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State of the Grid Report

CALIFORNIA

Energy & Resources | Networks

May 2025

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Executive Summary

High wind speeds and extreme heat are key drivers of severe outages in CA, but the diverse climate of the state warrants further, asset-level analysis to determine optimal investments

PROGRAM OBJECTIVE

Help state energy offices and select utilities assess how to use **40101(d) funding** to best strengthen the power grid against extreme weather, by:

- **Assessing** the unique **needs** of each state energy office
- **Analyzing future exposure to extreme weather** in the state, its coincidence with energy assets, and potential impacts
- **Attributing outages to weather events** and commenting on the alignment of utility capital spending with historical exposure
- Outlining a **benefit-cost methodology** to improve asset planning

DELIVERABLE OBJECTIVE

This deliverable seeks to:

- Attribute historical outages in the state to specific weather events and **comment on which events are driving the most customer interruptions in the state**
- Analyze a select utility's capital plan and **assess the alignment between their resilience spending and the weather events driving outages in their service territory**

KEY FINDINGS

Hazard Analysis:

High wind speeds and extreme heat are the key drivers of severe outages* on the California grid

- Windstorms, extreme heat, and wildfire (largely a factor of heat and wind) account for 65% of customer interruptions driven by extreme outages
- 13% of interruptions associated with extreme outages are not coincident with extreme weather (far above the WECC average), which are likely the result of aging asset failure or human/wildlife interaction
- A group of counties along the Sierra Nevada mountain range experience a high volume of interruptions per customer due to dense vegetation, high winds, and a high percentage of radial, overhead distribution infrastructure

Capital Planning Insights:

- PUBLIC-1 exhibits better than average reliability but slightly higher spend per line mile compared to other utilities in WECC
- PUBLIC-1's capital spending is highly aligned with its historical climate exposure, although it could consider potentially expanding investment addressing windstorms

*A severe outage is defined as one in which >50% of customers in a county are out simultaneously, or at least 30,0000 customers in a county experience an outage simultaneously, whichever is less

Sources: Found in slide notes

High Cost | Moderate Cost | Low Cost

Given the prevalence of wind and wildfire in the West, utilities should bolster their capital alignment with historical & future risk by conducting asset-level vulnerability assessments

STATE OF THE GRID REPORT | FINAL INVESTMENT CONSIDERATIONS

Invest against windstorms: Windstorms are the most widespread and severe cause of extreme outages across WECC in the past 5 years. While utilities are investing some capital against wind risk, the universal elevated exposure requires an increased volume of capital towards mitigations. Given its homogenous exposure, wind upgrades could be pursued as updates to design standards rather than targeted, ad hoc investments like substation upgrades.

Continue existing wildfire mitigations: While wildfire exposure of the past 5 years varies by geography, the cost of ignition remains inordinately high in comparison to other hazards. Therefore, even though ignition probability may be low, the high expected cost, coupled with the expected increase in exposure due to changes in climate, substantiates increased investment in mitigation. Utilities can better justify expensive investments like undergrounding by ensuring upgrades are done on feeders that are exposed to multiple hazards, having a double dividend effect on the investment.

Quantify extreme weather risk in dollars: In order to optimally allocate capital expenditures to buy down the most extreme weather risk for the least amount of dollars, utilities must quantify the cost and benefits of the risk and subsequent investment. The utilities that are most effectively optimizing their plans are implementing asset-level vulnerability assessments, using down downscaled climate projections to predict impacts out to mid-century. Baringa will be expanding on how to conduct such analysis in phase 4 of this project.

ASSET	INVESTMENT	COST	HAZARDS
POLES & STRUCTURES	Pole Reinforcement	M	MORE INFORMATION ON FOLLOWING SLIDE
	Pole Upgrades	M	
	Dead-End Structures	M	
	Decreased Span	M	
	Pole Wrapping	L	
CONDUCTORS	Undergrounding	H	
	Reconductoring	M	
	Covered Conductors	M	
	Hardening/Rebuilds	L	
SUBSTATIONS	Substation Elevation	H	
	Control House Remediation	H	
	Enclosures	H	
	Reclosers/Switchgear	M	
	Flood Walls	M	
	Cooling Mechanisms	M	
PLANNING TOOLS	Vegetation Management	H	
	Dynamic Line Rating (DLR)	L	
	Wildfire Planning Tools	M	

Selecting optimal adaptions requires a quantification of the tradeoffs between costs and benefits, however a strategic view can be helpful for high level prioritization.

ASSET	ADAPTATION	COST	HAZARD #	FLOOD	WIND	COLD	FIRE	HEAT
POLES & STRUCTURES	Pole Reinforcement	M	3	✓	✓	✓		
	Pole Upgrades	M	3		✓	✓	✓	
	Dead-End Structures	M	2		✓	✓		
	Decreased Span	M	2		✓	✓		
	Pole Wrapping	L	1				✓	
CONDUCTORS	Undergrounding	H	4		✓	✓	✓	✓
	Reconductoring	M	4		✓	✓	✓	✓
	Covered Conductors	M	1				✓	
	Hardening/Rebuilds	L	4		✓	✓	✓	✓
SUBSTATIONS	Substation Elevation	H	1	✓				
	Control House Remediation	H	1	✓				
	Enclosures	H	3	✓	✓	✓		
	Reclosers/Switchgear	M	2		✓	✓		
	Flood Walls	M	1	✓				
	Cooling Mechanisms	M	1					✓
PLANNING TOOLS	Vegetation Management	H	3		✓	✓	✓	
	Dynamic Line Rating (DLR)	L	1					✓
	Wildfire Planning Tools	M	1				✓	

High Cost Moderate Cost Low Cost

Project Approach

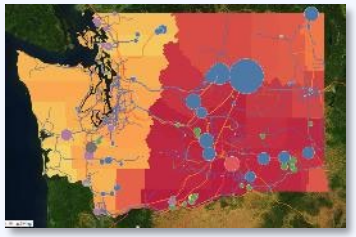
Project Overview

The State of the Grid Report provides recommendations and insights into most effective **resilience projects**, **highest risk locations**, and strategies for **improving capital spend efficiency**

1 STATE OF THE GRID REPORT | **BENEFITS**

Improved understanding of **how extreme weather impacts outage and ignition rates** in your service territory

DELIVERABLE | **EXTREME WEATHER ANALYSIS**



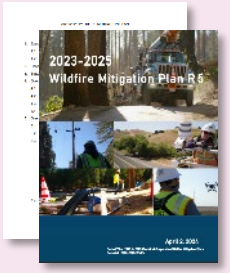
Analyze 5 years of publicly available extreme weather and outage data to **determine which type of events cause the largest outages and ignitions**.

Comment on expected change in outages and ignitions as a function of climate projections.

2 STATE OF THE GRID REPORT | **BENEFITS**

Actionable insights to **improve capital effectiveness** that addresses extreme weather risk

DELIVERABLE | **INVESTMENT PLAN REVIEW**



Review most recent investment plan to determine **effectiveness of normalized capital spend** in mitigating outages and ignitions from extreme weather.

Results will be anonymously compared with other participants to help outline resilience best practices and most effective mitigations.

Baringa is conscious of data privacy and sensitivities and is more than willing to work with your team to address concerns.

Extreme Weather Outage Analysis

Project Overview

Severe outages were mapped to corresponding weather events to better understand which forms of extreme weather are driving customer interruptions and how utilities can respond

DEFINE EXTREME WEATHER EVENTS

Purpose: Begin with a definition of extreme weather to focus on the most impactful events.

Definition: weather events are considered extreme if they are above the 90th percentile of severity for that state.

Data: Western Regional Climate Center (WRCC)

Time: 2018 - 2022

FILTER EXTREME OUTAGE EVENTS

Purpose: Define extreme outage events to highlight highest cost outages

Definition: outage events are considered extreme if:

At least 50% OR >30,000 of customers are out in a single county

*modified from Oak Ridge National Labs definition

Data: EAGLE-I

Time: 2018 - 2022

ANALYZE EVENT COINCIDENCE

Purpose: Identify the extreme outages that occur at the same time as extreme weather events.

Analysis Areas:

- WECC Overview
- Most Impactful Hazard Analysis
- Hazard by Total Interruptions (Pareto Chart)
- Spatial Analysis
- Historical Ignition Analysis
- Hazard Deep Dives

DETERMINE ASSET PLANNING INSIGHTS

Purpose: Provide implications for asset planning and funding priorities

Example Insights

- Historical severe outage locations
- Historical extreme ignitions
- Historical primary drivers of outages
- Distribution of outages across hazards
- Design standard implications

KEY WEATHER EVENTS

WILDFIRE | WINTER STORMS | SUMMER STORMS | WINDSTORM | EXTREME PRECIPITATION | RAINSTORM | EXTREME HEAT | EXTREME COLD | FLOOD

Weather events were mapped to raw data to capture both single hazard and multi-hazard events. Events are considered extreme if the raw data is above the 90th percentile for the state

WEATHER EVENT	PRESENT WEATHER METRICS (Above 90th percentile)
EXTREME COLD	Min Temperature
EXTREME HEAT	Max Temperature
WILDFIRE*	Fire Weather Index (FWI)
EXTREME PRECIPITATION	Precipitation

WEATHER EVENT	PRESENT WEATHER METRICS (Above 90th percentile)
WIND STORM	Wind
RAIN STORM	Wind + Precipitation
SUMMER STORM	Wind + Precipitation + Max Temperature
WINTER STORM	Wind + Precipitation + Min Temperature
FLOODING	Surface Runoff

*Outages occurring within two days of a documented wildfire ignition in the county of origin were also attributed to wildfire, overriding other hazard combinations

Mapping outages to weather events more accurately captures the impact of coincident hazards, avoids double counting outages, and allows for flexible event definitions

Coincident Hazards

- **EXPLANATION:** Mapping to events captures unique threats posed to assets from coincident hazards
- **BENEFIT:** Multiple hazards occurring simultaneously can have different impacts on assets than considering each individually (e.g. coincident wind and snow/ice contributes to line galloping, wind and extreme heat could increase probability of vegetation contact given line sag due to heat).

No Double Counting

- **EXPLANATION:** Variable combinations are mapped to specific events
- **BENEFIT:** Ensuring that other hazards are below the 90th percentile isolates the most important hazards. Just looking at one hazards could capture outages that are actually attributable to other hazards.

Flexible Event Definitions

- **EXPLANATION:** Multiple different hazard combinations can be mapped to the same weather event given similar impacts to assets
- **BENEFIT:** Mapping to events allows for historical ignitions and extreme fire weather to be mapped to the same category, as both reflect ignition potential and can be addressed by similar upgrades.

