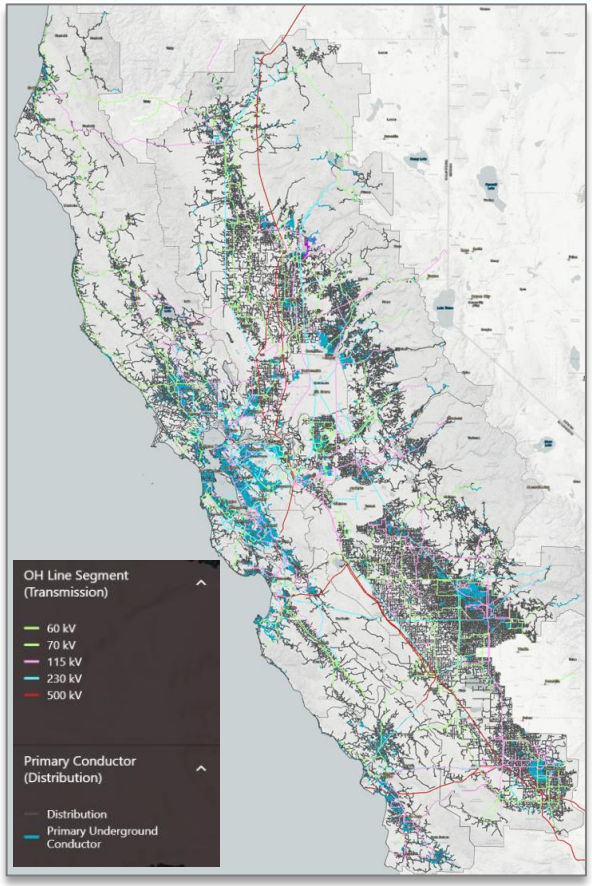
Outage Prediction Modeling at PG&E

ESIG 2026

Together, Building a Better California

PG&E's Electric Infrastructure – Northern and Central CA

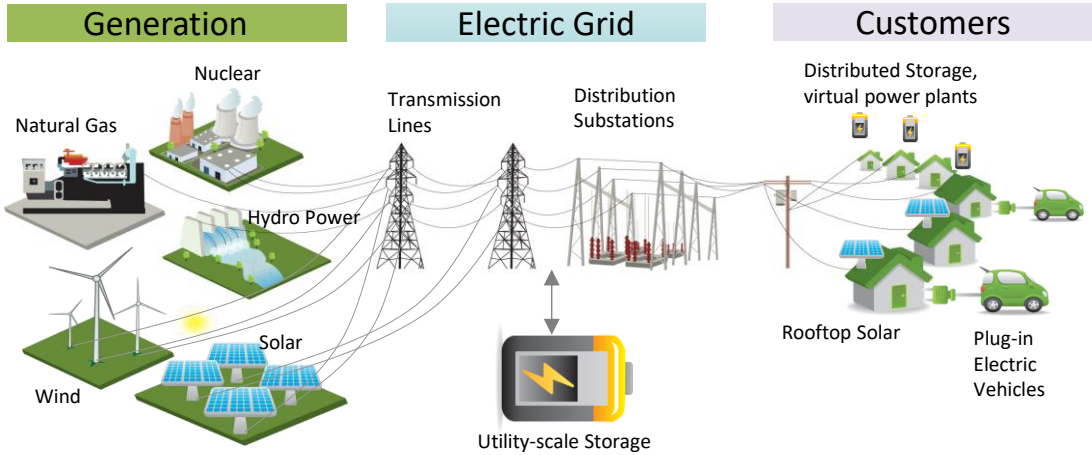


~202,000 km — **Electric lines** *Could wrap Earth 5x stacked end-end*

~170,000 km — **Distribution lines**
- **~137,000 km** Overhead
- **~33,000 km** Underground

~50,000 km — **Overhead Line Miles in High Fire Threat Districts (HFTD)**

>5 Million — **Trees that can strike lines in HFTD**



Meet The Meteorology & Fire Science Team

Leadership

Scott Strenfel Sr. Dir. Meteorology and Fire Science
Sean Gilleran Chief, Machine Learning Scientist
Evan Duffey Manager, Meteorology Operations
Shaun Tanner Manager, Systems and Analytics

Meteorology Operations

Richard Bagley
Elisabeth Saarnak
Kyle Anderson
Neil Flaiz
Rihaan Gangat
Ted Schlaepfer

+Contract Support (meteorologists)

