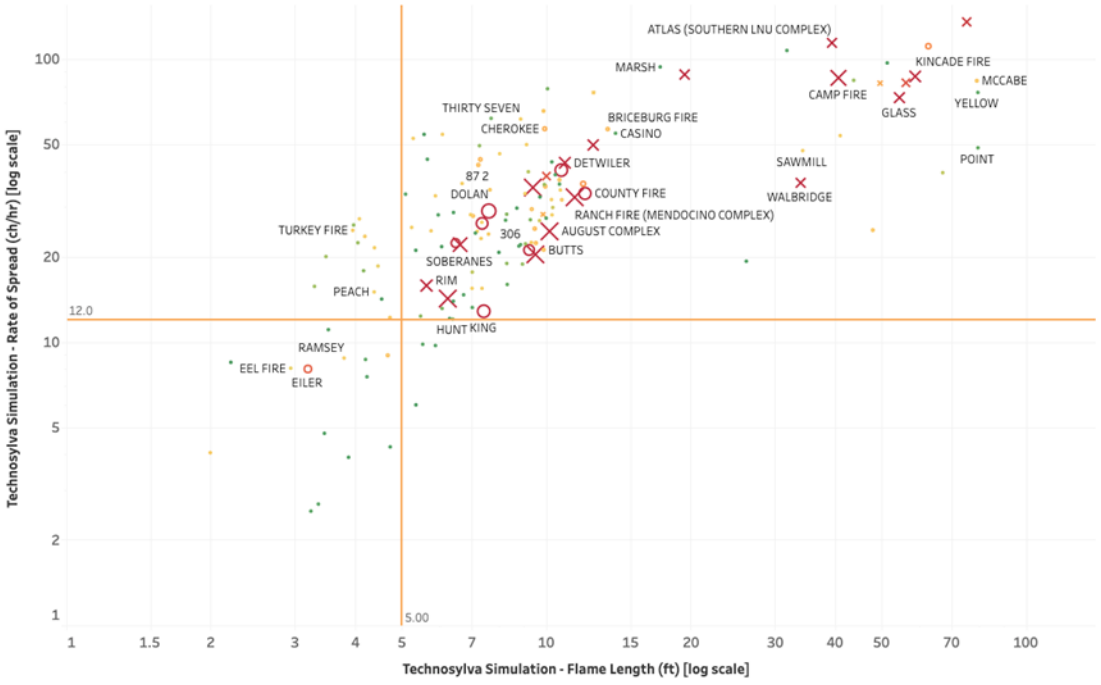
Additional assumptions and limitations of Technosylva inputs include:

- The wildfire simulations are 8-hours long. This only results in reasonably accurate.
- It is assumed that using outputs of wildfire simulations is sufficiently representative of real-world outcomes. The purpose of the WFC model is to accurately link the simulations to the historical outcomes but can be limited by the simulation accuracy and assumptions.
- The wildfire simulations exclude “unburnable” mostly urban or suburban locations—it is assumed that such locations are correctly characterized, and that these locations would not, in fact, support ignition and propagation of wildfires.

7. *Model verification and validation*

a. *Documentation describing the verification basis of the model, demonstrating that the software is correctly solving the equations described in the technical approach.*

FIGURE PG&E-4.5.1-11:
VISUALIZATION OF DESTRUCTIVE FIRES USING TECHNOSYLVA DATA



Data from historical fires has been used to visualize and validate the conditions that have led to destructive fires—see Figure PG&E 4.5.1-11 above. The boundaries do separate the space of historical fires and capture the destructive/catastrophic fires (upper-right).

In addition, please see additional documentation of verification and validation in Section 4.5.1(b) regarding the validation process for 2022 WDRM v3, which includes review of the WFC model.

b. *Documentation describing the validation basis of the model, demonstrating the extent to which model predictions agree with real-world observations.*

The model itself is a calibration of simulation inputs to the historical observations. By construction the model parameters, the threshold values of FPI R score, ROS, and FL, were chosen to: (1) partition the historical fires making sure to capture destructive fires entirely in one partition and (2) describe the partitions using the mean of historical MAVF consequence.

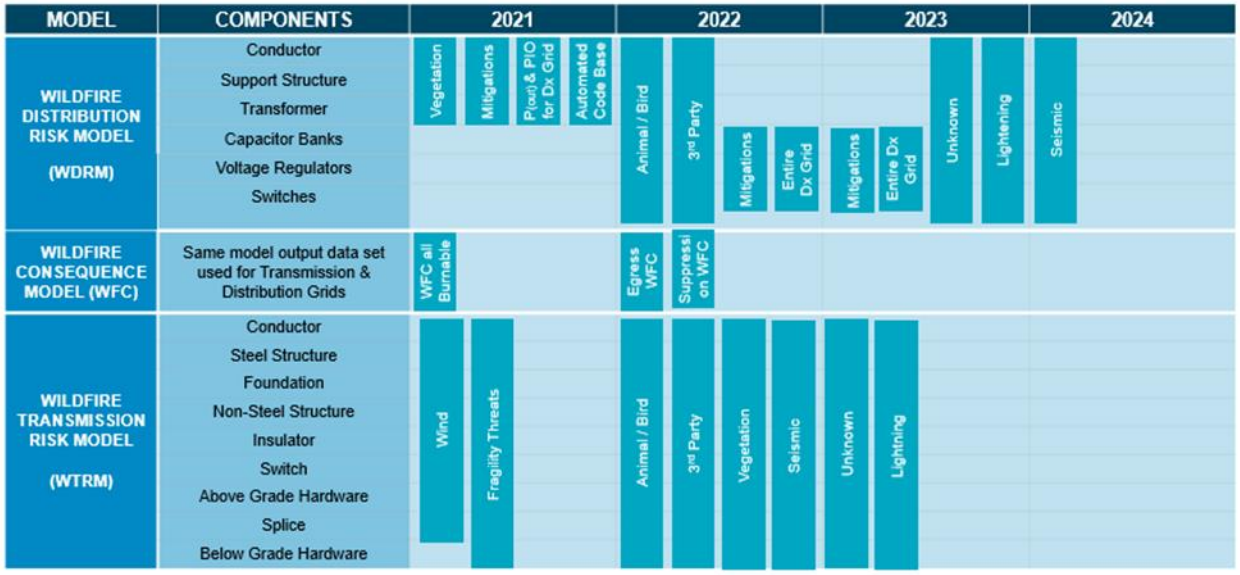
8. Modeling frequency

The WFC is updated annually.

9. Timeline for model development

The schedule for the WDRM, WTRM and WFC are outlined below in Figure PG&E-4.5.1-12. For the WFC, future improvements include accounting for egress and fire suppression.

FIGURE PG&E-4.5.1-12:
WFC MODEL DEVELOPMENT SCHEDULE



10. Application and results

See Section 4.5.1(b) above for discussion of how the Wildfire Consequence model's predictions are utilized in the 2022 WDRM v3.

11. Key improvements from working group

No recommendations have been provided from the Wildfire Risk Modeling Working Group to date for the WFC Model.

4.5.1(e) Enhanced Vegetation Management Tree Weighted Prioritization

1. Purpose of model

The purpose of the EVM Tree Weighted Prioritization is to produce a risk-ranked list of circuit segments in HFTD areas for our EVM program. PG&E used the resulting list of circuit segments to develop our 2021 EVM Scope of Work, as well as our current 2022 EVM Scope of Work.

2. Relevant terms

- Circuit Protection Zone (CPZ) – A CPZ is a segment of a distribution circuit between two protection devices. CPZs are also sometimes referred to as circuit segments.
- EVM Scope of Work – The scope of work planned for PG&E's EVM program in a year.

3. Data elements

a. Scope and granularity (or, resolution) of data in time and location (i.e., date range, spatial granularity for each data element, see example table above).

The EVM Tree Weighted Prioritization was developed by starting with the 2021 WDRM v2 and making three refinements to that model. The refinements and the data sets used are described in Table PG&E-4.5.1-13 below.

TABLE PG&E-4.5.1-13:
EVM TREE WEIGHTED PRIORITIZATION DATASETS

Data Set	Category	Source	Spatial Resolution	Units	Descriptions
Re-aggregation from 100m x 100m pixels to 1km x 0.7km grid areas (Unified Grid Maps)	Risk/ Consequence Data	(1) WDRM Risk pixel data (2) PG&E Unified Grid spatial layer	100m		Uses a spatial join between the WDRM pixel location and the PGE Unified Grid layer to identify all the100m x 100m pixels in a 1km x 0.7km GRID area. The total area of the pixels contained in each grid, along with the total Risk Value of the pixel area within each grid is calculated.
Estimation of Tree Count per Grid area using 2019/2020 LiDAR Survey Data and VM Inspection results	Estimated Tree Count	(1) 2019/2020 LiDAR survey data analysis output produced on 2/4/2020. (2) EVM Inspection Data (3) Statistical analysis of LiDAR accuracy		Tree Count	LiDAR data includes a GRID area identifier. Data is summarized by GRID area, and an adjustment is made to the GRID area Tree Count based on a statistical analysis of the LiDAR Grid Tree Count accuracy.
Estimation of Remaining Tree Work on CPZ from EVM Execution Records	Estimated Remaining Tree Work Count	(1) LiDAR Estimated Tree Count per Grid Area (2) EVM completed Tree Work count (3) List of CPZs by Unified Grid Map area that shows the primary CPZ within the Grid area		Tree Count	LiDAR data from above is used to estimate the number of trees requiring work within a Grid Area. EVM data includes a GRID area identifier. This EVM data is matched with the LiDAR data to determine the estimated count of trees remaining to be worked within a Grid area. The estimated count of trees remaining to be worked within a Grid area is then summed among all the Grid Areas for a CPZ where the CPZ is listed as the Primary CPZ in the Grid area.

b. Explain the frequency of data updates.

PG&E has not updated the EVM Tree Weighted Prioritization since it was developed in 2021. The EVM Tree Weighted Prioritization has been used to inform the 2021 EVM Scope of Work, as well as the 2022 EVM Scope of Work. PG&E will evaluate the need to update the EVM Tree Weighted Prioritization after it completes a review and validation of the 2022 WDRM v3.

c. Sources of data. Explain in detail measurement approaches.

Sources of data for the EVM Tree Weighted Prioritization datasets can be found in Table PG&E-4.5.1-13 above.

d. Explain in detail approaches used to verify data quality.

For data included in the WDRM models, which was the basis for the EVM Tree Weighted Prioritization, please see the description of data verification efforts above in Section 4.5.1(b). The additional data used in the EVM Tree Weighted Prioritization was either a result of reaggregation of data or was data available for PG&E's VM program.

e. Characteristics of the data (field definitions/schema, uncertainties, acquisition frequency).

Sources of data for the EVM Tree Weighted Prioritization datasets can be found in Table PG&E-4.5.1-13 above.

f. Describe any processes used to modify the data (such as adjusting vegetative fuel models for wildfire spread based on prior history and vegetation growth).

As noted above, our VM Asset Management Team made three refinements to the 2021 WDRM v2 vegetation output when we were developing the EVM Tree Weighted Prioritization.

First, the team re-aggregated the risk from 100 m x 100 m pixels used in the 2021 WDRM v2 to approximately 1 kilometer (km) x 0.7 km grid areas. We refer to these re-aggregated areas as Unified Grid Maps. The rationale for re-aggregating is to align the output of 100 m x 100 m pixel risk scores from the 2021 WDRM v2 located on the circuit segments into how work is assigned and executed by our VM tree crews. The re-aggregated grid areas are assigned to a single circuit segment.