Outages were classified as “severe” if more than 50% of customers OR more 30,000 customers in a given county are out at a single point in time

1 OUTAGE EVENT HANDLING

Define outage events to analyze coincidence with weather events and avoid double counting

METHODOLOGY

1. In a new column, assign “y” if “Customers Out” entry >0 in the data row, “n” if “Customers Out” = 0
2. Assign a unique event number to each string of consecutive “y” entries, separated by at least one “n” entry
3. For each unique event, keep the row with the maximum “Customers Out” value

DATASET | **EAGLE-I**

U.S. DEPARTMENT OF ENERGY

Comprehensive outage dataset from 2014-2022 created through a partnership between Oak Ridge National Lab and the U.S. DOE

OAK RIDGE National Laboratory

Data is collected from utility’s public outage maps and provides 92% coverage of US and Territories

2 SEVERE OUTAGE CLASSIFICATION

Define “severe” outages in order to determine which weather events are coincident with the costliest outages in the state

DEFINITION

At least 50% of customers out in a given county

OR

At least 30,000 customers out in a given county

*whichever is less

SEVERE OUTAGES | **JUSTIFICATION**

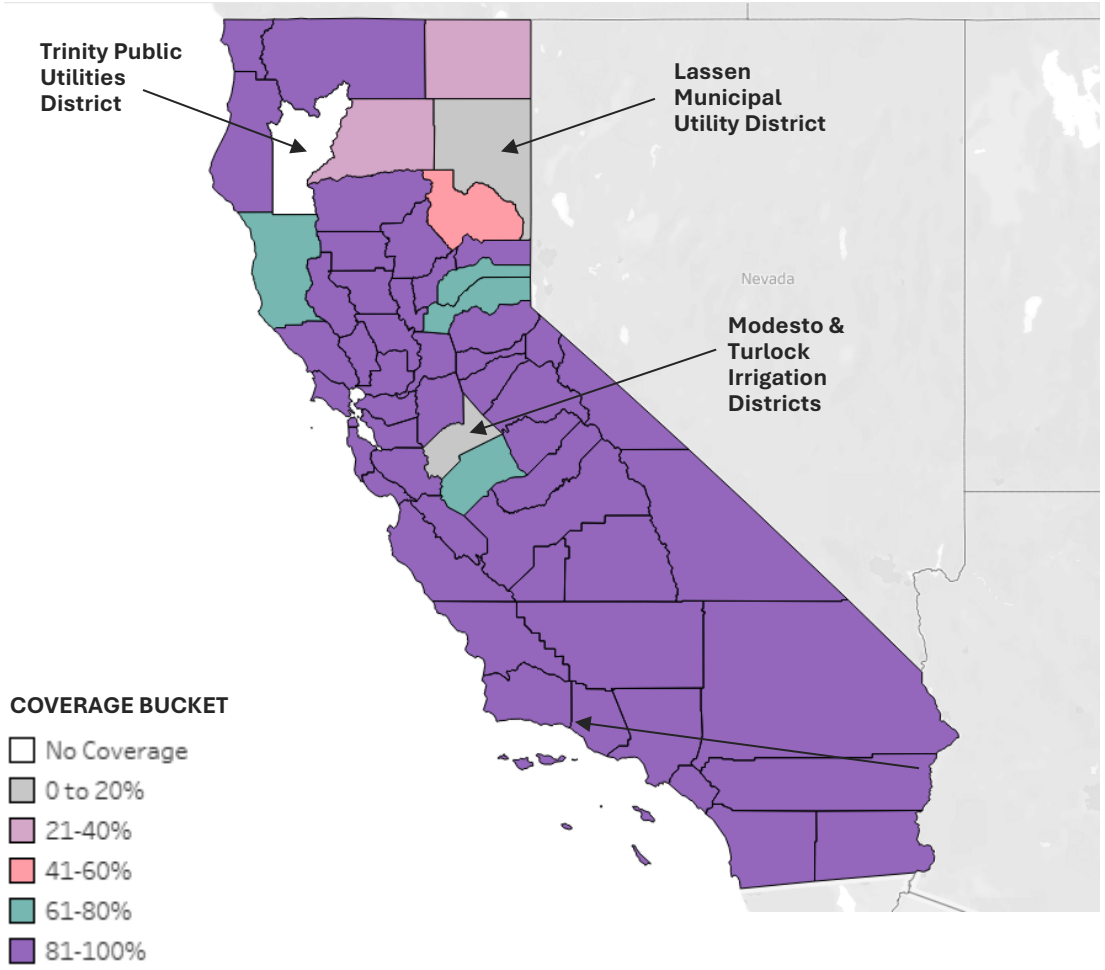
Draws on ORNL’s “Analysis of Historical Power Outages in the United States and the National Risk Index,” in which the researchers determined the 30,000 customer metric as a conservative threshold to isolate extreme, weather-cause events

While ORNL uses a 15% customer outage threshold, we have increased it to 50% for this analysis to focus our insights on how to address the costliest and most severe outages in the state

Baringa

The large proportion of customers served by IOUs gives CA some of the best EAGLE-I coverage in WECC, despite missing data for a few rural utility districts in the northern part of the state

EAGLE-I CUSTOMER COVERAGE (%) (CA, 2018-2022)



INSIGHTS

Outage data generally has better fidelity in the southern region of the state than the northern region

- Outage data is generally better in the southern portion of the state given it is more populated and is primary served by large IOUs
- Rural utility districts in the northern part of the state generally have the worst outage coverage in the EAGLE-I dataset

Counties with sparse outage coverage only account for 5% of customers within the state

- Over 95% of customers in the state are covered in the EAGLE-I dataset
- Insights surrounding the volume of customer interruptions in the state will be aligned with real world exposure

Additional consideration could be given to the hazards faced by counties without outage data

- The weather events driving outages in counties without data will be underrepresented in this analysis
- While this may not have a large impact on the distribution of the volume of customer interruptions, it could significantly change the distribution of the count of outages associate with different hazards
    - Northern Counties (Climate Zone-16): Cold, Flood, Rain
    - Central Counties (Climate Zone-12): Rain, Heat, Wind

WECC Summary

Windstorms are often the primary driver of customer interruptions in WECC, especially among smaller counties, but heat, wildfire, and rainstorms drive many interruptions along the coast

INSIGHTS

Windstorms are the most common primary driver of customer interruptions across WECC

- This is especially true among states in the eastern portion of the region such as Montana, Wyoming, and Colorado
- Wind is frequently the primary driver for counties with relatively fewer customer interruptions, indicating that it has an outsize impact on rural communities with radial networks and more overhead line mileage

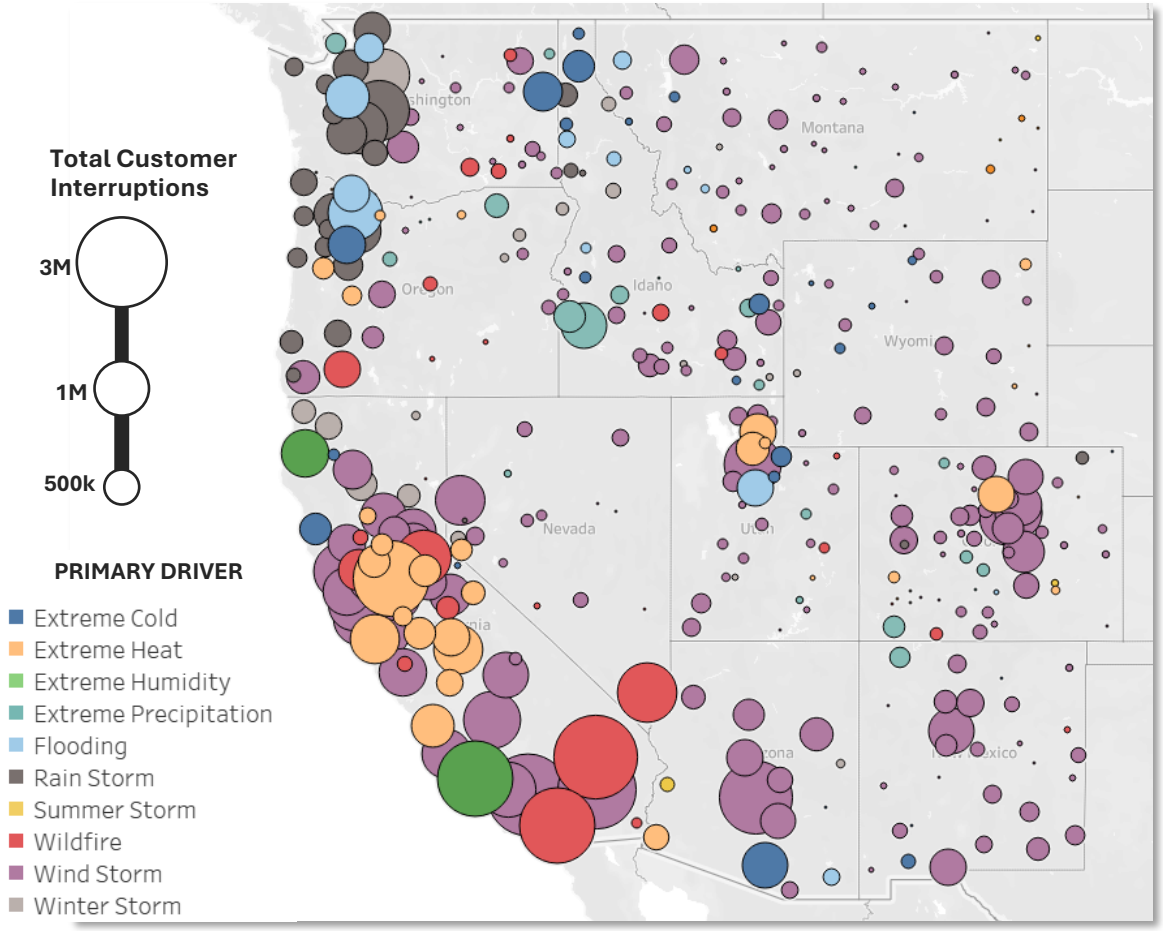
A higher volume of total customer interruptions is generally concentrated along the coast

- More populous counties in CA, WA, and OR drive a higher volume of customer interruptions
- Costal states demonstrate a wider range of primary driving hazards, including wildfire, extreme heat, flooding, and rainstorms

Extreme heat and wildfire still remain major hazards across WECC

- While they aren't always the primary driver of outages in a county, extreme heat and wildfire account for significant customer interruptions and more importantly, cause a disproportionate amount of damage in comparison to other hazards
- Per Baringa's Grid Resilience Reports, heat and wildfire exposure is projected to increase across the region out to mid- and end-century, potentially justifying hardening in historically less-exposed regions where this change will be most dramatic