Systems and Analytics

A.J. Eiserloh
Bereket Habtezion
Elaine Yang
Ariana Moncada
Jonathan Wong
Koorosh Davoodian

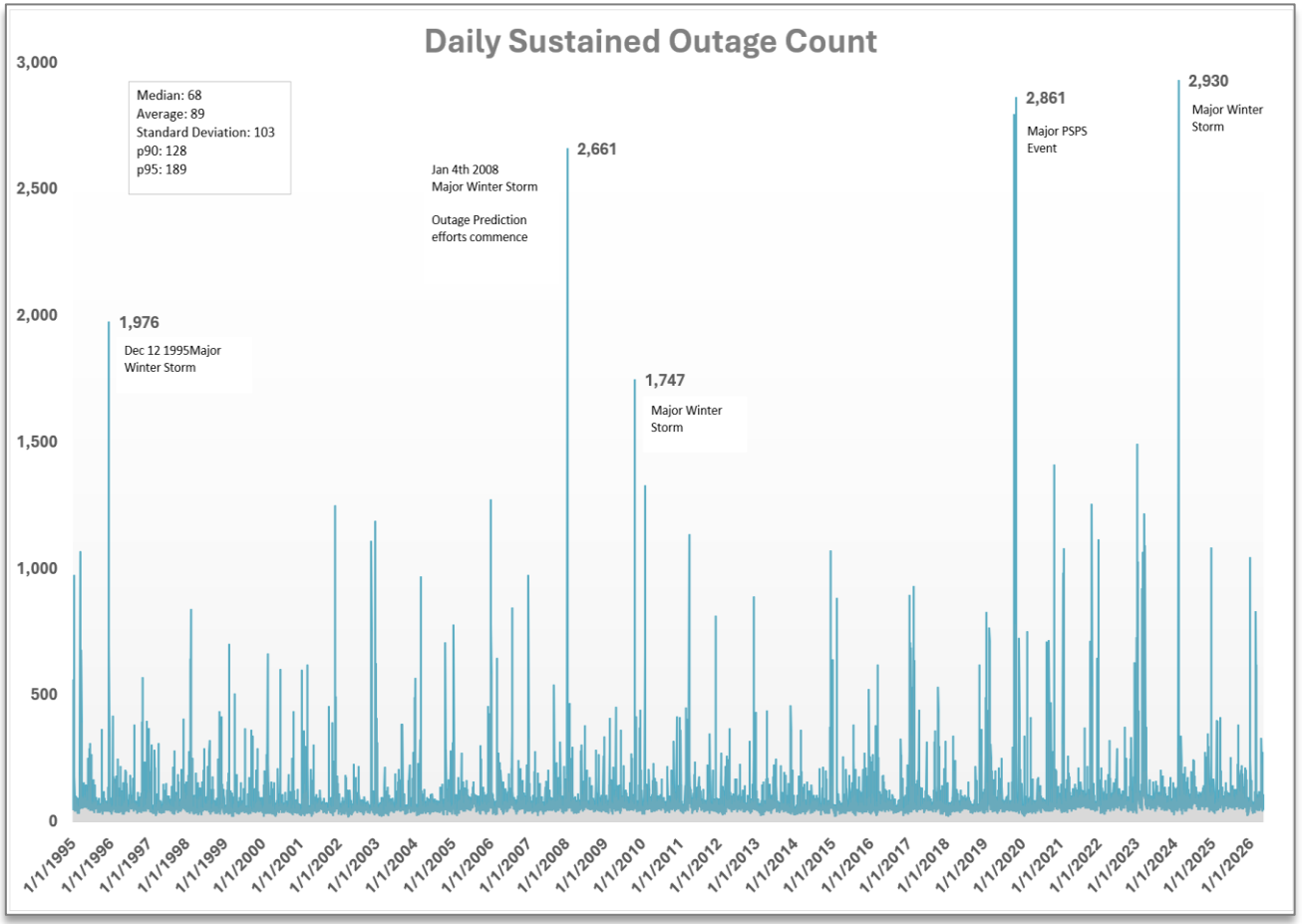
+Contract Support (developers/software engineers)

Who we partner with inside PG&E:

