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State of the Grid Report

COLORADO

Energy & Resources | Networks
May 2025

Table of contents

Executive Summary

High wind speeds and winter storms drive a high volume of customer interruptions in Colorado, especially among sparsely-populated counties along the Rocky Mountains

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 winter storms are key drivers of severe outages* on the Colorado grid

- 63% of customer interruptions driven by extreme outages are coincident with wind speeds above the 90th percentile in the state
- Windstorms, winter storms, and extreme cold account for 78% of customer interruptions associated with extreme outages, indicating that these hazards could be prioritized for additional investment
- Sparsely-populated counties along the Rocky Mountains experience a high volume of interruptions per customer due to high wind and snow exposure, as well as a high percentage of radial, overhead distribution infrastructure

Capital Planning Insights:

- COOP-1 spends efficiently and experiences a relatively average level of SAIDI minutes compared to other utilities in WECC
- COOP-1's capital spending is generally aligned with historical climate exposure, although it could consider expanding investment addressing windstorms and winter storms

*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 importance of wind and wildfire in the West, utilities could 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	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	4
	Hardening/Rebuilds	L	1
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

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

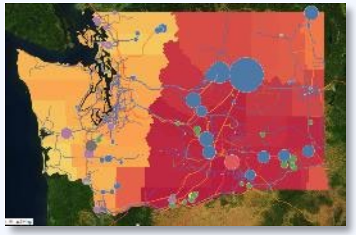
Project Overview

The State of the Grid Report will provide 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**



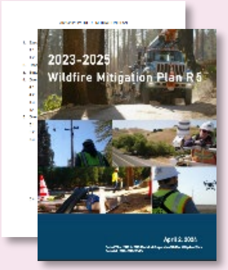
Analyze 5 years of publicly available extreme weather and outage data to **determine which type of events cause the largest outages and ignitions**.

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) OR Historical Ignition*
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

WEATHER EVENT MAPPING METHODOLOGY

Baringa analyzed 22 years of historical weather data for Colorado to determine 90th percentile weather hazard values across the state. During the mapping process, the algorithm considered whether the weather variables coincident with an outage were above or below the respective 90th percentile value and attributed the outage to a weather event based on the combinations show above. In the case of combinations not explicitly listed (i.e. extreme heat and high wind), the outage was mapped to the hazard deemed more likely to drive an outage (i.e. extreme heat and high wind → windstorm). A full list of mapping combinations can be provided upon request.

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

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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 90^{th} 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

