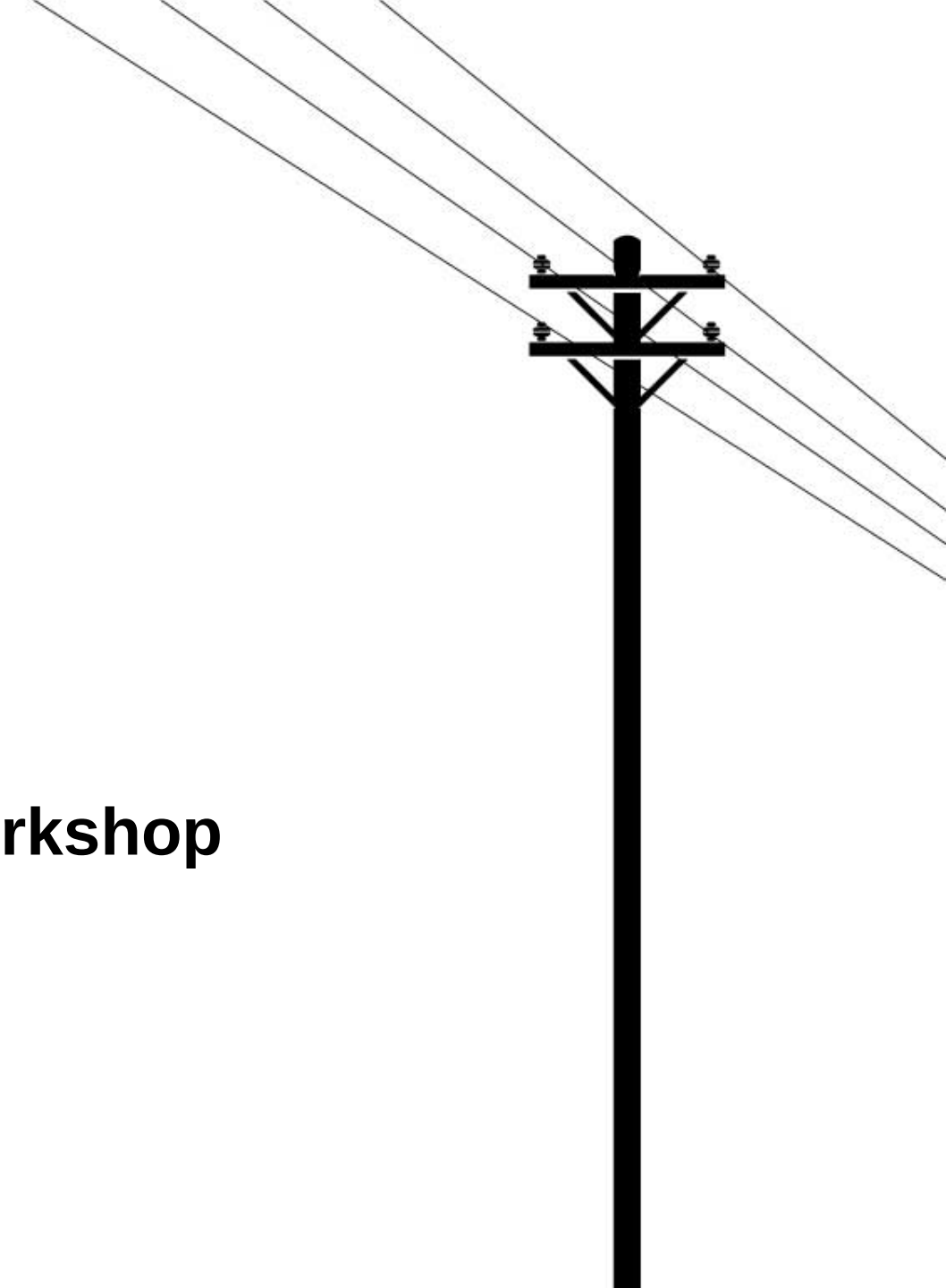


SDGE™

& WILDFIRE SAFETY

OEIS Risk Modeling Workshop

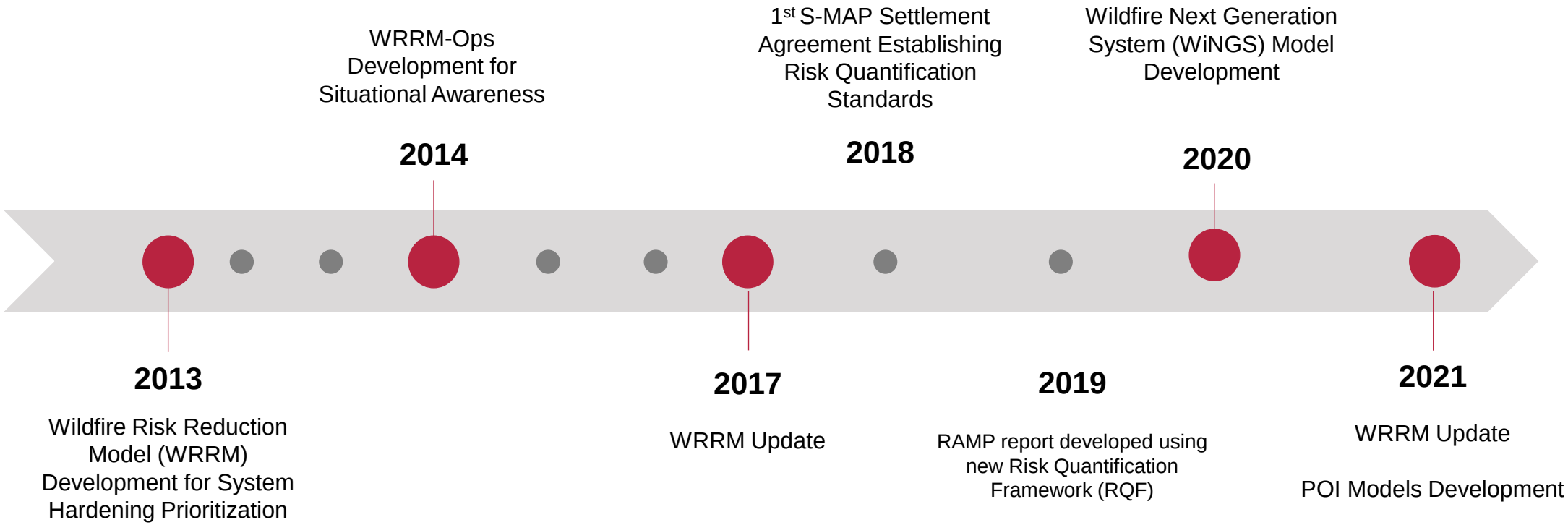
October 5 – 6, 2021

Agenda

1. Overview of current models
2. Model deep-dives
3. 2022 WMP update
4. Joint IOU efforts

Wildfire Risk Modeling Evolution

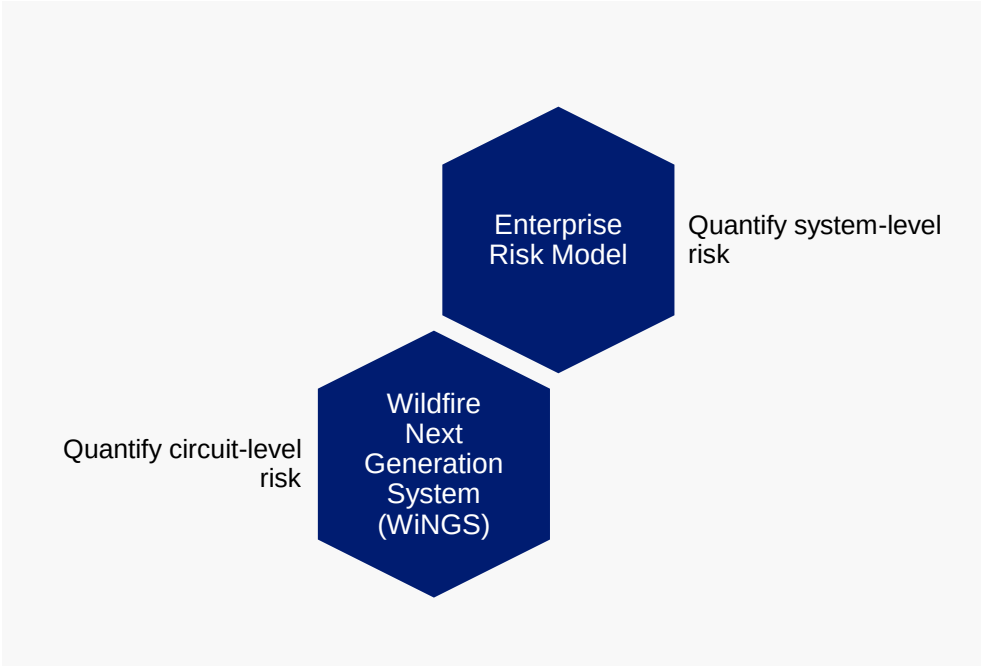
SDG&E continues to evolve its risk modeling capabilities to adapt to emerging challenges



Current Risk Models

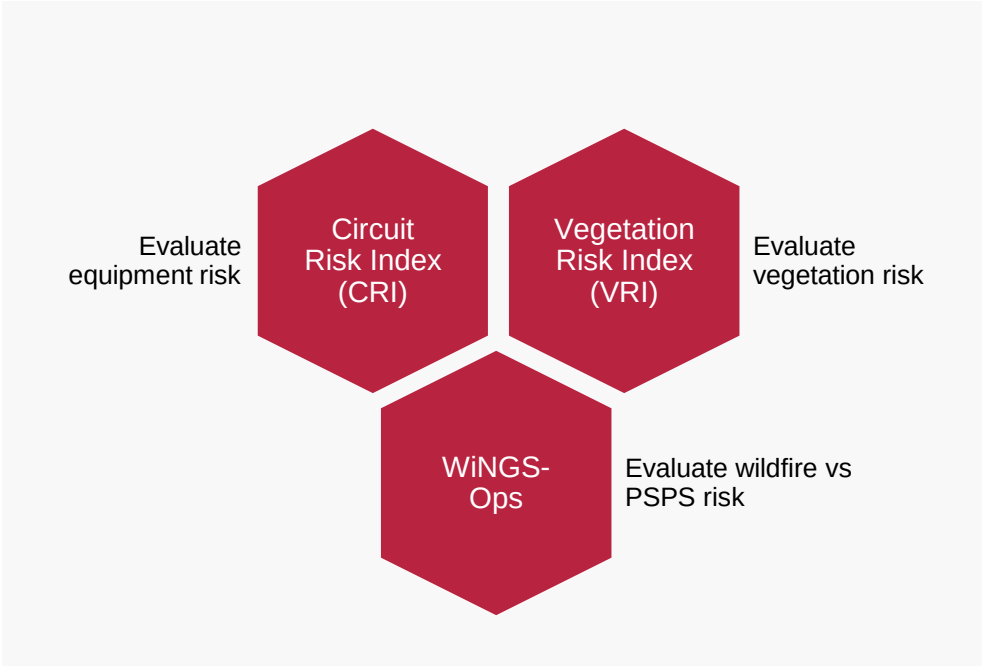
Investment Planning Models

Quantify risk levels and develop cost-benefit analysis of projects and programs to inform investment decisions



Operational Models

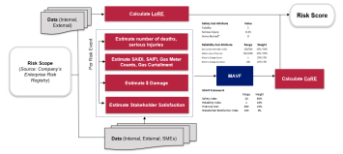
Provide situational awareness to support safe operations of our electric system



Current Risk Models

Enterprise Risk Model

Multi-attribute value framework with weights and scales that allows for comparable risk scoring
Monte Carlo simulation for wildfire risk

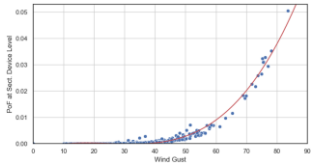


Wildfire Next Generation System (WiNGS)

Multi-attribute value framework with weights and scales that allows for comparable risk scoring

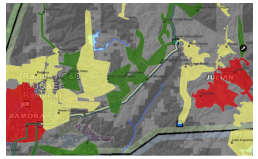
Circuit Risk Index (CRI)

Linear regression model predicts likelihood of conductor failure and likelihood of ignition given a failure



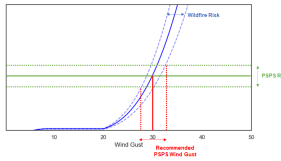
Vegetation Risk Index (VRI)

Relative model that compares and ranks vegetation risk across polygons tied to weather stations



WiNGS-Ops

Multi-attribute value framework with weights and scales that allows for comparable risk scoring leveraging linear regression modeling capability



Enterprise Risk Model

Enterprise Risk Model

Wildfire Risk

Inputs

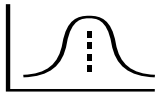
Likelihood of Ignition:

- Historical fires
- Annual ignitions
- Climate change
- System hardening
- Operational changes

Consequence of Ignition:

- Wildfire behavior modeling (WRRM)
- Financial treatment of consequences

Outputs



- Ignition probability distribution
- Financial consequence distribution

MAVF

Health & Safety | Reliability | Financial | Stakeholder Impact

Wildfire Risk Score

PSPS Risk

Inputs

Likelihood of PSPS:

- Historical weather events
- Historical PSPS operations

Consequence of PSPS:

- Number of customers impacted
- Type of customers impacted
- Duration of PSPS

Outputs

- Estimates of impacts of PSPS with multipliers for different types of customers

MAVF

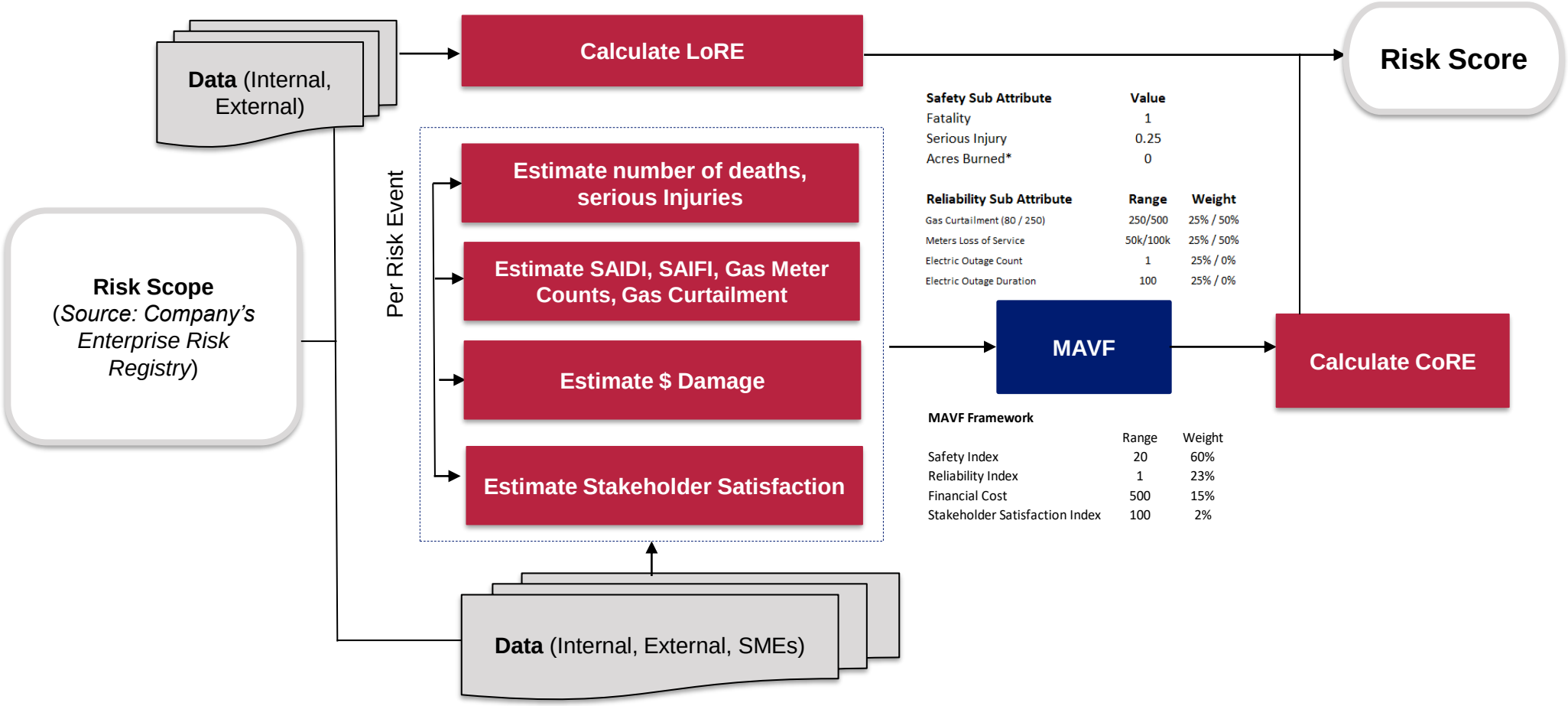
Health & Safety | Reliability | Financial | Stakeholder Impact

PSPS Risk Score

Enterprise Risk Model

Risk Quantification Framework

Risk Score = Likelihood of Risk Event (LoRE) x Consequence of Risk Event (CoRE)



Enterprise Risk Model

Current Application:

- Enterprise risk reporting
- System-wide risk evaluation
- RAMP assessments
- GRC assessments
- Development of RSEs for WMP initiatives

Enterprise Risk Assessments

Line No.	2021 RAMP Risk	LoRE	CoRE	Risk Score
1	Wildfires Involving SDG&E Equipment (WF/PSPS)	22/4	579/1,366	18,085 (12,623/5,462)
2	Electric Infrastructure Integrity	1,500	4	6,423
3	High Pressure Gas Incident (Excluding Dig-in)	0.88	2,117	1,866
4	Incident Involving a Contractor	1.67	1,061	1,768
5	Contact with Electric Equipment	1.09	1,375	1,500

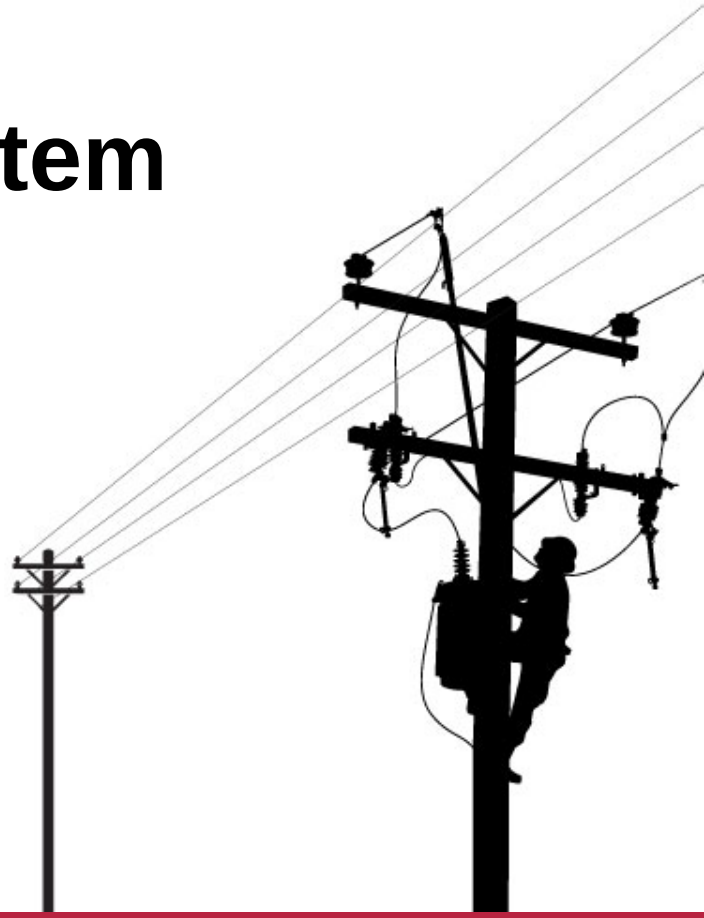
Risk Spend Efficiency

Mitigation: Hot Line Clamp Replacement	
Annual Reduction of Likelihood of Risk Event	.008
Cost	$2M
Life of Benefits	25 years

	Pre-Mitigation	Post-Mitigation
LoRE	**21.8**	**21.792**
CoRE	((0.067 / 20) * 60% + (0.002) * 20% + (10.56 / 500) * 15% + (0.5 / 100) * 5%) * 100000 = **579**	((0.067 / 20) * 60% + (0.002) * 20% + (10.56 / 500) * 15% + (0.5 / 100) * 5%) * 100000 = **579**
Risk Score	LORE * CORE = 21.8 * 579= **12,623**	New LORE * CORE = 21.792 * 579= **12,618**
RSE	-	(12623 - 12618) * 25 / $2M= **58**

Wildfire Next Generation System

(WiNGS)



WiNGS

Inputs

Wildfire

Likelihood

- Historic ignitions
- Wind speed
- Tree strikes
- Hardening status
- Vegetation density
- Critical Health Index (CHI)
- Conductor age