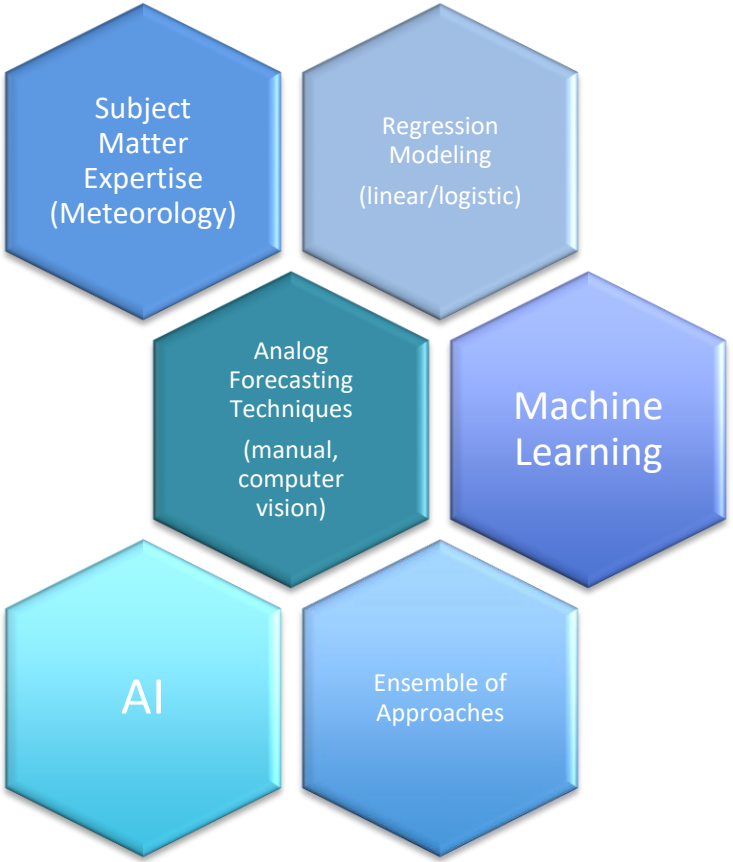
- Electric Transmission and Distribution
- Gas Systems Operations
- Diablo Canyon Power Plant (DCPP)
- Power Generation – Hydro/Solar
- Customer Energy Solutions
- Short Term Electric Supply
- Gas Construction and Planning

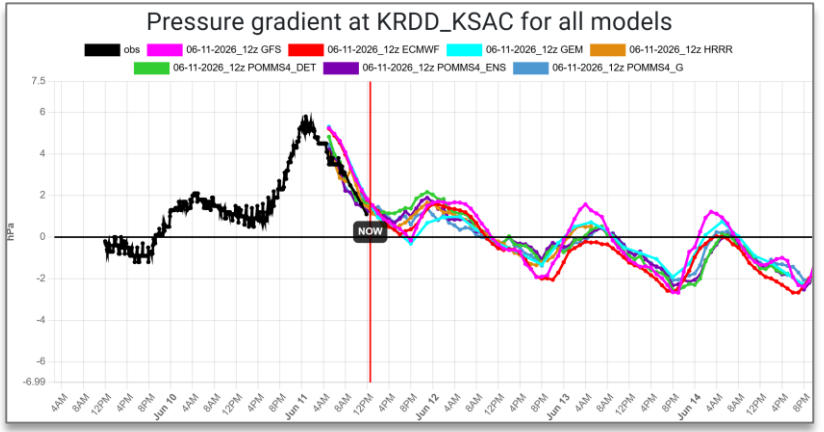
PG&E Outage History

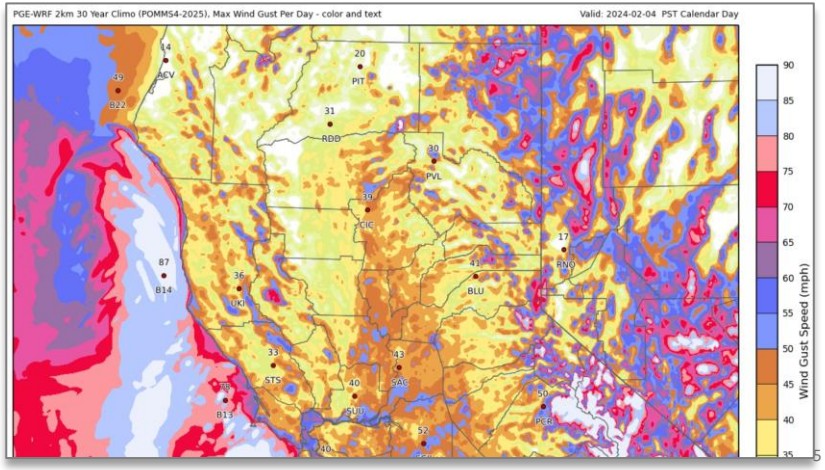
- ~70 unplanned Sustained Outages (SO) on a typical BlueSky day
- We experience a >1000 SO event ~1/year and >2000 SO event ~1/10 years.
- Outage prediction efforts began after the Jan 4th 2008 storm, which disrupted service to 1.4M customers



