PSPS 10-Year Lookback Consequence Risk Model

Contents

Abbreviations, Definitions, and Conventions

List of abbreviations/definitions, conventions used in whitepaper

PSPS – Public Safety Power Shutoff

RAMP - Risk Assessment and Modeling Phase

WMP – Wildfire Mitigation Plan

SMAP - Safety Modeling Assessment Proceeding

CMIN – Customer Minutes Interrupted

EF – Effective Fatalities

CoRE – Consequence of Risk Event

LoRE – Likelihood of Risk Event

MAVF - Multi-Attribute Value Function

Dx – Distribution

Tx – Transmission

1 Introduction

1.1 Background

The purpose of the PSPS consequence model is to represent the spatial/circuit variation in PSPS risk, to prioritize PSPS mitigation efforts in high-risk locations based on frequency, customer, and duration of PSPS impact. This more granular, circuit level model will help assess the impacts of PSPS de-energizations in support of making decisions to make PSPS events smaller, shorter, and smarter (e.g., sectionalizing, mitigation strategies …).

Public Safety Power Shutoff (PSPS), a wildfire mitigation program that 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 are de-energized for a period, meaning that some customers will be without power for potentially extended periods. The PSPS Consequence Model quantifies these consequences and aggregates to the circuit level, differentiating between the risk driven by distribution scoped impact or transmission scoped impact.

The PSPS consequence model addresses the 2021 WMP Commitment ID A.06*: "Develop a more granular, circuit level model, to assess PSPS customer impacts."*

1.2 PSPS Consequence Level Risk Model Overview

Table 1 describes three primary data elements that enable development of the PSPS Consequence Model (herein referred to as "the Model"). Following, Figure 1 provides a flow diagram of the data elements and model outputs.

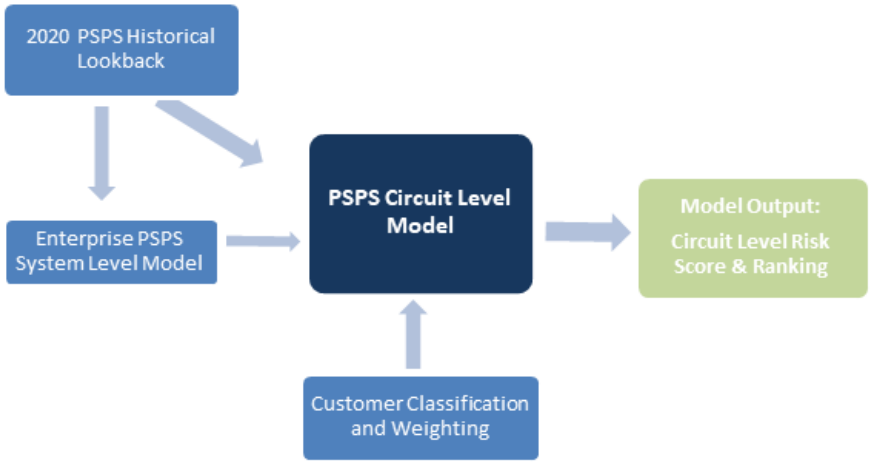
Table 1: PSPS Consequence Model Data Elements

Data Element	Description
PG&E Enterprise PSPS Risk Model at the System Level	• Calculates overall PSPS Risk Score that is used in the Circuit Level Analysis. Uses 2020 PSPS Lookback and estimates risk at the system 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[1] 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.

[1] This "historical lookback" evaluates actual weather events and models the associated PSPS events that would have occurred, including both transmission and distribution system impacts. This analysis identifies 30 weather events across the past 10 years that would have triggered a PSPS event under the 2020 PSPS decision-making protocols. See 2021 WMP page 920 "Efforts to Make PSPS Smaller in 2021".

	• This primary data is used to estimate distribution and transmission risks at the circuit and substation level.
Customer Classification and Weighting	• Weighting assessment by customer classifications to adjust risk and prioritization for critical customers based on the Subject Matter Expert feedback • Data set includes customer classifications from customer care & billing (CC&B), aggregated to at the circuit level.