Second, the team estimated the number of trees per grid area using LiDAR survey data and VM inspection results along approximately 25,000 miles of distribution circuits in the HFTD. The LiDAR data was obtained in mid-2019 to early 2020 and helped identify trees that could potentially require EVM work. Inspectors subsequently visited approximately 5,000 miles of circuit segments to validate the data that was collected by LiDAR. They added data points where the LiDAR analysis did not identify a tree that would require work. The data that the inspectors collected along the approximately 5,000 miles of circuit was used as part of a regression analysis to predict the amount of work that exists along the remaining approximately 20,000 miles of circuits. This provided the predicted tree work in a grid area and associated circuit segment.

The third modification weighted each grid area and associated circuit segment by the remaining tree work. The results of the predicted tree work in each grid map and associated circuit segment was combined with the number of trees that have already been completed in the grid area and associated circuit segment to estimate the Remaining Tree Work on that circuit segment. The number of remaining trees were then used to weigh the circuit segment risk.

4. *Modeling assumptions and limitations*

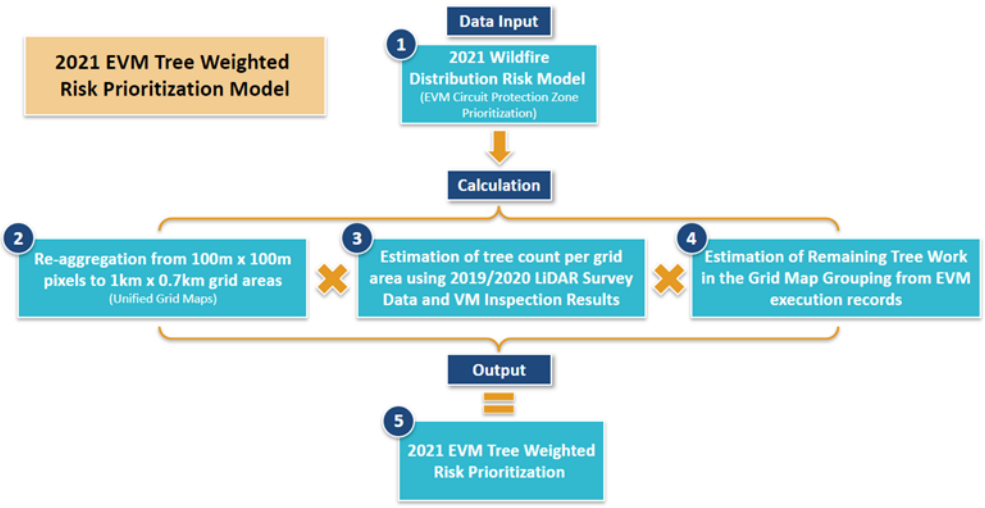
The EVM Tree Weighted Prioritization is built on the assumption that past events predict future outcomes, as well as assumptions underlying the 2021 WDRM v2. For assumptions regarding the WDRM models, see Section 4.5.1(b) above.

5. *Modeling methodology*

a. *Model equations and functions*

2021 EVM Tree Weighted Risk Prioritization is calculated as shown in Figure PG&E-4.5.1-13 below.

FIGURE PG&E-4.5.1-13:
CALCULATION OF EVM TREE WEIGHTED PRIORITIZATION



b. *Any additional input from Subject Matter Experts (SME) input*

Input from the VM team used in the development of the EVM Tree Weighted Prioritization is described above in (3)(f).

c. *Any statistical analysis or additional algorithms used to obtain input*

See (3) above for a description of the elements of the EVM Tree Weighted Prioritization.

d. *Details on the automation process for automated models*

See (3) above for a description of the elements of the EVM Tree Weighted Prioritization.

6. Model uncertainty

In addition to any uncertainties associated with the 2021 WDRM v2, additional uncertainties for the EVM Tree Weighted Prioritization include the accuracy of data elements such as the estimations of tree count and remaining tree work count.

7. Model verification and validation

a. Documentation describing the verification basis of the model, demonstrating that the software is correctly solving the equations described in the technical approach.

PG&E has previously provided to Energy Safety and the CPUC documentation describing the verification of the 2021 WDRM v2, including an external review by E3. We do not have any additional documentation regarding verification of the EVM Tree Weighted Prioritization.

b. Documentation describing the validation basis of the model, demonstrating the extent to which model predictions agree with real-world observations.

The dataset used to train the EVM Tree Weighted Prioritization achieved an AUC score of 0.73. The 2019 dataset was used as an out-of-sample test dataset to evaluate the model fit and achieved a score of 0.64 but a randomly withheld test sample from several years achieved a score of 0.72. The minimal reduction in AUC score between the training and testing datasets gives confidence that the model is not overfitting to the training dataset but also raises the possibility that the spatial pattern and other characteristics of 2019 vegetation-caused ignitions deviated slightly from 2015-2018.

8. Modeling frequency

The EVM Tree Weighted Prioritization was performed once to establish a list of risk ranked CPZs or circuit segments. This list was then used to inform the 2021 EVM Scope of Work and the 2022 EWM Scope of Work.

9. Timeline for model development

We do not currently have a timeline for any further development or updates to the EVM Tree Weighted Prioritization. Development will be dependent in part on the review and approval of the 2022 WDRM v3.

10. Application and results

The 2021 EVM Tree Weighted Prioritization method was applied to planning the 2021 and 2022 EVM Scope of Work.

11. Key improvements from working group

No recommendations have been provided from the Wildfire Risk Modeling Working Group to date for the EVM Tree Weighted Prioritization.

4.5.1(f) Fire Potential Index (FPI) Model

1. Purpose of model

To better understand and predict the potential for large and catastrophic fires to occur across our service territory, we developed the FPI Model in 2015 and have improved the model several times since.

The FPI Model combines fire weather parameters (wind speed, temperature, and vapor pressure deficit), dead and live fuel moisture data, topography, and fuel model data to predict the probability of large and/or catastrophic fires. The FPI Model was trained on an enhanced fire occurrence dataset that combines agency fire information with sub-daily growth from satellite fire detections.

The FPI Model is used as a daily and hourly tool to drive operational decisions to reduce the risk of utility-caused fires. On a day-by-day basis, the FPI Model informs crews and operators what precautions must be taken to reduce the risk of fire ignitions as directed by utility standards. The FPI Model also informs the potential need and execution for PSPS events.

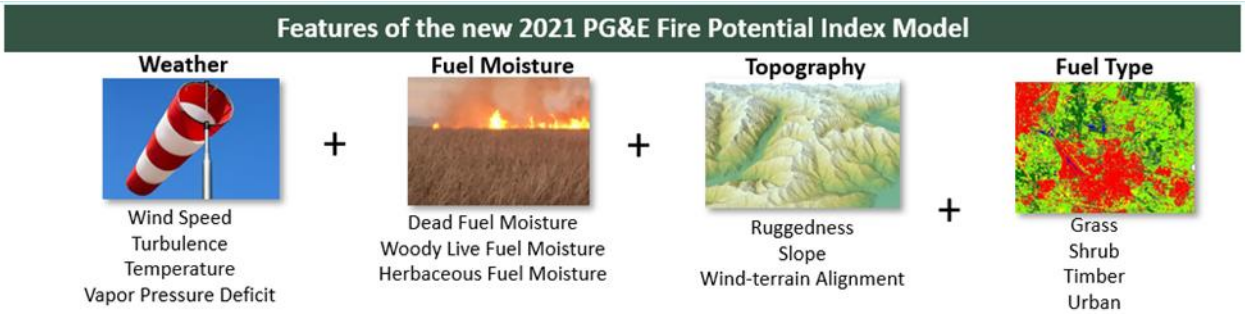
2. Relevant terms

- Dead Fuel Moisture (DFM) – Moisture content of dead vegetation, which responds current and antecedent environmental conditions and is critical in determining fire potential.
- Fire Index Area (FIA) – A geographical area over which fire danger determinations are produced.
- Live Fuel Moisture (LFM) – Moisture content within living vegetation. Living vegetation contains more moisture than dead vegetation because it is biologically active.
- PG&E Operational Mesoscale Modelling System (POMMS) – A configuration of the Weather Research and Forecasting (WRF) model. A numerical weather prediction model.

3. Data elements

The list of model features used in the machine learning FPI Model are discussed in this section. These feature build upon the traditional “fire behavior triangle” that incorporate the effects of fuel, weather and topography on fire behavior. The FPI Model features can be grouped into four main categories: (1) Weather; (2) Fuel Moisture; (3) Topography; and (4) Fuel Type. The balanced random forest classifier in the FPI Model offers advantages over the previously used logistic regression, as the model learns how features may interact and captures non-linearities between the features and catastrophic fire spread.

FIGURE PG&E-4.5.1-14:
FPI MODEL DATA ELEMENTS



The weather data is sourced from the 2 x 2 km POMMS weather forecast model and 31-year climatology. The company, DTN, is the vendor of this numeric weather prediction information. The dead fuel moisture at multiple time lag classes and live fuel moisture is derived from coupling the weather and climatology to fuel moisture models developed by Atmospheric Data Solutions (ADS). New measures of live fuel moisture were added as features to the FPI Model and are sourced from Technosylva. These take advantage of remote sensing to estimate the amount of available moisture in woody and herbaceous plant species.

Topography characteristics of terrain ruggedness, slope, and wind-terrain alignment were also evaluated and added as features for the FPI Model. These features are derived from USGS 30m Digital Elevation Models. Terrain ruggedness, which provides a measure of the terrain change in slope and aspect within each 2 x 2 km model grid cell, also proved useful as fire suppression can be impacted by how rugged (or not) the terrain is. The slope is also considered and shows to have a positive effect on fire size where there is existence of steep slopes.

A dynamic wind-terrain alignment factor is computed each hour to provide an assessment of the wind-terrain alignment in each 2 x 2 km grid cell. During Diablo wind events, scientific literature has shown that winds can accelerate down the lee of the terrain feature when the wind flow is perpendicular to terrain. During model testing, a similar pattern emerged, which shows that winds perpendicular to terrain (upslope or downslope winds) have a positive relationship to fire size compared to terrain-aligned (cross slope) winds.

A continuous fuel model type is considered in each 2 x 2 km model grid cell. This information is sourced from Technosylva. The fuel model map baseline is the latest iteration from LANDFIRE but is then enhanced to account for recent burn scars and vegetation regrowth after fires that are not considered in LANDFIRE. The fuel model map resolution is 30 x 30 m. The fuel models are aggregated into six parent fuel type groups of Urban, Grass, Grass-Shrub, Shrub, Timber-litter or Timber-understory. PG&E worked closely with Technosylva fire scientists to consolidate the 40+ fuel model types into these six parent categories. Each fuel type group is a separate feature of FPI and is represented as the fraction of the 2 x 2 km model grid cell that is that fuel type. Each model feature used in the FPI Model is presented in Table PG&E-4.5.1-14 below.

The FPI is a machine learning classification model and outputs the fire growth probability (p) across three fire classes shortly (typically within 12 hours) after an ignition occurs. More detail is found in the FPI methodology section. Thus, for each 2 x 2 km model grid cell every hour, the FPI provides outputs for each class as defined below.

FPI Classification Definitions[70] based on first satellite fire detection area:

- <70 acres – FPI P(Small)
- 70-500 acres – FPI P(Large)
- >500 acres – FPI P(Catastrophic)

[70] These definitions only apply to the FPI classification for fire size as they are based on the fire size shortly after ignition and not final fire size.