PRIMARY DRIVER OF CUSTOMER INTERRUPTIONS BY COUNTY
(WECC, 2018-2022)



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State Summary

California

Legend: Most Impactful Hazard | Tertiary Hazard | No Extreme Hazard

Windstorms are coincident with the most frequent and severe power outages in the state, followed by extreme fire weather and extreme heat

HAZARD INSIGHTS

Windstorms are some of the most impactful weather events on the grid

- Windstorms exert force on overhead utility infrastructure and surrounding vegetation. Limbs and tree breakage are commonly found to interact with utility infrastructure, causing high impedance faults or pulling down poles and wires, though old and degraded assets themselves can fail at high speeds.
- Windstorms are over 2x more frequent than extreme heat events, holding outage ratios constant

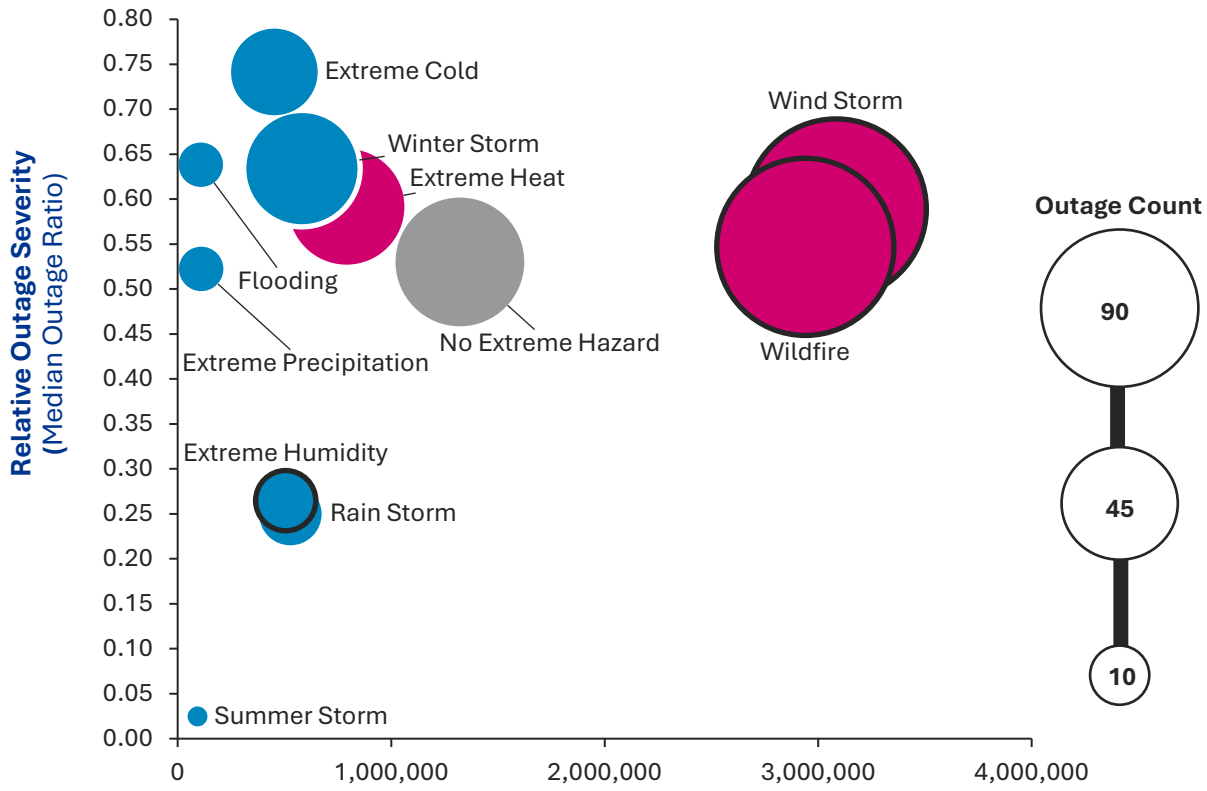
Extreme fire weather and extreme heat are attributable to a high number of outage events

- The two weather events are coincident with over 35% of customer interruptions cause by severe outages across the state

Exposure to extreme fire weather and extreme heat is projected to intensify in future years found in the CA Grid Resilience Report (GRR)

MOST IMPACTFUL HAZARDS	FUTURE OUTLOOK**	EVENT COUNT	MED. OUTAGE RATIO	TOTAL CUST. INTS.	AVG. CUST. INTS. / EVENT
Windstorm	same	82	.58	3,083,988	37,610
Wildfire	worsen	79	.55	2,940,011	37,215
Extreme Heat	worsen	34	.60	790,762	23,258

SEVERITY & FREQUENCY OF EXTREME OUTAGES* DURING EXTREME WEATHER
(CA, 2018-2022)



*A severe outage is defined as one in which >50% of customers in a county are out simultaneously, or at least 30,0000 customers in a county experience an outage simultaneously, whichever is less
**Future outlook for the hazard severity based on Baringa's Grid Resilience Report, completed as part of phase 2 of this analysis CA Grid Resilience Report

Source: EAGLE-I, WRCC

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The majority of customer interruptions associated with severe outages are concentrated 3 key weather events, including windstorms, extreme fire weather, and extreme heat

OUTAGE INSIGHTS

A handful of hazards drive the majority of customer interruptions across the state

- The top 3 events (wind storm, fire weather, and extreme heat) account for about 65% of all customer interruptions driven by severe outages
- CEC could consider prioritizing allocating grid resilience funding to projects that address these key weather events

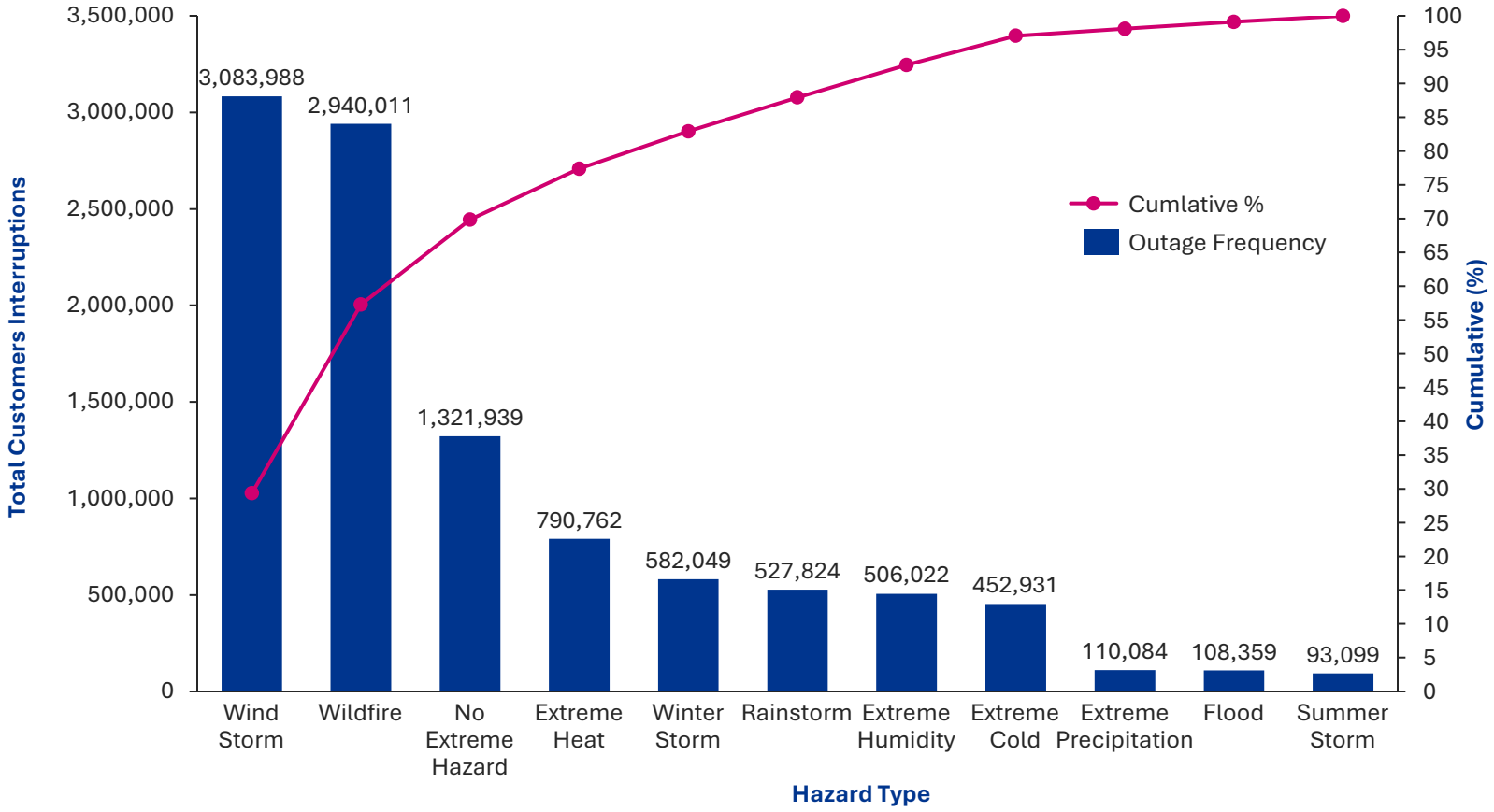
Utilities could consider upgrades that address outages not caused by extreme weather

- 13% of interruptions were not coincident with any extreme weather values, which could indicate wildlife interference, motor vehicle accidents, equipment failure, etc.
- Grid upgrades that also address non-weather outages can maximize outage avoidance

Utilities could consider which events impact their climate zone

- Highly variable climate across the state indicates that local analysis is needed to determine the highest priority events

SEVERE OUTAGES BY HAZARD & TOTAL CUSTOMER INTERRUPTIONS
(CA, 2018-2022)