Consequence

- WRRM conditional impact

PSPS

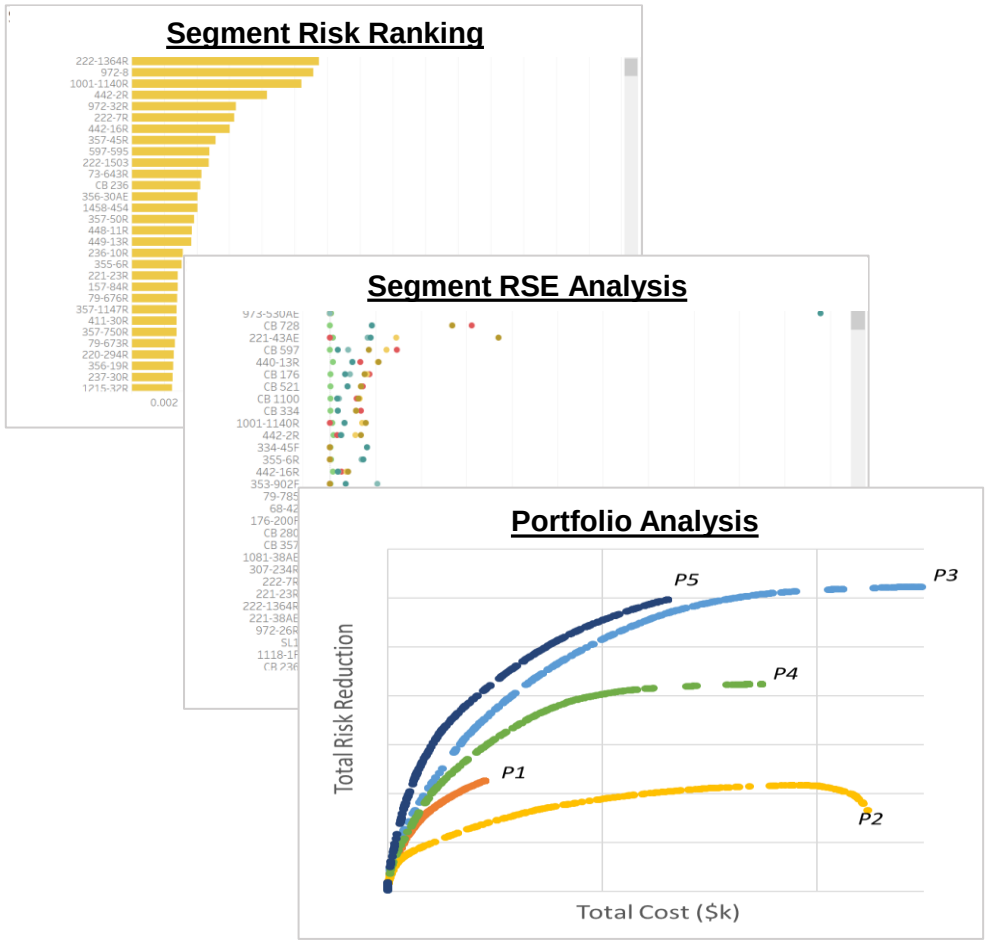
Likelihood

- Annual RFW data
- Historic wind speed patterns
- Circuit connectivity

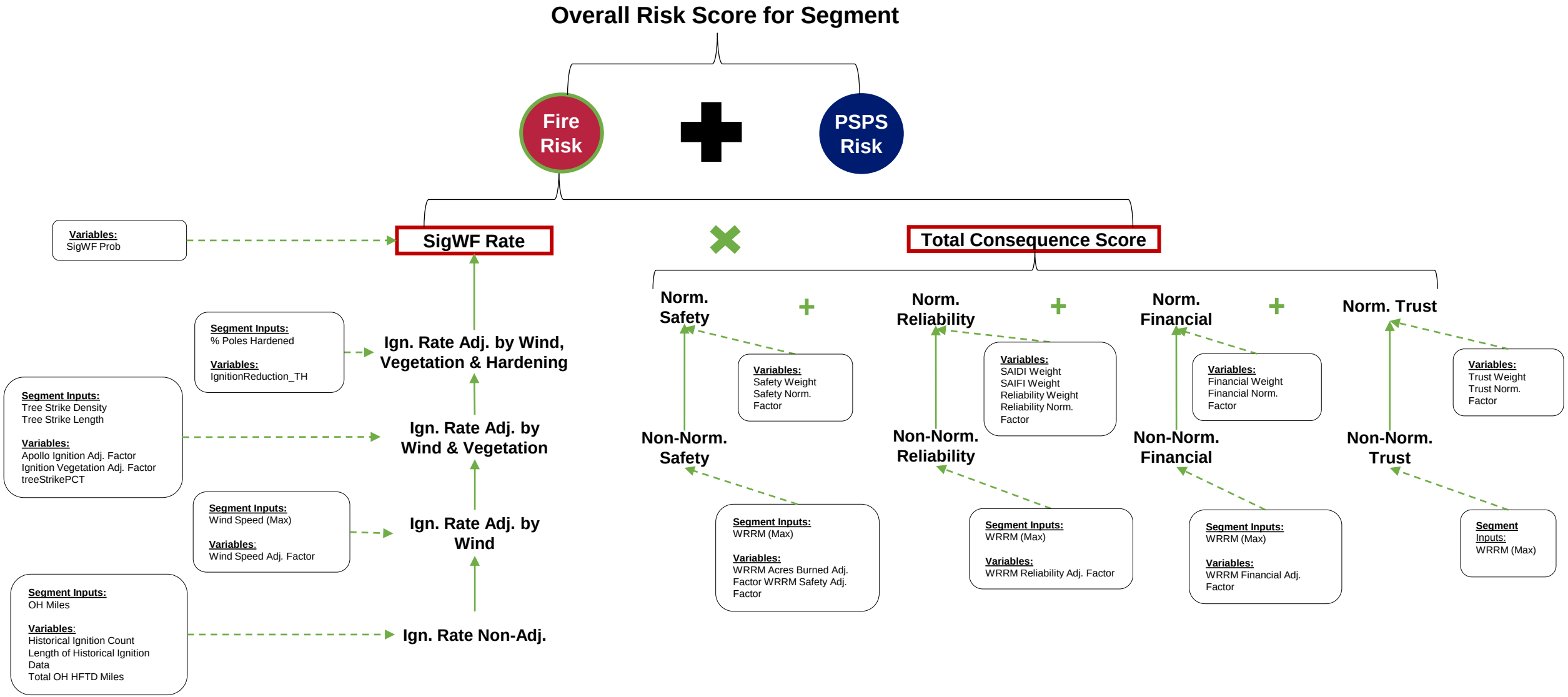
Consequence

- Number of customers
- Customer type
- Outage duration

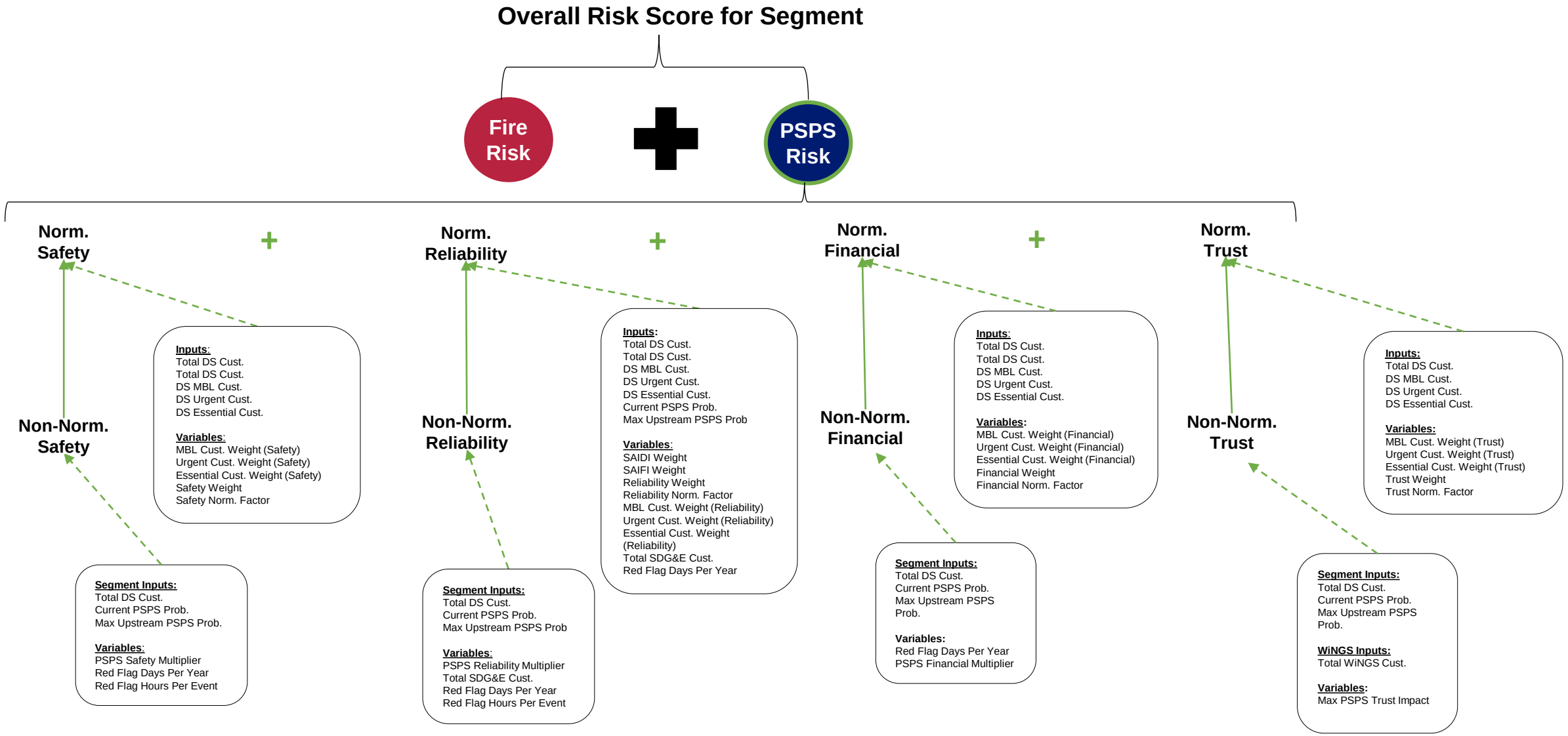
Outputs



WiNGS - Fire Risk Methodology



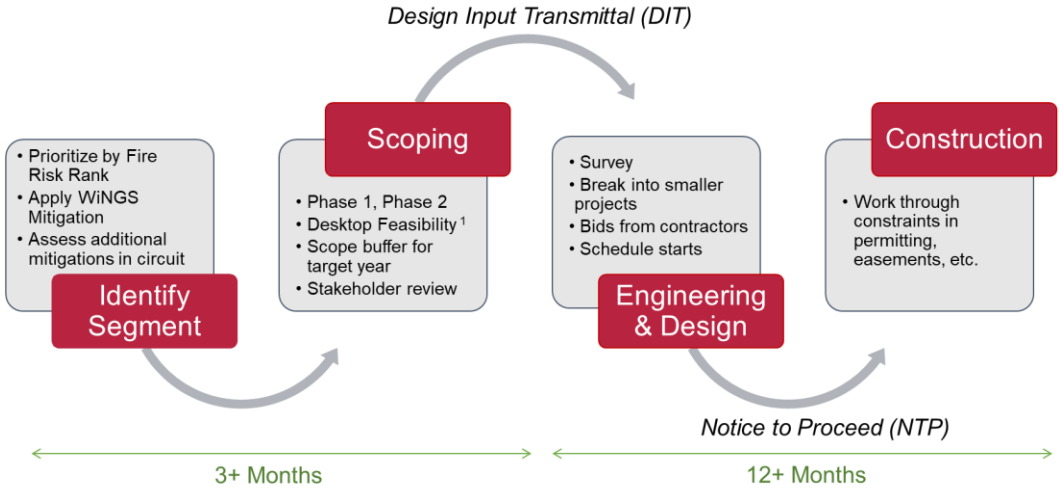
WiNGS - PSPS Risk Methodology



WiNGS

Current Application:

- Circuit and sub-circuit (segment) risk evaluation
- Grid hardening alternatives analysis
- Identification of scope for undergrounding and for covered conductor



1. Considerations in Desktop Feasibility Study: Geography, prior hardening, loading district, standards, land, environmental, easement constraints, PSPS Improvements, line/reliability improvements, construction cost savings

Balancing Risk Reduction and Costs

Illustrative

				Underground			Covered Conductor		
Seg.	WF Risk	PSPS Risk	Total Risk	Risk Reduction	Cost	RSE	Risk Reduction	Cost	RSE
1	15	5	20	18	$15M	55	10	$7M	85
2	23	15	38	30	$30M	45	15	$12M	60
.....	...	...	...	...	...	...	...	...	...
n	10	8	18	16	$10M	60	5	$5M	35

Circuit Risk Index

Circuit Risk Index

This model quantifies the conductor risk based on type, size of conductors, location as well as other factors for a segment as a function of wind gusts

Inputs

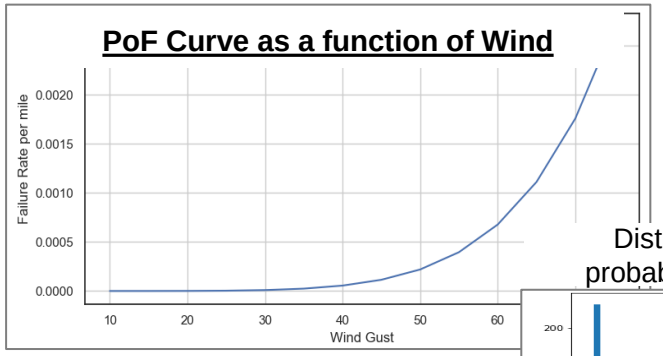
Probability of Failure

×

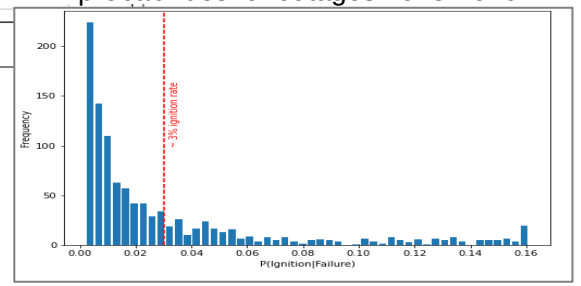
Probability of Ignition

Outputs

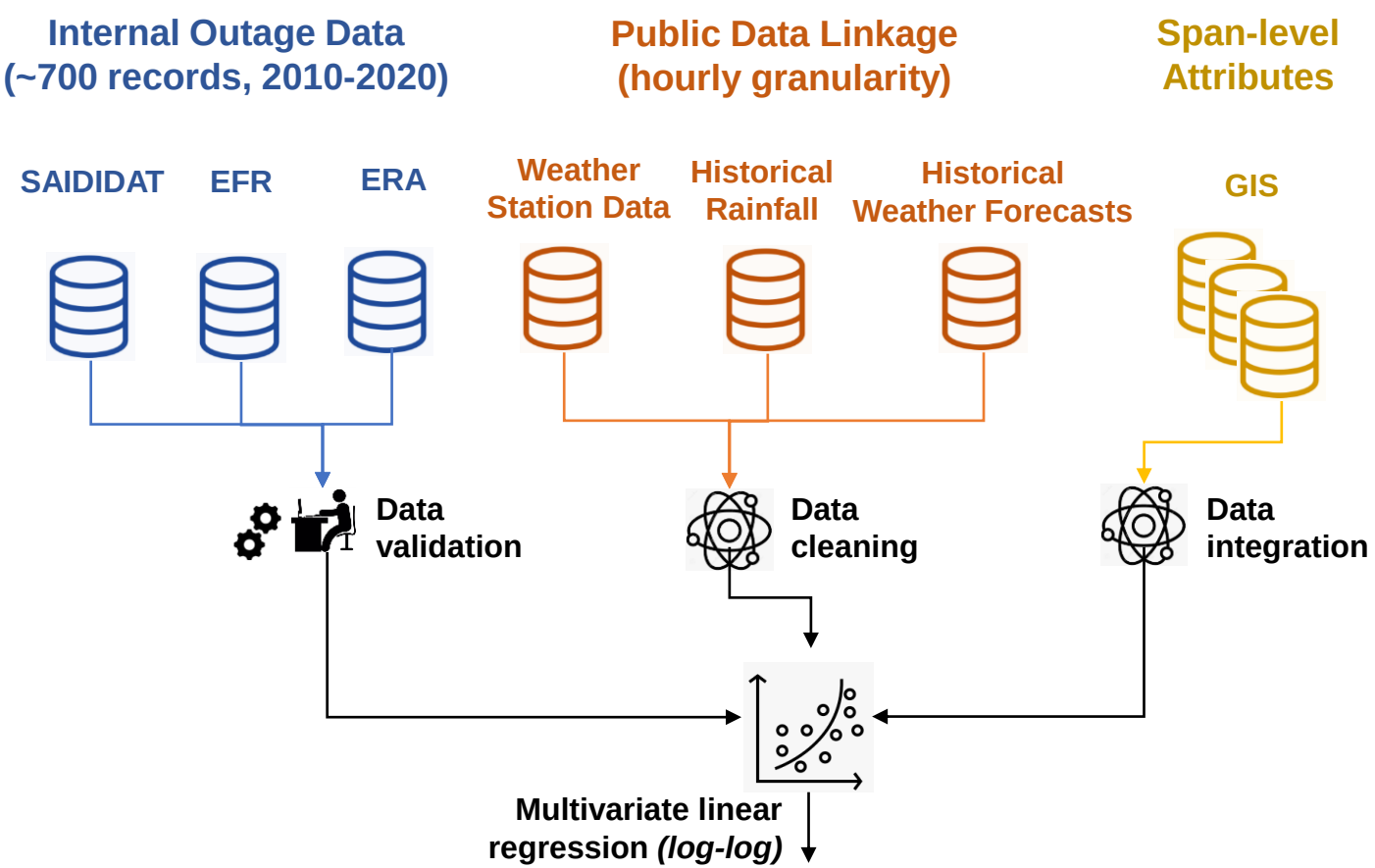
- Time-dependent likelihood
- Conductor Risk is H, M, L
- Wire Type and # of Spans