TABLE PG&E-4.5.1-14:
FIRE POTENTIAL INDEX MODEL FEATURES

Feature Group	Feature	Altitude	Description	Source	Update Cadence	Spatial Granularity	Temporal Granularity
Weather	Temperature	Surface	Temperature at the surface in Fahrenheit	POMMS	4x per day	2 km	Hourly
Weather	Vapor Pressure Deficit	Surface	Measure of lack of water vapor relative to saturation in millibars	POMMS	4x per day	2 km	Hourly
Weather	Wind Speed (sustained)	Surface	Wind speed at the surface in mph	POMMS	4x per day	2 km	Hourly
Weather	Wind Speed (sustained)	300 m	Wind speed at 300m above surface in mph	POMMS	4x per day	2 km	Hourly
Weather	Friction Velocity (u_*)	Surface	Wind shear stress in velocity terms.	POMMS	4x per day	2 km	Hourly
Weather	Turbulent Kinetic Energy	50 m	Kinetic energy per unit mass observed in eddies characteristic of turbulent flow in Joules/kg	POMMS	4x per day	2 km	Hourly
Fuel Moisture	Dead Fuel Moisture - 1000hr	Surface	1000-hour fuel moisture content	POMMS & ADS	4x per day	2 km	Hourly
Fuel Moisture	Dead Fuel Moisture - 100hr	Surface	100-hour fuel moisture content	POMMS & ADS	4x per day	2 km	Hourly
Fuel Moisture	Dead Fuel Moisture - 10hr	Surface	10-hour fuel moisture content	POMMS & ADS	4x per day	2 km	Hourly
Fuel Moisture	Live Fuel Moisture - Chamise New	Surface	Live fuel moisture content of Chamise (new growth) species	POMMS & ADS	Daily	2 km	Daily
Fuel Moisture	Live Fuel Moisture - Herbaceous	Surface	Live fuel moisture content of herbaceous species	Technosylva	Daily	2 km	Daily

TABLE PG&E-4.5.1-14:
FIRE POTENTIAL INDEX MODEL FEATURES
(CONTINUED)

Feature Group	Feature	Altitude	Description	Source	Update Cadence	Spatial Granularity	Temporal Granularity
Fuel Moisture	Live Fuel Moisture - Woody	Surface	Live fuel moisture content of woody species	Technosylva	Daily	2 km	Daily
Topography	Terrain Ruggedness Mean	Surface	Terrain ruggedness average in POMMS grid cell.	USGS 30m DEM (Digital Elevation Model)	USGS 30m DEM	30 m -> 2km	Static after being updated
Topography	Slope Degree Mean	Surface	Slope of terrain averaged over POMMS grid cell.	USGS 30m DEM	USGS release cadence	30 m -> 2km	Static after being updated
Topography	Wind-Terrain Alignment	Surface	Alignment between wind direction and dominant aspect	POMMS & USGS 30m DEM	4x per day	30 m -> 2km	Hourly
Fuel Type	Urban	Surface	Fraction of fuel category in POMMS grid cell attributed to urban	Technosylva	At least once per year	30 m -> 2km	Static after being updated
Fuel Type	Grass-Shrub	Surface	Fraction of fuel category in POMMS grid cell attributed to grass-shrub	Technosylva	At least once per year	30 m -> 2km	Static after being updated
Fuel Type	Shrub	Surface	Fraction of fuel category in POMMS grid cell attributed to shrubs	Technosylva	At least once per year	30 m -> 2km	Static after being updated
Fuel Type	Timber Litter	Surface	Fraction of fuel category in POMMS grid cell attributed to timber litter	Technosylva	At least once per year	30 m -> 2km	Static after being updated

TABLE PG&E-4.5.1-14:
FIRE POTENTIAL INDEX MODEL FEATURES
(CONTINUED)

Feature Group	Feature	Altitude	Description	Source	Update Cadence	Spatial Granularity	Temporal Granularity
Fuel Type	Grass	Surface	Fraction of fuel category in POMMS grid cell attributed to grasslands	Technosylva	At least once per year	30 m -> 2km	Static after being updated
Fuel Type	Timber Understory	Surface	Fraction of fuel category in POMMS grid cell attributed to timber understory	Technosylva	At least once per year	30 m -> 2km	Static after being updated

4. Modeling assumptions and limitations

The FPI Model requires the requisite input forecast data as described above to produce a forecast each hour. This high-resolution forecast data is currently available with about a 4-5 day ahead forecast horizon. The FPI Model is driven largely from the weather forecasts and will have similar limitations as general weather forecasting.

5. Modeling methodology

The FPI Model was first created in 2015 and has been significantly enhanced in subsequent model versions. For example, the FPI Model was enhanced in 2019 by coupling the weather and fuels data around the ignition of each fire in the USFS's Fire Program Analysis – Fire-Occurrence Database (FPA-FOD). The 2019 version of the FPI Model was trained with a USFS fire occurrence dataset that provided information on each fire, the ignition location and the final fire size. This provided valuable information to train the 2019 FPI Model, but we sought to test if model performance could be improved by utilizing daily to sub-daily fire growth data. For PSPS, we are primarily concerned with those fires that ignite and have a rapid rate of spread shortly after ignition. These fires pose a higher risk to nearby communities than slow spreading fires since populated areas have less time to evacuate.

The end goal was to create an FPI Model that could predict, based on forecasted weather and fuels conditions, the probability of a large or catastrophic fire given an ignition. This FPI Model represents the next evolution that takes advantage of additional model features, an enhanced fire occurrence dataset based on satellite fire detections, and further evolves the machine-learning model approach.

To help build an improved fire occurrence dataset, we partnered with Sonoma Technology, Inc. (STi) to combine historical satellite fire detections with agency fire occurrence datasets to derive sub-daily fire growth statistics. These detections come from high-resolution instruments aboard polar orbiting satellites that can detect fires from their infrared radiance during each pass. The sample rate of these satellites is at least 2 times per day. By leveraging a GIS platform, STi was able to compile satellite data for each pass to determine the amount of fire growth between each pass. The satellite data was combined with agency records from CAL FIRE's Fire and Resource Assessment Program (FRAP), ICS-209 reports, GeoMAC, USFS FIRESTAT, and USFS FPA FOD data sets to provide growth metrics for large, named fires and small, unnamed fires. This new fire occurrence dataset allowed us to train the FPI on fires that show rapid growth shortly after ignition.

The FPI Model leveraged new data sources in the 2 x 2 km weather and fuels climatology as well as the STI enhanced fire occurrence dataset. The goal of this project was to build a more accurate FPI Model that can be used in forecast mode to inform daily and PSPS operations to reduce the risk of utility-caused catastrophic fires.

Data scientists, meteorologists, and fire scientists tested dozens of new model features and various model configurations. Among the model-types tested were logistic regression and multiple machine-learning model types. Model results were tested using a train-test split ratio of 70 percent-30 percent. This involved training the model with 70 percent of the input data and testing predictions against the remaining 30 percent.

The FPI Model is a Multi-Classification Balanced Random Forest Machine Learning model which was selected based on model fit and performance. Random Forest models like other decision tree frameworks, models non-linearities and interactions of the features.

The FPI Model predicts how fast a fire will grow shortly after an ignition, should one occur. Fires that were observed to grow >500 acres based on the first satellite fire detection ultimately grow on average, to a final fire size of ~20,000 acres. Some of the fires observed to grow the fastest based on the first satellite detection are the Zogg, Tubbs, Atlas, Camp, and Kincade fires, which were all observed to grow >9,000 acres in the first day after ignition.

6. Model uncertainty

Please see (7) below which provides model verification statistics.

7. Model verification and validation

The FPI Model was validated statistically and climatologically by reviewing results for past fires. Model results were tested using a train-test split ratio of 70 percent-30 percent. This involved training the models with 70 percent of the input data and testing predictions with the remaining 30 percent. The performance metric utilized was the Area Under the Receiver Operating Characteristic (ROC AUC or AUC), which is widely used to evaluate classification models. AUC is a performance metric designed to test the model's ability to discriminate between cases that were correctly classified (positive examples) and versus non-cases (negative examples).[71] The FPI Model's ability to classify fires that grow >500 acres, yielded an AUC score of 0.88. For comparison, the previous FPI Model (2019 - 2020) yielded an AUC score of 0.71.

The FPI Model was also evaluated against past catastrophic fires using historical weather data matched in both time and space for each fire. With the class separation at 70 and 500 acres, the FPI performs well, differentiating between the natural categories of fires: catastrophic fires with a high rate of spread—typical of wind-driven events, large fires with low to moderate rate of spread, and small fires.

Scatter plots are presented below to show FPI Model output compared to the final fire size (top) and fire size shortly after ignition as measured by the first satellite detection (bottom). The fire size at the first satellite fire detection of a fire from the Visible Infrared Imaging Radiometer Suite (VIIRS), typically within first 12 hours or less of the start of the fire, is shown in these figures to illustrate those fires with high rate of spread shortly after ignition. This data includes all fires in the PG&E service territory regardless of cause.

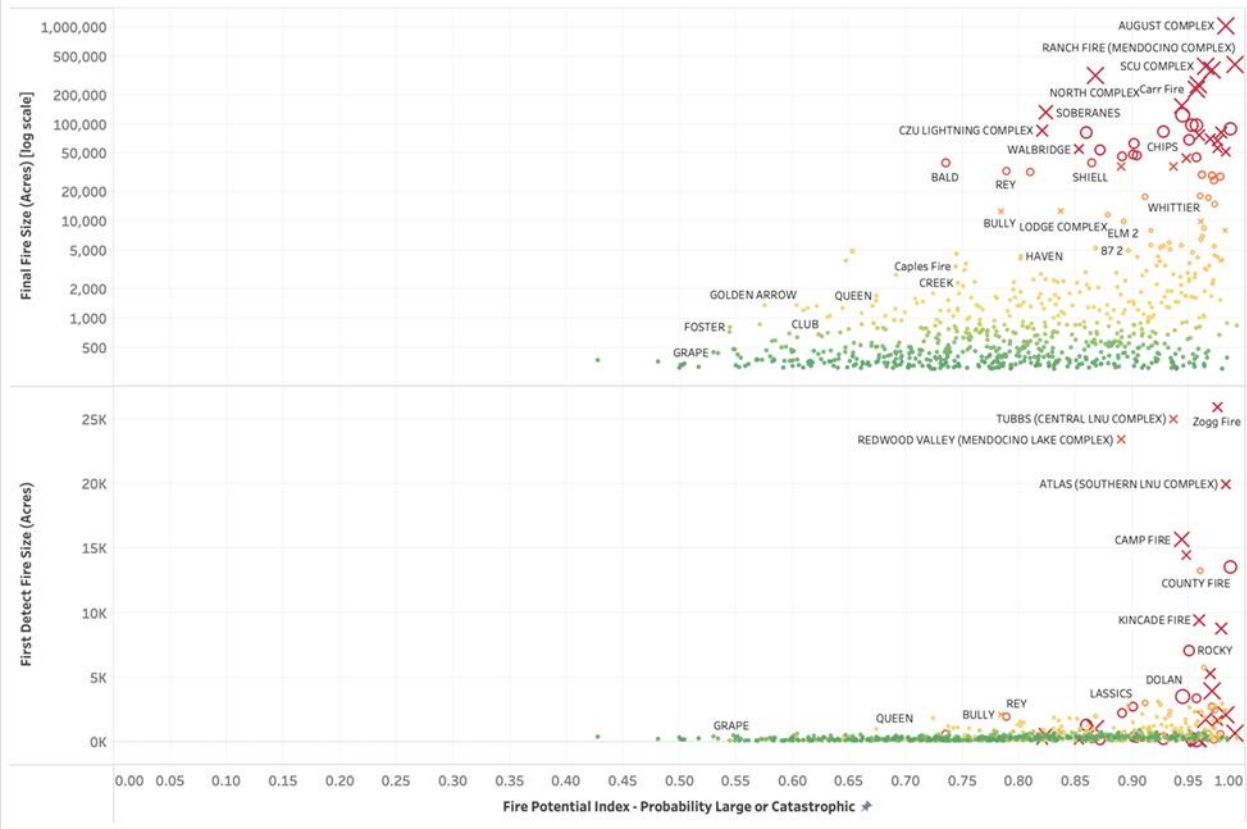
Two sets of scatter plots are also provided. The first, Figure PG&E-4.5.1-15, shows the FPI Model output of probability large or catastrophic for each fire, where P(Large or

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[71] Generally, an AUC score of 1 is a perfect model, scores above 0.8 are considered to have excellent performance, while scores near and above 0.70 are considered to have good performance. A model with no skill has an AUC score of less than 0.5.