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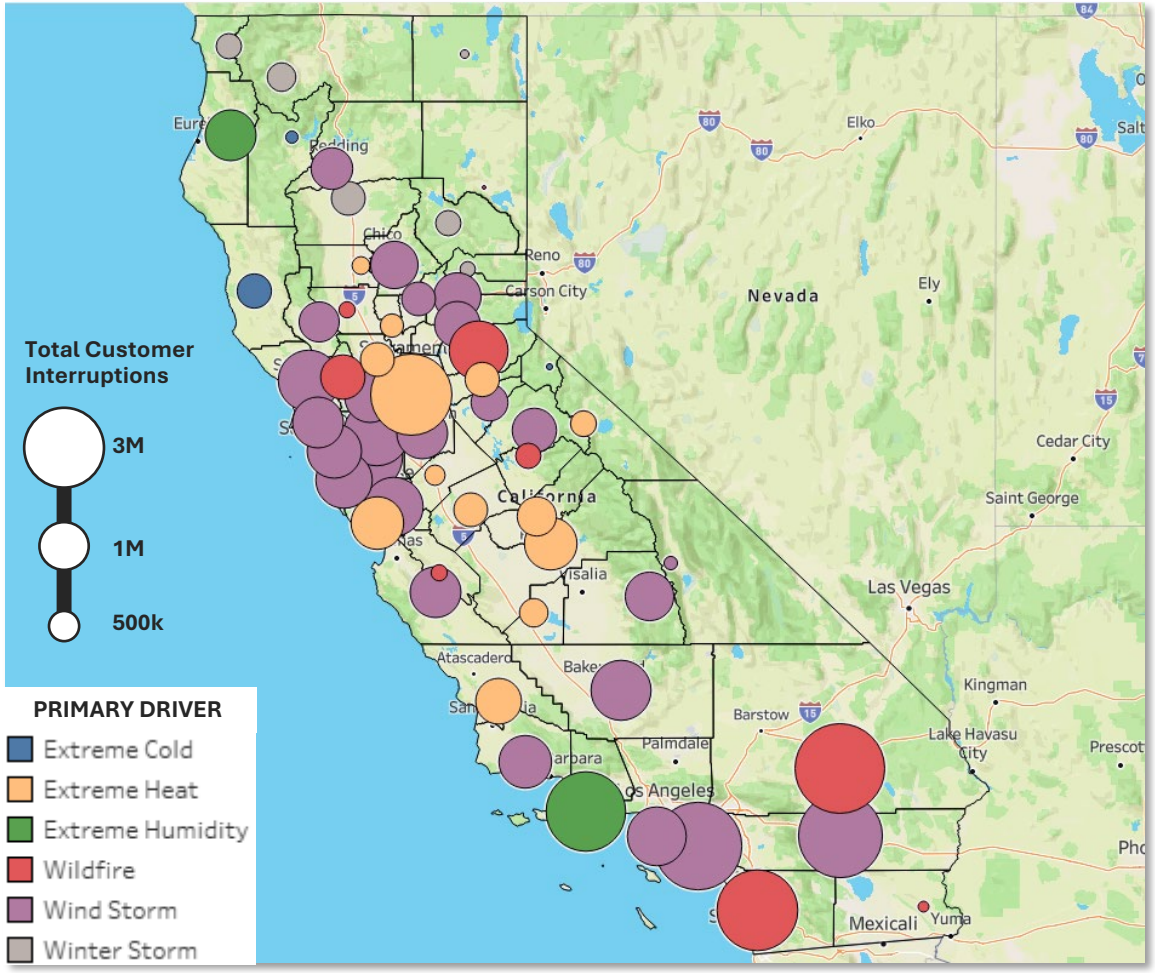
Windstorms are coincident with the largest number of severe outages in most counties across CA, while southern counties account for the largest volume of customer interruptions

PRIMARY DRIVER OF CUSTOMER INTERRUPTIONS BY COUNTY (CA, 2018-2022)



INSIGHTS

The highest volume of customer interruptions is concentrated in southern counties

- Highly populated southern counties account for the largest number of customer interruptions, but experience a wider variety of most concerning hazards than other regions of the state
- Undergrounding projects could be particularly effective in this region given dense population and exposure to fire, wind, and heat

Windstorms are coincident with the majority of outages in the Bay Area

- Substantiates GRR finding that the Bay Area is subject to peak wind gust exposure in the state, with 100-year return period values >150 mph

Extreme heat and wildfire drive outages in the north-central portion of the state

- While this region does not see peak heat or fire levels in the state, these hazards may drive more outages because the infrastructure is less equipped to weather these events
- The Grid Resilience Report details how extreme heat and fire exposure in this region is likely to become more extreme in the future, necessitating grid upgrades to avoid outages

PRIMARY DRIVER METHODOLOGY

1. Map weather variable combinations to event definitions (see slide 15)
2. Count the number of total customer interruptions at the county level (> 0 customers out) coincident with 90th percentile or greater weather variables for each of the combinations associated with a weather event
3. Deem the event with the most coincident interruptions as the “primary driver”

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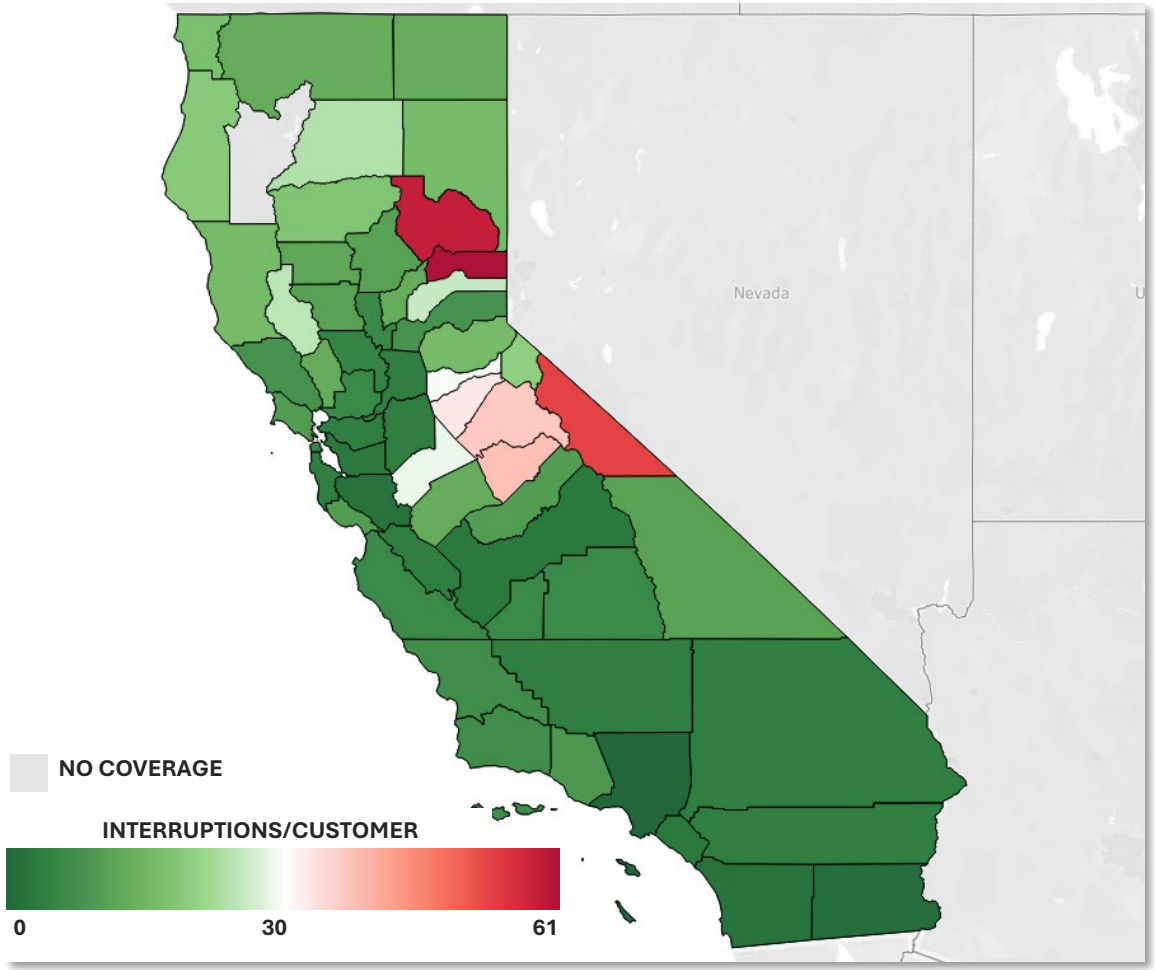
Rural counties in the central- and northeast portions of the state generally experience the most interruptions per customer due to dense vegetation, high winds, and vast OH lines

TOTAL CUSTOMER INTERRUPTIONS PER COVERED CUSTOMER BY COUNTY (CA, 2018-2022)



INSIGHTS

Central-east counties tend to experience the greatest number of customer interruptions per capita due to dense vegetation and wind

- This portion of the state is characterized by relatively dense vegetation, which could contribute to the increased frequency of outages
- These counties fall along a corridor of high wind exposure along the Sierra Nevada mountain range that was highlighted in the GRR

More populated counties tend to have fewer outages per customer

- Large counties in the southern portion of the state and the Bay Area have high reliability given limited vegetation (in the south) and the prevalence of underground infrastructure (both)
- The Bay Area also experiences a relatively milder climate compared to other portions of the state
- Counties with more customer interruptions per customer tend to be among the least populated in the state, as they likely have a large volume of overhead, radial distribution infrastructure that is particularly vulnerable and may not be well maintained

A mix of hazards contribute to low reliability in the central-east pocket with low reliability