Distribution of modeled ignition probabilities for outages 2015-2020



Probability Of Failure Modeling



$$\text{Failure rate per mile} = f\left(\begin{array}{c} Wind\ Gust, \\ Wind\ Direction, \\ Conductor\ Type, \\ Elevation, \\ District \end{array}\right)$$

Data sources

Modeling

Results

What it is included:

- Wire downs caused by extreme weather
- Wires that slap together due to wind gusts
- Wire that comes out of sleeve during high winds

What it is not included:

- Vegetation, customer, crew, or foreign object contacts
- Lightning Arrester - Transformer failure
- De-energization for safety
- Ice or snow equipment failure

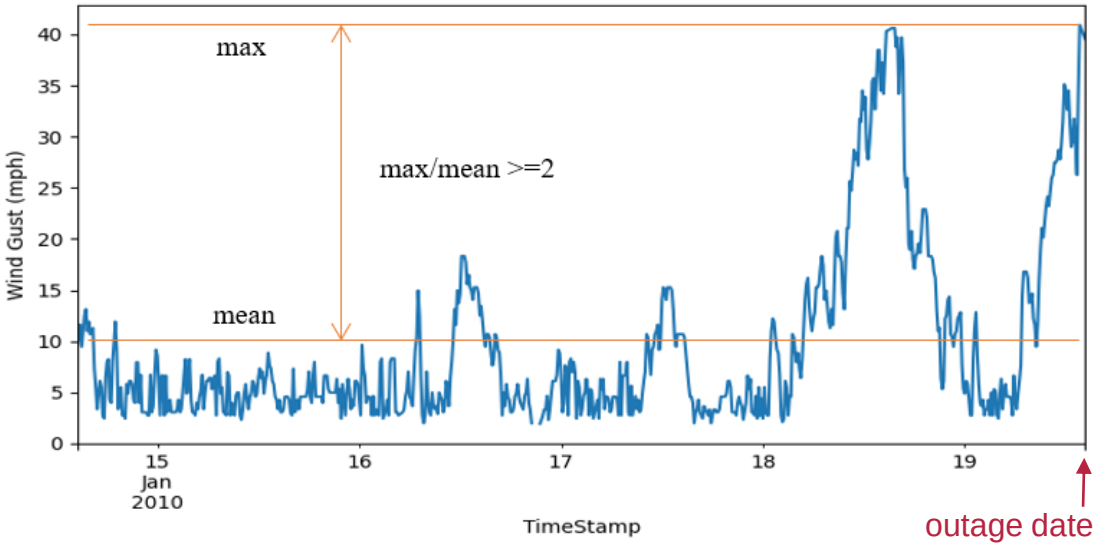
Key Assumptions

For every outage, failure rate per mile is calculated based on:

1. Total number of miles for same conductor type, size and material
2. Total number of miles in similar elevation and span length
3. Total number of miles that experienced similar weather conditions (buffer of 10 miles around the outage location)
4. Total number of miles perpendicular to most common wind direction in 5-day weather window
5. Outage weather condition must meet Wind Gust Step function rule in 5-day weather window

Wind Gust Step Function

1. Removed observations where a step function in wind gust (max/mean >=2) is not present in 5-day weather window



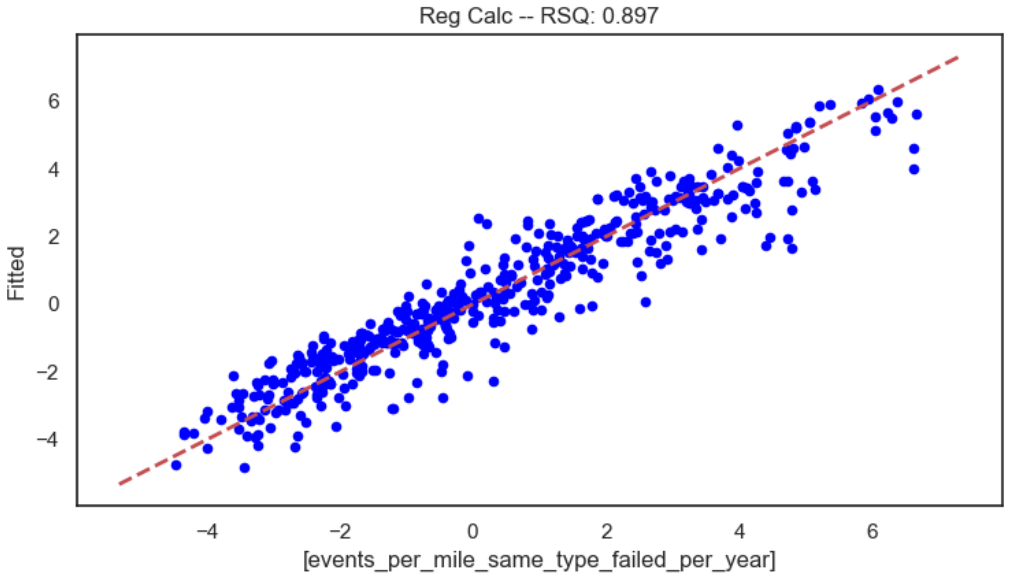
Probability of Failure Model

Failure rate per mile ≈ $\int$ (Wind Gust, Wind Direction, Cond. Type, Elevation, District)

OLS Regression Results

Dep. Variable:	events_per_mile_same_type_failed_per_year	R-squared:	0.897
Model:	OLS	Adj. R-squared:	0.892
Method:	Least Squares	F-statistic:	161.9
Date:	Tue, 27 Jul 2021	Prob (F-statistic):	6.07e-211
Time:	13:33:59	Log-Likelihood:	-581.97
No. Observations:	489	AIC:	1216.
Df Residuals:	463	BIC:	1325.
Df Model:	25		
Covariance Type:	nonrobust		

Confidence level is set to 95%



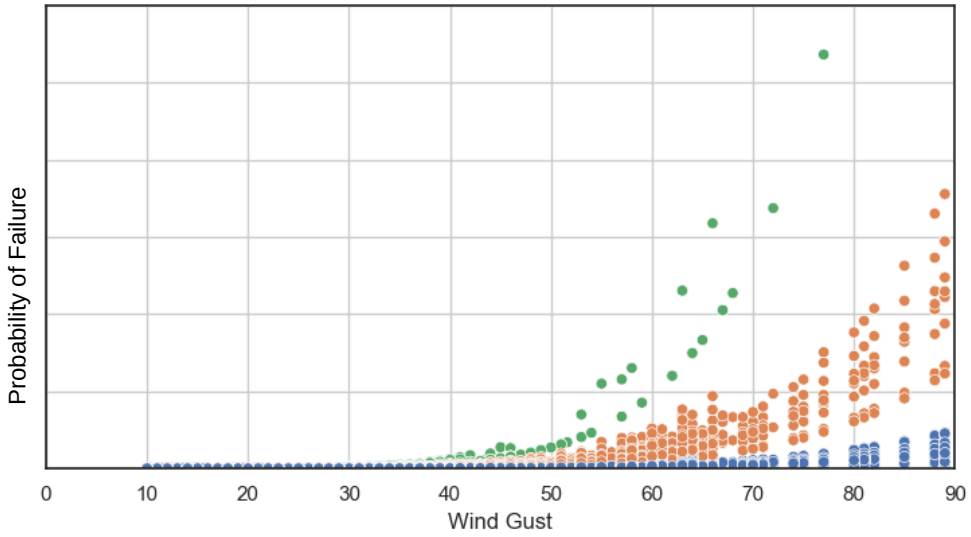
Model Insights

- Cu#6 wire is 1.5x more prone to failure than AL 5/2 AWAC #2
- For Cu#4 and Cu#6 wires, probability of failure increases by a factor of ~900, when wind gust increases from 20mph to 60mph

Dynamic Probability of Failure

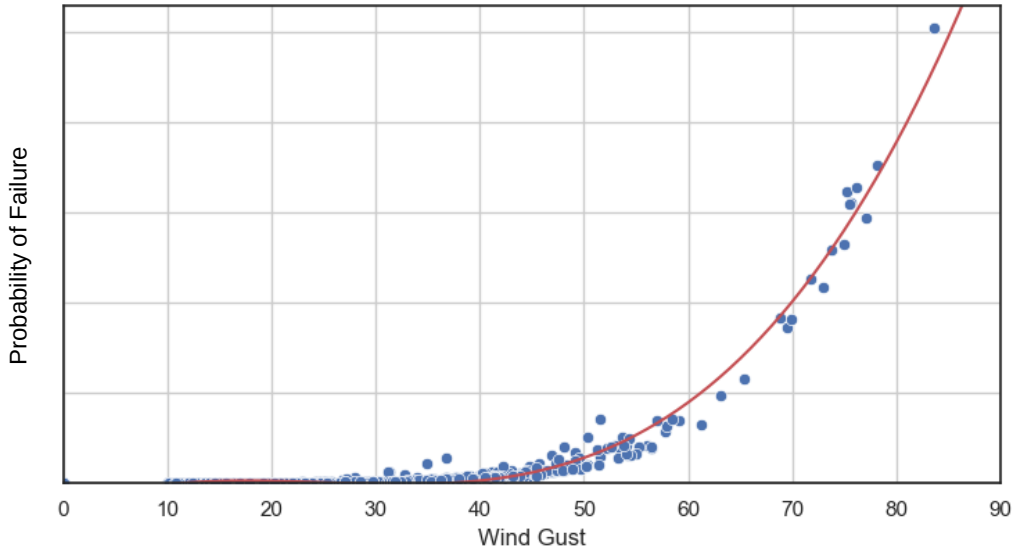
Failure rate per mile ≈ $\int$ (Wind Gust, Wind Direction, Cond. Type, Elevation, District)

PoF at Span Level



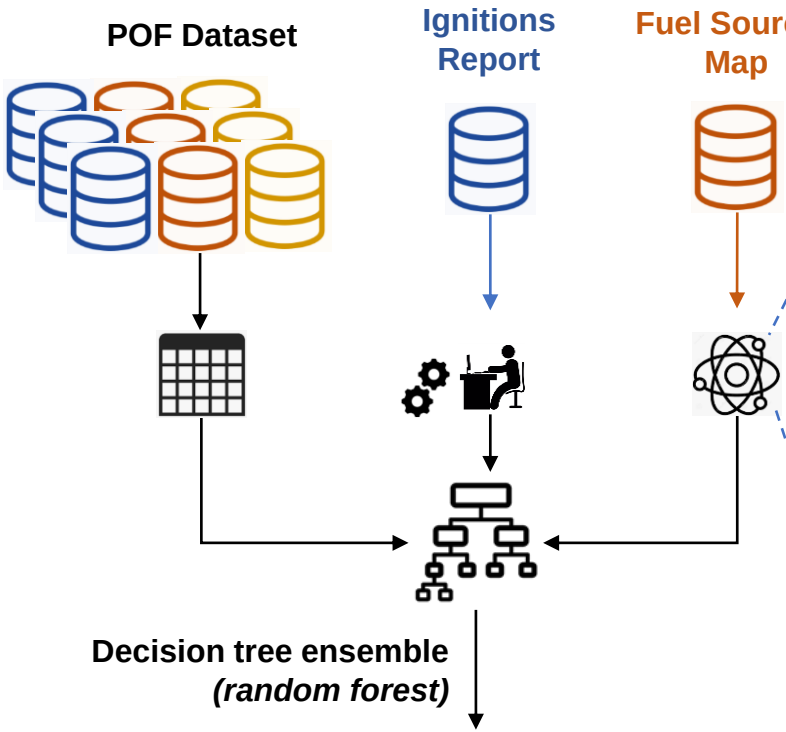
- Probability of conductor failure curve for each span in segment
- Color dot indicate different conductor types