Outage Forecasting Methods





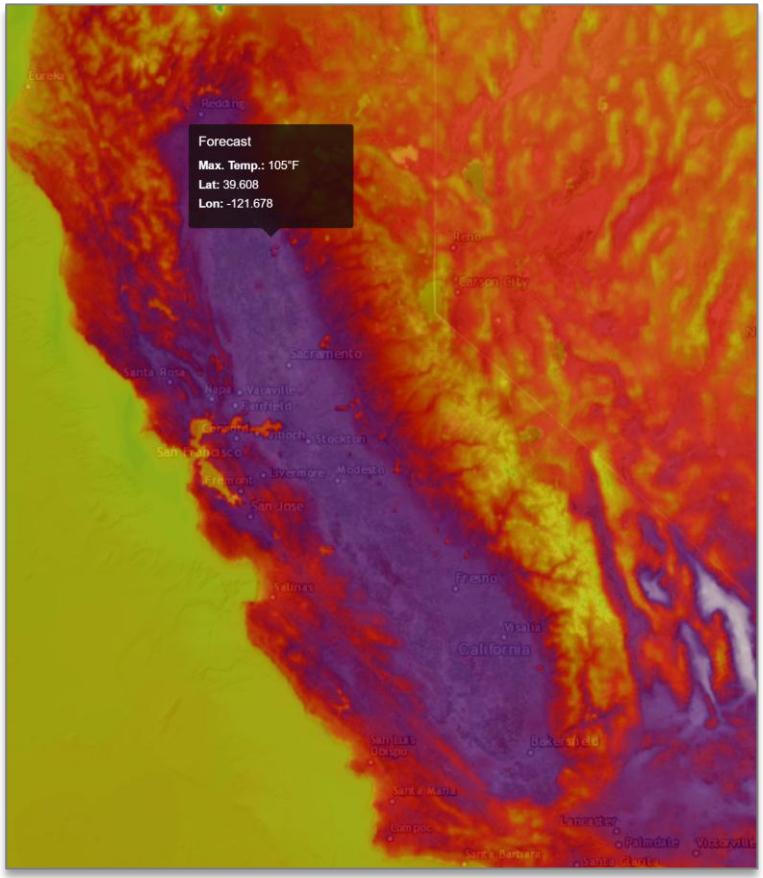


High Resolution Weather Model & 30+ Yr. Climatology

Carpenter *et al.*, 2024

Weather/fuel moisture forecasts and 30-year climatology

- Described in detail via Carpenter *et al.,* 2024
- 129 hour forecast horizon **(~10 billion data surface data points per day**)
- 2km^2 spatial resolution, hourly temporal resolution
- On demand numerical simulations at 0.67km^2
- ML and AI downscaling to weather stations and 0.7km^2 grid
- 9-member ensemble based on ECMWF, 1-GFS deterministic
- **1995 – 2025 climatology dataset, updated annually - same 2x2km, hourly resolution as forecast model (~4.5 trillion data points)**



Applications

- Train/Deploy weather-outage-ignition models (**OPW, IOPW, IPW**).
- Build Fire Probability model (**FPI**).
- Build and execute PSPS models
- **Calibrate PSPS guidance for operational use**
- Climatology used for long term planning decisions (*e.g.*, undergrounding)
- Input to dynamic fire spread models (*e.g.*, Technosylva)

Partners

technosylva DTN aws

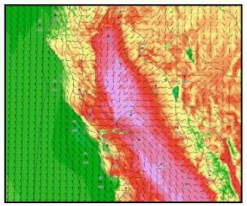
Partnerships with Research Institutions

Wildfire Interdisciplinary Research Center
wildfirecenter.org

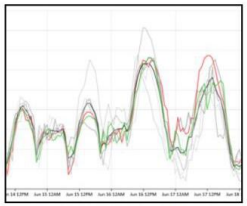
SAN JOSÉ STATE UNIVERSITY

PG&E has partnered with the Wildfire Interdisciplinary Research Center (WIRC) on research to operations projects

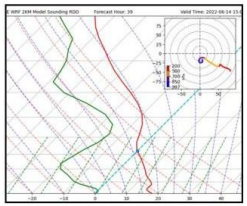
PG&E and SJSU 2 KM WRF Model Visualization Project



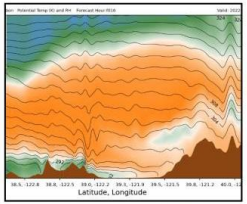
WEATHER MAPS
Selected weather maps.