Figure 1: Data Elements and Model Outputs



2 Methodology: Circuit Level Risk Calculations

This section aims to provide a comprehensive guide to the quantitative analysis involved in estimating the 1) Potential PSPS Risk at the System Level; 2) PSPS circuit level and transmission level risk; 3) Customer Adjusted Risk Scores and any other necessary data used in the calculations.

2.1 Potential PSPS Risk

The PG&E Enterprise PSPS Risk Model (System Level Risk Model) utilizes the Multi-Attribute Value Function (MAVF) framework, as defined through the Safety Modeling Assessment Proceeding (SMAP). 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 GRC[2] filings.

Figure 2 presents the risk bowtie for PSPS and Table 2 describes our overall MAVF risk units based on the assessment. Please note, PSPS is a program that is wildfire mitigation and what is represented in the risk bowtie only represents the consequence of PSPS when this wildfire mitigation program is utilitzed, and does not show the benefits of wildfire mitigation in this view. Subsequent sections describe the assumptions and formulas used to estimate risk scores related to safety, reliability, and financial consequences that were applied in PG&E Enterprise PSPS Risk Model.

Figure 2: MAVF Attribute Weighting

[2] Full details of the MAVF methodology are provided through the Risk Assessment and Modeling Phase (RAMP) Report RAMP Report, pp. 3-3 to 3-15 and General Rate Case (GRC) workpapers in response to Energy Division GRC-2023-PhI_DR_ED_001_Q01Supp01.

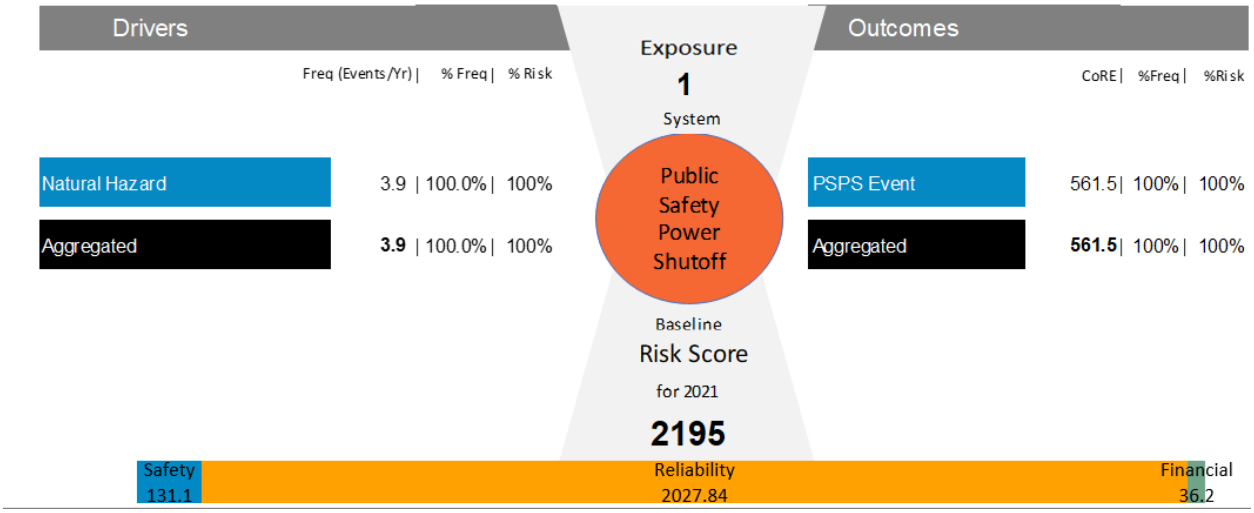


Table 2: Potential PSPS Risk

Component	Units	Percentage
Baseline MAVF Risk Score - Safety	131	6%
Baseline MAVF Risk Score - Reliability	2,028	92%
Baseline MAVF Risk Score - Financial	36	2%
Total	2,195	100%