OAK RIDGE National Laboratory

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

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

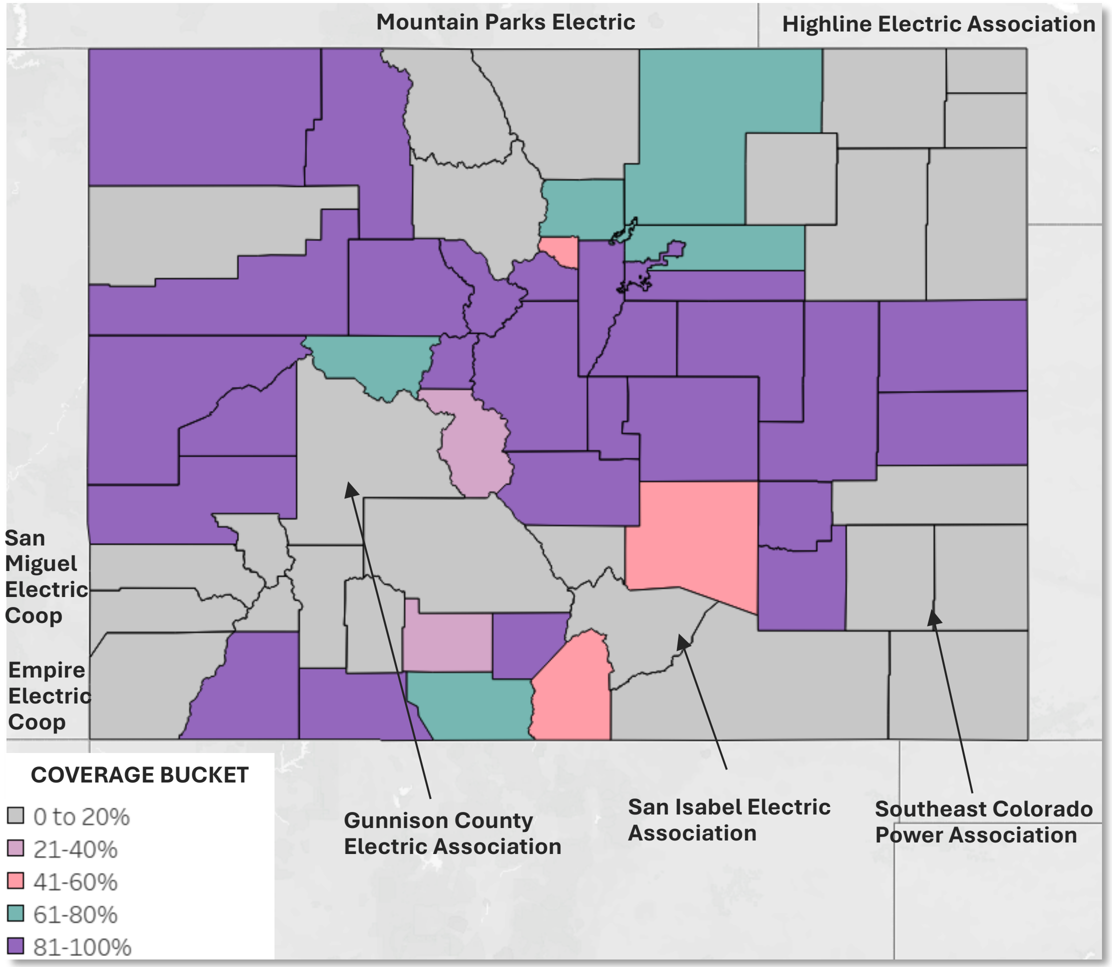
SEVERE OUTAGES | **JUSTIFICATION**

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

The EAGLE-I dataset provides coverage for 83% of CO customers, but is missing data from smaller cooperatives throughout the state

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



INSIGHTS

Outage data generally has better fidelity in the highly-populated, central region of the state

- These counties are mostly served by IOUs or larger cooperatives, which are more likely to collect and report comprehensive outage data

83% of CO customers are covered in the EAGLE-I dataset, indicating that it is still valuable for volumetric analysis

- Insights regarding which hazards drive high volumes of customer interruptions in the state will largely 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
    - SE Counties: Extreme heat, wind
    - SW Counties: Wildfire
    - North-Central Counties: Extreme cold, wind

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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

