PACIFIC GAS AND ELECTRIC COMPANY

PUBLIC SAFETY POWER SHUTOFF: MODELS AND GUIDANCE FOR DECISION MAKING

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1 Introduction – Public Safety Power Shutoff

1.1 PSPS - Extreme Weather and Wildfires

Please Note: This document represents PG&E's PSPS criteria as of August 2024 and is subject to further refinement and adjustments. Lessons are learned from each large fire and PSPS activation that may lead to further refinement and adjustments to PG&E's PSPS criteria.

The purpose of the document is to give the reader a thorough understanding of the models, tools and methodologies developed to support PG&E's Public Safety Power Shutoff (PSPS) decisions. This document includes detailed information on how models were developed to understand the probability of an ignition and the potential consequences of a resulting fire.

PG&E's PSPS program was developed in 2018 in response to the continued and growing threat of catastrophic wildfires. PSPS is a proactive de-energization of electric equipment as a measure of last resort to reduce wildfire risk. The most catastrophic fires attributed to PG&E equipment have occurred during dry offshore wind events also known as Diablo, Mono, or Santa Ana winds. Dry conditions and strong winds resulted in the rapid spread of many devastating wildfires such as Tubbs, Nuns, Atlas, Redwood Valley, Sulphur, Pocket, Camp, Zogg and Kincade fires in Northern California. These dry offshore wind events are most frequent from September to mid-November and coincide when live and dead fuel moisture values are near seasonal minimums.

PG&E considers PSPS when winds are strong, conditions are dry, and the fuels are receptive to fire. These events often occur during Red Flag Warnings issued by the National Weather Service and/or High-Risk forecasts issued from Predictive Services. PG&E's PSPS program will not eliminate all risk of utility-caused fires and ignitions but does significantly reduce the risk of igniting a rapidly spreading wildfire during strong wind events.

During and outside of dry wind events, PG&E has additional programs in place to reduce the overall ignition risk such as Enhanced Powerline Safety Settings (EPSS), system inspection programs, system hardening, and daily mitigation actions. These additional layers of protection are not discussed in this document but are described in detail in PG&E's Wildfire Mitigation Plan.

1.2 Historical Overview of Models informing PSPS

PG&E's PSPS decision making models have evolved since the PSPS program inception in 2018. After each PSPS season, opportunities for improvement are evaluated. There has been significant work to improve the models that inform PSPS, including improving weather prediction, enhancing input data, testing new models and model features. This work aims to better inform when PSPS should be applied. Since 2018, PG&E has based PSPS decision making on a risk-informed basis considering both the potential for increased outage activity that may lead to ignitions, combined with the potential for catastrophic fires.

In 2018, PG&E created Version 1 of models to inform PSPS by combining outputs from the Storm Outage Prediction Project (SOPP) with a newly developed index-based Fire Potential Index (FPI). This FPI mirrored FPIs currently deployed at other electric utilities including SCE and SDG&E. For Version 2 in 2019 the Outage Producing Weather (OPW) model was developed, that forecasted the likelihood of an outage hourly, and a new FPI model was also deployed that forecasted likelihood of a large fire based on weather and fuel inputs. This new FPI model was a logistic regression model and trained using a climatology of historical weather and fuels together with historical fire occurrence data. In 2020 for Version 3 PG&E increased the granularity of the core weather model from 3x3km to 2x2km and significantly enhanced the granularity of the OPW model. In 2021 for Version 4, both OPW and FPI were significantly enhanced using new datasets and advanced machine-learning. The OPW probability of an outage output was translated into an ignition probability using outage and ignition causes and their respective ignition to outage rates. The resulting ignition model, named the Ignition Probability Weather (IPW) model, better represented the likelihood of a utility caused ignition. Additionally, after years of testing fire spread simulations across both historical climatologies and operational forecasts, PG&E added Technosylva fire spread simulation outputs into the PSPS decision making framework in 2021.

In August 2024 PG&E deployed the most accurate outage, ignition and fire models to date after years of development and testing new weather models, fuel moisture models, datasets, model frameworks and enhanced resolutions. The 2024 Version 5 models leveraged the latest published science and research to inform PG&E's PSPS program. This document provides an overview of the Version 5 models and framework made operational on August 1st, 2024.

1.3 Key Decision Factors for Distribution PSPS

The key elements informing PSPS on the distribution system include:

- Minimum Fire Potential Conditions (mFPC)

- Catastrophic Fire Probability Distribution (CFP_D) comprised of the following models:
    - Ignition Probability Weather (IPW)
    - Fire Potential Index (FPI)
- Catastrophic Fire Behavior (CFB) based on Technosylva fire spread simulations
- Consideration of known high risk vegetation and electric corrective (EC) tags
- Event criteria

The minimum Fire Potential Conditions (mFPC) are a set of criteria intended to create a low-pass filter on weather and fuels based on relative humidity, wind speed, and fuel moisture that must be near to or exceeded for PSPS to be considered. These values were established from an examination of historical fire occurrence in the PG&E territory as well as information published by federal agencies regarding fire behavior and criteria used to issue warnings to the public.