2.1.1 Safety Consequence

Safety Consequence is calculated from an estimate of Equivalent Fatalities (EF) per Million Customer Minutes Interrupted (MCMI)[3]. Based on the number of customers and the outage duration:

$$MCMI = [Duration\ of\ Outage] * [Number\ of\ Customers\ Impacted] \quad (1)$$

$$EF_{PSPS} = \frac{(MCMI) * \left(\frac{Equivalent\ Fatalities}{MCMI} ratio^4\right) * \left(\frac{Number\ of\ Customer\ Meters}{Population\ Impacted} ratio^5\right)}{1{,}000{,}000} \quad (2)$$

[3] Equivalent Fatalities (EF) is derived from Million Customer Minutes Interrupted (MCMI) through a ratio of EF/MCMI that is calculated as a weighted average of this same ratio from previous PG&E PSPS events and other large external outage events (see Appendix 4.1)

[4] The EF/MCMI ratio is used to convert MCMI to Equivalent Fatalities (see Appendix 4.1)

[5] The [Number of Customer Meters Impacted]:[Population] ratio is used as a constant to convert from customer meters impacted to population impacted. This ratio is currently set to 1 (see Appendix 4.1)

This natural unit consequence value is the input for the MAVF risk score calculation function for PSPS Potential Safety Risk.

2.1.2 Electric Reliability Consequence

PSPS Electric Reliability Risk is calculated directly from the potential number of customers impacted and outage duration, which multiply to form the Million Customer Minutes Interrupted (MCMI). The calculation for MCMI is shown above in equation (1). This natural unit consequence value is the input for the MAVF risk score calculation function for PSPS Potential Electric Reliability Risk.

2.1.3 Financial Consequence

PSPS Financial Risk is represents the cost of executing PSPS. The financial estimate is based off the cost of historical 2019-2020 PSPS event costs and fits a curve for a deterministic component as a fixed cost and an exponential distribution based on customers per event. These costs represent EOC support, IT, aviation services, ground patrols, customer outreach, electric distribution operations of de-energization, recovery, and restoration, mutual assistance, customer resource centers, in-event vegetation management, and others (hydro support, etc.).

$$WF\ Financial\ Cost\ (Projected) = \frac{Cost\ of\ Execution}{Number\ of\ Circuits\ in\ PSPS\ Event} + ((Number\ of\ Customers) * (Projected\ Cost/Customer\ )) \quad (3)$$

This natural unit consequence value is the input for the MAVF risk score calculation function for PSPS Potential Financial Risk.

2.2 Circuit Risk

The following section goes into detail on the process to estimate risk scores for distribution and transmission events at the circuit level. This analysis enables the ability to rank and prioritize circuits. This process includes:

1) Calculating the overall PSPS Risk Score based on the 10-year lookback as defined in section 2.1.
2) Consolidating data to understand customers impacted by the type of PSPS Event (Dx-only, Tx-only, or combined Dx/Tx)
3) Calculating total customer duration impacts at the circuit level by event type to estimate risk scores
4) Calculating % contribution due to Distribution and Transmission level risk impacts at the circuit level
5) Allocating the overall PSPS risk score from Step 1 to the circuit level from Step 3 and 4 based on annualized customer minutes interrupted
6) Output of Step 5 represents PSPS risk scores at the circuit level, including risk ranking at the circuit level , separated by Dx & Tx contribution for risk scores.

2.2.1 Event Impacts on Customers

The Model utilizes meteorology's PSPS impact based off the 2020 PSPS protocols looking back on weather conditions since 2010.[8] Consolidation of the 2020 PSPS Historical Lookback data is performed to determine the number of customers that are impacted by the type of event (Dx-only, Tx-only, Dx/Tx event) and the duration of the outage occurring at the circuit and substation level. This categorization of variables enables the quantification of risk, based on event type, and informs the effectiveness of a mitigation strategy.

The PSPS Lookback Dx & Tx data are combined into one dataset, to create an overall risk calculation. This data includes enough granularity to identify 1) the number of customers impacted by a Dx-only event, 2) Tx-only event, and 3) a combined Dx/Tx event. For each of these events, distribution data is available at the circuit level, whereas transmission data is provided at the substation level.