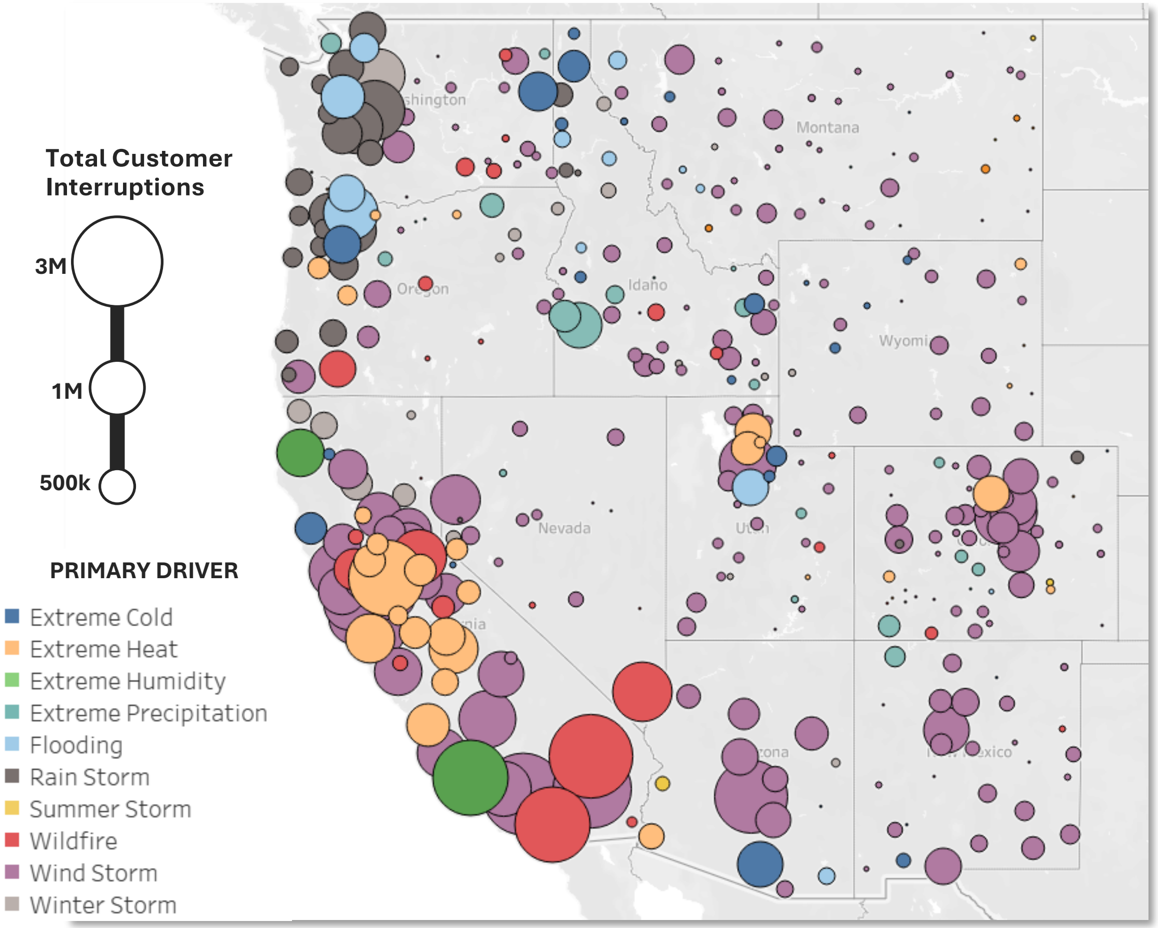
A higher volume of total customer interruptions is generally concentrated along the coast

- 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 are primary drivers of customer interruptions even in northern counties of the state

- While the northern portions of the state generally face less heat and wildfire exposure, these hazards are still driving customer interruptions because grid infrastructure could be less prepared for these events
- 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

Colorado

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

High winds and cold temperatures drive the most frequent and impactful power outages in the state by a wide margin, potentially justifying additional investment to address these hazards

HAZARD INSIGHTS

Winter storms frequently drive severe outages on the Colorado grid

- Winter storms are attributable to both high outage minutes and outage events
- Combined with extreme cold, at least 58% of all customer interruptions caused by severe outages occur when the minimum daily temperature is below 30°F