The IPW and FPI models are combined in space and time to form Catastrophic Fire Probability (CFP_D) output at $0.7km^2$ resolution. The CFP_D model provides hourly output and highlights locations that have increased probability of ignitions on the distribution system and an increased probability for catastrophic fire.

The Catastrophic Fire Behavior (CFB) criteria based on Technosylva fire spread simulations is used to identify locations that may have lower probability of ignition but could result in fires that are not easily suppressed and have potentially high consequences.

The current PSPS models and framework for Distribution PSPS are summarized in the figure below. The framework structure has been the same since 2021.

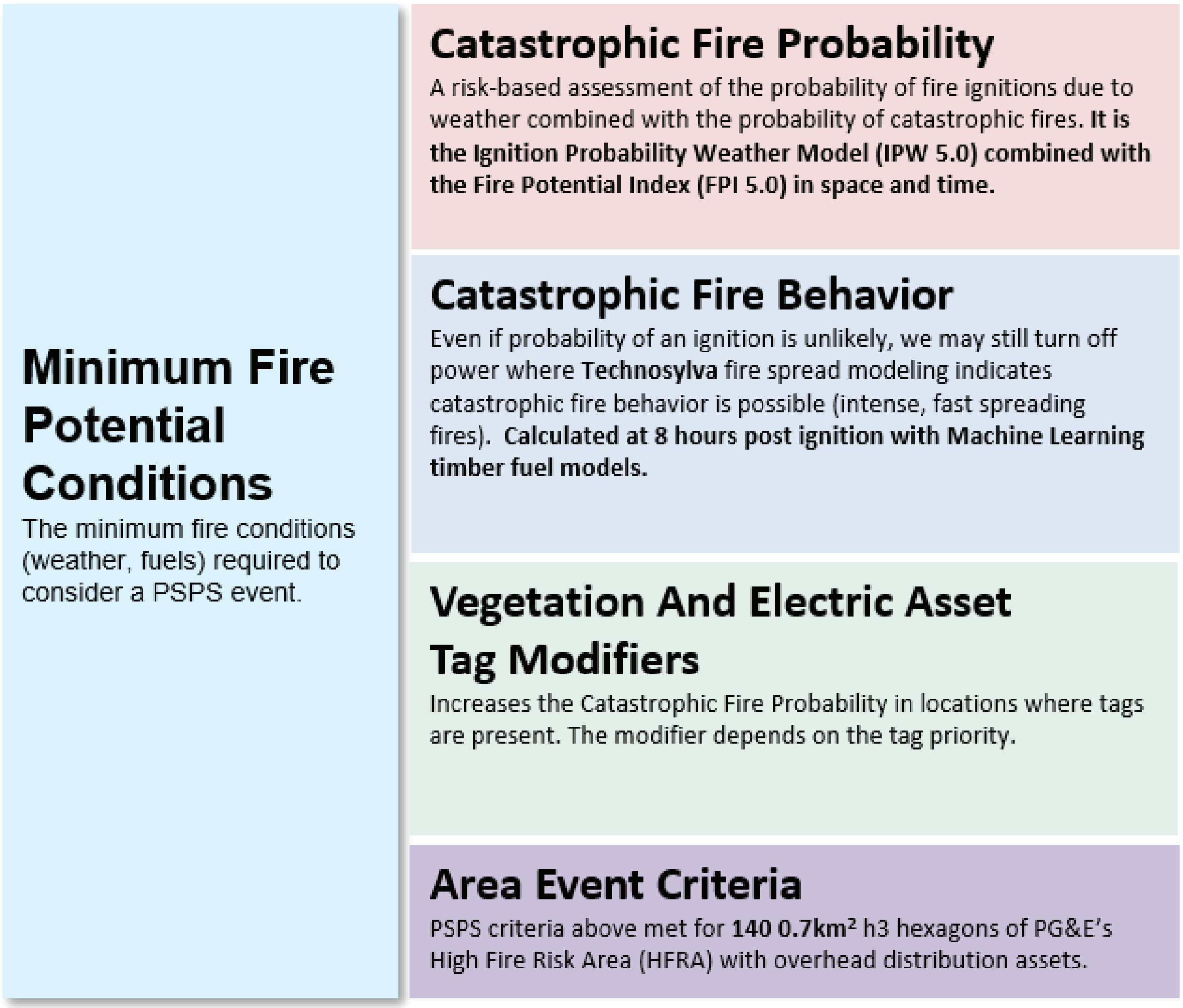

Fig. 1. High level overview of Distribution PSPS guidance

1.4 Key Decision Factors for Transmission PSPS

PSPS decision making on the Transmission system is approached using a very similar framework as distribution. The main differences are utilization of Transmission-specific outage models instead of the Distribution OPW model described in this document.

