2021 Wildfire Mitigation Plan Workshop

February 22, 2021

Risk Assessment, Mapping & Resource Allocation Methodology

Paul McGregor
Director, Electric Operations Risk Management & Analytics

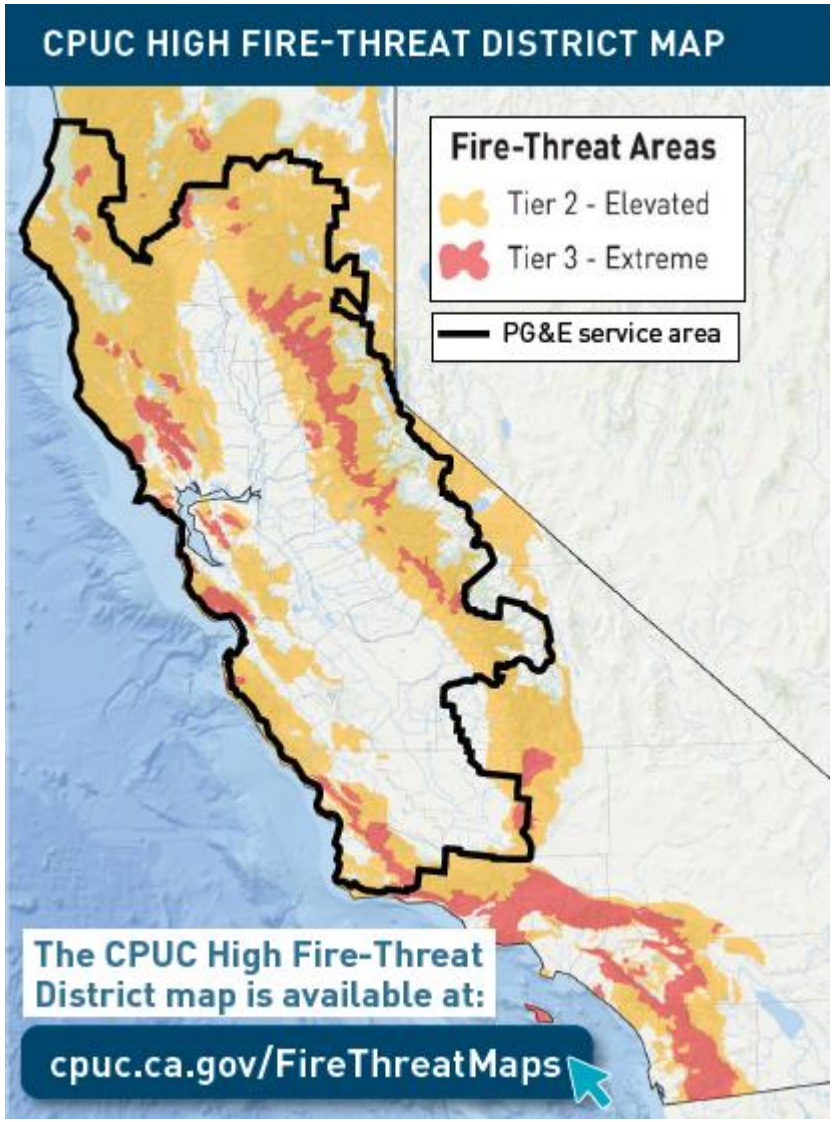
2021 Wildfire Mitigation Plan

Overview

Wildfire Risk Across PG&E's Service Territory

Wildfire Risk Across PG&E's Service Area	PG&E SYSTEMWIDE	HIGH FIRE-THREAT DISTRICTS
Electric customers served	5.5M	505,600
Overhead distribution line miles	81,000	25,500
Overhead transmission line miles	18,200	5,500

- Over half of PG&E's service territory lies in the High Fire Threat Districts (HFTD) Tiers 2 and 3
- Nearly one-third of the electric lines that provide power to our customers are now located in HFTD areas
- High temperatures, extreme dryness, and record-high winds have increased fire risks across the areas that PG&E serves
- 2020 was another unprecedented wildfire season with five of the six largest wildfires in California's history occurring in 2020, all in PG&E's service territory



Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

Introduction to the 2021 Wildfire Mitigation Plan

PG&E recently submitted its Wildfire Mitigation Plan where it outlines the steps the company will take this year, and into the future, to help prevent wildfires

- 2021 WMP continues many of the actions undertaken in our 2019 and 2020 WMPs
- Reflects an evolution to a more precise, technology-based approach to assess and mitigate wildfire risk
- Implements lessons learned from 2020 WMP, and incorporates feedback received from the Wildfire Safety Division, PG&E's Federal Monitor, and many other partners
- 2021 WMP has three overarching goals