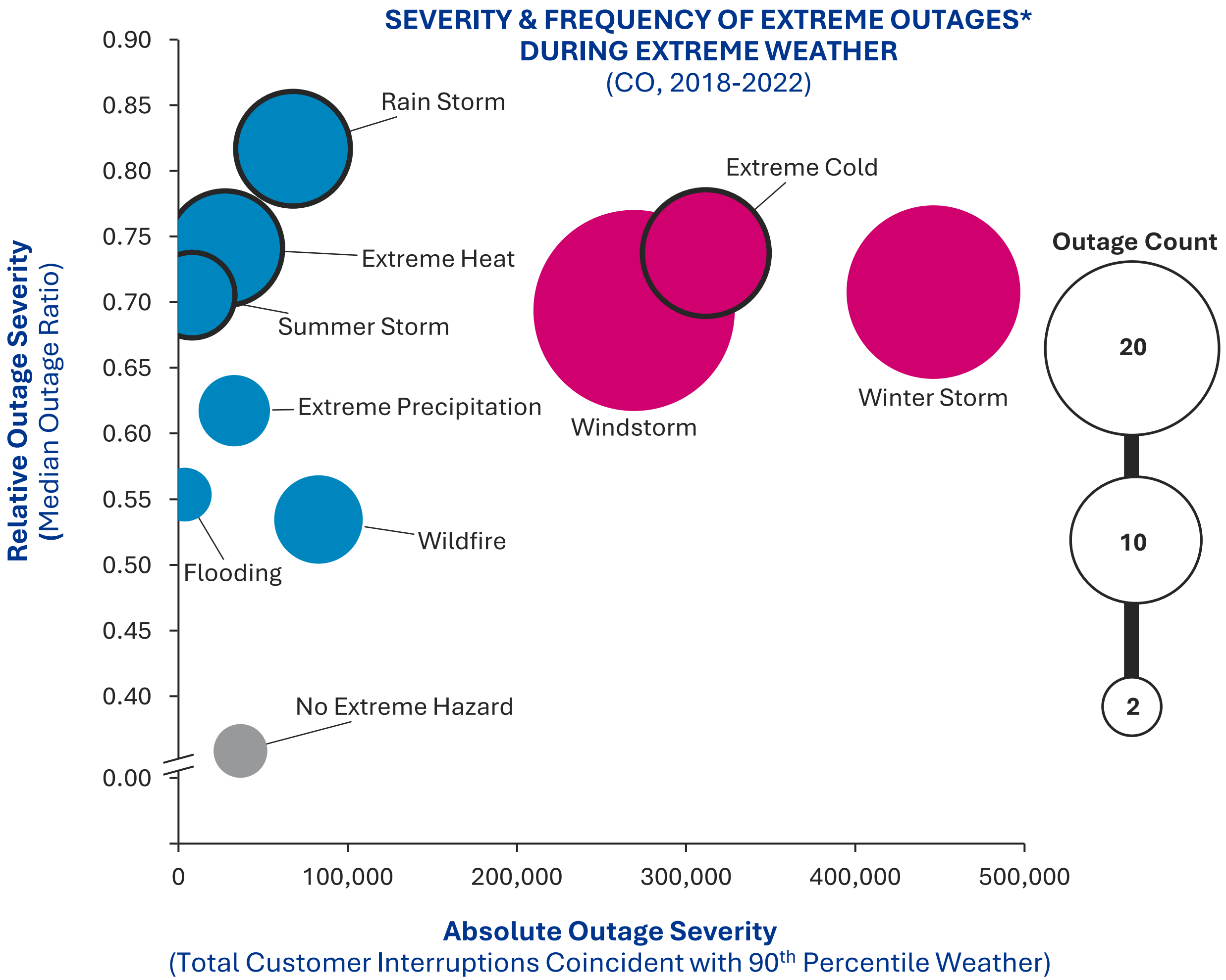
High wind speeds are often coincident with severe outages in Colorado

- About 63% of extreme outages from 2018-2022 were coincident with above 90^{th} percentile wind gust speeds (25 mph)

Wildfire's contribution to severe outages may be underrepresented in this analysis

- Severe outages associated with high fire weather index (FWI) values or historical ignitions were mapped to wildfire, but ignitions that started in another state would not be captured, despite posing a significant threat to assets

MOST IMPACTFUL HAZARDS	FUTURE OUTLOOK**	EVENT COUNT	MED. OUTAGE RATIO	TOTAL CUST. INTS.	AVG. CUST. INTS. / EVENT
Winter Storm	→	22	.71	446,154	20,280
Extreme Cold	→	11	.74	311,624	28,329
Windstorm	FURTHER RESEARCH NEEDED	28	.70	269,247	9,616



*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 (Insert link to the GRR here)

Source: EAGLE-I, WRCC

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The majority of customer interruptions from severe outages are concentrated among a few key weather events, including winter storms, extreme cold, and windstorms

OUTAGE INSIGHTS

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

- The top 3 events (winter storms, extreme cold, and windstorms) account for about 78% of all customer interruptions resulting from severe outages
- This concentration is generally more extreme than other states in WECC