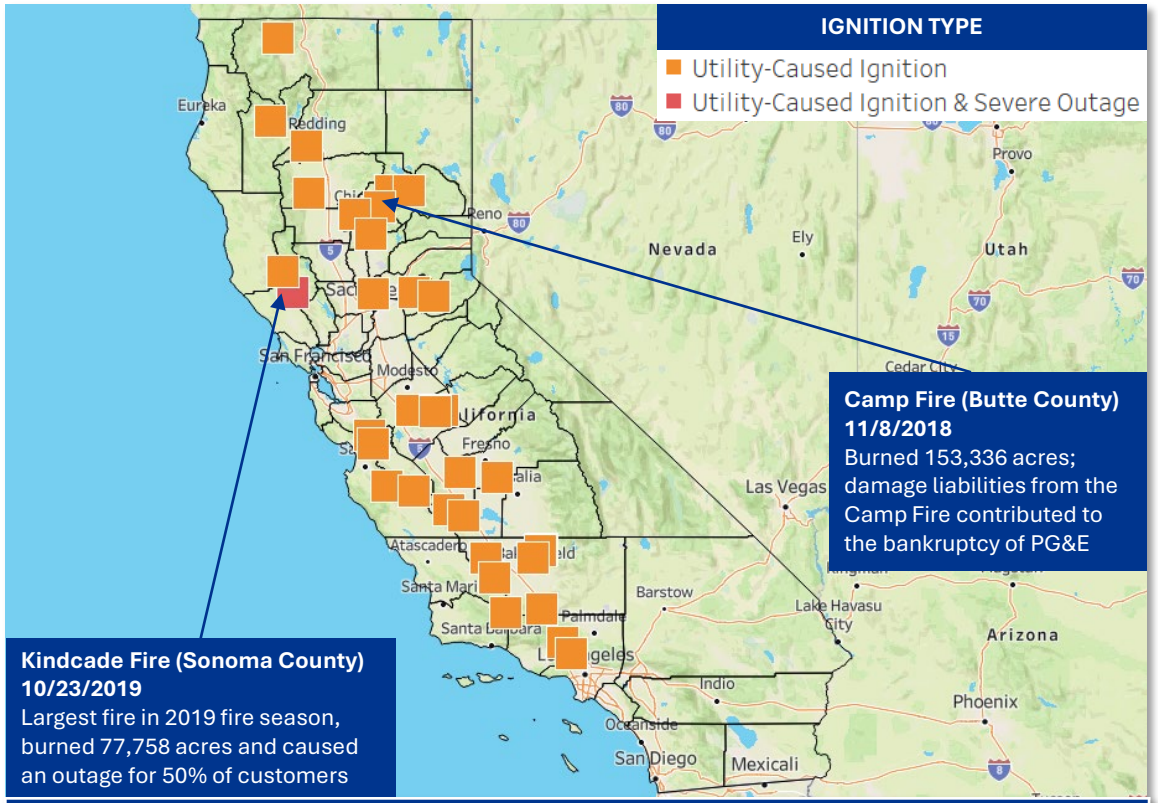
- Counties with the lowest reliability generally fall within Climate Zones 12 and 16, which are highly exposed to wind, extreme temperatures, and precipitation
- Wind, extreme heat, and wildfire are all primary drivers of customer interruptions among counties in this low reliability region

METHODOLOGY

1. Calculate the total number of customer interruptions that occur in a particular county, ensuring outage events are not double counted
2. Divide this number by EAGLE-I's "covered customers" metric for the county

Utility-caused ignitions are generally concentrated in a band of central/western counties with lower population and more vegetation than other areas of the state

UTILITY-CAUSED IGNITIONS, TOP 10% BY ACRES BURNED (CA, 2018-2022)



IGNITION STATS (2018-2022)			
CA Ignitions in WECC Top 10%	1,824	**Average Fire Size (acres burned)**	350
Total Ignitions	28,017	**Utility-caused ignitions in CA Top 10%**	36

INSIGHTS

Utility-caused ignitions are relatively evenly distributed throughout the state, but are generally consolidated in central/western counties

- This generally differs from Baringa's Grid Resilience Report, which depicted peak state wildfire exposure in the southwestern portion of the state
- Ignitions tend to be consolidated in relatively less-populated counties, which are more likely to have a high volume of overhead distribution infrastructure that could be aging or inadequately maintained
- This corridor of ignitions is largely coincident with grassland and woodland environments, providing ample fuel for fire spread once an ignition occurs

A high volume of historical utility-caused ignitions occurred in PG&E's service territory

- PG&E has made aggressive wildfire mitigation investments in the years following this time period, including substantial undergrounding
- Regulators and stakeholders could monitor whether this additional investment is effective in reducing ignitions compared to this historical baseline

IGNTIONS METHODOLOGY

- Historical ignition data was collected from the FPA-FOD and the WFIGS Interagency Fire Perimeter Database
- We focused on the **top 10% of ignitions by fire size across states in WECC**
- The map at left depicts these top 10% ignitions that also **listed "Power generation/transmission/distribution" as their NWCG cause code**
- The red boxes denote top 10% utility-caused ignitions that were also coincident with a severe outage in the ignition county within 2 days of the discovery date

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Extreme outages are generally attributable to higher wind speeds, but a high coincidence of outages with low wind speeds indicates vegetation contact could be driving many outages

UNDERSTANDING THE DATA

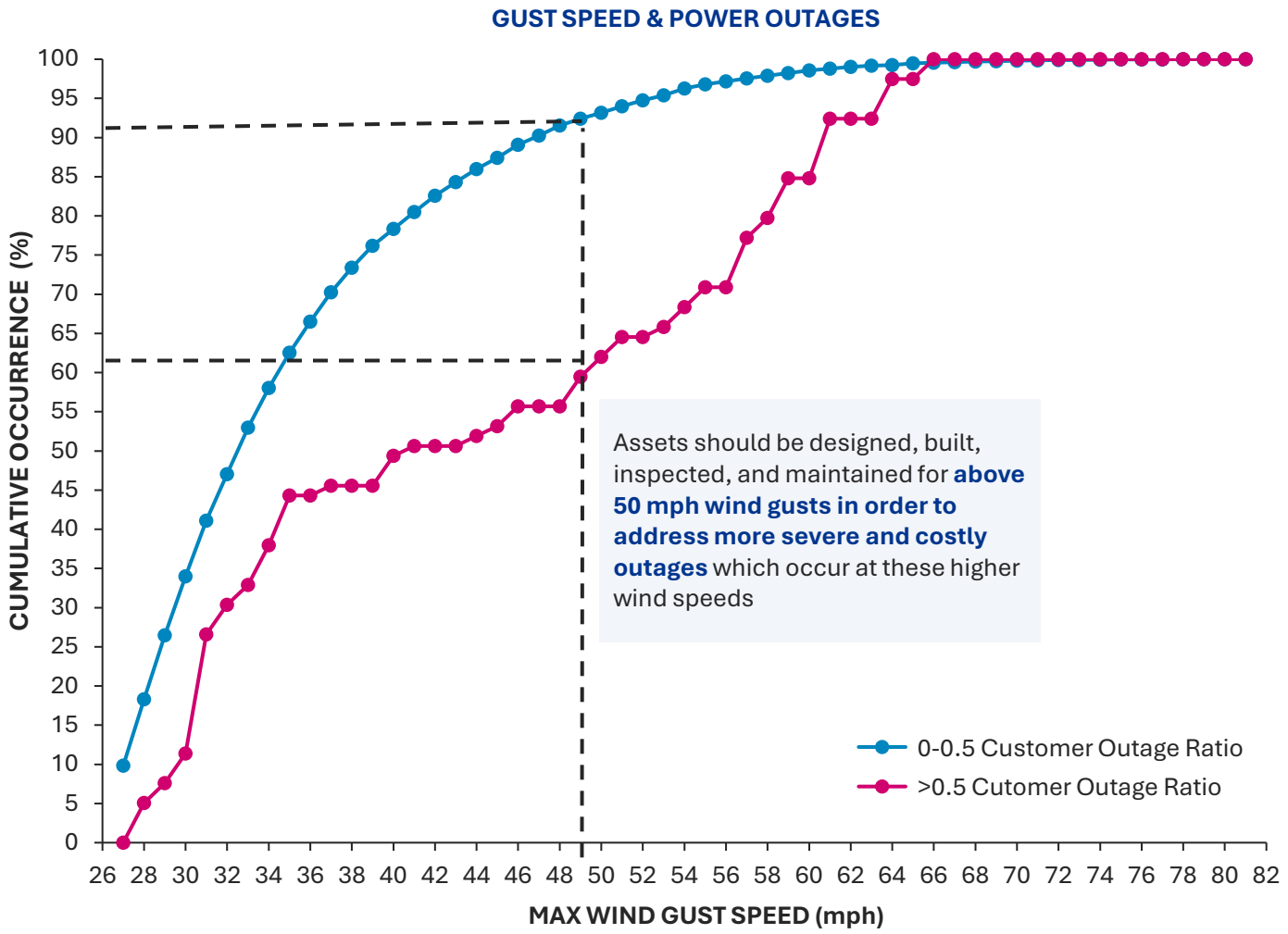
Extreme outages (>50% of customers out) are more likely to be coincident with >50 mph wind speeds than non-extreme outages

- About 40% of extreme outages are attributable to wind speeds above 50 mph, compared to just 8% of non-extreme outages
- Significant gap between the curves from 34 mph to 56 mph implies that these wind speeds are generally causing less severe outages, likely through contact with vegetation

ASSET PLANNING INSIGHTS

Designing and inspecting assets to the 50 mph wind speeds could historically mitigate about 60% of extreme outages

- Assets are unlikely to experience direct failure under 50 mph wind gusts, making this threshold more relevant for vegetation management and asset inspection program design
- Designing above 62 mph would address over 90% of extreme outages, demonstrating outsized reliability improvements at high wind speeds
- **Low-Cost:** Pole Reinforcement (Trussing, Guy Cables, Concrete Base, etc.), Pole Material Upgrades, Decreased Spans, Vegetation Management
- **High-Cost:** Undergrounding



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Moderate and extreme outages are equally sensitive to extreme temperatures, indicating that heat-related adaptations could be focused at the feeder level