PoF at Sectionalizing Device

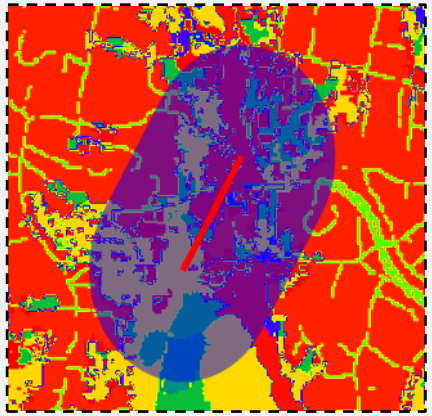


- Probability of conductor failure curve for a segment
- Aggregation is possible by assuming a constant PoI and Consequence value.
- Red line represent best fitted line (x^3 polynomial)

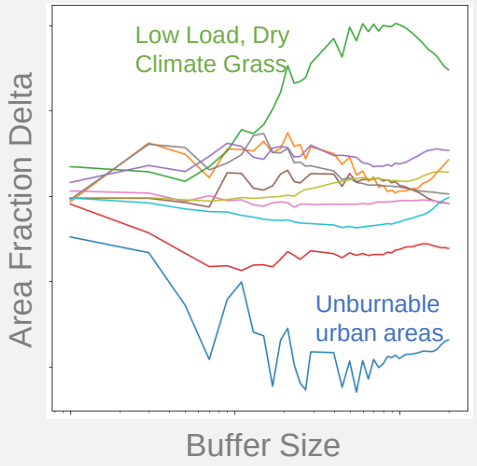
Conditional Probability of Ignition



$$P(Ign|Failure) = f\left(\begin{array}{c} Wire\ type, \\ Weather\ conditions, \\ Nearby\ fuel\ sources, \\ Wire\ length \end{array}\right)$$



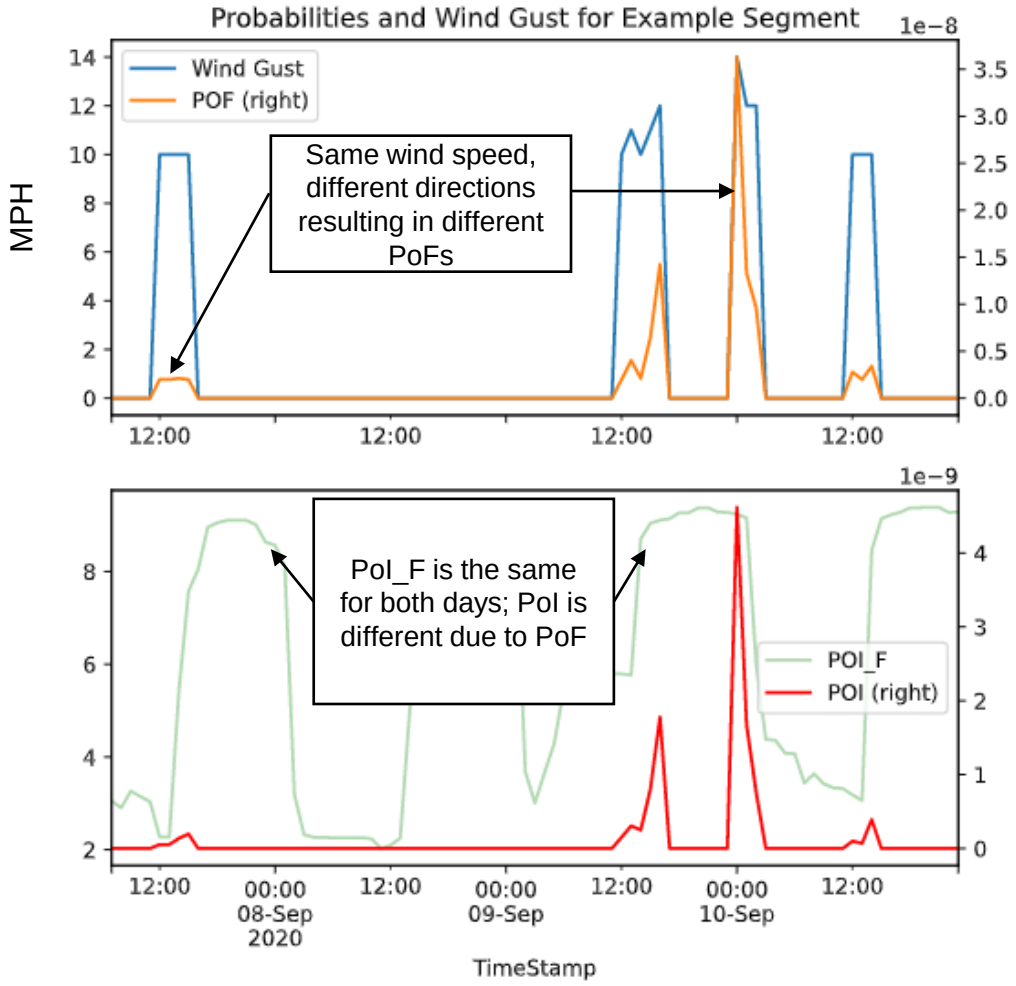
- Each wire-related outage is mapped to one or more wire spans (red line)
- Buffers created around the spans to calculate the fraction of each fuel type around the span



- Statistical models generate ignition probabilities as a function of:
  - Weather conditions
  - Nearby fuel sources
  - **Wire type**
- Data shows that we can detect fuel sources more prevalently under spans that have caused ignitions
- The net result is **distribution of span-level ignition probabilities**, which is more *targeted* than taking a fixed rate.

Dynamic Modeling Capability

PoI = PoF × PoI_F

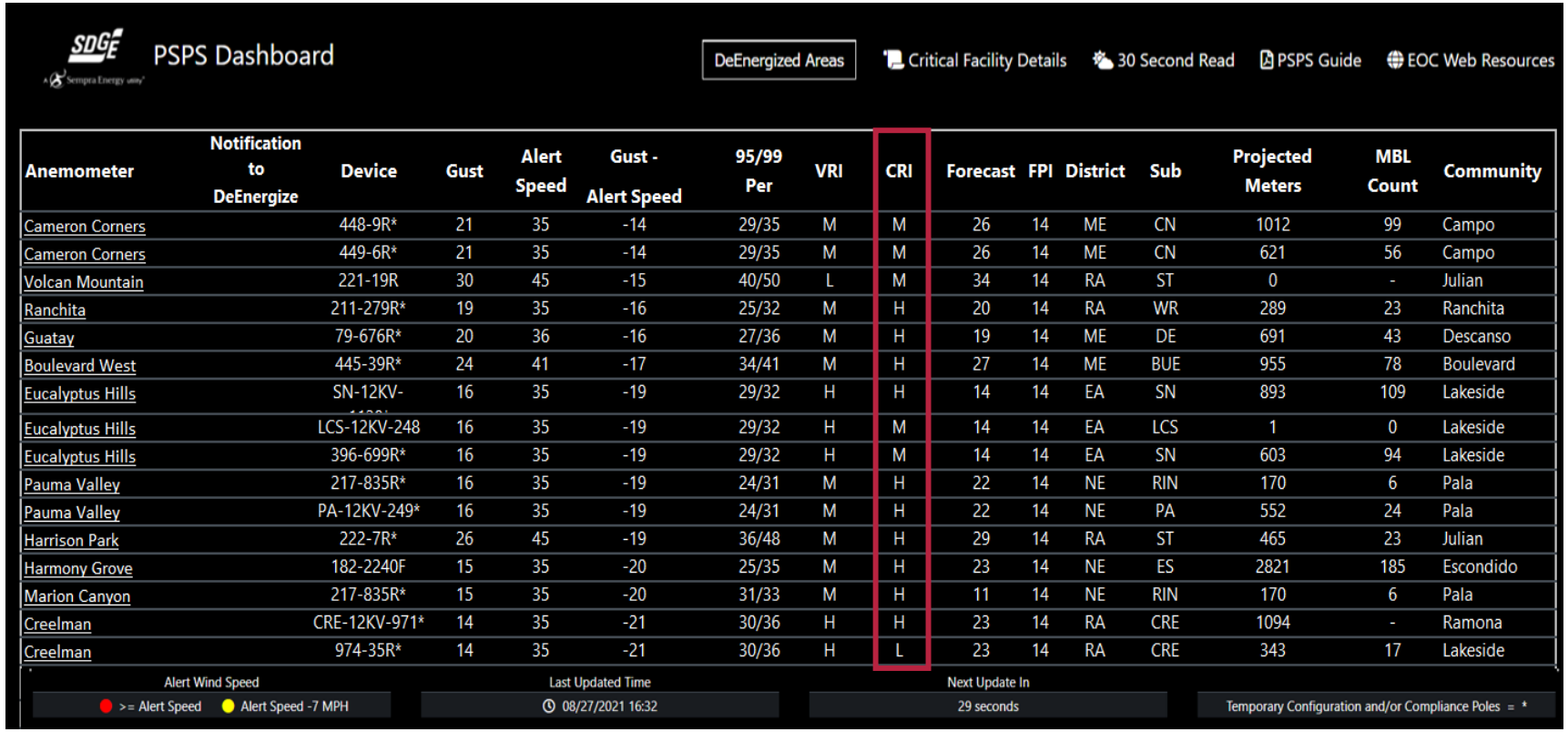


- Models are granular enough to enable differentiation in risk
- **POF** is mostly dependent on **wind conditions**
  - POI primarily takes the shape and behavior of this model
- **POI_F** is strongly dependent on **time of day** due to weather conditions

Circuit Risk Index

Current Application:

- Situational awareness during severe weather events
- Alert speed setting for PSPS operations
- Identification of segments with high **conductor risk**



PSPS Dashboard

DeEnergized Areas | Critical Facility Details | 30 Second Read | PSPS Guide | EOC Web Resources

Anemometer	Notification to DeEnergize	Device	Gust	Alert Speed	Gust - Alert Speed	95/99 Per	VRI	CRI	Forecast	FPI	District	Sub	Projected Meters	MBL Count	Community
Cameron Corners		448-9R*	21	35	-14	29/35	M	M	26	14	ME	CN	1012	99	Campo
Cameron Corners		449-6R*	21	35	-14	29/35	M	M	26	14	ME	CN	621	56	Campo
Volcan Mountain		221-19R	30	45	-15	40/50	L	M	34	14	RA	ST	0	-	Julian
Ranchita		211-279R*	19	35	-16	25/32	M	H	20	14	RA	WR	289	23	Ranchita
Guatay		79-676R*	20	36	-16	27/36	M	H	19	14	ME	DE	691	43	Descanso
Boulevard West		445-39R*	24	41	-17	34/41	M	H	27	14	ME	BUE	955	78	Boulevard
Eucalyptus Hills		SN-12KV-	16	35	-19	29/32	H	H	14	14	EA	SN	893	109	Lakeside
Eucalyptus Hills		LCS-12KV-248	16	35	-19	29/32	H	M	14	14	EA	LCS	1	0	Lakeside
Eucalyptus Hills		396-699R*	16	35	-19	29/32	H	M	14	14	EA	SN	603	94	Lakeside
Pauma Valley		217-835R*	16	35	-19	24/31	M	H	22	14	NE	RIN	170	6	Pala
Pauma Valley		PA-12KV-249*	16	35	-19	24/31	M	H	22	14	NE	PA	552	24	Pala
Harrison Park		222-7R*	26	45	-19	36/48	M	H	29	14	RA	ST	465	23	Julian
Harmony Grove		182-2240F	15	35	-20	25/35	M	H	23	14	NE	ES	2821	185	Escondido
Marion Canyon		217-835R*	15	35	-20	31/33	M	H	11	14	NE	RIN	170	6	Pala
Creelman		CRE-12KV-971*	14	35	-21	30/36	H	H	23	14	RA	CRE	1094	-	Ramona
Creelman		974-35R*	14	35	-21	30/36	H	L	23	14	RA	CRE	343	17	Lakeside