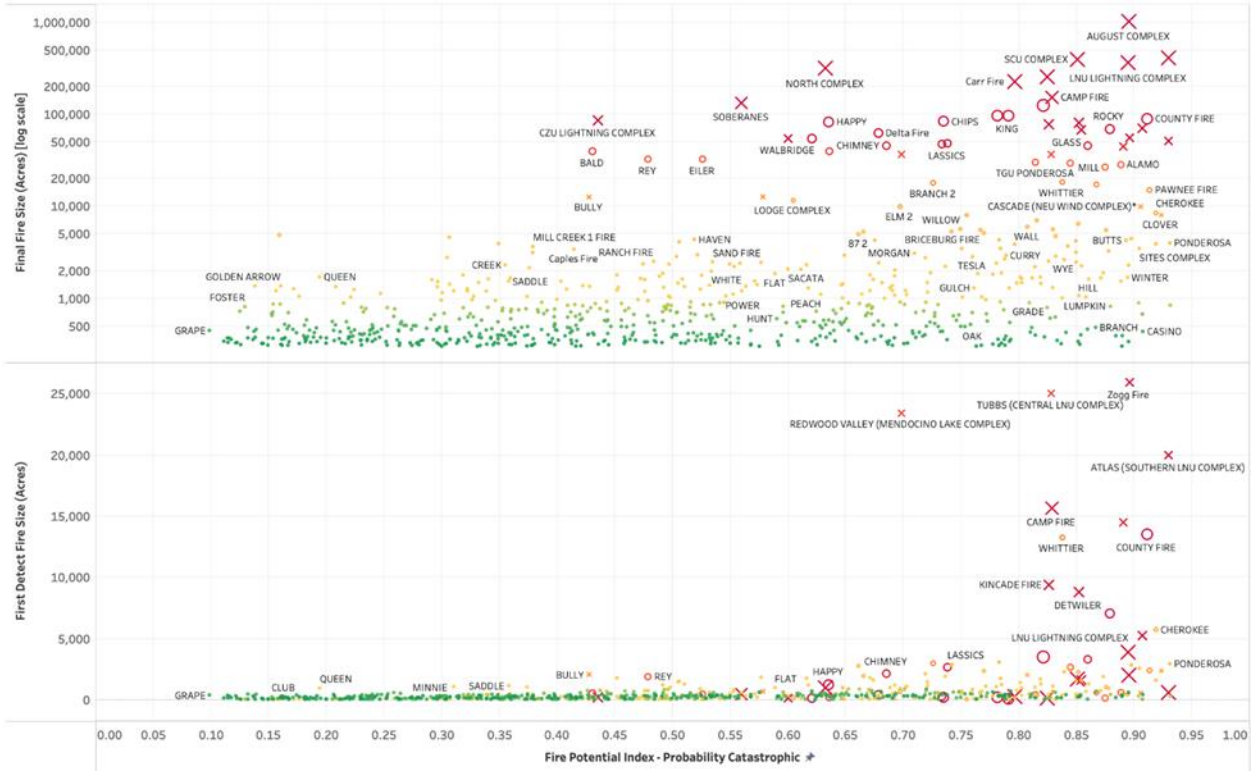
Catastrophic) = P(Large) + P(Catastrophic). Note that many destructive and catastrophic fires of the past (including the Zogg, Tubbs, Camp, Atlas, and Kincade) have values near the top of the range (maximum value of 1). The second set of scatter plots, Figure PG&E-4.5.1-16, shows the FPI probability catastrophic class for each fire, P(Catastrophic). This scatter plot is provided to illustrate how the FPI classification model multi-classification approach is able differentiate between those fires with rapid rate of spread shortly after ignition through P(Catastrophic), and large fires with low to moderate rates of spread through P(Large or Catastrophic). Note that many destructive and catastrophic fires of the past including the Zogg, Tubbs, Camp, Atlas, and Kincade, have FPI P(Catastrophic) values >0.8.

FIGURE PG&E-4.5.1-15:
FPI P(LARGE OR CATASTROPHIC) FOR FIRES VS THE FINAL FIRE SIZE (TOP) AND THE FIRE SIZE AT FIRST SATELLITE FIRE DETECTION ONLY (BOTTOM)



Note: For fires of any cause >300 acres from 2012-2020, compared to the size of the fire based on the final fire size (top) [log scale for clarity] and the fire size at the first satellite fire detection (bottom). Colored by final fire size, and shape of X given to those fires that resulted in a fatality or destroyed more than 50 structures, and shape O otherwise.

FIGURE PG&E-4.5.1-16:
FPI P(CATASTROPHIC) ONLY FOR FIRES VS THE FINAL FIRE SIZE (TOP) AND THE FIRE SIZE AT FIRST SATELLITE FIRE DETECT ONLY (BOTTOM)



Note: For fires of any cause >300 acres from 2012-2020, compared to the size of the fire based on the final fire size (top) [log scale for clarity] and the fire size at the first satellite fire detection (bottom). Colored by final fire size, and shape of X given to those fires that resulted in a fatality or destroyed more than 50 structures, and shape O otherwise.

8. Modeling frequency

The FPI Model is refreshed when new weather and fuel moisture outputs are available. These outputs are updated four times per day.

9. Timeline for model development

The FPI Model has been updated, on average, every two years after it was first developed in 2015. The latest model version was operationalized in 2021.

10. Application and results

The FPI Model outputs the probability from 0 – 1 (or 0 to 100 percent) that a fire will be one of the three fire classes of small, large, or catastrophic (see classification definitions above). The FPI Model is run hourly on the same model domain as the POMMS weather and Ignition Probability Weather Model (IPW Model).

For PSPS applications, the FPI P(Catastrophic) is used as input into the PSPS decision-making framework together with IPW Model at a 2 x 2 km resolution. For daily operational decisions and applications, the FPI P(Large) plus FPI P(Catastrophic) is categorized into ratings and spatially aggregated by geographic areas called “Fire Index Areas (FIAs)” to represent the highest level of fire potential in that area per day—see Figure PG&E-4.5.1-17 and Figure PG&E-4.5.1-18 for examples of the FPI output.

The FPI P(Large) plus FPI P(Catastrophic) is translated onto a fire danger rating scale from R1 (low) to R5 (extreme) based on breakpoints. These breakpoints were established by reviewing climatological percentiles as well as FPI output for historic fires in the PG&E territory from 2008 – 2020. This methodology is identical to how federal agencies translate numeric outputs of the National Fire Danger Rating System to a fire adjective rating (e.g., “low” or “extreme”). These daily ratings are used by field crews and operators to mitigate the potential for utility-caused wildfires. These mitigation actions are discussed in Utility Standard TD-1464S, Preventing and Mitigating Fires While Performing PG&E Work. The FPI rating of “R5-Plus” is issued when a PSPS event is likely. This is utilized to not only illustrate that PSPS is possible in these areas, but to differentiate between R5 driven by the high FPI and R5 coupled with increased probability for utility outages and ignitions during strong wind events.

FIGURE PG&E-4.5.1-17:
EXAMPLE OUTPUT FROM THE PG&E UTILITY FPI WEB APPLICATION

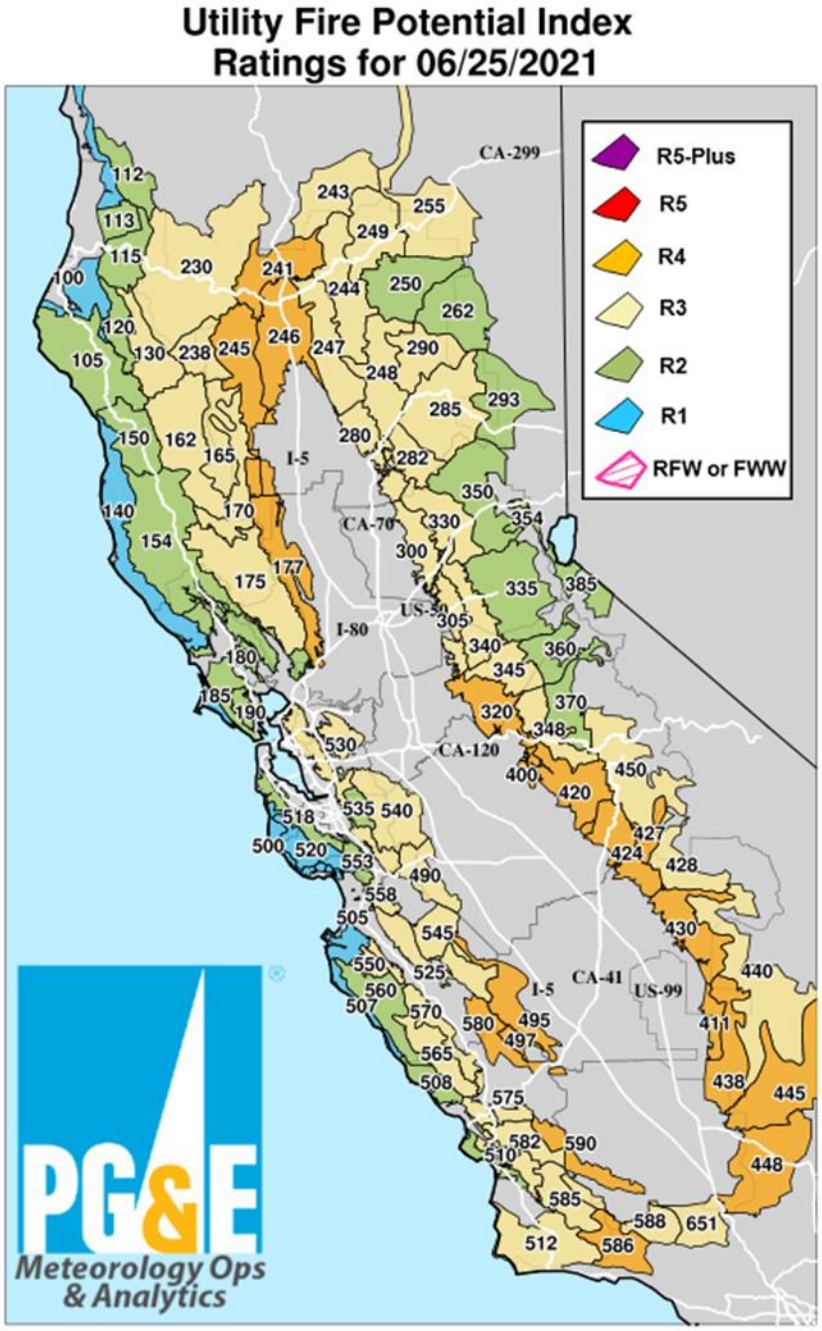
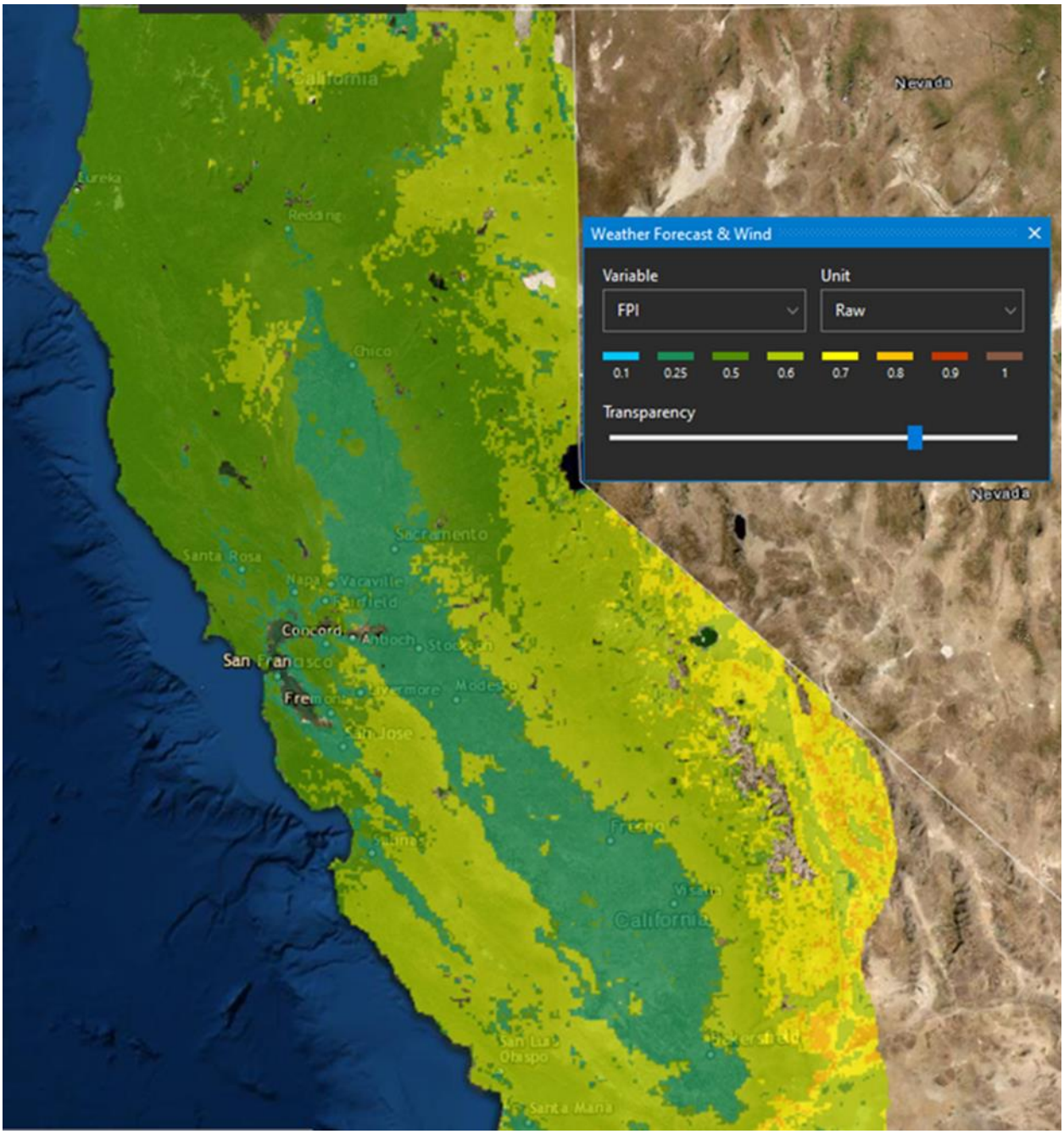