REDUCE WILDFIRE IGNITION RISK

- Asset inspection and repair
- Enhanced vegetation management (EVM)
- System hardening
- Public Safety Power Shutoffs (PSPS)

ENHANCE SITUATIONAL AWARENESS

- Weather stations
- High-definition cameras
- Wildfire Safety Operations Center
- Meteorology

REDUCE IMPACT OF PSPS

- Reduce number of impacted customers
- Reduce duration
- Improve timeliness and accuracy of information

Supported by updated Wildfire Risk Modeling that informs prioritization and decision making

The 2021 Wildfire Mitigation Plan is available at: www.pge.com/wildfiremitigationplan

Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

2021 Wildfire Mitigation Plan

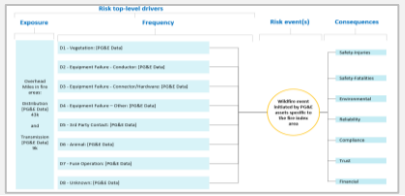
Risk Assessment, Mapping & Resource Allocation Methodology



Evolution of Risk Assessment and Modeling

2017 RAMP/ 2020 GRC

- First Generation RAMP Model using Probabilistic Modeling and Monte Carlo Simulation
- Multi Attribute Risk Score (MARS) & Risk Spend Efficiency (RSE)
- High Fire Threat Districts Definition



2019 WMP

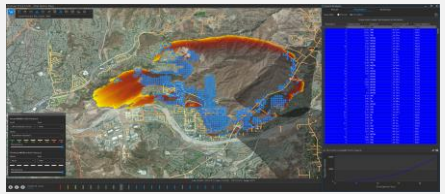
- Community Wildfire Safety Program
- Enhanced Wildfire Safety Inspection Program
- Ignition Analysis for Distribution & Transmission Voltage Classes



- Initial Fire Propagation Modeling (Reax)
- First-of-a-Kind Circuit Prioritization Models for System Hardening & Enhanced Vegetation Management Programs

2020 WMP

- Enhanced VM & SH
- Asset Inspection and Repair
- System Automation
- PSPS Improvements



- Improved Meteorology
- Inclusion of initial Egress methodology
- Fire Risk Model interaction between Outage Producing Winds (OPW) & Fire Potential Index (FPI)

2020 RAMP

- Second Generation RAMP Model using Python
- Enhanced Multi Attribute Value Function (MAVF) in accordance with SMAP Settlement Agreement

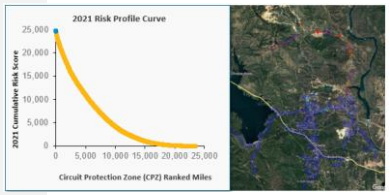
MAVF

Range	Natural Units	Weight	Scaling Function
0 - 100	Equivalent Fatalities[2]	50%	
0 - 4 Billion	Customer Minutes Interrupted (CMI)	20%	
0 - 750,000	Customers Affected	5%	
0 - $5B	Dollars ($)	25%	

- Enhanced Bowtie with Sub-drivers and Outcomes
- Exposure and Tranching performed various levels of granularity

2021 WMP

- Enhanced Risk Assessment and Prioritization Models for System Hardening and Enhanced Vegetation Management using:
  - Probability of Ignition
  - Fire Propagation & Consequence
- Risk Assessed at 100m grid-squares and aggregated to Circuit Segments



Please visit the 2021 Wildfire Mitigation Plan Sections 4.2 and 4.5.1 for more detailed information

Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

2021 Wildfire Risk Modeling Approach

PG&E's wildfire risk modeling framework is aligned with our wildfire risk bowtie defined in the 2020 RAMP, and is used to assess Probability of Ignition or Likelihood of Risk Event (LoRE) and the Consequence of Risk Event (CoRE)