The key elements informing PSPS criteria on the Transmission system include:

- Minimum Fire Potential Conditions (mFPC)
- Catastrophic Fire Probability Transmission Asset (CFP_T) comprised of the following:

    - Transmission Operability Assessment (OA)
    - Fire Potential Index (FPI)
- Catastrophic Fire Probability Transmission Vegetation (CFP$_{\text{T-Asset}}$) comprised of the following:
    - Transmission Vegetation Model
    - Fire Potential Index (FPI)
- Catastrophic Fire Behavior (CFB) based on Technosylva fire spread simulations
- Consideration of known high risk vegetation and electric corrective (EC) tags

Comparing the key elements of the Transmission and Distribution PSPS frameworks, the distribution Ignition Probability Weather (IPW) model is replaced by the Transmission Operability Assessment (OA) model and the Transmission Vegetation model, which provide probability of failure for each transmission structure and tree strike respectively. For Transmission, the FPI model is combined with the OA and Transmission Vegetation models in space and time to form Catastrophic Fire Probability Transmission Asset and Vegetation models respectively (CFP$_{\text{T- Asset}}$, CFP$_{\text{T- Vegetation}}$).

PG&E partnered with Exponent to develop the Operability Assessment (OA) model for Transmission. This model combines historical wind speeds for each structure, historical outage activity, and the condition of assets based on inspection programs and asset characteristics such as materials and age to model the wind-related failure probability of each structure. The model can be driven with forecast wind speeds to output the probability of failure at the structure level.

No single factor drives the determination of whether PSPS is necessary, as each situation is dynamic and unique. While PG&E uses these key elements to inform PSPS decisions, each decision to de-energize is made with guidance from a trained meteorologist assessing the specific conditions present. Once the period of risk of a PSPS event has been identified, coordination with both grid experts and other meteorology professionals occurs, and evaluation of the risk of the event is informed by a wide variety of data. These factors are discussed in detail in this document, including further explanations of why these metrics were selected.

1.5 Additional PSPS Decision Factors

In addition to PG&E's PSPS models, PG&E carefully reviews an array of available data and federal forecast information to verify if multiple authorities recognize an upcoming or imminent period of risk.

During high-risk periods, PG&E meteorologists participate in daily interagency conference calls that normally include multiple National Weather Service (NWS) local offices, the NWS western region headquarters, and representatives from the North or South Predictive Services or Geographic Area Coordination Centers (GACC). This call is hosted by the Northern CA or Southern CA Predictive Services - GACC offices. Agreements with CAL FIRE and United States Forest Service (USFS) leadership allow utility participation on these calls. The agencies present their expert assessment on the upcoming period(s) and location(s) of risk, wind speeds and fuel moisture levels, and any other relevant factors to consider, which PG&E takes into consideration for PSPS events. PG&E appreciates this collaboration with external and independent forecast agencies on upcoming risk periods.

The lead PG&E meteorologist for the event, called the Meteorologist in Charge (MIC), summarizes external forecasts and discussions for the Officer in Charge (OIC) and Incident Commanders (ICs), who make the decision to execute a PSPS. If external agencies are not in alignment with PG&E models and do not see an upcoming event as high risk for large fires, the OIC may use this intelligence to inform the OIC's decision if PSPS is warranted in the interests of public safety.

In addition, PG&E carefully reviews and considers the location of existing fires and where new fires are detected using multiple sources including the Satellite Fire Detection & Alerting System (FDAS), PG&E's Hazard and Awareness Warning Center (HAWC), Alert California wildfire cameras, and Watch Duty, among others.

Examples of sources and tools besides PG&E's PSPS models and framework considered during each event include:

1. Fire Weather Watches and Red Flag Warning (NWS - Federal)
2. Significant Fire Potential for Wind (Geographic Area Coordination Center (GACC), Federal)
3. Storm Prediction Center (Federal, part of National Oceanic and Atmospheric Administration (NOAA))
4. Daily outlooks from the CAL OES Wildfire Threat and Intelligence Integration Center (WFTIIC)
5. Daily Interagency Conference Call with agencies during high-risk periods

6. Any information from the field, such as from Public Safety Specialists (PSS), Safety Infrastructure and Protection Teams (SIPT)
7. Live weather data from weather stations
8. Location of existing fires or emerging incidents
9. Weather forecasts data from numerous models

1.6 PSPS - PG&E's High-Resolution Weather and Fuels Forecasts and Climatology

PG&E builds, operates, and maintains core models and datasets used to train machine learning models and forecast PSPS events. This section provides details on these foundational datasets and models.