FIGURE PG&E-4.5.1-18:
EXAMPLE OUTPUT FROM THE PG&E UTILITY FPI WEB APPLICATION



11. Key improvements from working group

No recommendations have been provided from the Wildfire Risk Modeling Working Group to date for the FPI Model.

4.5.1(g) Ignition Probability Weather Model

1. Purpose of model

The Ignition Probability Weather (IPW) Model is used in unison with the FPI Model to assess the need for a PSPS event. A PSPS event may be initiated when there is a high probability of utility caused ignitions (IPW) combined with a high probability of catastrophic fires (FPI) in both space and time.

2. Relevant terms

- 2021 Outage Probability Weather (OPW) Model – A machine learning model that outputs the probability of outage by cause (e.g., vegetation) as a function of weather.

- PG&E Operational Mesoscale Modelling System (POMMS) – A configuration of the Weather Research and Forecasting model. A numerical weather prediction model.

3. Data elements

The weather variables used to train the IPW Model include wind speed at 10m and 50m, turbulent kinetic energy at 50m, friction velocity, vapor pressure deficit at 2m, temperature at 2m, and precipitation. The aerial LiDAR tree overstrike for each tree is summed per 2 x 2 km grid cells to provide the IPW Model with a measure of tree density and risk in each grid cell. The “node” is a key categorical variable that allows the model to learn outage trends specific to each location that is not otherwise explained (e.g., due to asset condition, vegetation stress, materials, soils, cars, balloons, animals, and other exogenous factors). The IPW Model features are described below in Table PG&E-4.5.1-15.

TABLE PG&E-4.5.1-15:
IPW MODEL FEATURES

Predictor	Altitude	Description	Source	Update Cadence	Spatial Granularity	Temporal Granularity
Temperature	Surface	Temperature at the surface in Fahrenheit	POMMS	4x per day	2 km	Hourly
Wind Speed (sustained)	Surface	Wind speed at the surface in mph	POMMS	4x per day	2 km	Hourly
Wind Speed (sustained)	50 m	Wind speed at 50m above surface	POMMS	4x per day	2 km	Hourly
Vapor Pressure Deficit	Surface	Measure of lack of water vapor relative to saturation in millibars	POMMS	4x per day	2 km	Hourly
Turbulent Kinetic Energy	50 m	Kinetic energy per unit mass observed in eddies characteristic of turbulent flow in Joules/kg	POMMS	4x per day	2 km	Hourly
Friction Velocity (u_*)	Surface	Wind shear stress in velocity terms.	POMMS	4x per day	2 km	Hourly
Precipitation	Surface	Precipitation in mm per hour	POMMS	4x per day	2 km	Hourly
Tree Overstrike	Surface	The length in ft of tree overstrike. Overstrike is calculated by measuring the tree's point of contact on a conductor to the top of the tree if it were to fall directly towards the conductor.	Vegetation Management Aerial LiDAR	Updated when new Aerial LiDAR data is available	Point tree data, aggregated to 2 km	Static until next Aerial LiDAR update

4. Modeling assumptions and limitations

The IPW Model requires the requisite input forecast data as described above to produce a forecast each hour. This high-resolution forecast data is currently available with about a 4-5 day ahead forecast horizon. The IPW Model is driven largely from weather forecasts and will have similar limitations as general weather forecasting.

5. Modeling methodology

The IPW Model represents the next generation of distribution outage and ignition probability models building on the 2020 OPW Model previously discussed in the 2021 WMP, Section 4.2.A. The core IPW Model is a new multi-classification outage model, that now can forecast outage probability by specific outage causes. The probability of outage output for each class is transformed to an ignition probability (IPW) using outage to ignition rates for each cause class.

The IPW Model is trained on windspeeds and other weather features from our 31-year down-scaled climatology at 2 x 2km resolution and approximately 500,000 sustained and momentary outages occurring on the distribution grid from 2008 to end of 2020. Asset damage and hazards found during PSPS events were also included in the training set. Outages were excluded from the training dataset if they were underground or occurred on non-weather driven major event days, such as fires and earthquakes. The operational application of the IPW Model is forecast four times per day producing 3-hourly outage and ignition probabilities. The model has a forecast horizon of 129 hours ahead at the same 2 x 2 km resolution as POMMS, a configuration of Weather Research and Forecasting model. The enhancements to the IPW Model, which is a Machine Learning non-linear model, multi class, exponential time weight ensemble, represent significant enhancements over the 2020 OPW Model. The end goal was to better model ignition probabilities to inform when PSPS is needed.

The IPW Model is a multi-classification Cat Boost Machine Learning model. It is a state-of-the-art model based on decision trees with advanced categorical feature support.

The IPW Model outputs the probability of five outage classes and a no-outage class for each 2 x 2 km grid cell based on weather variables, tree overstrike per 2 x 2 km grid cell from aerial LiDAR, and a local “node” categorical variable. The five outage classes are: Animal/Third-Party contact, such as cars and balloons; Equipment – Electrical, which includes transformers and fuses; Equipment – Structural, which includes assets, such as poles, cross-arms, connectors, conductors, etc.; Vegetation outages; Unknown; and with the final prediction being No-Outage. The cause classes are presented below.

$$cause\ classes$$
$$= \{\text{Animal/3rdParty}, \text{Equipment Electrical}, \text{ Equipment Structural}, \text{Unknown}, \text{Vegetation}\}$$
$$class\ \in cause\ classes$$

The probability of an outage by class by cell per hour can be represented by:

$$P(Outage_{class,cell,hour})$$
$$= f(wind\ speed_{cell,hour},\ turbulent\ kinetic\ energy_{\ cell,hour}, vapor\ pressure\ deficit_{\ cell,hour},$$
$$temperature_{\ cell,hour}, lidar\ tree\ overstrike_{\ cell}, node).$$

The outage probabilities for each outage class are multiplied by the probability of ignition given outage to determine the utility ignition probability. The IPW Model is represented by:

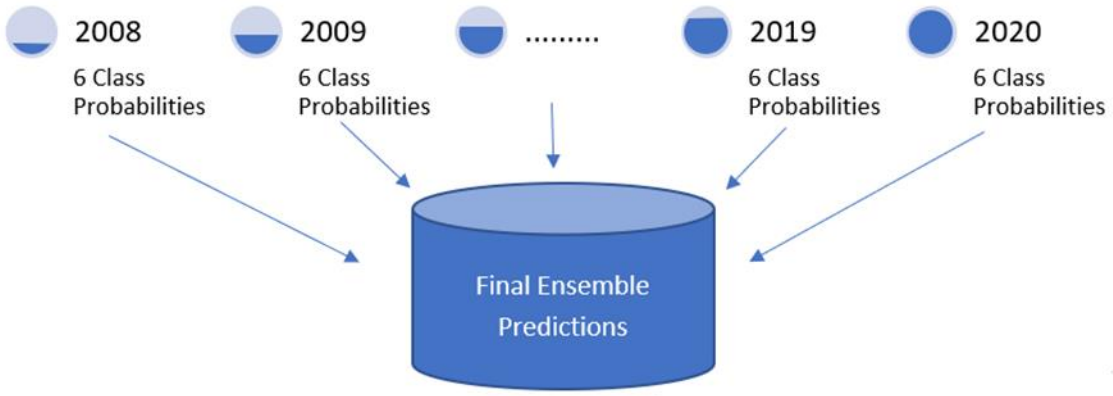
$$IPW = P(utility\ ignition_{cell,hour})$$

$$= \sum_{class}^{cause\ clases} P(Outage_{class,cell,hour}) * P(Ignition_{class}|Outage_{class})$$

The probability of ignition given outage is based on the mean arrival rate of CPUC-reportable ignitions to outages observed from 2015-2020 between May-November excluding weather days that included rain, winter storm, low snow, and lightning, for each of those cause classes. This filter provides the summer to fall outage to ignition ratios to apply to the IPW Model input to the PSPS model. Vegetation cause outage class, for example, has the highest propensity to cause an ignition.

To address positive and negative trends in grid performance and reliability year-over-year, we apply a time-weighted approach to weight current years more heavily in the final model output. The IPW Model is comprised of 13 models trained on each year separately from 2008-2020, and then the class probabilities are combined using a weighted mean with the weight of each model contribution as an exponential weight function (weight $=e^{bt}$ where b is the exponential growth weight we are applying over time in years t from 2008). An optimal b was selected as 0.1 out of a grid search of values based off an evaluation of 2020 prediction using an ensemble model trained with 2008-2019 data. This exponential weighted mean allows changes in local areas to be learned (both negative – increased tree mortality, asset degradation, etc.; and positive – conductor and pole replacement, vegetation management, etc.). A schematic and example formula for P(vegetation outage) is presented below in Figure PG&E-4.5.1-19.

FIGURE PG&E-4.5.1-19:
OUTAGE PROBABILITY WEATHER MODEL ENSEMBLE CONSTRUCTION



6. Model uncertainty

Please see (7) below which provides model verification statistics.