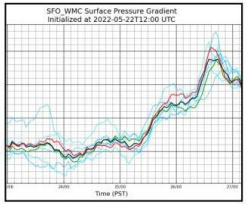
POINT FORECASTS
Precip |Temp | Fosberg FWI



SOUNDINGS
Selected model station soundings.



CROSS SECTIONS
Selected cross-sections.



GRADIENTS
Selected pressure gradients.

LIGHTNING
Lightning page and archive.

View data here: http://www.met.sjsu.edu/weather/wirc-prod/

- PG&E's high-resolution weather model data is available to the public
- Researchers have access to our 30+ year climatological weather, fuels and fire occurrence datasets
- Multiple papers published
- PG&E is a member of the Industry Advisory Board of the NSF supported Industry –University research collaborative w/ WIRC

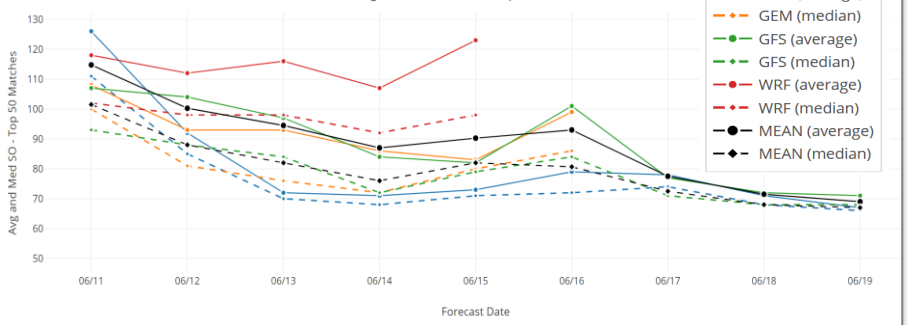
Analog Forecasting Tools

Wildfire Interdisciplinary Research Center

PG&E Analog Matching System (PAMS) Version 2.04

Top 50 | Top 10 | Match Engine: Winter Storm | Wind | Heat | Snow | Lightning | Model Cycle: 00Z | Model Run: 2026-06-11 00Z

Date	SO Model Mean				fraction of matches showing WD					WX Risk	
	Avg	Med	High	Low	AVG	GFS	ECM	GEM	WRF	WX1	WX2
2026-06-11	115	102	246	52	0.72	0.64	0.86	0.58	0.80	HT	
2026-06-12	100	88	289	49	0.56	0.58	0.52	0.44	0.72	HT	
2026-06-13	94	82	254	49	0.47	0.52	0.20	0.42	0.74	HT	
2026-06-14	87	76	235	49	0.35	0.28	0.12	0.38	0.64	HT	
2026-06-15	90	82	215	48	0.39	0.34	0.16	0.36	0.68	HT	
2026-06-16	93	81	296	48	0.37	0.42	0.20	0.48		HT	
2026-06-17	78	72	136	51	0.24	0.26	0.22			HT	
2026-06-18	72	68	155	39	0.18	0.20	0.16			HT	LG
2026-06-19	69	67	131	40	0.12	0.16	0.08			LG	



PGE-WRF Climo Viewer

Daily | Monthly | Daily Max or Total

Date:

2025 | 02

Updated through 2025-12

ERA5 Reanalysis Viewer

1990-2026 Daily | 1990-2026 Monthly | 1940-1989 Daily | 1940-1989 Monthly

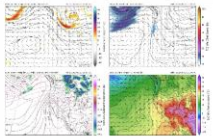
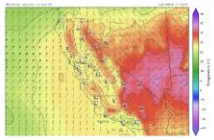
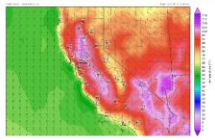
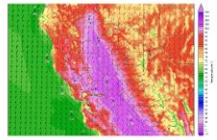
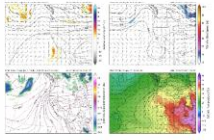
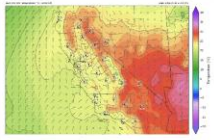
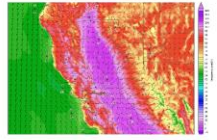
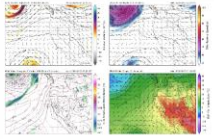
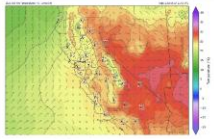
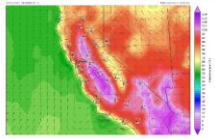
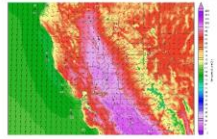
Date:

2018 | 06 | 23

Updated through 2026-04-30

Extent:

- Pacific
- Western US
- California

Rank	Match Day	D-DIFF	Tot	Average M-RMSE	4-Panel	850temp	SfcTemp	WRF viewer	Tot	Day
1	2018-06-23	12	100	0.243					100	SD
2	2009-07-14	33	112	0.243					112	GS
3	2020-05-27	15	128	0.245					128	GS

PG&E Outage And Ignition Probability Models (OPW & IPW)

OPW is a multi-classification machine learning model predicting the probability of outage for each cause class

IPW predicts ignition probability by combining OPW with a machine learning p(ignition given outage) model

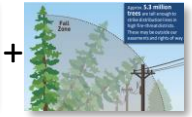
Model Features

Weather

Wind Speed
Turbulence
Temperature
Precipitation

+

Vegetation Exposure



Tree Height + Canopy Cover of Strike Trees from Planet Labs

+

Environmental

Slope
Soil Moisture

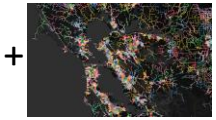
+

Asset Age

Pole Age

+

Local Performance



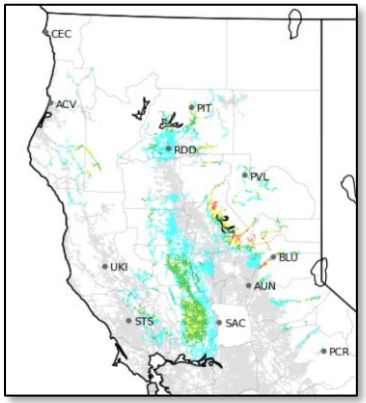
Outage trends specific to each location

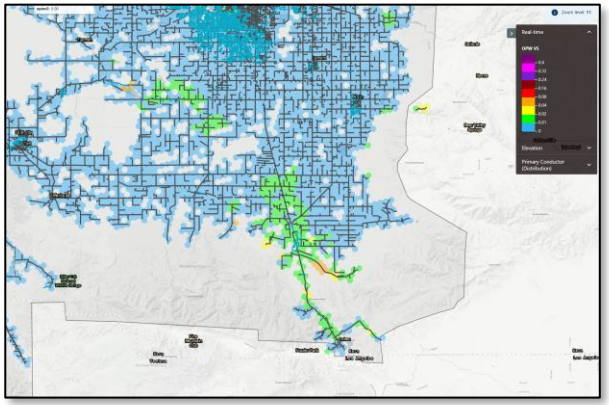
$$OPW = P(Outage_{cell,hour}) = \sum_{class}^{cause\ clases} P(Outage_{class,cell,hour})$$

Model Approach

- **Outage model (OPW)** trained on all hours since 2008 and whether an unplanned (momentary and sustained) outage was observed or not in each location. All outages and 270 billion data points were evaluated to develop model.
- **Model Output = p(outage)** at 0.7km^2 hourly (forecast & historical)
- **Verification** Macro AUROC = 0.72 | Vegetation = 0.84

Model Outputs





From Outages to Ignition

- We **translate from p(outage) to p(ignition)** using machine learning **predicts the probability of an ignition given an outage**
- Features such as weather (hot, dry, windy), fine dead fuels, herbaceous LFM, solar irradiance, and grid setting like EPSS
- The result is the **Ignition Probability Weather (IPW)** model:

$$IPW = P(\text{Ignition}) = P(Outage) * P(Ignition|Outage)$$

The Daily Outage Forecast – Distribution

Distribution System Operations Impact Forecast

Wednesday, June 10, 2026

1 OUTAGE RISK BY WEATHER TYPE

	Wednesday 6/10/26	Thursday 6/11/26	Friday 6/12/26	Saturday 6/13/26	Sunday 6/14/26	Monday 6/15/26	Tuesday 6/16/26	Wednesday 6/17/26
Heat		1						
Flashover								
Heavy Rain								
Thunderstorms								
Low Snow								
South Wind								
Northwest Wind								
Northeast Wind	1	1						
RISK LEGEND	No Risk		(1) Slight Risk		(2) Moderate Risk		(3) High Risk	

* A Extended Divisional Outage Forecast will be issued when Risk(s) meet or exceed "Moderate" during that period