UNDERSTANDING THE DATA

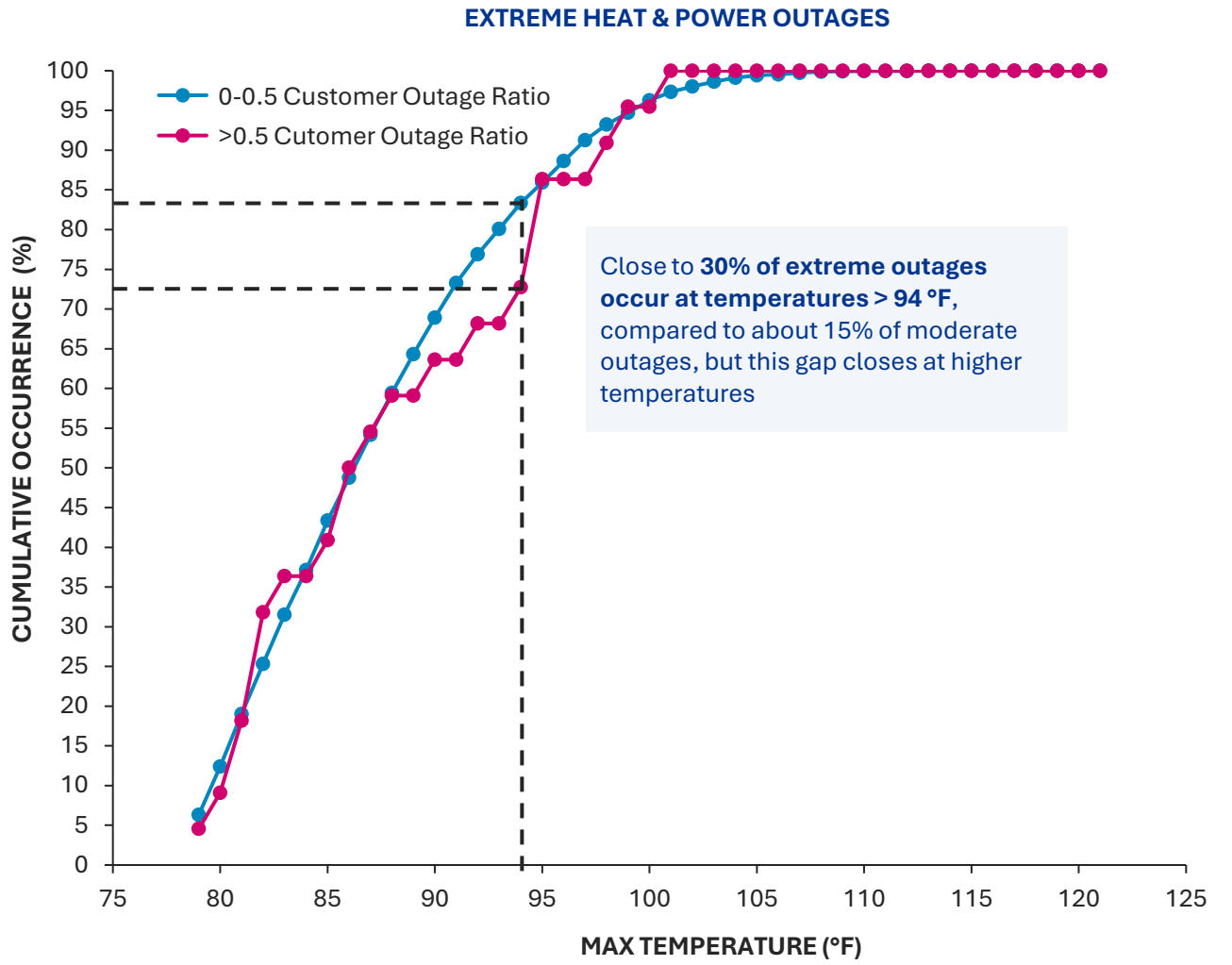
The frequency of moderate and extreme outages are equally sensitive to extreme temperatures

- The moderate and extreme outage curves converge at 95 °F, indicating that extreme temperatures do not necessarily contribute to more extreme outages
- Regions of CA that regularly experience temperatures above 95 °F appear well-positioned to limit the severity of outages associated with extreme heat events

ASSET PLANNING INSIGHTS

Asset adaptations addressing extreme heat should be focused at the local feeder level, particularly in areas that have not historically been exposed to this hazard

- Limited severe outages at extreme heat thresholds implies that most outages are contained at the local level
- Robust load shedding and demand response programs in CA help avoid cascading severe outages due to extreme heat and could be expanded
- **Low-Cost**: Vegetation Management, Monitors & Sensors, Dynamic Line Rating (DLR), Reclosers/Circuit Breakers, Relays, Fuses
- **High-Cost:** Reconductoring, Undergrounding



Close to **30% of extreme outages occur at temperatures > 94 °F**, compared to about 15% of moderate outages, but this gap closes at higher temperatures

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Designing and inspecting assets to the 99th percentile winter storm event could address about 50% of extreme outages

UNDERSTANDING THE DATA

Extreme outages (>50% of customers out) are more likely to be coincident with more severe winter storms

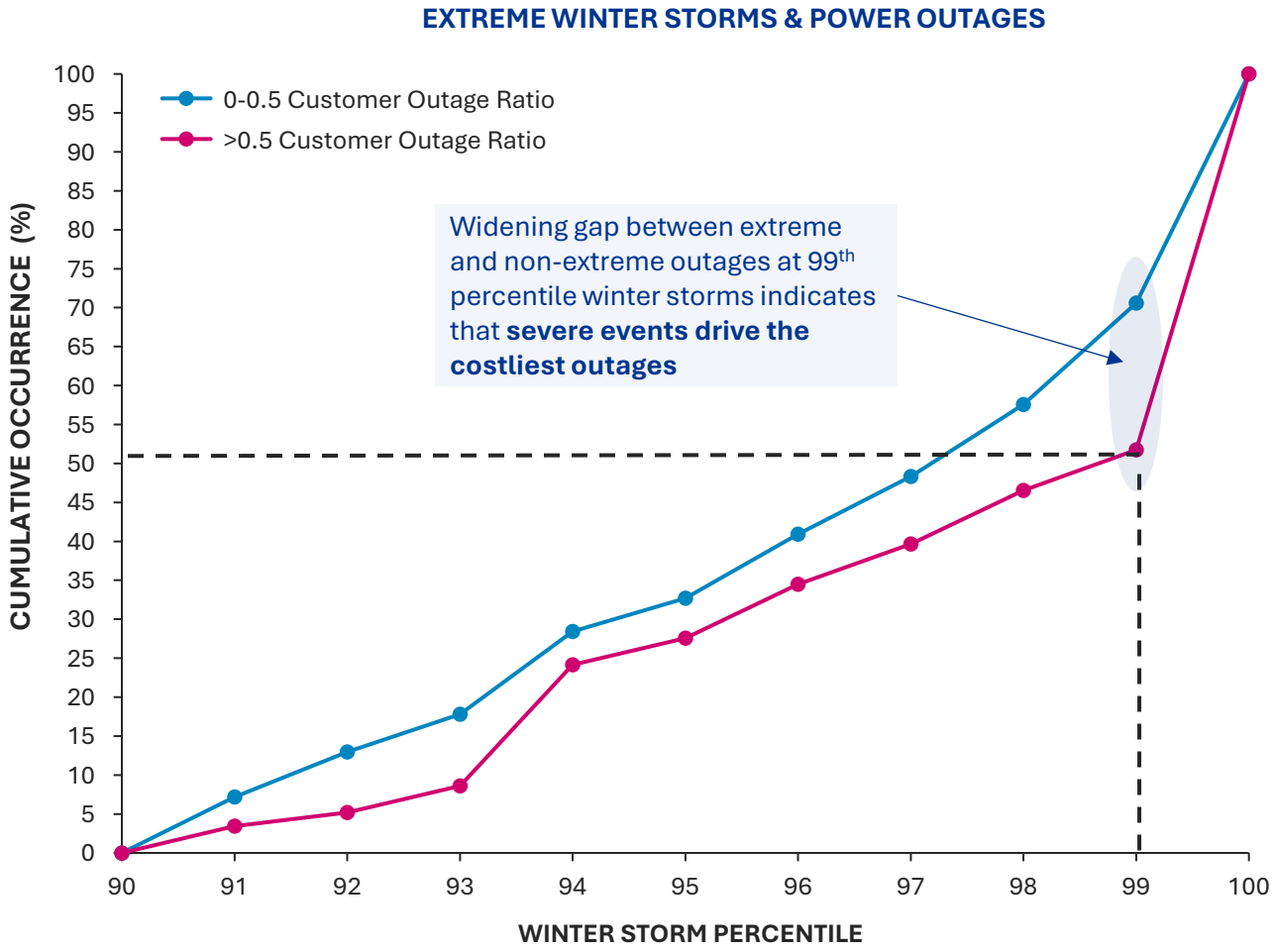
- The rightward shift of the extreme outage curve demonstrates an increasing probability that extreme outages occurred coincidentally with severe winter storms
- 50% of extreme outages are coincident with winter storms in the 99th percentile or greater, compared to 30% of non-extreme outages

ASSET PLANNING INSIGHTS

Designing and inspecting assets to the 99th percentile could historically mitigate about 50% extreme outages

- **Low-Cost:** Pole Reinforcement (Trussing, Guy Cables, Concrete Base, etc.), Pole Material Upgrades, Decreased Spans, Vegetation Management
- **High-Cost:** Undergrounding

HAZARD	PRECIP	GUST SPEED	MIN TEMP	RELATIVE HUMIDITY	VIC RUNOFF
90TH PERCENTILE	0 (in.)	27 (mph)	38°F	97	.039 (mm)



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Utility Capital Plan Analysis

Background & Approach

Public Power Cooperative IOU

We have a total of 12 utilities across WECC participating in this analysis, 5 public power, 5 cooperatives, 2 investor-owned utilities

STATE	UQID
California	PUBLIC-1
Arizona	PUBLIC-2
Washington	PUBLIC-3
Nevada	PUBLIC-4
Washington	PUBLIC-5

STATE	UQID
Colorado	COOP-1
New Mexico	COOP-2
Oregon	COOP-3
Utah	COOP-4
Wyoming	COOP-5

STATE	UQID
Montana	IOU-1
New Mexico	IOU-2

Severe outages were mapped to corresponding weather events to better understand which forms of extreme weather are driving customer interruptions and how utilities can respond

ANALYZE 2024 UTILITY CAPITAL PLANS

Purpose: Review projects listed in capital plans and categorize into standardized buckets of utility spending

CAPITAL PLAN	
Project	**$(k)**
Undergrounding	900
Reconductoring	75
Substation Upgrade	500

TECHNOLOGY, PREDICTION, IMAGING
ASSESSMENT & REPAIR
VEGETATION MANAGEMENT
... additional spend categories in slide 34

Individual projects in utility capital plans are **mapped to standardized buckets in order to compare spend between utilities**

MAP RESILIENCE INVESTMENTS TO HAZARDS

Purpose: Determine which types of investments mitigate or adapt the utility network to certain extreme weather events

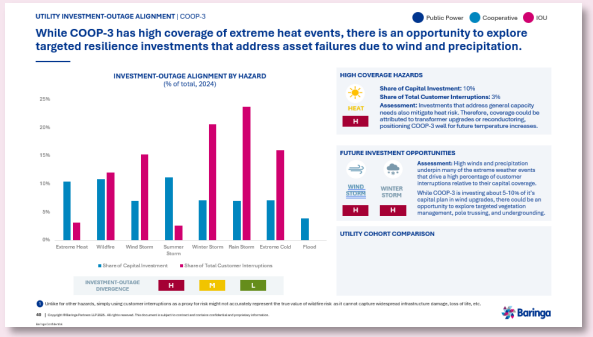
TECHNOLOGY, PREDICTION, IMAGING
ASSESSMENT & REPAIR
VEGETATION MANAGEMENT
... additional spend categories in slide 34

WILDFIRE
EXTREME HEAT
MAPPED TO 9 SEPARATE EVENTS

Project categories are ascribed a value as to generally how effective they are at **addressing each extreme weather variable**.