7. Model verification and validation

The 2021 IPW Model was validated statistically and climatologically by testing outage predictions per outage class. The year 2020 and outages from 2020 were withheld from the model training dataset and used to evaluate performance. The performance metric applied was the standard Area Under the Receiver Operating Characteristic (AUC ROC). A strength of the model is predicting the probability in the vegetation cause class, which were also found to have the highest outage to ignition propensity. The AUC ROC score for vegetation-caused outages is 0.81 for example. In post-PSPS event patrols, the majority of damages and hazards found to date have been caused by vegetation. The AUC ROC is reported for each other cause class: Equipment-Structural is 0.69, 3rd-Party-Animal is 0.68, Equipment-Electrical is 0.67, Unknown Cause is 0.64, Negative Class is 0.67, and finally the Macro Average of AUC ROC for all classes is 0.70. Third Party, Animal and Equipment-Electrical and Unknown cause classes are harder to predict cause classes which is reflected in the AUC ROC values.

After model performance was verified on the year 2020, data from 2020 were incorporated into the IPW Model for operations in 2021. The final IPW Model candidate with 2020 included was calculated in hind-cast mode hourly through the 2 x 2 km climatology from 2008-2020. This IPW Model climatology enables evaluation of key historical event days by Operational Meteorologists. Major weather events since 2017 where significant outages and fire ignitions occurred due to weather were evaluated using an interactive event dashboard that allows rapid exploration of model outputs during key days (e.g., 10/8/2017 and 11/8/2018). The dashboard also includes all the PSPS damages and hazards with ability to filter to see individual events by hour. Operational Meteorologists used the dashboard to evaluate model performance against key historical storm events, evaluating timing of weather onset compared to modeled outage probability increases, and relative magnitude of outage probabilities.

8. Modeling frequency

The IPW Model is refreshed when new weather outputs are available. These outputs are updated four times per day.

9. Timeline for model development

PG&E first deployed the OPW Model in 2019, which was used to forecast the probability of an outage based on wind speed. In 2020, the OPW Model was enhanced from the ground up. The 2020 OPW Model was more granular and had the ability to run on the new 2 x 2 km weather model grid. The model was trained on both sustained and momentary outages, as well as damages and hazards found in 2018 and 2019 PSPS events. During the 2021 model development, we wanted to bridge the gap between outages and ignitions and leveraged our CPUC-reportable ignitions to achieve this goal. The 2021 IPW Model version represents the next generation of distribution outage and ignition models building on the 2020 OPW Model.

10. Application and results

For PSPS applications, the IPW Model is used as input into the PSPS decision-making framework together with FPI Model at a 2 x 2 km resolution.

11. Key improvements from working group

No recommendations have been provided from the Wildfire Risk Modeling Working Group to date on the IPW Model.

4.5.1(h) Transmission Operability Assessment Model

1. Purpose of model

The Transmission Operability Assessment Model or OA Model provides probability of failure of transmission line assets (at a structure level) in windy conditions. The OA Model is primarily used to scope Electric Transmission PSPS events but also provided input for 2022 enhanced inspection and maintenance planning. During PSPS events, the OA Model is combined with the FPI Model and the WFC Model to inform transmission line de-energization decisions.

PG&E discussed the OA Model in detail in our 2021 WMP, Section 4.5.1(f).

2. Relevant terms

- Bayesian updating – A methodology by which the wind-based asset strength and uncertainty estimation provided by the OA Model is continuously improved as additional outage data is received (typically on a yearly cadence). In this manner, the OA Model works to maintain relevancy by incorporating new data in the form of newly-reported failures and survivals of transmission assets subjected to windy conditions.

- Fragility curve – Represents the probability of failure for any value of a demand parameter.

- Input data – Any dataset that is fed into the OA model and used as a means of calculating the OA probability of failure (Pf). The input datasets to the OA model are detailed in Section 3. Data elements

- Probability of failure (Pf) – A calculated likelihood that an electric transmission asset (structure or related component) will fail at a given windspeed from 1 to 120 MPH.

- Transmission asset – Any component of the electric transmission system such as, the primary structure (tower or pole); crossarms; hangers; insulators; conductor wire; foundation; guy wires; and support structures.

3. Data Elements

Table PG&E-4.5.1-16 provides details on the data the OA Model takes as inputs to the probability calculations.

TABLE PG&E-4.5.1-16:
OA MODEL DATA ELEMENTS

Input Data	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity	Description
PLS-CADD	2019 - present	Bi-monthly	N/A	Bi-monthly	Advanced analysis of assets
Corrosion	2020 - present	Yearly	N/A	Daily	Air and soil* corrosivity factors
Inspection results	2019 - present	Daily	N/A	Daily	Current condition of assets
Outage	2007 - present	Yearly	N/A	Daily	Historical outages and causes
Structure details	1899 - present	Daily	N/A	Daily	Age, material, GIS
Pole test and treat	2006 - present	Yearly	N/A	Daily	Wood pole analysis
Repairs	2019 - present	Daily	N/A	Daily	Repair details
Asset feature list data	2021 - present	Once	N/A	Daily	Enhanced asset records
Bayesian updating	2019 - present	Yearly	N/A	Daily	Historical data
Wind gust percentile	2019 - present	Yearly	N/A	Daily	Wind gusts data
Wind speed analysis	2019 - present	Yearly	N/A	Daily	Analyzed wind data
Structure material	2019 - present	Yearly	N/A	Daily	Analyzed structure data

4. Modeling assumptions and limitations

The OA Model employs the same modeling framework as the WTRM that is outlined in Section 4.5.1(c) above. The key difference is that the OA Model is an operational model which produces the probability of failure for conditions at a given time and the WTRM is a planning model that provides an annual probability.

The OA Model relies on varying types of input data and on real-world-representative equations to calculate accurate and usable fragility curves. The input data to the OA Model has expanded each year since program inception (2019). This allows the model to calculate physical world threats to the electric transmission infrastructure, such as corrosion, but the model is limited by the data available.

5. Modeling methodology

The OA Model computes an asset-based fragility (probability of failure due to wind gust speed) by quantitatively assessing the condition (or health) of transmission structures and components and accounting for known degradation mechanisms. Probability is calculated based on an asset fragility curve that is a function of windspeed. Asset failure curves are adjusted from “brand new” based on various factors such as inspection condition, age, environment, and previous performance.

6. Model uncertainty

The uncertainty, or dispersion, aspect of the asset-based fragilities is handled by various uncertainty terms that include age and environmental factors, such as

atmospheric corrosion, below grade corrosion, wear, fatigue, outage density (the prevalence of historical outages), splice density (the prevalence of conductor splices), and Bayesian Updating. Uncertainty can be pictured as a change in the shape of the fragility curve—higher uncertainty can be pictured as a "flattening" of the fragility curve and, therefore, an increase in the range of wind gust speeds over which probability of failure values are nontrivial.

7. Model verification and validation

For transmission, the OA Model methodology is derived from the performance-based engineering framework supported by the Pacific Earthquake Engineering Research (PEER) program, which is a consortium of research and industry experts who have extensively published peer-reviewed technical papers related to this topic. PG&E SMEs reviewed the OA Model methodology in numerous meetings and workshops, where the nature, purpose, and preliminary outcomes of the model were discussed. An independent, external review was also performed by experts in probabilistic engineering analysis with the B. John Garrick Institute for Risk Sciences at UCLA.

Best practices from data science and software development were employed to integrate the OA Model methodology into Python and Power BI. These best practices included code peer review, automated scripts that compare the model outputs from two independent systems, and automated unit tests of the code for repeatable validation.

Updates and enhancements to the OA Model go through the same review and validation processes, with the additional step of PG&E's transmission consultant preparing a delta study that identifies the impact of these updates or enhancements on the model outputs. OA Model documentation, including the technical basis of the methodology, is maintained by the Transmission OA team.

8. Modeling frequency

The OA Model updates daily for use in PSPS events.

9. Timeline for model development

The OA Model was initiated in 2019 and is continuously updated/enhanced each year in preparation for fire season. Planned 2022 enhancements to the OA model include updated conservative age assumption logic, updated Bayesian updating, enhanced below-grade corrosion modeling, and the incorporation of flashover probabilities. Additional use of PLS-CADD modeling data will also be incorporated, which is also discussed in Section 7.3.4.8.

10. Application and results

The OA Model is primarily used for transmission line de-energization guidance for PSPS events but aspects of the model were also used in the transmission 2022 enhanced inspection and maintenance planning.

11. Key improvements from working group

No recommendations have been provided from the Wildfire Risk Modeling Working Group to date on the OA Model.

4.5.1(i) PSPS Consequence Model

1. Purpose of model

The purpose of the PSPS Consequence Model is to represent the spatial/circuit variation in PSPS consequence and to prioritize PSPS mitigation efforts in high-risk locations based on frequency, customer, and duration of PSPS impact. This more granular model will help assess the impacts of PSPS de-energizations in support of making PSPS mitigation planning decisions based on lookback analysis.

PSPS is used as a measure of last resort, is called as a proactive and protective measure to prevent potential ignitions which could cause catastrophic wildfires. As a result of a PSPS event, circuits or circuit segments are de-energized, meaning that customers will be without power until critical fire weather conditions subside. The PSPS Consequence Model quantifies these consequences and aggregates to the circuit level, differentiating between the consequence driven by distribution system scoped impact or transmission system scoped impact.

In Q4 2021, PG&E refreshed the model to take into account the 2021 lookback, as well as develop more granular modelling results at the circuit segment level to support PG&E Remedy 21-05, described in Section 4.6.

2. Relevant terms

- Customer Minutes Interrupted (CMI) – The number of minutes a customer is without service during a PSPS event.

3. Data elements – Details of data elements used for analysis. Including at minimum the following:

In Table PG&E-4.5.1-17 below, we provide the data elements of the PSPS Consequence Model:

TABLE PG&E-4.5.1-17:
PSPS CONSEQUENCE MODEL DATA ELEMENTS

Data Element	Description
Enterprise Risk Model – PSPS Overall System	Calculates the overall PSPS Consequence Score using the Enterprise Risk Model. This uses the same PSPS historical lookback data but uses a Monte Carlo simulation based on probability distributions as described in Section 4.2. This leads to slightly different MAVF scores at the overall system level. As such, the ERM calibrates this PSPS Consequence Model to consistent MAVF score at a more granular level.
2020 PSPS Historical Lookback	Dataset that provides a 10-year historical lookback of possible PSPS events determined based off 2020 PSPS protocols. These protocols represent the guidelines from meteorology on the criteria to initiate PSPS, as well as the representation of the system configuration (e.g., sectionalization devices) at that point in time Information includes circuits, total customers impacted, and duration for specific events for transmission and distribution circuits. This primary data is used to estimate distribution and transmission consequence at the circuit level.
2021 PSPS Historical Lookback	Dataset that provides a 11-year historical lookback of possible PSPS events determined based off 2021 PSPS protocols. These protocols represent the guidelines from meteorology on the criteria to initiate PSPS, as well as the representation of the system configuration (e.g., sectionalization devices) at that point in time Information includes circuits, total customers impacted, and duration for specific events for transmission and distribution circuits. This primary data is used to estimate(?) consequence at a circuit isolation zone level.
Customer Classification and Weighting	Weighting assessment by customer classifications to adjust consequence and prioritization for critical customers based on the SME feedback Data set includes customer classifications from customer care & billing (CC&B), aggregated at the circuit level.

a. Scope and granularity (or, resolution) of data in time and location (i.e., date range, spatial granularity for each data element, see example table above).

The results of the PSPS Consequence Model is as granular as at the Service Point Identification, or customer meter level, and can be aggregated all the way up to a circuit isolation zone, circuit segment, circuit, or PG&E system level. The input data set is evaluated back through 2010-2021 and represents best available view of consequence looking forward into 2022 onwards.

b. Explain the frequency of data updates.