2 SYSTEM-WIDE OUTAGE CATEGORY PROBABILITY

	Wednesday 6/10/26	Thursday 6/11/26	Friday 6/12/26	Saturday 6/13/26	Sunday 6/14/26	Monday 6/15/26	Tuesday 6/16/26	Wednesday 6/17/26
Category 1	65%	45%	100%	100%	100%	100%	100%	100%
Category 2	35%	55%	0%	0%	0%	0%	0%	0%
Category 3	0%	0%	0%	0%	0%	0%	0%	0%
Category 4	0%	0%	0%	0%	0%	0%	0%	0%
Category 5	0%	0%	0%	0%	0%	0%	0%	0%

OUTAGE LEGEND

Category	Generalized Risk	Staffing
Category 1	Significant Adverse Weather Unlikely	Normal, but have a plan
Category 2	Adverse Weather Possible	Have plan for escalation
Category 3	Adverse Weather Likely	Staffing & Timing as Directed
Category 4	Extreme Weather Possible	Staffing & Timing as Directed
Category 5	Extreme Weather Likely	Staffing & Timing as Directed

3 OUTAGE FORECAST & RISK TIMING BY DIVISION

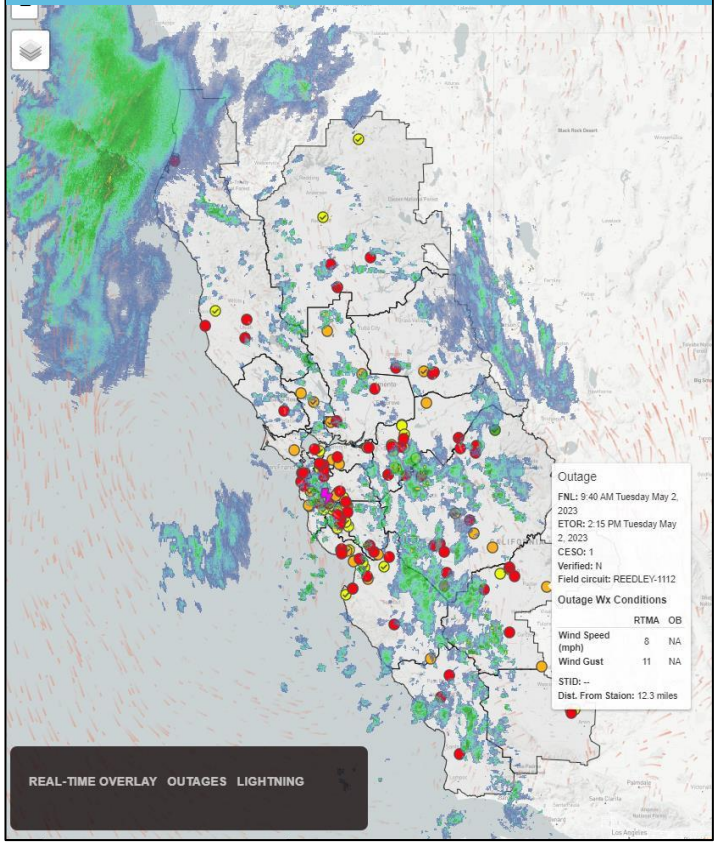
		Wednesday 6/10/26			Thursday 6/11/26			Friday 6/12/26			Saturday 6/13/26		
		Outage Range*		Risk Timing**	Outage Range*		Risk Timing**	Outage Range*		Risk Timing**	Outage Range*		Risk Timing**
SYSTEM TOTAL		117	135	13:00 - 24:00	119	157	00:00 - 20:00	104	114		75	92	
North Coast	Humboldt	5	7		6	9		5	6		4	5	
	Sonoma	6	7		6	7		5	6		4	5	
	North Bay	5	8	22:00 - 24:00	7	11	00:00 - 14:00	4	5		3	4	
	TOTAL	16	22	22:00 - 24:00	19	27		14	17		11	14	
North Valley & Sierra	North Valley	11	18	13:00 - 24:00	10	17	00:00 - 14:00	8	11		6	9	
	Sierra	9	14	13:00 - 24:00	9	13	00:00 - 12:00	7	9		5	7	
	Sacramento	13	17	13:00 - 24:00	13	16	00:00 - 14:00	9	12		6	9	
	TOTAL	33	49	13:00 - 24:00	32	46	00:00 - 14:00	24	32		17	25	
Bay Area	San Francisco	1	3		1	2		2	3		1	2	
	East Bay	4	5		4	5		3	4		2	3	
	Diablo	4	6		6	8	16:00 - 20:00	3	4		3	4	
	Peninsula	3	5		4	5		3	4		3	4	
	Mission	4	5		4	5		3	4		2	3	
	TOTAL	16	24		19	25	16:00 - 20:00	14	19		11	16	
South Bay & Central Coast	De Anza	3	4		3	4		3	4		2	3	
	San Jose	4	5		5	8	16:00 - 20:00	4	5		3	4	
	Central Coast	8	10		8	10		9	11		5	7	
	Los Padres	6	7		4	5		4	5		3	4	
	TOTAL	21	26		20	27	16:00 - 20:00	20	25		13	18	
Central Valley	Stockton	8	9		7	8		8	9		5	6	
	Yosemite	8	10		9	10		9	10		6	8	
	Fresno	9	13		9	13		10	13		8	11	
	Kern	6	7		4	5		5	6		4	5	
	TOTAL	31	39		29	36		32	38		23	30	