Alert Wind Speed: >= Alert Speed | Alert Speed -7 MPH

Last Updated Time: 08/27/2021 16:32

Next Update In: 29 seconds

Temporary Configuration and/or Compliance Poles = *

Vegetation Risk Index

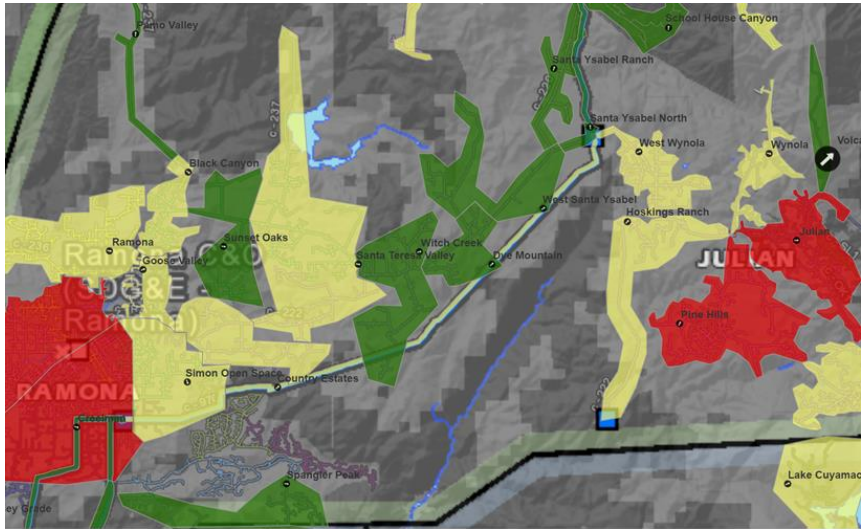
Vegetation Risk Index

Inputs

- Distribution circuit segments and transmission lines within the Hight Fire Threat District
- Vegetation Management's Tree Database
  - Location
  - Height
  - Species
- Tree-related outages since 2000

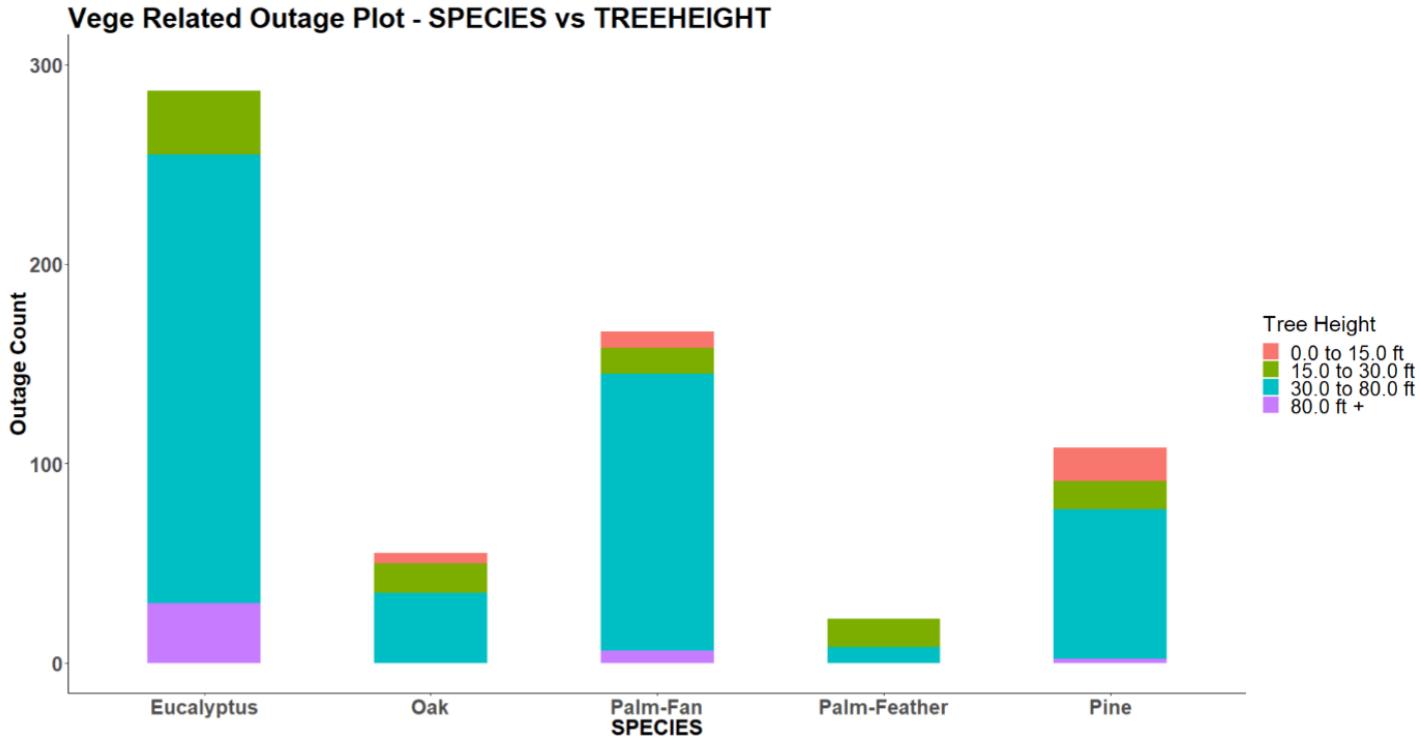
Outputs

Vegetation Risk: H / M / L



Vegetation Risk Index

- Most veg-related outages occurred during high wind events, especially in winter and spring
- Strong relationship between upper-level soil moisture, recent rainfall and outages
- Tree species vs veg-related outages
  - Eucalyptus (34.6%)
  - Palm-Fan (23.7%)
  - Pine (11.9%)
  - Palm-Feather (2.5%)
  - Oak (6.0%)
- Tree height vs veg-related outages
  - 0-15 ft (7.0%)
  - 15-30 ft (12.3%)
  - 30-80 ft (52.4%)
  - Above 80 ft (3.6%)
  - No record (24.7%)



Vegetation Risk Index

VRI Algorithm

VRI = T + 2(Oh)

$$T = Tt \times (Th \times Ts) \times 10^{-3}$$

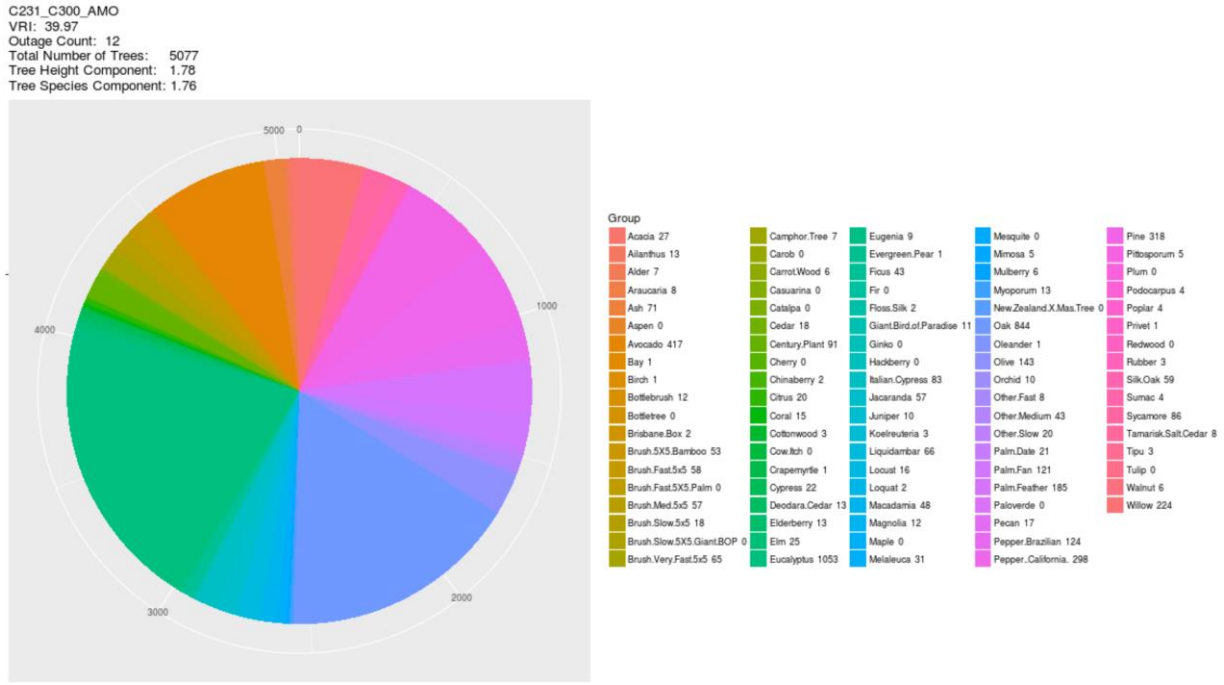
Tt = Total number of inventory trees along the circuit segment

Th = Tree height component = $1(H_1) + 2(H_2) + 3(H_3)$

(H_1) = Percentage of inventory trees with height < 20ft
(H_2) = Percentage of inventory trees with height 20 – 40ft
(H_3) = Percentage of inventory trees with height > 40ft

$Ts = Tree\ species\ component = 1(S_1) + 2(S_2) + 3(S_3) + 4(S_4)$

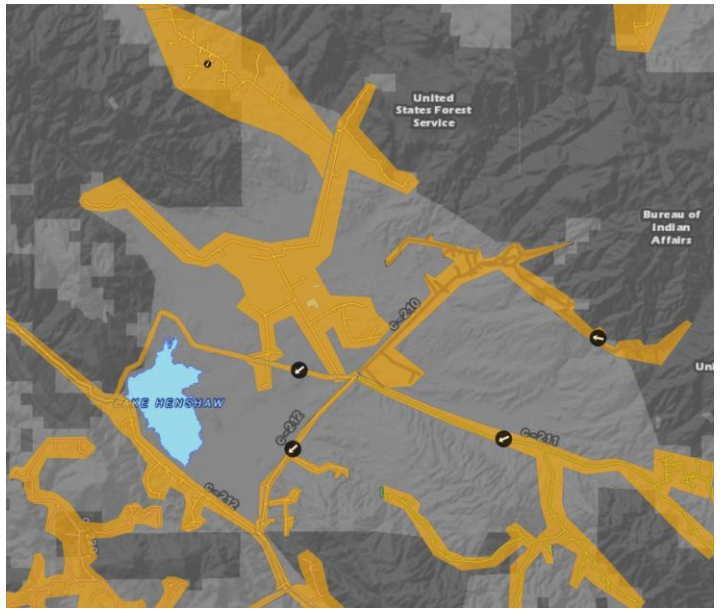
(S_1) = Percentage of low-risk trees (Species outage percent < 0.12%)
(S_2) = Percentage of medium risk trees (Species outage percent 0.12% - 0.47%)
(S_3) = Percentage of high-risk trees (Species outage percent 0.47% - 2.29%)
(S_4) = Percentage of extreme risk trees (Species outage percent > 2.29%)



***Oh** = Outage History Component: Total number of tree-related outages (excluding tree trimming) along a circuit segment since 2000*