Frequency of data updates is based on when new lookbacks are created, typically after a significant change in PSPS protocols. In 2021, PG&E updated our PSPS protocols and lookback, which is referred to as 2021 historical lookback, and PG&E updated this model to capture the data refresh, in support of activities for PG&E Remedy 21-05 discussed in Section 4.6.

c. Sources of data. Explain in detail measurement approaches.

See Table PG&E-4.5.1-17.

d. Explain in detail approaches used to verify data quality.

Most of the data quality verification occurs during the lookback dataset development. As part of this model specifically, data quality is verified by taking a top-down vs a bottom-up approach. PG&E employs the top-down approach by calculating the risk scoring using the ERM to estimate the overall PSPS consequence score in the form of MAVF units. From a bottom-up approach, PG&E calculates the MAVF score of each individual lookback event and aggregating the results across the lookbacks to represent a bottom up MAVF score. This is to verify that the high level estimates of PSPS consequence is similar to the results by aggregating the consequence scores of each circuit isolation zone.

e. Characteristics of the data (field definitions/schema, uncertainties, acquisition frequency).

See Table PG&E-4.5.1-17.

f. Describe any processes used to modify the data (such as adjusting vegetative fuel models for wildfire spread based on prior history and vegetation growth).

Not applicable

4. Modeling assumptions and limitations

A variety of assumptions are used in the PSPS Consequence Model to facilitate calculations. A list of assumptions used in calculating consequence scores is provided below in Table PG&E-4.5.1-18, where these assumptions directly impact the results of the model:

TABLE PG&E-4.5.1-18:
PSPS CONSEQUENCE MODEL CONSIDERATIONS

Risk Type	PSPS Risk Modeling Considerations
Safety	Consequence score calculated based on estimated Equivalent Fatalities (EF) due to a PSPS event. EF calculated based on a ratio of Equivalent Fatalities (EF) per million Customer Minutes Interrupted (MCMI), as estimated from previous PG&E PSPS and other large external outage events.[(a)] Customer Minutes Interrupted (CMI) calculated using circuit estimates for number of customers impacted and expected duration of de-energization for a PSPS event.
Reliability	Consequence score calculated using CMI circuit estimates for number of customers impacted and expected duration of de-energization.
Financial	Consequence score calculated based on two financial cost estimates of a PSPS event: (1) distribution of a lump sum cost of execution across all relevant circuits; and (2) an estimated proxy cost per customer per PSPS event.

(a) Previous PG&E PSPS events include 2019-2020 events, and other large external outage events include 2003 Northeast Blackout in New York City, 2011 Southwest Blackout in San Diego, 2012 Derecho Windstorms, 2012 Superstorm Sandy, and 2017 Hurricane Irma.

Limitations for the PSPS Consequence Model result from the fact that the model is based off of historical lookback of what our PSPS protocols would be.

5. Modeling methodology

The PSPS Consequence Model involves estimating: (1) potential PSPS consequence at the system level, 2) PSPS circuit level and transmission level consequence, and (3) Customer Adjusted Consequence Scores and any other necessary data used in the calculations.

1. The PG&E Enterprise Risk Model utilizes the MAVF framework, as defined through the S-MAP. The tool's calculations for risk use an industry-wide standard MAVF, with a non-linear scaling of consequences reflecting PG&Es focus on low-frequency/high-consequence risk events without neglecting high-probability/low-consequence risk events. The MAVF is a unitless number that captures the safety, reliability, and financial impact of identified potential risk events. Once the consequence values (safety, reliability, financial) are estimated, they are converted into MAVF risk scores as defined through our RAMP and 2023 GRC[72] filings.

[72] Full details of the MAVF methodology are provided through the RAMP Report, pp. 3-3 to 3-15 and 2023 GRC workpapers in response to Energy Division GRC-2023-PhI_DR_ED_001_Q01Supp01.

2. Described below are the primary modeling equations used to estimate the consequence values:

PSPS Potential Electric Reliability Consequence:

$$Customer\ Minutes\ Interrupted = [Duration\ of\ Outage] * [Number\ of\ Customers\ Impacted]$$

PSPS Potential Safety Consequence:

$$EF_{PSPS} = \frac{(Customer\ Minutes\ Interrupted) * \left(\frac{Equivalent\ Fatalities}{MCMI}\ ratio\right) * \left(\frac{Number\ of\ Customer\ Meters}{Population\ Impacted}\ ratio\right)}{1{,}000{,}000}$$

PSPS Potential Financial Consequence:

$$WF\ Financial\ Cost\ (Projected) = \frac{Cost\ of\ Execution}{Number\ of\ Circuits\ in\ PSPS\ Event} + ((Number\ of\ Customers) * (Projected\ Cost/Customer))$$

The process to estimate consequence scores for distribution and transmission events at the circuit level results in the ability to rank and prioritize circuits. Both distribution and transmission customer durations are calculated separately to recognize the distinct levels of consequence and mitigation strategies. Since distribution and transmission events pose different consequence onto the system, it is necessary to delineate between the number of customers and duration between these event types.

Described below are the primary modeling equations used to estimate distribution and transmission outage durations, consequence percentages, and consequence scores:

Outage Duration:

$$Dx\ Only\ Outage\ Duration = Distribution\ Customers * Event\ Duration$$

$$Tx\ Only\ Outage\ Duration = \ Transmission\ Customers * Event\ Duration$$

If customer is impacted by Tx and Dx, the consequence would not be double counted but the consequence would be allocated between Tx and Dx.

$$Dx\ Component\ Outage\ Duration = \ 0.5 * Distribution\ Customers * \ Event\ Duration$$

$$Tx\ Component\ Outage\ Duration = \ [(0.5 * Distribution\ Customers) + (Transmission\ Customers - Distribution\ Customers)] * Event\ Duration$$

Consequence %:

$$Distibution\ Consequence\ \% = \frac{Distribution\ Customer\ Duration}{Total\ Customer\ Duration} * 100\%$$

$$Transmission\ Consequence\ \% = \frac{Transmission\ Customer\ Duration}{Total\ Customer\ Duration} * 100\%$$

Consequence Score:

$$Total\ Circuit\ Consequence\ Score = \frac{(Circuit\ Customer\ duration\ )}{(Total\ Customer\ Duration)} * (PSPS\ Consequence\ Score)$$

$$Dx\ Consequence\ Score$$

$$= Distribution\ Contribution\ \%\ per\ circuit\ * Total\ Consequence\ Score\ per\ circuit$$

$$Tx\ Consequence\ Score$$

$$= Transmission\ Contribution\ \%\ per\ circuit\ * Total\ Consequence\ Score\ per\ circuit$$

The PSPS Consequence Model uses customer classification and weighting information to calculate an adjusted MAVF consequence score at the circuit level needed to re-prioritize circuits based on the customer types that reside on a specific circuit. Described below are the primary modeling equations used to estimate adjusted consequence scores, and distribution and transmission circuit consequence scores:

Attribute Adjustments:

Safety: $(Total\ Customers\ per\ Event + Critical\ Customer\ Weighted\ Count) * Average\ Customer\ Duration$

Reliability/ Financial: $(Total\ Customers\ per\ Event) * Average\ Customer\ Duration$

Consequence Score:

$$Critical\ Customer\ Adjusted\ Consequence\ Score$$

$$= (Safety * 6\% + Reliability * 92\% + Financial * 2\%)$$

$$Customer\ Adjusted\ Circuit\ Factor = \frac{Customer\ Adjusted\ Consequence\ Score\ @\ Circuit}{\sum Customer\ Adjusted\ Consequence\ Score}$$

$$Adjusted\ Customer\ Circuit\ Score$$

$$= Customer\ Adjusted\ Circuit\ Factor\ X\ ERM\ PSPS\ Consequence\ Score\ (2195)$$

$$Dx\ Circuit\ Risk\ Score = Adjusted\ Customer\ Consequence\ Score\ X\ Distribution\ Consequence\ \%$$

$$Tx\ Circuit\ Risk\ Score = Adjusted\ Customer\ Consequence\ Score\ X\ Transmission\ Consequence\ \%$$

6. Model uncertainty

Model uncertainty is based purely on the impacts from the PSPS lookback. Any uncertainty relates back to uncertainty with the PSPS lookback.

7. Model verification and validation

As our meteorology team develops PSPS protocols and doing a lookback analysis, as part of their validation and verification, they are looking at historical events to decide if it makes sense based on these conditions.

8. Modeling frequency

The PSPS Consequence Model is updated annually when new PSPS lookback information is available.

9. Timeline for model development

Similar to what was provided in Section 4.6, PG&E Remedy 21-05:

In developing the PSPS Consequence Model, we were able to achieve the following milestones as shared in the Progress Report:

- October 2021: Finalization of 2021 Circuit Segment List
- November 2021: Finalization of 2021 PSPS protocol historical lookback
- December 2021: Overlay the 2021 Circuit Segments with the 2021 historical lookback
- January 2022: Finalization of PSPS risk scores at the circuit segment level.

As of January 2022, PG&E is in the process of sharing the results with stakeholders and management to help validate the results of the PSPS Consequence Model. Once validated and approved, PG&E plans to use this model to support the development of 2023+ workplans, especially for the undergrounding initiative, which would consider both risk reduction from wildfire and PSPS. PG&E anticipates updating the PSPS Consequence Model annually, subject to the timing and availability of either new PSPS lookback data and/or refreshed circuit segment designations. Additionally, PG&E continues to share developments during joint IOU working groups, and any actionable feedback for adjustments would drive further modelling developments.

10. Application and results

PG&E is using this model into our quantification of risk reduction and RSE in support of Table 12 in Attachment 2022-07-26_PGE_22_RNR_R1_Section 7.3.a_Atch01. Overall, PG&E is in the process of utilizing this model into planning for PSPS reduction programs, like informing locations for our undergrounding initiative.

11. Key improvements from working group – For each model, describe changes which have been implemented as a result of wildfire risk modeling working group discussions. Provide a high-level summary of recommendations from the wildfire risk modeling working group.

No recommendations have been provided by the Risk Modeling Working Group that impact the PSPS Consequence Model.

4.5.2 Calculation of Key Metrics

Report details on the calculation of the metrics below. For each metric, a standard definition is provided with statute cited where relevant. The utility must follow the definition provided and detail the procedure they used to calculate the metric values aligned with these definitions. The utility must cite all data sources used in calculating the metrics below. In addition, the utility must include GIS layers showing Red Flag Warning (RFW) frequency and High Wind Warning (HWW) frequency (use data from the previous five years, 2016-2021), as well as GIS layers for distribution of Access Functional Need (AFN) customers, and urban/rural/highly rural customers, and disadvantaged communities[73] *in its service territory.*

1. *Red Flag Warning overhead circuit mile days – Detail the steps to calculate the annual number of red flag warning (RFW) overhead (OH) circuit mile days. Calculate as the number of circuit miles that are under an RFW multiplied by the number of days those miles are under said RFW. Refer to the National Weather Service (NWS) Red Flag Warnings. For historical NWS RFW data, refer to the Iowa State University archive of NWS watch/warnings.*[74] *Detail the steps used to determine if an overhead circuit mile is under a RFW, providing an example of how the RFW OH circuit mile days are calculated for a RFW that occurred within the utility service territory over the last five years.*

RFWs are issued by the NWS in defined fire zones (https://www.weather.gov/gis/FireZones). These zones are different from the typical NWS public forecast zones. Because fire zones are used by the NWS for issuing RFWs, overhead circuit miles were calculated by the PG&E GIS team for each of the NWS fire zone polygons that intersect and are within the PG&E service territory. Then, RFW days for each year and/or quarter were calculated for each fire zone. A RFW day is defined as the number of days that a RFW was valid from issue date to expiration date. For example, if a RFW lasted for 12 hours before expiring, then it will be equal to 0.5 RFW days. Finally, the RFW overhead circuit mile days were calculated by multiplying the RFW days and the overhead miles for each NWS fire zone. All RFW overhead circuit mile days were summed up across the NWS fire zones to give the total RFW overhead circuit mile days. RFW archived data shapefiles were downloaded from the Iowa State University's public archived NWS Watch/Warning website (https://mesonet.agron.iastate.edu/request/gis/watchwarn.phtml). GIS layers showing RFW frequency can be found in the attached file, 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.2_Atch01.