LoRE

- Vegetation Ignition Model
- Equipment Ignition Model

Fire Event

CoRE

- Wildfire Consequence Model

Mitigation Programs

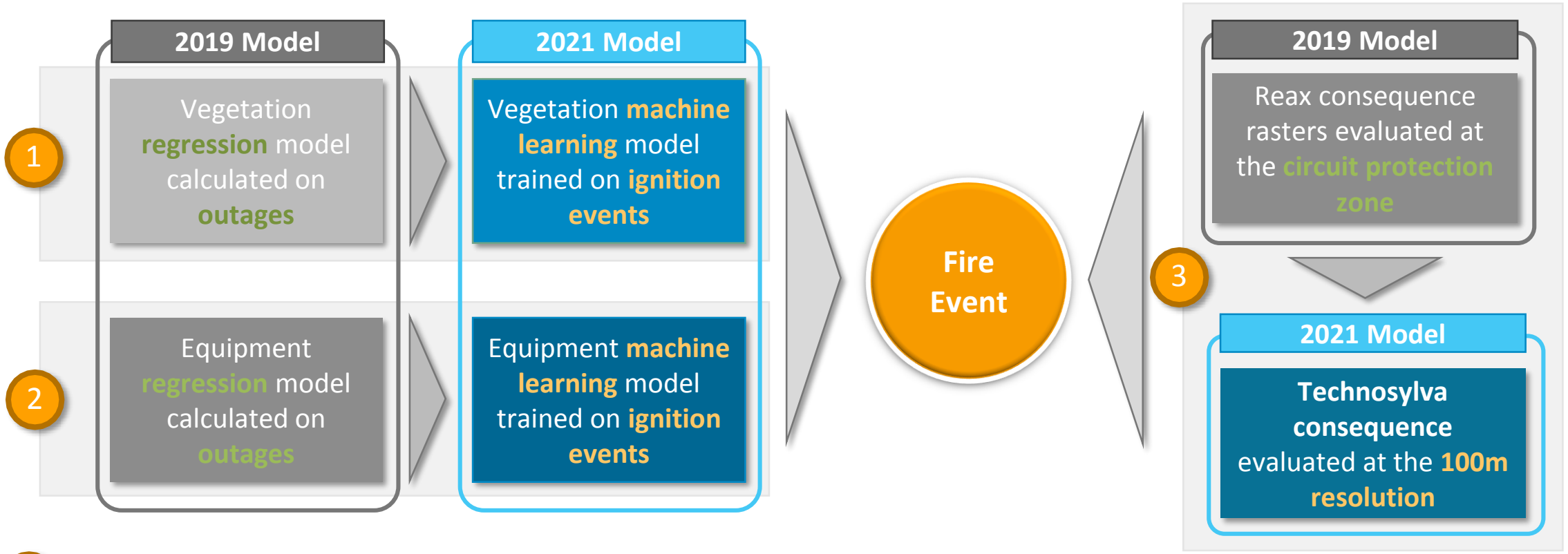
- System Hardening Prioritization
- Enhanced Vegetation Management Prioritization
- Inspection Ordering & Cadence
- Repair Prioritization

Risk = Ignition Probability x Wildfire Consequence

Please visit the 2021 Wildfire Mitigation Plan Section 4.5.1 for more detailed information

Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

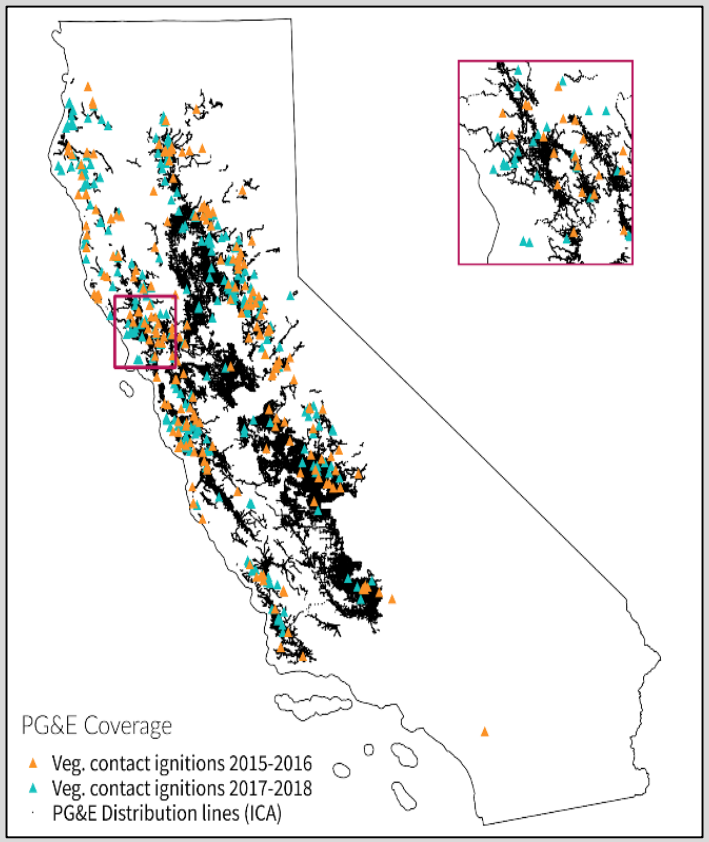
Enhancements to the previous Wildfire Risk Model