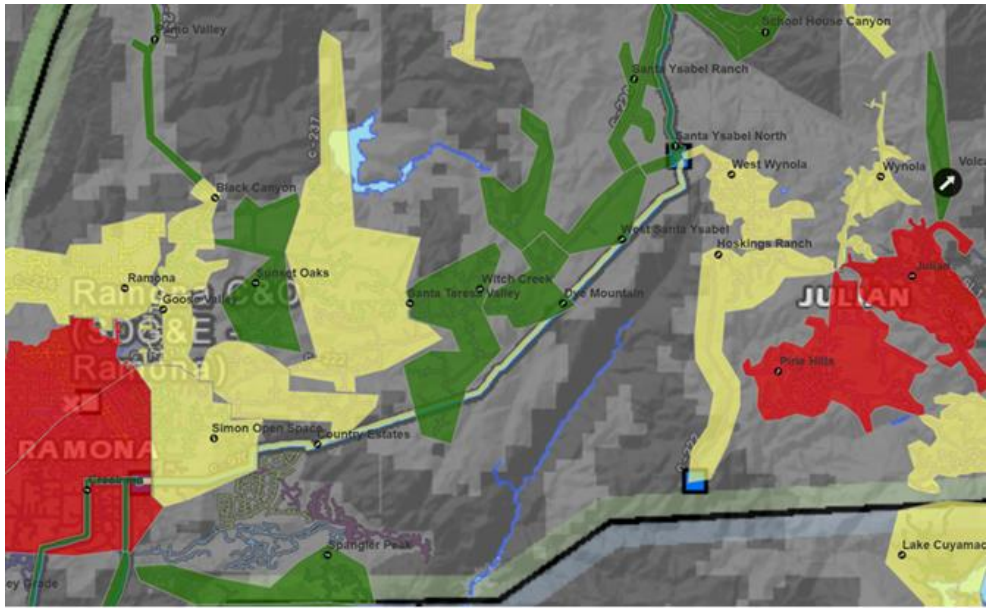
Vegetation Risk Index

Meteorology SMEs



atmospheric data solutions llc

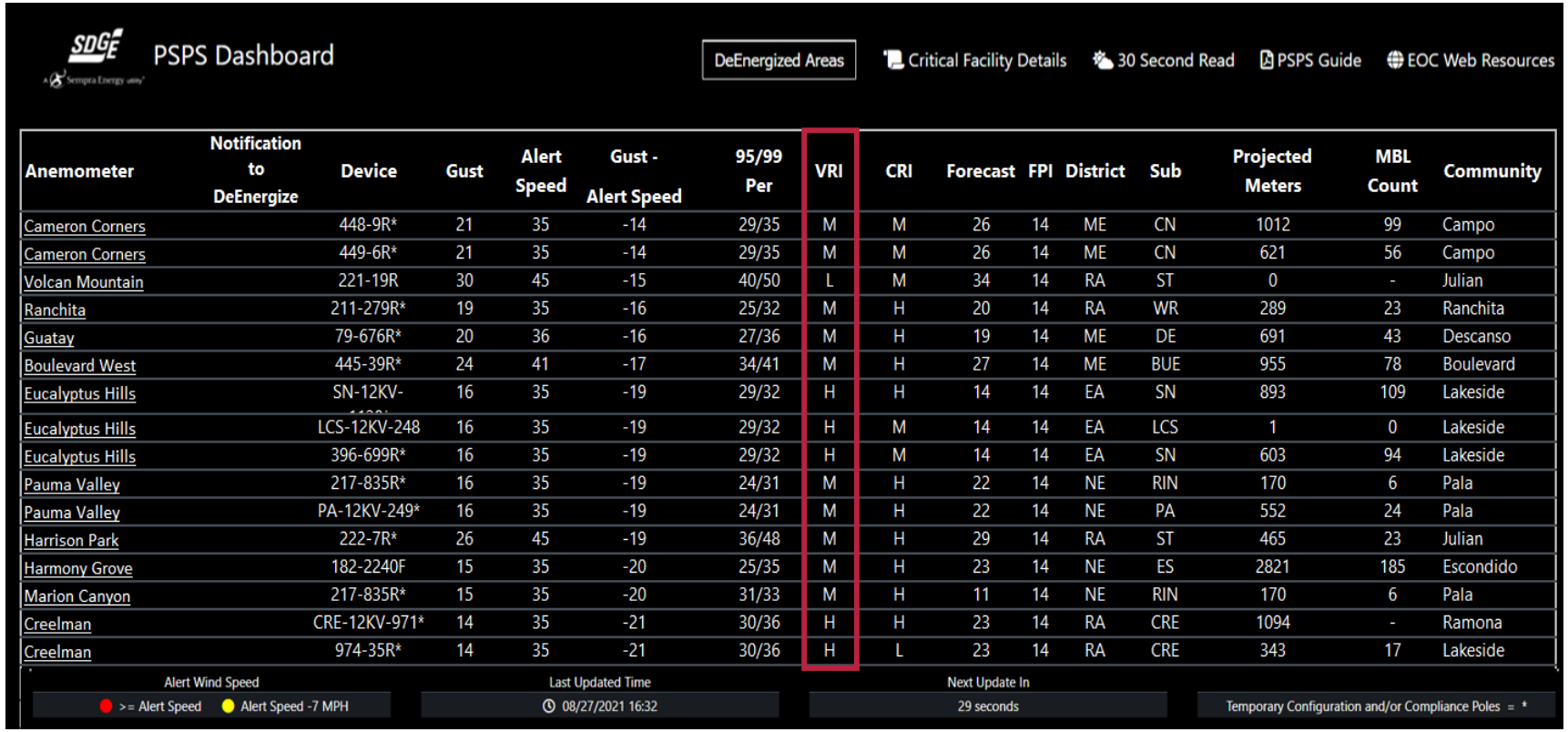
SDG&E Vegetation Management & Meteorology



Vegetation Risk Index

Current Application:

- Situational awareness during severe weather events
- Alert speed setting for PSPS operations
- Identification of segments with high **vegetation risk**



PSPS Dashboard

DeEnergized Areas | Critical Facility Details | 30 Second Read | PSPS Guide | EOC Web Resources

Anemometer	Notification to DeEnergize	Device	Gust	Alert Speed	Gust - Alert Speed	95/99 Per	VRI	CRI	Forecast	FPI	District	Sub	Projected Meters	MBL Count	Community
Cameron Corners		448-9R*	21	35	-14	29/35	M	M	26	14	ME	CN	1012	99	Campo
Cameron Corners		449-6R*	21	35	-14	29/35	M	M	26	14	ME	CN	621	56	Campo
Volcan Mountain		221-19R	30	45	-15	40/50	L	M	34	14	RA	ST	0	-	Julian
Ranchita		211-279R*	19	35	-16	25/32	M	H	20	14	RA	WR	289	23	Ranchita
Guatay		79-676R*	20	36	-16	27/36	M	H	19	14	ME	DE	691	43	Descanso
Boulevard West		445-39R*	24	41	-17	34/41	M	H	27	14	ME	BUE	955	78	Boulevard
Eucalyptus Hills		SN-12KV-	16	35	-19	29/32	H	H	14	14	EA	SN	893	109	Lakeside
Eucalyptus Hills		LCS-12KV-248	16	35	-19	29/32	H	M	14	14	EA	LCS	1	0	Lakeside
Eucalyptus Hills		396-699R*	16	35	-19	29/32	H	M	14	14	EA	SN	603	94	Lakeside
Pauma Valley		217-835R*	16	35	-19	24/31	M	H	22	14	NE	RIN	170	6	Pala
Pauma Valley		PA-12KV-249*	16	35	-19	24/31	M	H	22	14	NE	PA	552	24	Pala
Harrison Park		222-7R*	26	45	-19	36/48	M	H	29	14	RA	ST	465	23	Julian
Harmony Grove		182-2240F	15	35	-20	25/35	M	H	23	14	NE	ES	2821	185	Escondido
Marion Canyon		217-835R*	15	35	-20	31/33	M	H	11	14	NE	RIN	170	6	Pala
Creelman		CRE-12KV-971*	14	35	-21	30/36	H	H	23	14	RA	CRE	1094	-	Ramona
Creelman		974-35R*	14	35	-21	30/36	H	L	23	14	RA	CRE	343	17	Lakeside

Alert Wind Speed: >= Alert Speed | Alert Speed -7 MPH

Last Updated Time: 08/27/2021 16:32

Next Update In: 29 seconds

Temporary Configuration and/or Compliance Poles = *

WiNGS-Ops

WiNGS - OPS

This model quantifies wildfire and PSPS risk and provides a range of wind gusts where fire risk is likely greater than the PSPS risk.

Inputs

Wildfire

Likelihood	Consequence
• Conductor risk model (PoI) • Other preliminary models to predict other types of ignitions (e.g. vegetation)	• Maximum WRRM conditional impact

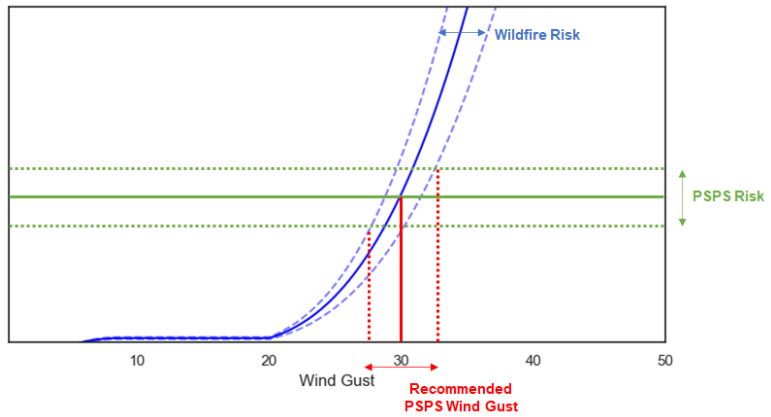
PSPS

Likelihood	Consequence
• Set to 100%	• Number of customers • Customer type • Outage duration

Outputs

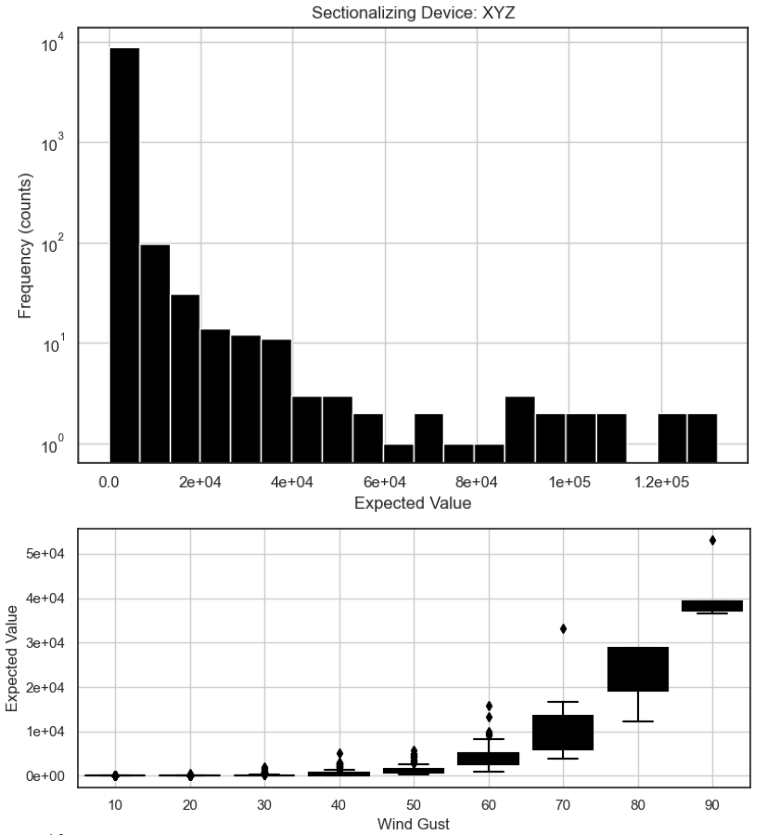
- Comparison of wildfire and PSPS risks
- Estimated range of windspeeds at which the two risks intersect

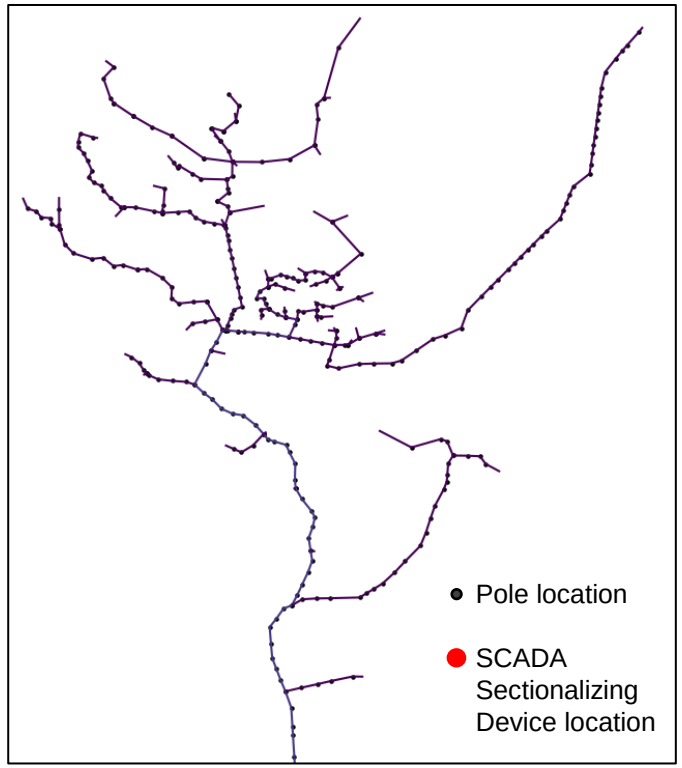
Forecasted Wildfire vs PSPS Risk based on Wind



Range of Segment Wildfire Risk

- POI, POF and Consequence are calculated at the span-level
- Therefore, for any given segment, there is a distribution of values, from which we may take the mean, max, min, or any value between
- Additionally, for forecasting, we may also consider historical values