2.2.2 Event Impacts on Customer Minutes Interrupted

For each individual circuit, the 2020 PSPS Historical Lookback also provides outage duration at the customer-circuit level. The data consolidation that occurs in section 2.2.1 also includes this information at the circuit level and enables calculating the % distribution and transmission risk impacts on Dx & Tx circuit (section 2.2.3) and the Circuit Risk Scores (section 2.2.4 and 2.2.5) to generate a circuit risk-ranking.

This step describes how the Model estimates total customer duration impacts based on event type (i.e., Dx-only, Tx-only, combined Dx/Tx) at the circuit level.

Total customer outage duration or customer minutes interrupted is the sum of each event's duration multiplied by the total number of customers impacted by the event. The total customer minutes interrupted across the 10-year lookback is then annualized to a per year level to estimate the annual expected customer minutes interrupted per event per circuit. Both Distribution and Transmission customer durations are calculated separately to recognize the distinct levels of risk and mitigation strategies. Since Dx and Tx events pose different risks onto the system, it is necessary to delineate between the number of customers and duration between these event types.

Distribution Events – Customer Minutes Interrupted

There are two steps in calculating the total Distribution customer outage durations and they are dependent on the type of event. The total distribution outage duration is the sum of these two approaches. The first step is for Dx-only events, where the total customer duration is allocated specifically to the distribution event.

$$Dx\ Only\ Outage\ Duration = Distribution\ Customers * Event\ Duration \quad (5)$$

The second step are for events that are driven by both Dx and Tx events, where the outage duration is allocated to both Transmission & Distribution event, by using a 50-50 allocation. An example of this event would be 1 customer is impacted by PSPS both from Distribution scoping but also impacted upstream by a transmission scoped line serving the customer. From a risk perspective, there is only 1 customer impacted,

[8] This "historical lookback" evaluates actual weather events and models the associated PSPS events that would have occurred, including both transmission and distribution system impacts. This analysis identifies 30 weather events across the past 10 years that would have triggered a PSPS event under the 2020 PSPS decision-making protocols. See 2021 WMP page 920 "Efforts to Make PSPS Smaller in 2021".

but from a risk scoring perspective, half the risk scoring is created by transmission impacts and the other half is created by distribution impacts, hence the risk score is allocated 50-50 between transmission and distribution.

$$Dx\ Component\ Outage\ Duration = 0.5 * Distribution\ Customers * Event\ Duration \quad (6)$$

To note, to estimate the distribution outage duration at the circuit level may or may not require both steps described above. These calculations are driven by the type of event that is defined by the 2020 PSPS Historical Lookback.

Transmission Events – Outage Duration

Like Distribution customer outage durations, Transmission customer outage durations are calculations are dependent depending on the type of event and is a two-step process. The total transmission outage duration is the sum of these two approaches. The first step is for Tx -only events, where the total customer duration is allocated specifically to the transmission event.

$$Tx\ Only\ Outage\ Duration = Transmission\ Customers * Event\ Duration \quad (7)$$

The second step are for events that are driven by both Tx and Dx events, the outage duration is allocated to both Transmission & Distribution event, by using a 50-50 allocation using the below formula. An example of this event would be 1 customer is impacted by PSPS both from Distribution scoping but also impacted upstream by a transmission scoped line serving the customer. From a risk perspective, there is only 1 customer impacted, but from a risk scoring perspective, half the risk scoring is created by transmission impacts and the other half is created by distribution impacts, hence the risk score is allocated 50-50 between transmission and distribution.

$$Tx\ Component\ Outage\ Duration = [(0.5 * Distribution\ Customers) + (Transmission\ Customers - Distribution\ Customers)] * Event\ Duration \quad (8)$$

To note again, to estimate the transmission outage duration at the circuit level may or may not require both steps described above. These calculations are driven by the type of event that is defined by the 2020 PSPS Historical Lookback.

Substation Events – Outage Duration

While not a direct output from this model, the impacts of customers can be aggregated to each substation and represented as substation PSPS risk scores. Unlike transmission and distribution outage duration impacts, substation impacts merely represent the summation of impacted customers served by such substation and do not represent additional or allocated risk. This is only presented for risk ranking purposes for substation level mitigation strategy.