1. Replacing the regression-based vegetation ignition likelihood with the 2021 Maximum Entropy machine learning vegetation ignition probability using an expanded covariate pool
2. Replacing the regression-based equipment ignition likelihood with the 2021 Maximum Entropy machine learning equipment ignition probability using an expanded covariate pool
3. Replacing the Reax fire propagation and consequence module with the Technosylva fire behavior solution with updated data layers and consequence output

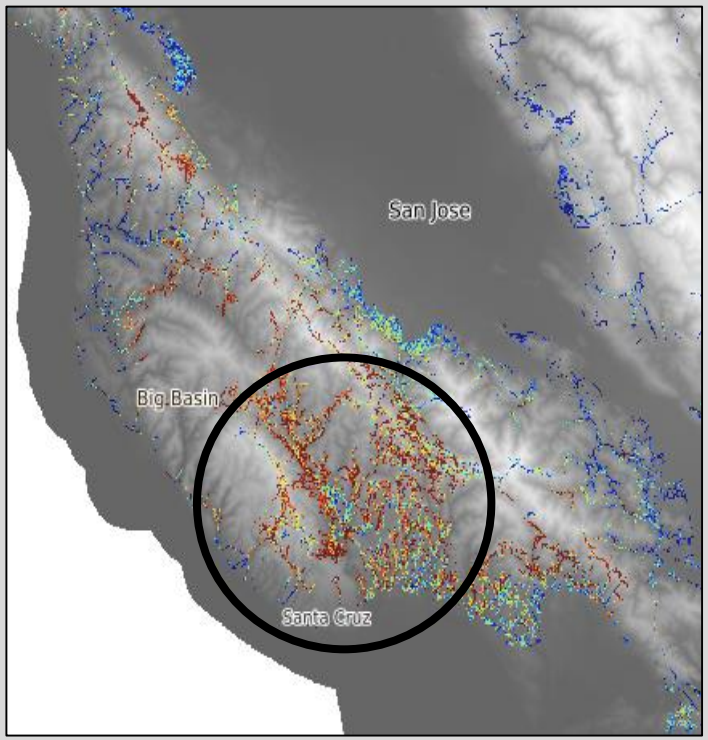
Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

Maximum Entropy (MaxEnt) Approach



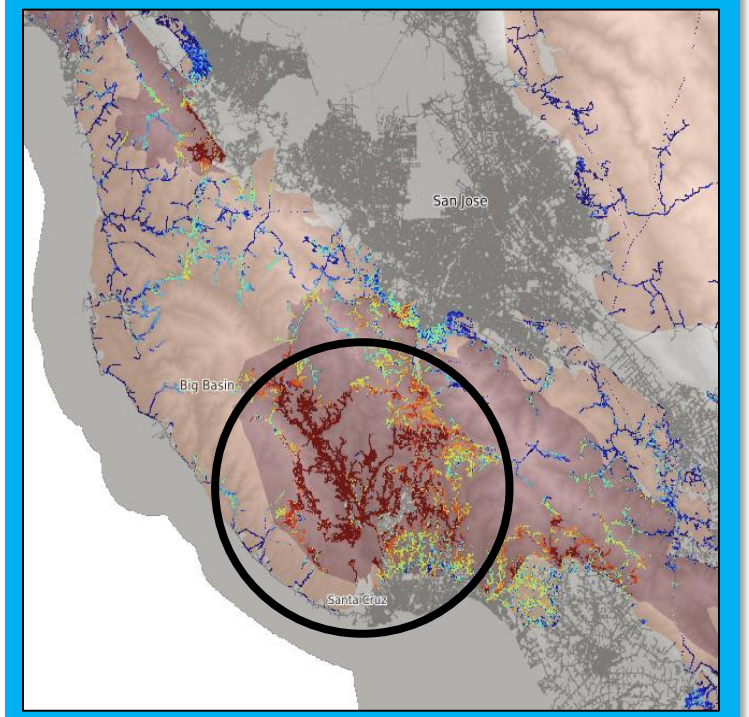
Locations and characteristics of areas where ignitions occur are collected and compiled

+



Similarities between the conditions at ignition points are identified, and evaluated for commonality