PG&E partners with two external experts and employs internal weather modeling experts to deploy and maintain PG&E's high-resolution weather models. In 2014 PG&E partnered with Weather Decision Technology (WDT), since acquired by DTN, to deploy the first version of PG&E's Operational Mesoscale Modeling System (POMMS), which is based on the Weather Research and Forecast (WRF) Model. A second external expert has also been engaged since 2014, Atmospheric Data Solutions (ADS), which was recently acquired by Technosylva. ADS-Technosylva has extensive knowledge of California fire weather and numerical weather prediction using WRF and they work extensively with SCE, SDG&E and other utilities as well as firefighting agencies across the world.

WRF is a mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. It features two dynamical cores, a data assimilation system, and a software architecture supporting parallel computation and system extensibility. WRF development was a collaborative partnership of the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (represented by the National Centers for Environmental Prediction (NCEP), the (then) Forecast Systems Laboratory (FSL)), the (then) Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). WRF continues to be supported and upgraded by a robust community of researchers around the world. WRF can produce simulations based on actual atmospheric conditions (i.e., from historical observations and analyses) or idealized/forecast conditions. WRF offers a flexible and computationally efficient platform for operational forecasting that incorporates recent advances in physics, numerics, and data assimilation contributed by developers from the expansive research community. WRF is currently being used operationally at NCEP and other national meteorological centers and in real-time forecasting configurations at laboratories, universities, utilities and hundreds of companies.

PG&E first deployed the high resolution in-house mesoscale forecast model, POMMS, in November of 2014 and PG&E continues to improve and build upon the model framework to generate short to medium-term weather, outage, and fire potential forecasts across PG&E's service territory.

POMMS is a high-resolution weather forecasting model that generates important fire weather parameters including wind speed, temperature, relative humidity (RH), and precipitation. Outputs from POMMS are used as inputs to the Nelson Dead Fuel Moisture (DFM) model, and Live Fuel Moisture (LFM) models developed by Technosylva to derive key fire danger indicators such as 1hr, 10hr, 100hr, 1000hr DFM, and LFM for multiple plant species. In late 2018 to 2019, PG&E successfully completed one of the largest known high-resolution climatological datasets in the utility industry: a 30+ year, hourly, 3km spatial resolution dataset consisting of weather, DFM, LFM, NFDRS outputs, and fire weather derivative products such as the Fosberg Fire Weather Index (FFWI).

With this robust weather, fuels and fire dataset, PG&E sought to develop outage and fire potential models in 2019 utilizing best-practices deployed in the utility industry, fire science and data science communities. In late 2019 to 2020, PG&E embarked on an intensive effort to improve the POMMS model by increasing the resolution from 3x3km to 2x2km as well as increasing the model accuracy through model configuration testing. The 2020 goal was to deploy a more accurate and granular high-resolution model to reduce customer impacts due to Public Safety Power Shutoff (PSPS). To achieve this goal, PG&E internal numerical weather prediction experts collaborated with external experts, DTN and ADS.

Over the course of half a year from late 2019 to early 2020, twenty different model configurations were tested to determine the optimal weather model configuration for deployment. This included extensive back-testing and validation of past PSPS events to fine-tune model parameterizations and physics options to achieve the most accurate model possible for deployment. After the optimal model was recommended by external experts DTN and ADS and agreed upon by internal experts, it was deployed in 2020 and utilized during all 2020 PSPS events.

The current POMMS model configuration deployed is WRF model version 4.1.2, which provides data at 2x2km spatial and hourly temporal resolution. Key features added or made default in version 4 of WRF include a hybrid vertical coordinate and a moist potential temperature prognostic variable. A nested grid configuration of 18-, 6-, 2-, and 0.67-km (on demand) grids are utilized. The vertical grid has 51 levels and a 20 hPa top. Adaptive time stepping is used for computational efficiency and the model was configured to run in the AWS cloud across different AWS regions for redundancy. The POMMS forecasts include two deterministic forecasts as well as an eight-member ensemble. One deterministic model is initialized using ¼° output from the National Centers for Environmental Prediction (NCEP) - GFS model data as well as 1/12° Sea Surface Temperature analyses. The GFS, often referred to as the American Model, is operated and maintained by NOAA's National Center for Environmental Prediction and is the United States' flagship global model. The second deterministic model is initialized with the European Center for Medium Range Weather Forecast (ECMWF) global model. The 6 remaining members are split evenly between GFS and ECMWF initialized simulations.

Advanced soil moisture cycling, and snow cover cycling were added in Q2 2021. Data assimilation (3DVAR) is applied on the outer grid. Data available for assimilation and initialization are taken from MADIS and include conventional surface and upper-air observations, as well as aircraft data and satellite-derived winds. The model domain and nesting configuration is presented below. Each grid is run 4x a day aside from the 0.67km domain, which is run on-demand during high