2.2.3 Event Impacts Between Distribution & Transmission Risk

This step describes how the Model estimates the % Dx and %Tx Risk that occur at the circuit level. This calculation is done at the circuit level and multiplied by the overall circuit risk score (section 2.2.4) to calculate a final risk circuit score (section 2.2.5) delineating between Dx and Tx risk.

Differentiating the risk by Distribution and Transmission will enable targeted mitigation planning. The % distribution and % transmission risk at the circuit is based on the outage duration compared to the total customer outage duration at the circuit level.

$$Distibution\ Risk\ \% = \frac{Distribution\ Customer\ Duration}{Total\ Customer\ Duration} * 100\% \quad (9)$$

$$Transmission\ Risk\ \% = \frac{Transmission\ Customer\ Duration}{Total\ Customer\ Duration} * 100\% \quad (10)$$

2.2.4 Transmission and Substation Risk Scores

While not a direct output from this PSPS circuit consequence model, customer impact upstream of distribution circuits are also aggregated to the Substation and Transmission level.

Substation risk scores and risk rankings are represented by the aggregation of distribution circuit risk scores that the substation serves.

Transmission risk scores and risk rankings are represented by allocating the substation risk scores to the transmission lines that serves the substation. This process is not entirely accurate without full power-flow analysis, but provides an approximation of risk per transmission circuit.

Substation and Transmission risk scores are not meant to be additive to the distribution level PSPS risk scores. It is meant to represent the customers impacted and resulting risk scores due to assets upstream of the customers. Further developments in both the substation and transmission level risk scoring is expected in future iterations of this model.

2.2.5 Total Circuit Risk Score Ranking (Dx & Tx Combined)

This step estimates the risk score at the circuit based on total customer duration minutes at the circuit level compared to the total customer outage duration for all events as defined by the historical PSPS Lookback. This value is multiplied by the total potential PSPS Risk (2,195) as defined by the Enterprise PSPS Risk model that is calculated at the system level. This step does not differentiate between Dx and Tx events and is the total risk associated for a particular circuit. Note that a higher customer duration will account for a higher risk score, pushing the circuit to the top of the list.

$$Total\ Circuit\ Risk\ Score = \frac{(Circuit\ Customer\ duration\ )}{(Total\ Customer\ Duration)} * (PSPS\ Risk\ Score) \quad (11)$$

2.2.6 Distribution & Transmission Circuit Risk Ranking

This step estimates the risk score at the circuit level differentiating between Dx and Tx risks. The results of this calculation enable a risk ranking and drive what mitigation strategies are appropriate. For example, a REFCL (Rapid Earth Fault Current Limiter) solution will not mitigate a transmission level event.

As part of the calculation, the Distribution and Transmission risk percentages calculated in section 2.2.3 are used to assign the risk scores per circuit. This step provides the differentiation of scores between Distribution & Transmission risks to customers.

$$Dx\ Risk\ Score = Distribution\ Contribution\ \%\ per\ circuit * Total\ Risk\ Score\ per\ circuit \quad (12)$$

$$Tx\ Risk\ Score = Transmission\ Contribution\ \%\ per\ circuit * Total\ Risk\ Score\ per\ circuit \quad (13)$$

2.3 Customer Adjusted Risk Score

PG&E recognizes that customers risks differ depending on their classification. This step describes how the Model incorporates customer weighting assumptions to adjust risk scores at the circuit level. Customer classifications and quantity of customer data at the circuit level is from PG&Es Customer Care and Billing database (CC&B). Table 3 shows classification weightings as defined by PG&Es Customer Care Team[9]. These two pieces of information are used to calculate an adjusted MAVF Consequence and Adjusted risk scores at the circuit level needed to re-prioritize circuits based the customer types that reside on a specific circuit.

2.3.1 Customer Classification & Weighting

The purpose of the weighting is to show that PSPS events have a greater impact on certain customer classes and therefore have an impact on the overall circuit prioritization ranking. These weightings were generated by Customer Care and internal subject matter experts, but are meant to be utilized as a proof of concept.