=



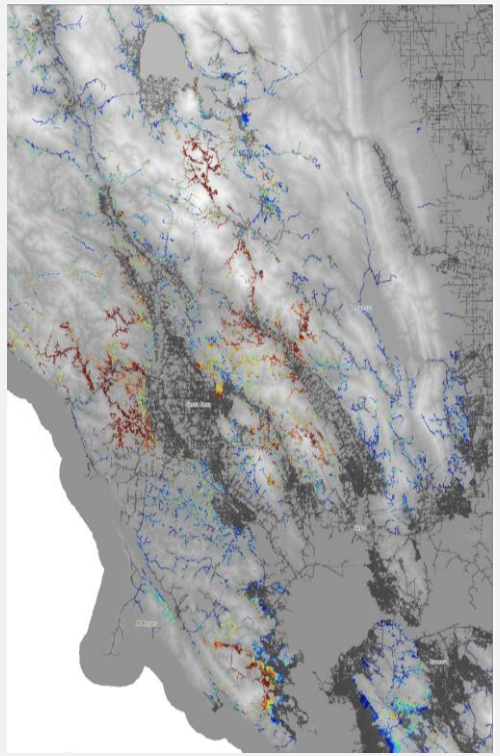
Places where there are similar conditions across the examined area are given a probability of the event occurring based on similarity to other ignition locations and a level of uncertainty

Please visit the 2021 Wildfire Mitigation Plan Section 4.3 for more detailed discussion on MaxEnt

Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

Probability and Consequence Visualization

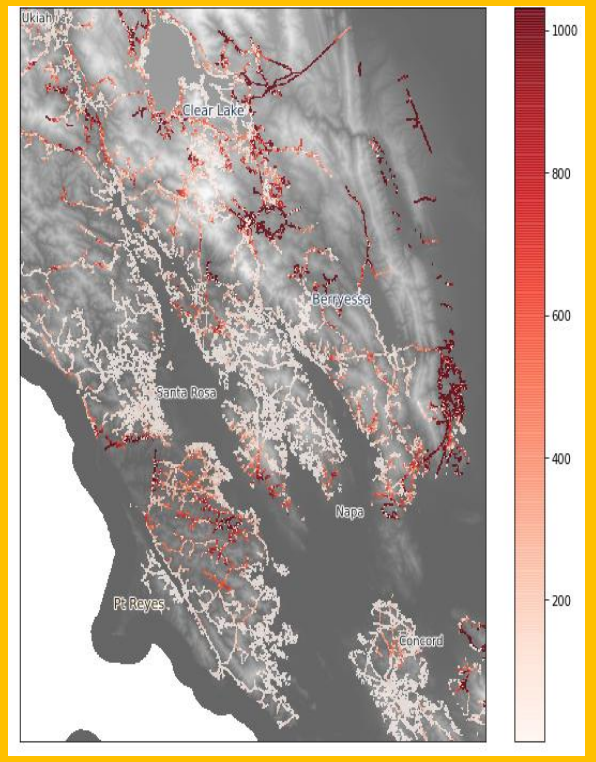
Ignition Probability



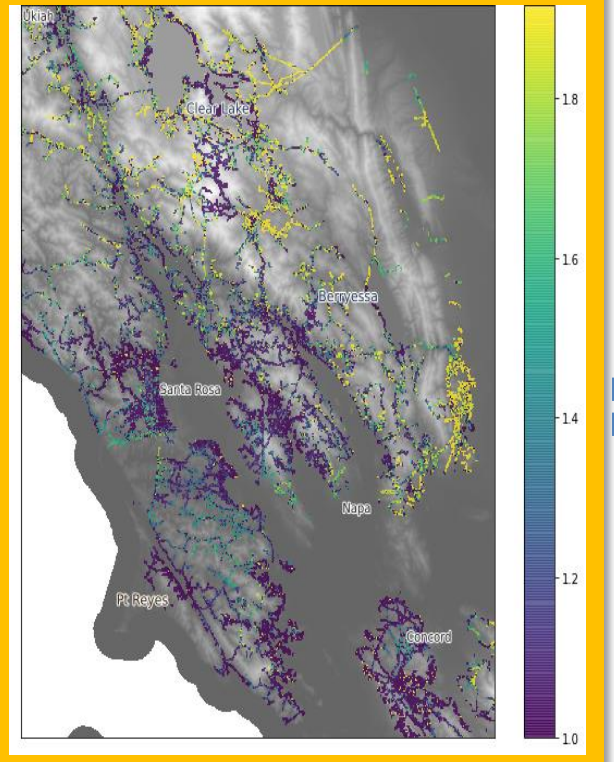
Probability of Ignition
(Red High, Blue is Low)