ASSESS INVESTMENTS-EXPOSURE ALIGNMENT

Purpose: Normalize spend across relevant utility metrics and determine the degree to which capital allocation aligns with historical extreme weather exposure



INVESTMENT-OUTAGE DIVERGENCE: L | M | H

The level of capital spend addressing each **weather event is compared to the share of customer interruptions it drives**

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Individual projects and line items within the capital plans were mapped to larger buckets to allow for standardized comparison across utilities

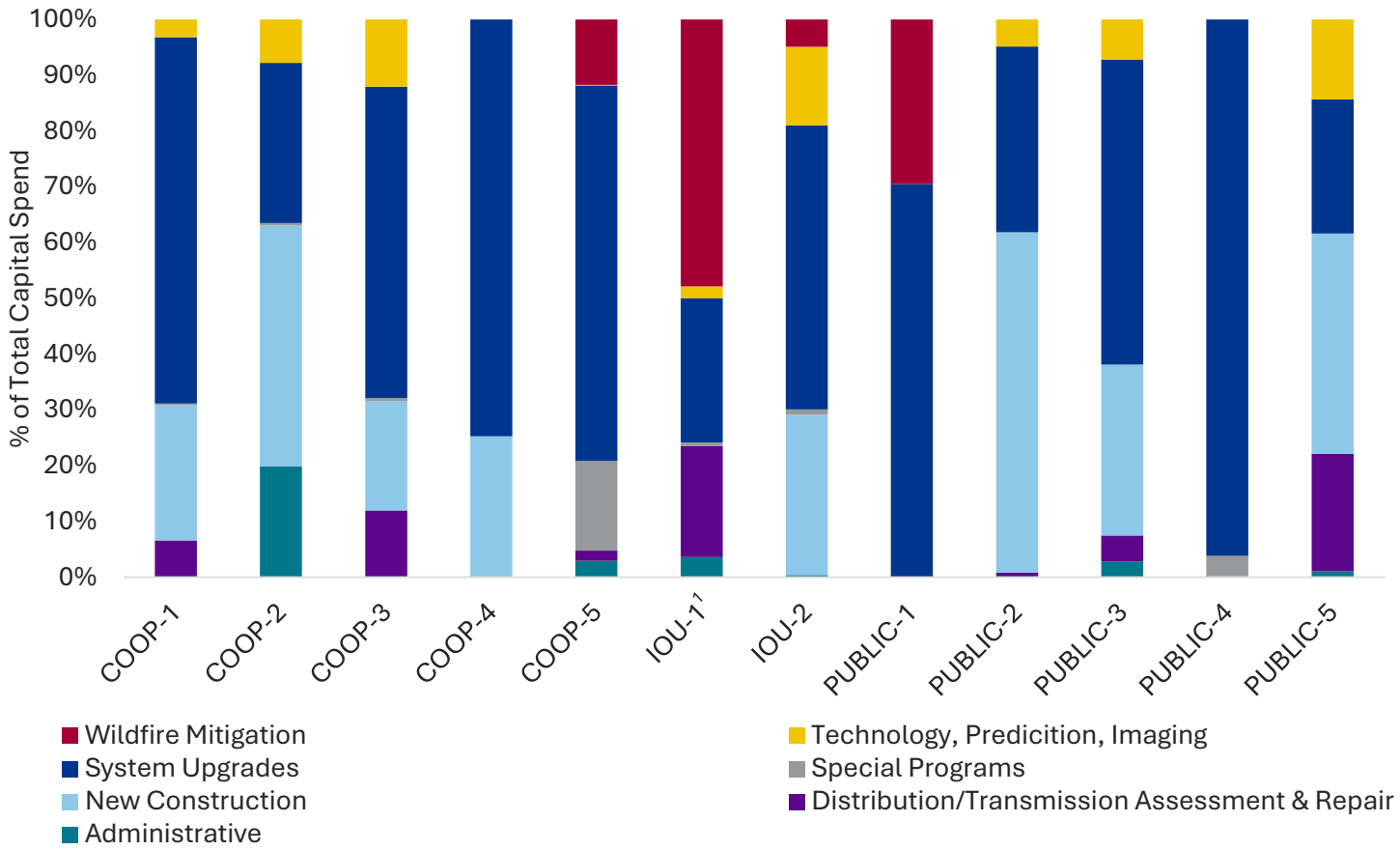
CATEGORY	DEFINITION	SUBCATEGORIES
TECHNOLOGY, PREDICTION, IMAGING	Investments in analysis and tools that improve asset management, asset planning, and operational efficiencies.	Modeling, Remote Sensing, Mapping
ASSESSMENT & REPAIR	Investments needed to repair or replace damaged or end-of-life distribution equipment like-for-like.	Like-for-like equipment replacement
SPECIAL PROGRAMS	Investments needed for non-traditional capital and other unique projects.	Demand Response/VPP, Wildfire Training Environmental/Ecological Protection
SYSTEM UPGRADES	Investments in existing assets that improve the capacity, reliability, resilience, etc. of the system.	Transformer Capacity Upgrades, Pole Replacement/Reinforcement, Reconductoring Undergrounding, Voltage/Phase Upgrades
NEW CONSTRUCTION	Investments in brand new assets and equipment.	New Lines, New Substations, New Customer Interconnection
ADMINISTRATIVE	Investments in supporting infrastructure and processes for capital planning and operations.	Fleet, Building Remodeling, Travel, Education, Salaries
VEGETATION MANAGEMENT	Investments in vegetation management activities and equipment.	Software & Technology, Tools & Equipment, Specialized Vehicles, ROW Clearing, Hazard Tree Removal, Tower Raises
WILDFIRE MITIGATION	Investments in system upgrades, adaptations, mitigations, that lower the likelihood of wildfire ignition and prevent damage to assets.	Investments that are specifically identified as mitigations for wildfire events*

*These investments include overlap with other categories. For example, upgrading poles to concrete could fall in system upgrades, however if a utility explicitly cited the justification as wildfire related, it will be captured in the wildfire mitigation bucket

Capital Plan Review

Cooperatives' and public power entities' highest categories include system upgrades and new construction, while IOUs generally spend more on wildfire mitigation

UTILITY CAPITAL SPEND BREAKDOWN ($, 2024/25)



ALL UTILITIES

- System upgrades make up a significant portion of capital spending across all utility types, indicating that resilience is a key focus area
- Many utilities are also spending substantially on new construction, increasing capacity to serve new customers and large loads
    - This corroborates recent data showing new transmission and distribution expenditures driving the bulk of utility spending increases in recent rate cases

COOPS

- Cooperatives typically prioritize system upgrades in their capital allocation, demonstrating a prevalence of aging equipment and focus on resilience

PUBLIC POWER

- Public power entities spend significant sums on both system upgrades and new construction and often have extensive undergrounding programs

IOUs

- Generally spend more on wildfire mitigation given the commonplace requirement to file Wildfire Mitigation Plans (WMPs) with the PUCs

1 IOU-1 provided their Wildfire Mitigation Plan rather than their exhaustive capital plan, resulting in a high percentage of wildfire mitigation spending

U.S. EIA, FERC

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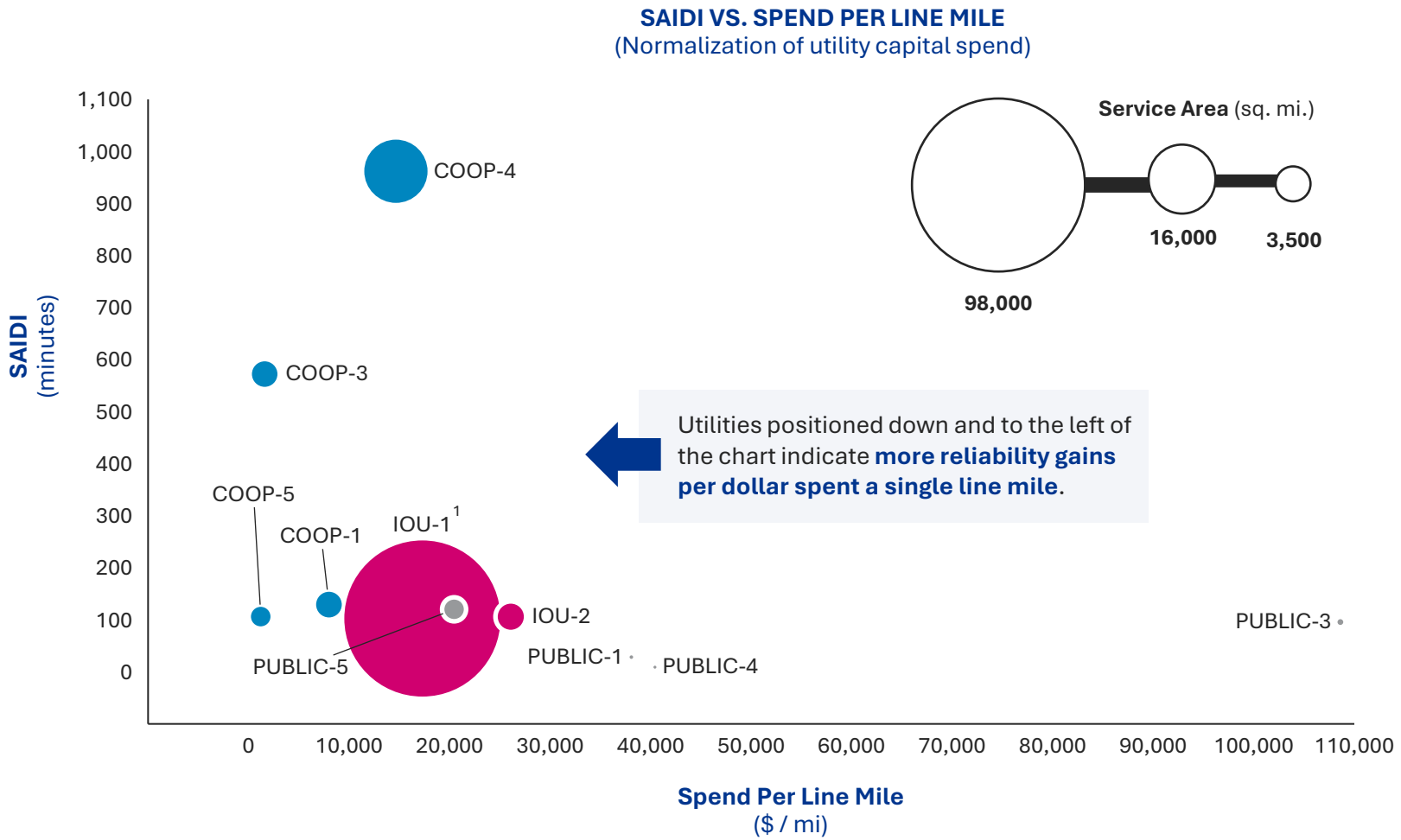
Public Power Cooperative IOU

Cooperatives spend less per line mile, while public power entities are generally more reliable; IOUs fall somewhere in between these two utility types on the spend vs. reliability matrix



INSIGHTS

COOPS

- Cooperatives typically spend less per line mile, indicating lower overall spend given their medium-sized service territories
- Wide range of reliability could be driven by different levels of spend effectiveness or extreme weather exposure

PUBLIC POWER

- Public power entities have higher reliability given their smaller territories and higher percentage of underground equipment
- Less area and more expensive upgrades indicate high spend per line mile, though entities that are outliers could be spending less effectively

IOUs

- IOUs see both high reliability and relatively low spend per mile
- Being subject to strict oversight from a state regulator could improve IOUs' reliability and spend effectiveness
- Given their larger service territories and customer counts, IOUs could benefit from economies of scale that increase spend effectiveness (i.e. admin, procurement, etc.)