Critical customers fall into three main categories, which are Public Safety Impact (e.g. CC1, TT1), Community Impact (e.g. CC3), and Schools (e.g. SC1, SC2, SC3). Additionally, other customer types are included such as Essential Customers (e.g. TE, CE, SE), Pandemic Response Site (e.g. PR1), customers with medical condition who depend on medical device (e.g. Medical Baseline, Life Support) and low-income customers (e.g. Low Income).

Critical customers are weighted based on the criticality of their group. A customer group that is classified with a higher priority such as Critical Customer (CC1); who provides emergency services such as fire & police stations, emergency hospitals; will have a higher weighting compared to a customer group with a slightly lower priority such as School Critical (SC3); which consists of pre-schools & daycares.

Table 3: Customer Class Weighting

Customer Class	Multiplier
CC1	100
CC2	50
CC3	25
CE1	125
CE2	75
CE3	50
EE	50
PR1	75
SC1	50
SC2	25
SC3	25
SE1	50

[9] Weightings provided was meant to be provided as a proof of concept for model development and values are expected to be refined over time. This does not represent PG&E's explicit prioritization from one customer class to another.

SE2	25
SE3	25
TE1	125
TE2	75
TT1	100
TT2	50
Life Support	15
Medical Baseline	10
Self-Identified Vulnerable	7
Self-Identified Disabled	5
Low Income	2
Medical Baseline & Low Income	20
Life Support & Low Income	30

2.3.2 Updated MAVF Scores and Adjusted Customer Risk Scores

The customer weighting in Table 2 is used in combination with Foundry customer classification data to calculate an adjusted MAVF Risk Score to re-evaluate the consequence at the circuit level based on customer type. To calculate the updated MAVF scores, the model compares 1) the unweighted average customers per event; 2) the average customer duration per event and 3) the critical customer weighted count. The critical customer weighting only impacts the Safety component of the MAVF score.

Safety: $(Total\ Customers\ per\ Event + \ Critical\ Customer\ Weighted\ Count) * Average\ Customer\ Duration$ (14)

Reliability/Financial: $(Total\ Customers\ per\ Event) * Average\ Customer\ Duration$ (15)

Once the adjusted attributes are re-calculated for each circuit, the MAVF risk scores are re-calculated using the formula below. This formula leverages the scaling factors described in Table 2.

$$Critical\ Customer\ Adjusted\ Risk\ Score = \ (Safety * 6\% + Reliability * 92\% + Financial * 2\%)$$ (16)

This is important to note that while a CC1 customer has a weighting of 100, the weighting of the impact on the MAVF Risk Score is only impacted against 6% of the critical customer adjusted risk score.

PG&E will continually be re-evaluating the method to account for customer classifications.

2.3.3 Circuit Factor and Customer Adjusted Total Circuit Risk Score Ranking

From this point, the Customer Adjusted Circuit Factor is calculated for each circuit, which is the multiplier used to estimate the updated overall Dx and Tx circuit risk score.

$$\text{Customer Adjusted Circuit Factor} = \frac{Customer\ Adjusted\ Risk\ Score\ @\ Circuit}{\sum Customer\ Adjusted\ Risk\ Score}$$ (17)

Once the customer adjusted circuit factor is calculated for each circuit, this value is then applied to the total circuit risk score calculated in section 2.2.4 using the formula below. This score is the updated total circuit risk score (Dx and Tx) based on customer classification weighting.

$$Adjusted\ Customer\ Circuit\ Score = Customer\ Adjusted\ Circuit\ Factor\ X\ Enterprise\ Model\ PSPS\ Risk\ Score\ (2195) \quad (18)$$

2.3.4 Customer Adjusted Distribution & Transmission Circuit Risk Ranking

The final step estimates the risk score at the circuit level differentiating between Dx and Tx risks, based on customer classification adjustments.