×

Wildfire Consequence



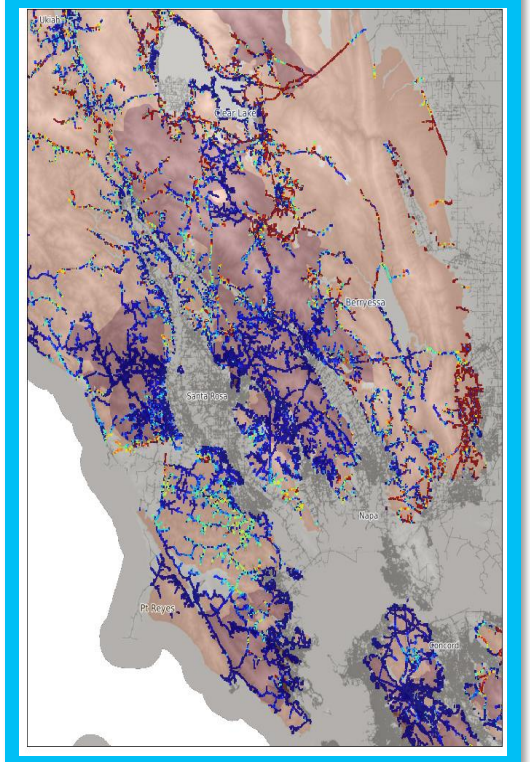
Technosylva Burn Area
Consequence



Technosylva Fire
Behavior Index

=

Risk Score



Risk Units (MAVF)
(Red High, Blue Low)

Risk = Ignition Probability x Wildfire Consequence

Please visit the 2021 Wildfire Mitigation Plan Section 4.5.1 for more detailed information

Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

Operationalizing the Model

Risk Model

- 2021 Wildfire Distribution Risk Model

Additional Considerations

- Updated 2020 LiDAR data on strike potential trees across the 25,000 miles of HFTDs
- Public Safety Specialist expertise regarding fire history by area and the details on specific locations in terms of terrain and egress routes
- System hardening projects and fire rebuilds underway and completed
- Frequency and number of customers impacted by PSPS events in 2019 and 2020

Workplans & Metrics

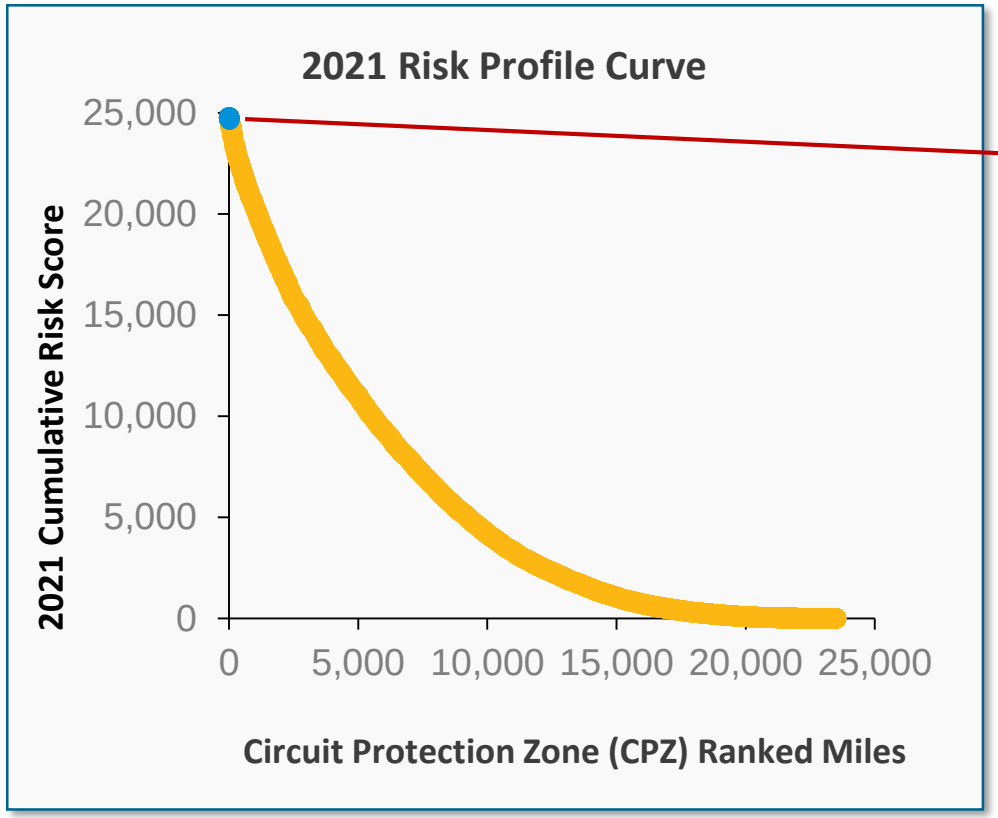
- Enhanced Vegetation Management
- System Hardening
- PG&E Public Safety Metrics