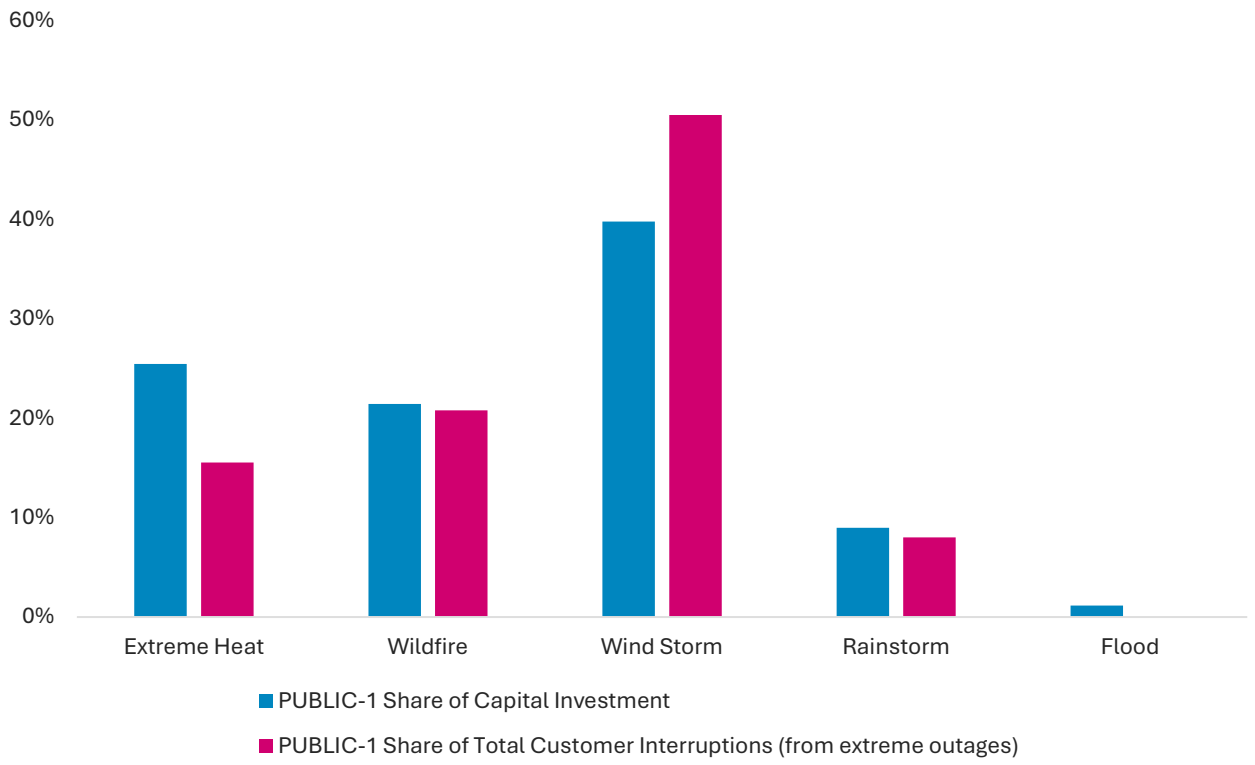
1 An estimate of IOU-1's total capital spend was considered in this view, not just Wildfire Mitigation Plan spending

Utility Investment-Outage Alignment

Public Power Cooperative IOU

PUBLIC-1 exhibits above average alignment with historical climate exposure and coincident outages, but could consider additional investment to address wind exposure

INVESTMENT-OUTAGE ALIGNMENT BY HAZARD
(% of total, 2024)



INVESTMENT-OUTAGE DIVERGENCE: H | M | L

HIGH COVERAGE HAZARDS

HEAT

M

Assessment: Investments that address general capacity needs also mitigate heat risk. Therefore, coverage could be attributed to distribution and substation transformer upgrades. Misalignment in this case does not necessarily require reallocation given escalating temperatures and demand growth in the region, but PUBLIC-1 could consider whether there are opportunities to buy down more risk by addressing more pressing weather events.

FUTURE INVESTMENT OPPORTUNITIES

WIND STORM

M

Assessment: Windstorms could be prioritized for additional investment given they account for close to 50% of customer interruptions resulting from severe outages in the service territory and adjacent counties.

While PUBLIC-1 has a significant portion of underground infrastructure and is continuing to underground additional lines, the volume of wind-caused interruptions could justify assessing whether investment addressing wind could be expanded.

UTILITY COHORT COMPARISON

INVESTMENT EXPANSION

Assessment: PUBLIC-1 exhibits better capital spend alignment with historical climate exposure than other utilities in WECC and should largely continue along the same investment course. Key hazards for continued investment include wind, wildfire, and extreme heat.

1 Unlike for other hazards, simply using customer interruptions as a proxy for risk might not accurately represent the true value of wildfire risk as it cannot capture widespread infrastructure damage, loss of life, etc.

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Utility Benchmark Analysis

Public Power Cooperative IOU

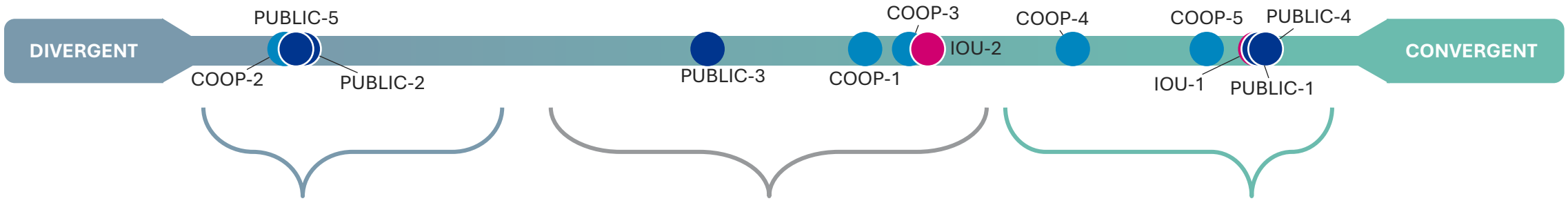
Utilities with convergent coverage are investing in upgrades that address hazards that have been historically responsible for the most severe outages in their service territory

RANKING OVERALL UTILITY COVERAGE OF EXTREME WEATHER EXPOSURE GIVEN CAPITAL INVESTMENTS

Utility Comparison Chart

Utilities that are **DIVERGENT** see a lower proportion of their capital plan cover the hazards that historically drive outages

Utilities that are **CONVERGENT** see a higher proportion of their capital plan cover the hazards that historically drive outages



REALLOCATION OPPORTUNITIES

Planning Considerations:

- Consider tradeoffs between resilience upgrades and other investments like new construction replacements
- Explore targeted investments to address hazards that historically drive outages
- Conduct asset-level risk assessment using future extreme weather data

UNCERTAIN COVERAGE

Planning Considerations:

- Investigate whether the share of customer interruptions from non-severe outages is better aligned with investment
- Conduct asset-level risk assessment using future extreme weather data to help clarify future exposure and prioritize resilience investments

INVESTMENT EXPANSION

Planning Considerations:

- Continue investment strategy to address the most pertinent hazards and prioritize resilience investments
- Pursue asset-level risk assessment to determine if current investments will continue to mitigate potential changes in most concerning hazards

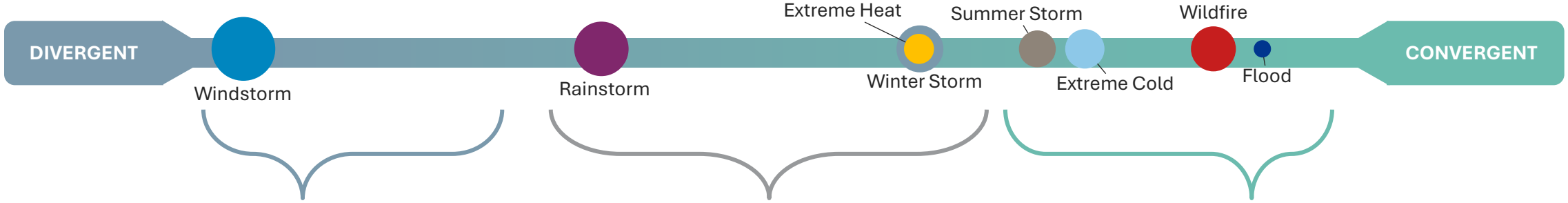
Utilities in WECC generally underinvest in windstorms given their widespread severity over utility service territories. Wildfire remains a highlight hazard for continued investment.

RANKING OVERALL UTILITY COVERAGE OF EXTREME WEATHER EXPOSURE GIVEN CAPITAL INVESTMENTS

Hazard Comparison Chart

Hazards that are **DIVERGENT** see a lower proportion of utility capital investments allocated towards them relative to exposure

Hazards that are **CONVERGENT** see a higher proportion of utility capital investments allocated towards them relative to exposure



REALLOCATION OPPORTUNITIES

Planning Considerations:

- Across WECC, windstorms are the primary driver of extreme outages
- While a large portion of capital spend is focused on wildfire and capacity upgrades, utilities could focus on targeted investments like vegetation management and pole reinforcements

UNCERTAIN COVERAGE

Planning Considerations:

- WECC sees high exposure to extreme heat. This is an opportunity for utilities to solve for both resilience and load growth challenges through capacity investments
- Rainstorms and winter storms include extreme wind, reinforcing the need for increased investment in things like pole reinforcement, vegetation management.

INVESTMENT EXPANSION

Planning Considerations:

- Continue investing in wildfire mitigations given high exposure and high cost of ignitions historically
- Unlike wind, extreme cold and summer storms are only issues in particular climate zones, meaning that overall investment sufficiently covers the limited exposure across WECC