As part of the calculation, the Distribution and Transmission risk percentages calculated in Section 2.2.3 are used to assign the risk scores per circuit. This step provides the differentiation of scores between Distribution & Transmission risks to customers.

$$Dx\ Circuit\ Risk\ Score = Adjusted\ Customer\ Risk\ Score\ X\ Distribution\ Risk\ \% \quad (19)$$

$$Tx\ Circuit\ Risk\ Score = Adjusted\ Customer\ Risk\ Score\ X\ Transmission\ Risk\ \% \quad (20)$$

3 Future Improvements

Separation of Critical Customers by Event. Future model improvements will enable the identification of critical customers by event, hence providing a better risk estimate.

Inclusion of Transmission Line Ranking. With the inclusion of Power Flow analysis in the future PSPS Lookback, substation to transmission line mapping will be available. This will enable the calculation of transmission line risks & ranking.

4 Appendix

4.1 PSPS Safety Calculation Assumptions

EF/MCMI Ratio = 0.002175

Calculated using previous PG&E PSPS events including 2019-2020 events, and other large external outage events include 2003 Northeast Blackout in New York City, 2011 Southwest

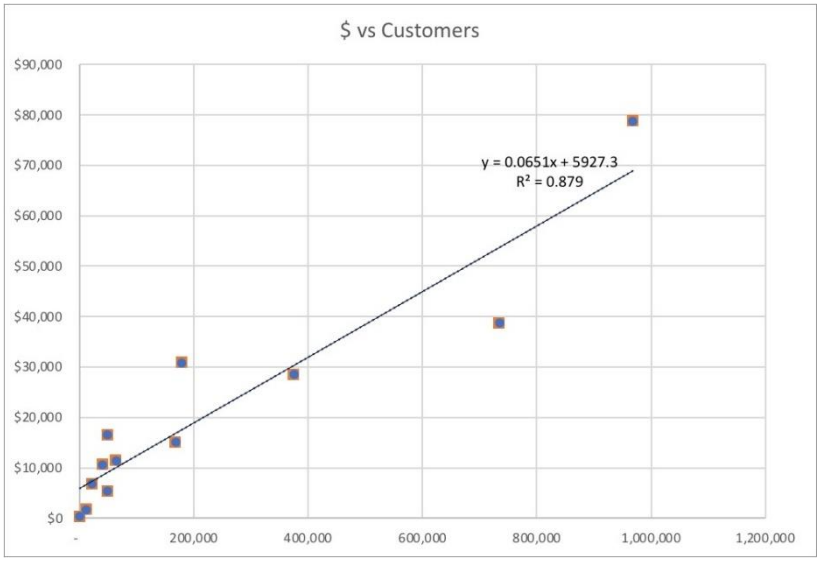
Blackout in San Diego, 2012 Derecho Windstorms, 2012 Superstorm Sandy, and 2017 Hurricane Irma.[10]

[Number of Customer Meters Impacted]:[Population Impacted] Ratio = 1

4.2 PSPS Financial Calculation Assumptions

Cost of Execution = $5,927,323.12; Cost per Customer = $65.14

Based on regression analysis of 2019-2020 PSPS Event data that includes cost per event and # customers[11]



4.3 Wildfire Safety Calculation Assumptions

[Population Impacted]: [Equivalent Fatalities] Ratio = 2000

Calculated based on maximum population impacts derived from Technosylva wildfire simulation models and a fatality ratio based on National Fire Protection Association (NFPA) data.

4.4 Wildfire Financial Calculation Assumptions

Cost per Structure = $1,000,000

Previously evaluated in 2020 RAMP A.20-06-012 report

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[10] Workpaper is General Rate Case on July 20, 2021. Please see PG&E response to Energy Division GRC-2023-PhI_DR_ED_001-Q01Supp01, workpaper EO-WPSPS-6_Safety Impacts from Widespread Unplanned Outage Events .pptx.

[11] Workpaper is General Rate Case on July 20, 2021. Please see PG&E response to Energy Division GRC-2023-PhI_DR_ED_001-Q01Supp01, workpaper EO-WPSPS-5_PSPS Event Financial Cost 2019-2020.xlsx.

5 References and Data Sources

Data Source

2020 10-Year Lookback[12]

[12] 10_year_Historic_PSPS_Summary_r4