* Outage range consists of an "Expected" and "Reasonable Worst Case" forecast of sustained transformer level outages and above

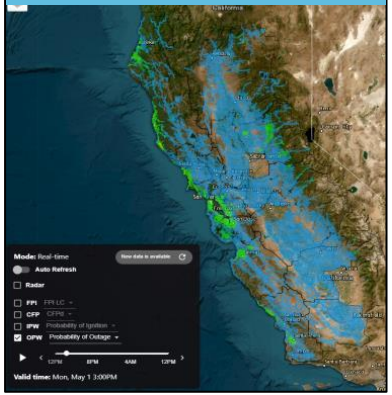
** Risk timing reflects the peak outage period

Meteorological Visualizations in AWS

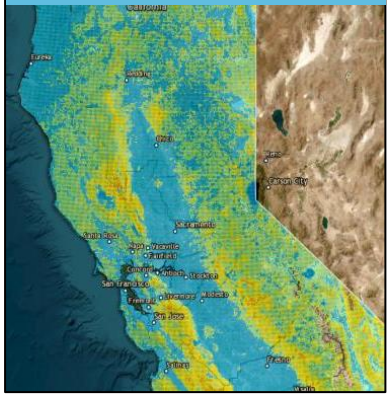
Radar, Wind Streaks, Outages, Lightning



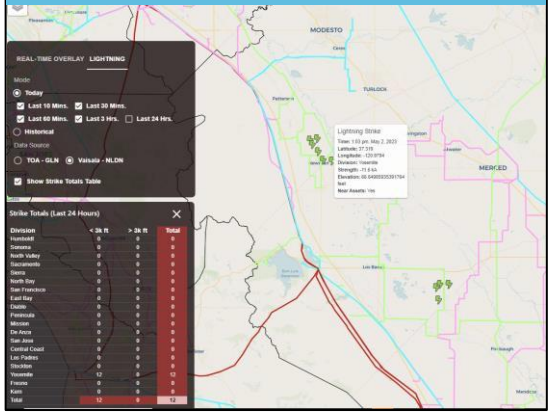
Outage Probability Map



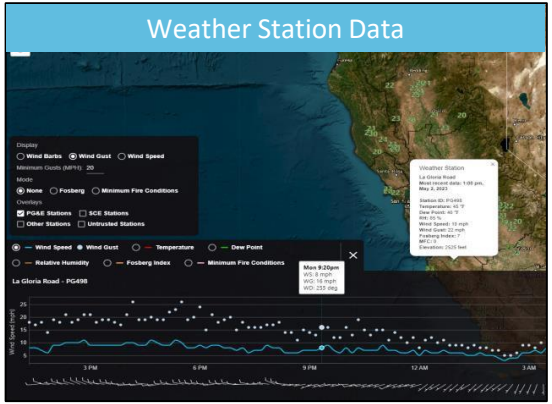
Fire Potential Index (FPI)



Lightning



Weather Station Data



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

Thank you!

Scott.Strenfel@pge.com

Together, Building
a Better California

PG&E Weather Station Project

We have installed **1,637 weather stations** to date. 35 installed in 2025. 1500 stations equipped with machine learning forecasts.

- All data collected is available to the public via MesoWest, National Weather Service (NWS) and Meteorological Assimilation Data Ingest System (MADIS)
- >200,000 observations daily, >75M per year
- 30 second observations available on-demand
- To determine optimal site locations, PG&E collaborates with NWS offices, CAL FIRE, US Forest Service and others

If interested in further information contact: Rihaan.Gangat@pge.com

PG&E Mt. Diablo Weather Station

Station Coverage Area