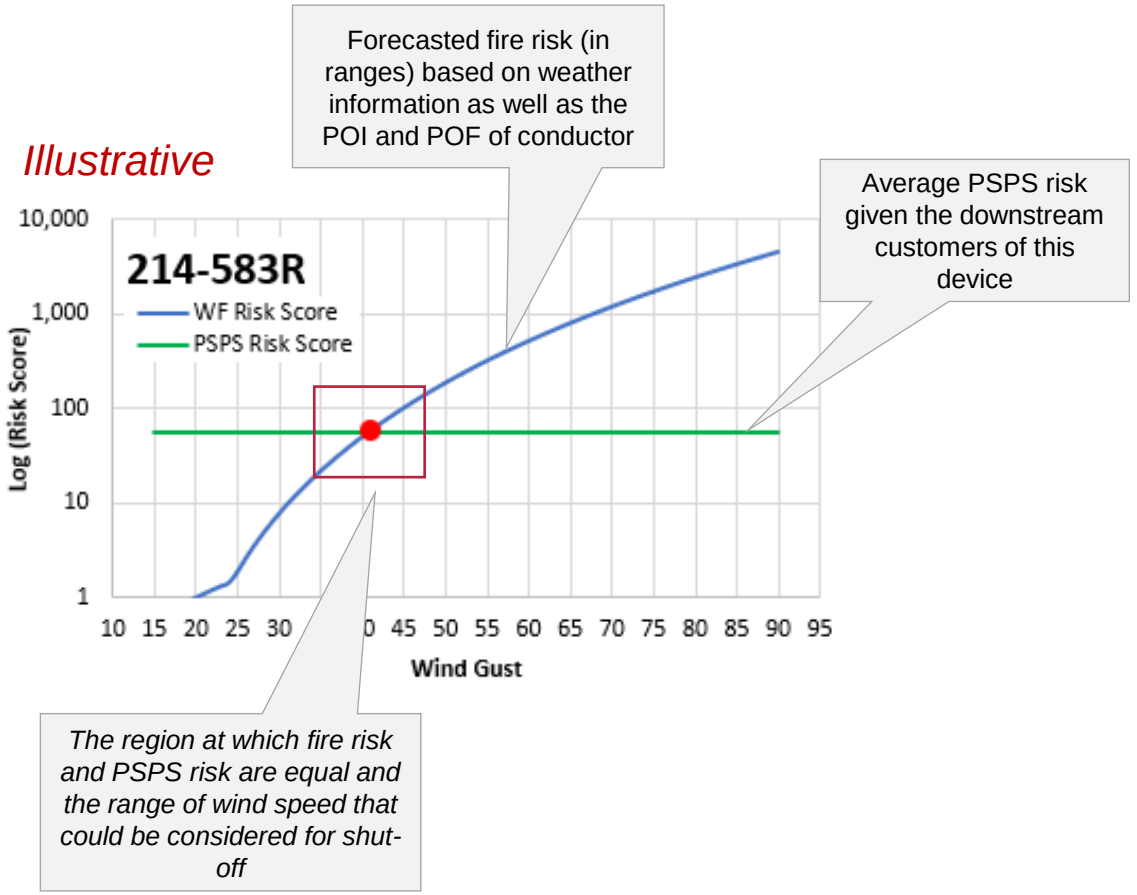




WiNGS - OPS

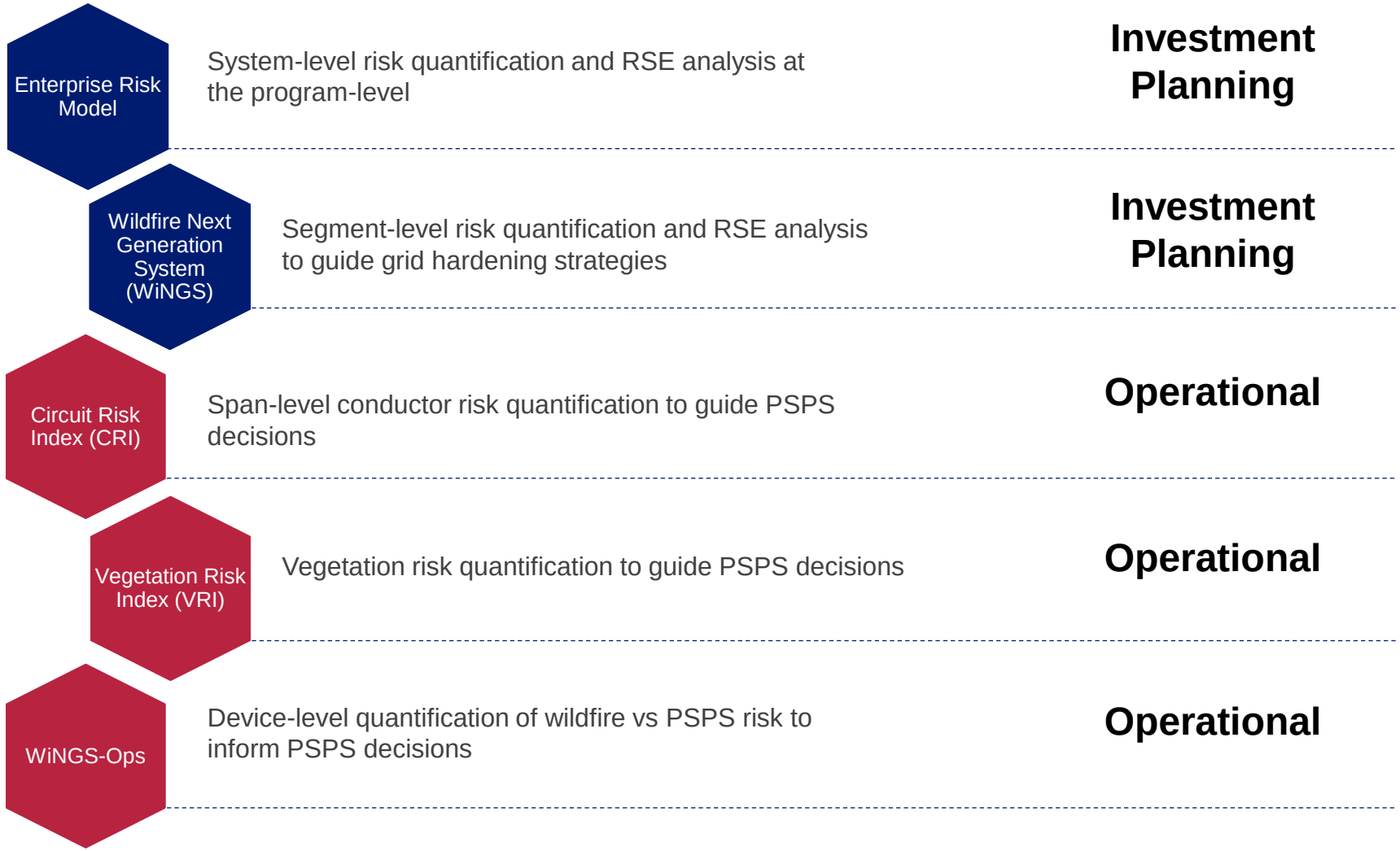
Current Application:

- Pre-event analysis for areas at potential risk of de-energization
- Information provided during situational awareness updates
- Post-event reporting to demonstrate benefit of de-energization compared to PSPS risks



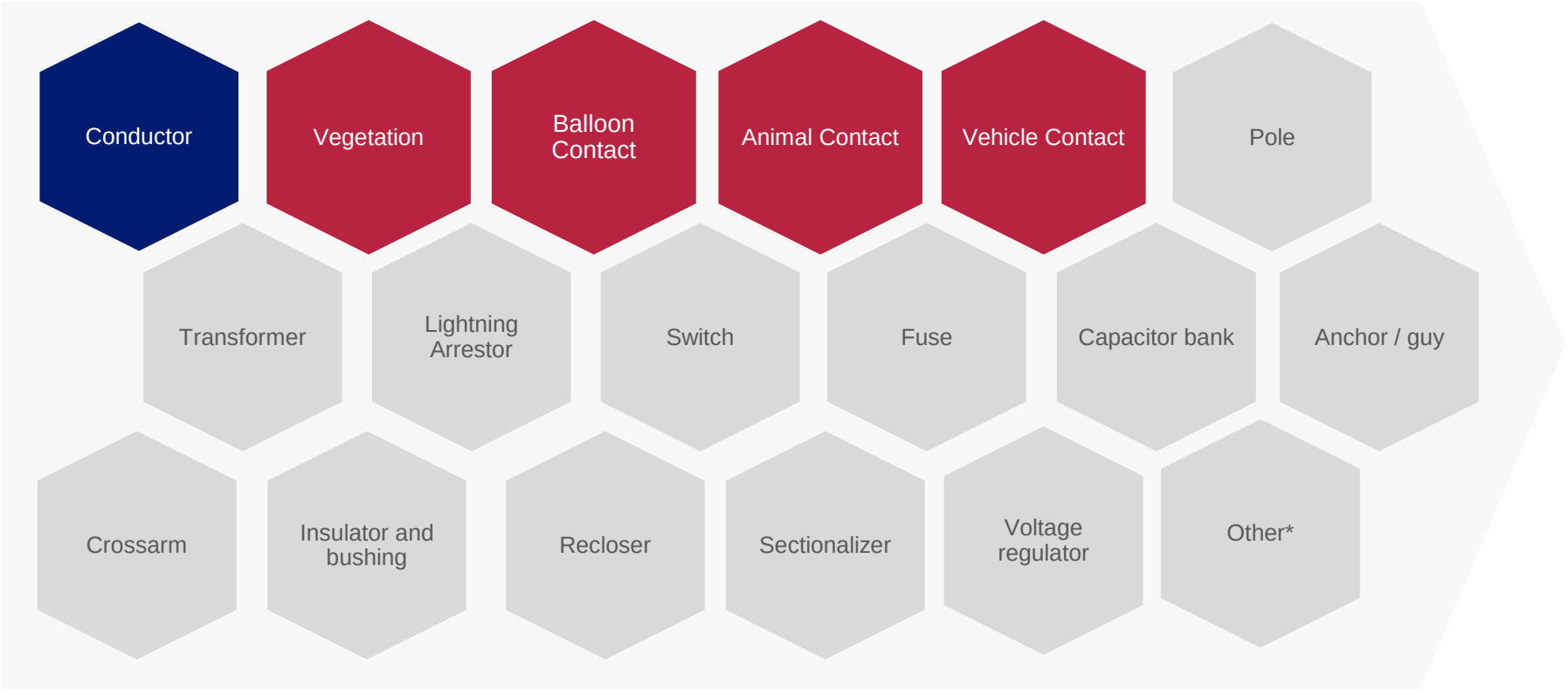
Close-Out

Risk Modeling Summary



Subsequent Models

Focusing risk modeling efforts on the development of more granular Probability of Ignition (PoI) models for different assets and failure modes



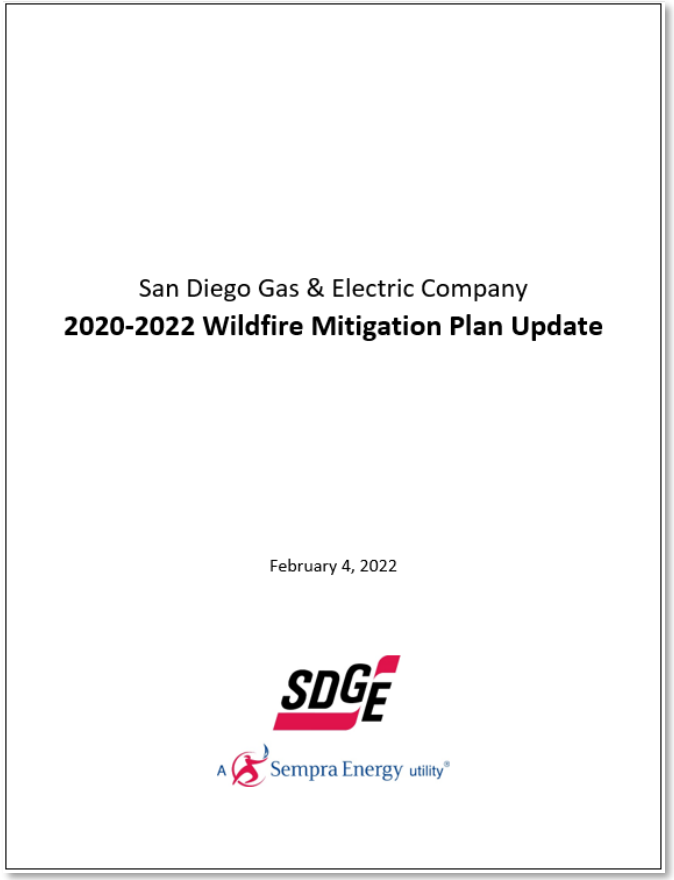
Improved Ignition Predictions to Enhance Decision-Making

Version 1 Complete

Version 1 In Progress

2022 WMP Updates

- RAMP Alignment
- New Models
- Joint IOU Collaboration


San Diego Gas & Electric Company

2020-2022 Wildfire Mitigation Plan Update

February 4, 2022

A Sempra Energy utility®

Joint IOU Efforts

- ✓ Since the 2019 WMP process, SCE, PG&E and SDG&E have conducted wildfire-related benchmarking sessions on various topics, including risk modeling, mitigation effectiveness, vegetation management activities, and PSPS operations.
- ✓ PG&E, SCE and SDG&E collaborated on at least 10 occasions in 2021 on risk assessment and modeling alignment opportunities.
- ✓ IOUs have evaluated elements of risk modeling where near-term alignment could be achieved.
- ✓ Currently developing a common vision (end-state) for long-term alignment on risk modeling, while recognizing differences.