2. *High Wind Warning overhead circuit mile days – Detail the steps used to calculate the annual number of High Wind Warning (HWW) overhead circuit mile days. Calculate as the number of OH circuit miles that are under an HWW multiplied by the number of days those miles are under said HWW. Refer to High Wind Warnings as issued by the National Weather Service (NWS). For historical NWS*

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[73] Energy Safety recommends using CalEnviroScreen and Senate Bill 535 to identify disadvantaged communities.

[74] https://mesonet.agron.iastate.edu/request/gis/watchwarn.phtml.

data, refer to the Iowa State University archive of NWS watch/warnings.[75] *Detail the steps used to determine if an OH circuit mile is under a HWW, providing an example of how the OH HWW circuit mile days are calculated for a HWW that occurred within the utility service territory over the last five years.*

HWWs are issued by the NWS in defined public forecast zones (https://www.weather.gov/gis/PublicZones), which are different from the NWS fire zones. The PG&E GIS team calculated the overhead circuit miles for all NWS public forecast zones that are within and intersect the PG&E territory. Then, HWW days were calculated for all the same NWS public forecast zones. A High Wind Warning Day is defined as the number of days that a High Wind Warning was valid from issue date to expiration date within an NWS public zone. For example, if a HWW was valid for six hours within a public zone, then the number of HWW days for that zone is equal to 0.25 days. Finally, the HWW overhead circuit mile days were calculated by multiplying the RFW days and overhead miles for each NWS public zone. All HWW overhead circuit mile days were summed up across the NWS public zones to give the total HWW overhead circuit mile days. HWW archived data shapefiles were downloaded from the Iowa State University's public archived NWS Watch/Warning website (https://mesonet.agron.iastate.edu/request/gis/watchwarn.phtml). GIS layers showing HWW frequency can be found in the attached file, 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.2_Atch01.

3. *Access and Functional Needs population – Detail the steps to calculate the annual number of customers that are considered part of the Access and Functional Needs (AFN) population. Defined in Government Code § 8593.3 and D.19-05-042 as individuals who have developmental or intellectual disabilities, physical disabilities, chronic conditions, injuries, limited English proficiency or who are non-English speaking,*[76] *older adults, children, people living in institutionalized settings, or those who are low income, homeless, or transportation disadvantaged, including, but not limited to, those who are dependent on public transit or those who are pregnant.*

PG&E follows the four-step process to calculate the annual number of customers that are considered part of the AFN population.

STEP 1 – Collect data from the following categories that apply to the CPUC's AFN definition for which data is available in PG&E databases:

1) Customers enrolled in the Medical Baseline program;

   - Data Source – Medical baseline enrollment data.

2) Customers enrolled in California Alternative Rates for Energy (CARE) program or Family Electric Rate Assistance (FERA) program;

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75 *Id.*

76 Guidance on calculating number of households with limited or no English proficiency can be found in D.20-04-003.

- Data Source – CARE or FERA enrollment data.

3) Customers that self-identify to receive an in person visit before disconnection for non-payment (e.g., vulnerable);

   - Data Source – Self-identification to receive in person visit before disconnection for non-payment enrollment data.

4) Customers that self-identify as having a person with a disability in the household (e.g., “disabled”);

   - Data Source – Self-identification as having a person with a disability in the household enrollment data.

5) Customers who self-select to receive utility communications in nonstandard format (e.g., in braille or large print);

   - Data Source – Self-selection to receive utility communications in nonstandard data enrollment data.

6) Customers who indicate a non-English language preference;

   - Data Source – Non-English language preference enrollment data.

7) Customers that self-identify as having a person in the household that uses durable medical equipment;

   - Data Source – Self-identification as having a person in the household that uses durable medical equipment;

8) Customers that self-identify as having a person in the household that uses Assistive Technology;

   - Data Source – Self-identification as having a person in the household that uses Assistive Technology;

9) Customers that self-identify as having a person in the household that has a Hearing Disability (e.g., Deaf or Hard of Hearing);

   - Data Source – Self-identification as having a person in the household that has a Hearing Disability (e.g., Deaf or Hard of Hearing);

10) Customers that self-identify as having a person in the household that has a Vision Disability (e.g., Low Vision);

    - Data Source – Self-identification as having a person in the household that has a Vision Disability (e.g., Low Vision)

    - 11) Customers that self-identify as having a person in the household that is Blind; and

- Data Source – Self-identification as having a person in the household that is Blind

12) Customers that self-identify as having a person in the household that is 65+ years old.

- Data Source – Self-identification as having a person in the household that is 65+ years old

STEP 2 – Calculate the number of customers in each of the categories above and add them together.

STEP 3 – Calculate the number of customers appearing in more than one of the above six categories.

STEP 4 – Subtract the result of Step 3 from the result of Step 2 to arrive at the total annual number of customers that are considered part of the AFN populations.

Please refer to 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.2Atch02 for a GIS layer showing the distribution of AFN customers, and a GIS layer showing the distribution of disadvantaged communities. The term 'Customer' in this dataset refers to a single electric (or gas) meter, or premise location, and inclusion in the AFN file means at least one person associated with that account is designated as meeting one or more AFN definitions. The disadvantaged communities layer was built using the publicly available SB535 Dataset.

Data Source – CC&B Characteristics from RQT Table in Teradata IDA Extracted: 1/28/2022

4. *Wildland-Urban Interface – Detail the steps to calculate the annual number of circuit miles and customers in Wildlife wildland-urban interface (WUI) territory. WUI is defined as the area where houses exist at more than 1 housing unit per 40 acres and (1) wildland vegetation covers more than 50% of the land area (intermix WUI) or (2) wildland vegetation covers less than 50% of the land area, but a large area (over 1,235 acres) covered with more than 75% wildland vegetation is within 1.5 mi (interface WUI) (Radeloff et al, 2005).*[77]

The annual number of circuit miles in the WUI is calculated by PG&E geospatial overlay/intersect of OH distribution and transmission circuits within WUI polygons and calculation of total circuit lengths in miles within the WUI. The sources of data used in the calculation of this information include University of Wisconsin Madison WUI GIS data layer[78] and PG&E's GIS data layer. The annual number of customers in the WUI is calculated by PG&E geospatial overlay of transformer locations as a proxy for the customer locations and summing up the number of service points associated with each

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[77] Paper can be found here: https://www.fs.fed.us/pnw/pubs/journals/pnw_2005_radeloff001.pdf with the latest WUI map (form 2010) found here - http://silvis.forest.wisc.edu/data/wui-change/.

[78] SILVIS Lab have not yet released a new WUI (their methodology is based on Census data) so PG&E is still using the same version of WUI that was used previously.

transformer to obtain total customer count within the WUI. The sources of data used in the calculation of this information include University of Wisconsin-Madison WUI GIS data layer provided by the University of Wisconsin-Madison SILVIS Lab, available here: http://silvis.forest.wisc.edu/data/wui-change/, which shows the WUI areas within California as of 2010, and the PG&E GIS data layer.

5. *Urban, rural and highly rural – Detail the steps for calculating the number of customers and circuit miles in utility territory that are in highly rural, rural, and urban regions for each year. Use the following definitions for classifying an area highly rural/rural/urban (also referenced in glossary):*

- Highly rural – In accordance with 38 CFR 17.701, "highly rural" shall be defined as those areas with a population of less than 7 persons per square mile as determined by the United States Bureau of the Census. For the purposes of the WMP, "area" shall be defined as census tracts.

- Rural – In accordance with GO 165, "rural" shall be defined as those areas with a population of less than 1,000 persons per square mile as determined by the United States Bureau of the Census. For the purposes of the WMP, "area" shall be defined as census tracts.

- Urban – In accordance with GO 165, "urban" shall be defined as those areas with a population of more than 1,000 persons per square mile as determined by the United States Bureau of the Census. For the purposes of the WMP, "area" shall be defined as census tracts.

Population density numbers are calculated using the American Community Survey (ACS) 1-year estimates on population density by census tract for each corresponding year (2016 ACS 1-year estimate for 2016 metrics, 2017 ACS 1-year estimate for 2017 metrics, etc.). For years with no ACS 1--year estimate available, we use the 1--year estimate immediately before the missing year.

PG&E calculates the number of customers in utility service area that are in highly rural, rural and urban regions each year by using population density by census tract, based on population totals in the ACS – 2019.[79] The population per square mile will be calculated for each census tract to define tracts as urban, rural, or highly rural, in accordance with the population density definitions. The number of customers that fall within these regions will be calculated by providing a geospatial overlay of transformer locations as a proxy for the customer locations and summing up the number of service points associated with each transformer to obtain total customer count with the urban/rural/highly rural census tracts and then calculating the total number of meters within each urban, rural, or highly rural region type.

The sources of data used in the calculation of this information include Topologically Integrated Geographic Encoding and Referencing (TIGER)/Line with Selected Demographic and Economic Data – 2018, ACS – 2019, PG&E GIS data layers.

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79 2020 census still not officially released so PG&E is still using the 2019 estimated.

Please refer to Attachment 2022-02-25_PGE_2022_WMP-Update_R0_Section 4.5.2Atch02 for a GIS layer showing the distribution of urban/rural/highly rural customers.

4.6 Progress Reporting on Key Areas of Improvement

Report progress on all key areas of improvement identified in Section 1.3 of the utility's 2021 Action Statement. Provide a summary table of the actions taken to address these key areas and report on progress made over the year. Summarize the progress in a table using a high-level bullet point list of key actions, strategies, schedule, timeline for completion, quantifiable performance-metrics, measurable targets, etc. The table must also include a cross-referenced link to a more detailed narrative and substantiation of progress in an appendix. The summary table must follow the format illustrated in Table 4.6-1.

ILLUSTRATIVE TABLE 4.6-1:
PROGRESS ON KEY AREAS OF IMPROVEMENT AND REMEDIES, 2021

Utility-#	Issue Title	Summary of Progress
e.g., Southern California Edison Company (SCE) 21-01	e.g., Risk Spend Efficiency (RSE) estimates not provided for all Public Safety Power Shutoff (PSPS)-related mitigation initiatives	Brief Narrative • Highlight 1 • Highlight 2 • Highlight 3 • Highlight # Refer to Appendix Section XXX for further detail

In the Final Action Statement issued by the Office of Energy Infrastructure Safety (Energy Safety or OEIS) on September 22, 2021, Energy Safety identified 29 remedies (Remedies) that we were required to address in a Progress Report submitted on November 1, 2021 (Progress Report). In addition, the Final Action Statement included Additional Issues and Remedies (Additional Issues) that were to be addressed in the 2022 Wildfire Mitigation Plan (WMP).

In this section of the WMP, as directed by Energy Safety, we are including tables that provide summaries of updates on the Remedies and Additional Issues:

- Table PG&E-4.6-1 below provides a summary update on the Remedies.
- Table PG&E-4.6-2 below provides a summary update on the Additional Issues.

We are providing more detailed information on the Remedies and Additional Issues, as necessary, in Attachments
2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Atch01 and
2022-02-25_PGE_2022_WMP-Update_R0_Section 4.6_Atch02.

Finally, please note that Tables PG&E-4.6-1 and PG&E-4.6-2, and the associated attachment, describe activities that we currently intend to undertake in 2022. However, these activities are not Initiative Targets and will not be included in our quarterly reporting or in the Annual Report on Compliance.