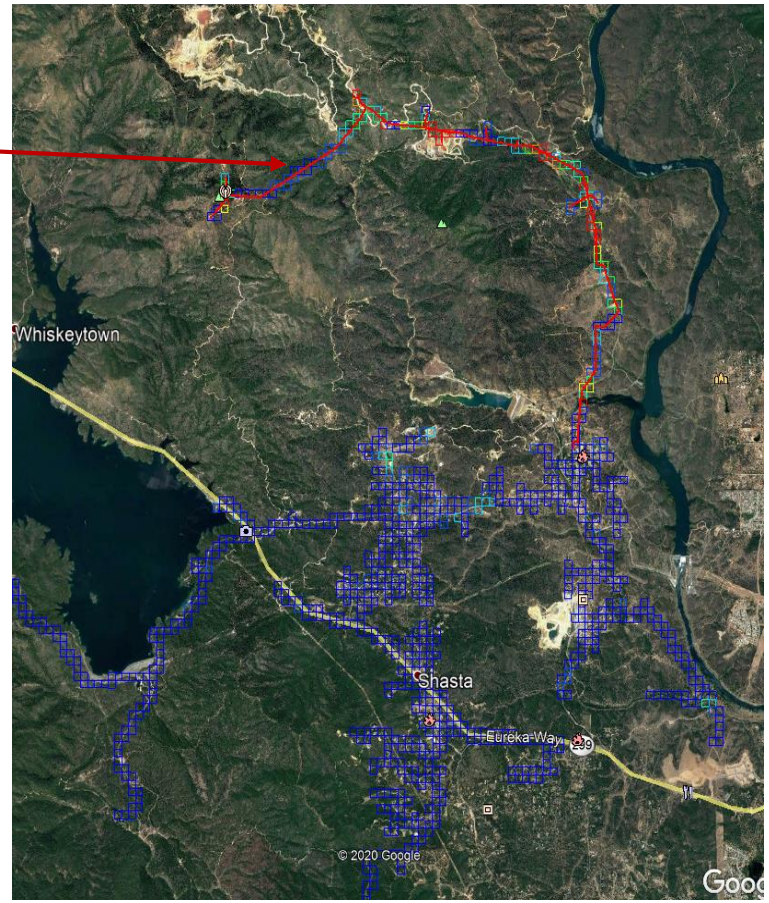
Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

System Hardening Example

Keswick 1101 Circuit Protection Zone (CPZ)

- This circuit segment is in the top 50 miles in the risk profile curve
- 6.6 miles in total length
- The 100m X 100m squares (blue, yellow and red) on the picture each have a risk score
- Total CPZ risk score is 48.84 MAVF units (sum of all the 100m grid squares along the circuit)
- Average risk score of all the grid points results in the CPZ mean risk score of 1.25 units
- Circuit segment was evaluated for OH and UG solutions





Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

2021 Outlook and Activities

During 2021, PG&E will work to build upon existing risk models and develop additional models to enhance its understanding of Wildfire Risk and Wildfire Mitigation Programs

- 2022 Wildfire Distribution Risk Model (under development)
  - Building on the capabilities of the 2021 Wildfire Distribution Risk Model
  - Additional assets to be added include Transformers and Poles

- 2022 Wildfire Transmission Risk Model (under development)

- Future State of PSPS Consequence Model (scoping)

Please visit the 2021 Wildfire Mitigation Plan Section 4.1 (d) and 4.5.1 for more detailed discussion on future models

Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

Thank you



Appendix

Ignition Modeling Approach using MaxEnt

MODEL DETAIL

Methodology/ Approach

- Divide Ignition Events into distinct categories of Vegetative or Conductor Caused
- Make vegetative or conductor ignition predictions with MaxEnt model at a scale of 100m x 100m "pixels" along the Dx grid
- Rolls-up pixels to Circuit Protection Zones
- For each pixel, assign risk score based upon the product of: LoRE X CoRE

Approach

- Use MaxEnt model technique due to its ability to predict rare and unique events in a given region and their probability of occurring both geospatially and under aggregated weather conditions
- Ignition probabilities calculated every 100m along conductor lines and then assigned to a pixel along Dx grid
- Ignition probabilities are combined with consequence (CORE) to determine overall risk

Ignition Probability

Likelihood: via ignition prediction (MaxEnt)

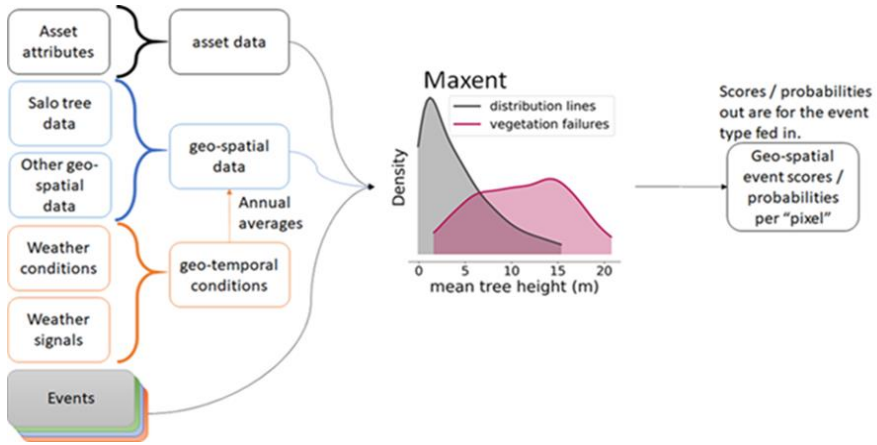
Effect: via :
(1) Ignition spread (Technosylva FireSim)
(2) Ignition consequence (Technosylva FireSim)

MAXENT MODEL

Training: On California Public Utilities Commission (CPUC) Reportable Ignition Events and related geospatial and temporal weather data

Vegetation/equipment Ignition Model: Two models were developed based on two specific risk mitigation priorities and their associated, relevant risk drivers – EVM and SH

Ignition likelihood:
The likelihood of ignition in 100m x 100m pixels determined by either Vegetation or Equipment



Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

Consequence Modeling Approach using Technosylva

MODEL DETAIL

Methodology/ Approach

- Understand how a fire spreads in varying weather conditions and environments along PG&E resources
- Results tied back to Ramp model with MAVF Scores
- Predict Fire spread along all HFTD assets with an ignition event.

Approach

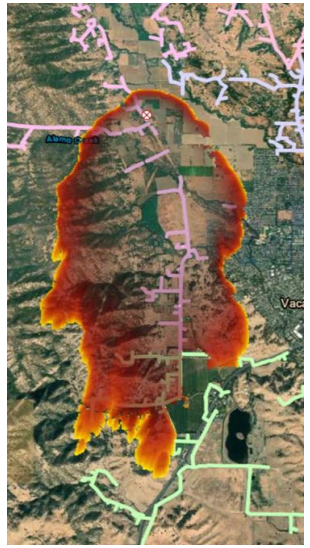
- Fire Spread simulations conducted at regular intervals along assets in HFTDs
- Utilize Technosylva Firesim a industry standard for fire burn simulations taking into account environment and weather effects
- Consult with Fire Experts to review results

Consequence Components

Spread: via 8 hour burn simulation (Technosylva Firesim)
Effect: via :
(1) Ignition spread (Technosylva Firesim Acres Burned)
(2) Rate of Spread(Technolylva Firesim FBI)
(3) Burn Intensity (Technosylva Firesim FBI)
(4) Building Impacted (Technosylva Firesim Structures Impacted)

TECHNOSYLVA BURN SIMULATION

- Technosylva simulation of 8-hour burn every 200m along HFTD lines
- Simulations conducted with weather data from 452 worst historical fire weather days
- Outputs key consequence metrics: acres burned, population and structures impacted, and fire behavior index (FBI).
- FBI score based on flame length (burn intensity metric) and rate of spread (ROS)



FBI Class		Description
1	LOW	Fire will burn and will spread however it presents very little resistance to control and direct attack with firefighters is possible
2	MODERATE	Fire spreads rapidly presenting moderate resistance to control but can be countered with direct attack by firefighters
3	ACTIVE	Fire spreads very rapidly presenting substantial resistance to control. Direct attack with firefighters must be supplemented with equipment and/or air support.
4	VERY ACTIVE	Fire spreads very rapidly presenting extreme resistance to control. Indirect attack may be effective. Safety of firefighters in the area becomes a concern
5	EXTREME	Fire spreads very rapidly presenting extreme resistance to control. Any form of attack will probably not be effective. Safety of firefighters in the area is of critical concern.

Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.

Ladder Effect

Ladder effect in wildland fires create the conditions for low **lying fast burning fuels to intensify** as they move from up the canopy and into more energy dense fuel sources. Accounting for this effect in wildfire modeling **de-emphasizes areas of dense fuels** as high risk for ignition, due to lack of potential surface fuels.

Additionally, locations that have large amounts of surface fuels that can **sustain high temperatures** are rated more highly as these are more likely to ladder into difficult to contain crown fires.

Progression of Wildland Fire Ladder Effect



Sourece: Idyllwild Fire https://idyllwildfire.com/defensible-space.html

Some of the measures included in this presentation are contemplated as additional precautionary measures intended to further reduce the risk of wildfires.