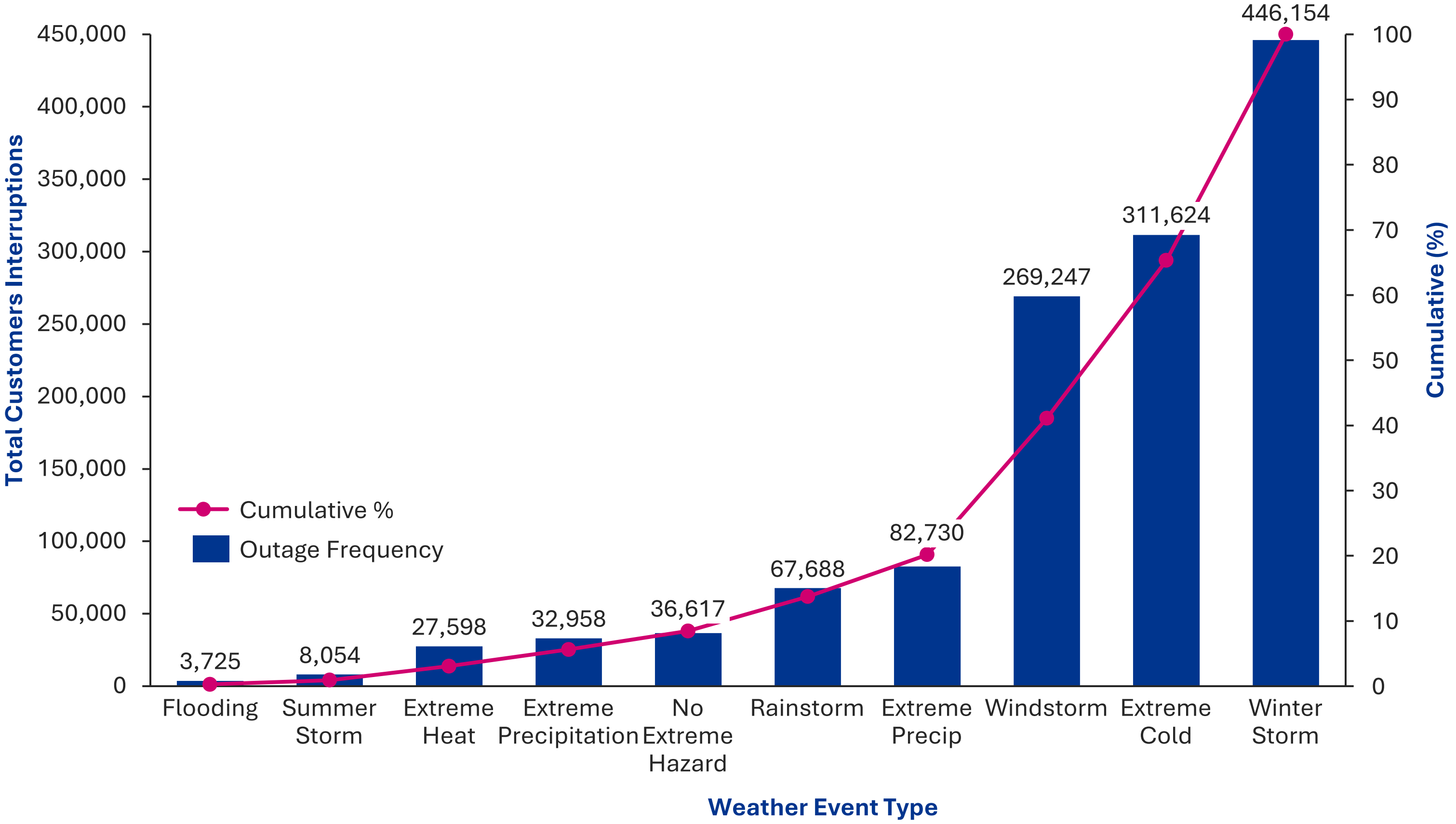
Statewide resilience initiatives could specifically target wind, cold, and precipitation

- Targeting these hazards would address the weather events driving the vast majority of customer interruptions from severe outages
- However, the high cost of utility-caused ignitions and stacked capacity benefits from upgrades addressing extreme heat make this a more complicated tradeoff

Utilities could consider which events impact their climate zone

- Variable climate across the state indicates that local analysis is needed to determine the highest priority events (see slide 24)
- Utilities could conduct asset-level vulnerability studies to inform asset planning, quantifying risk in dollars to compare across hazards and asset types

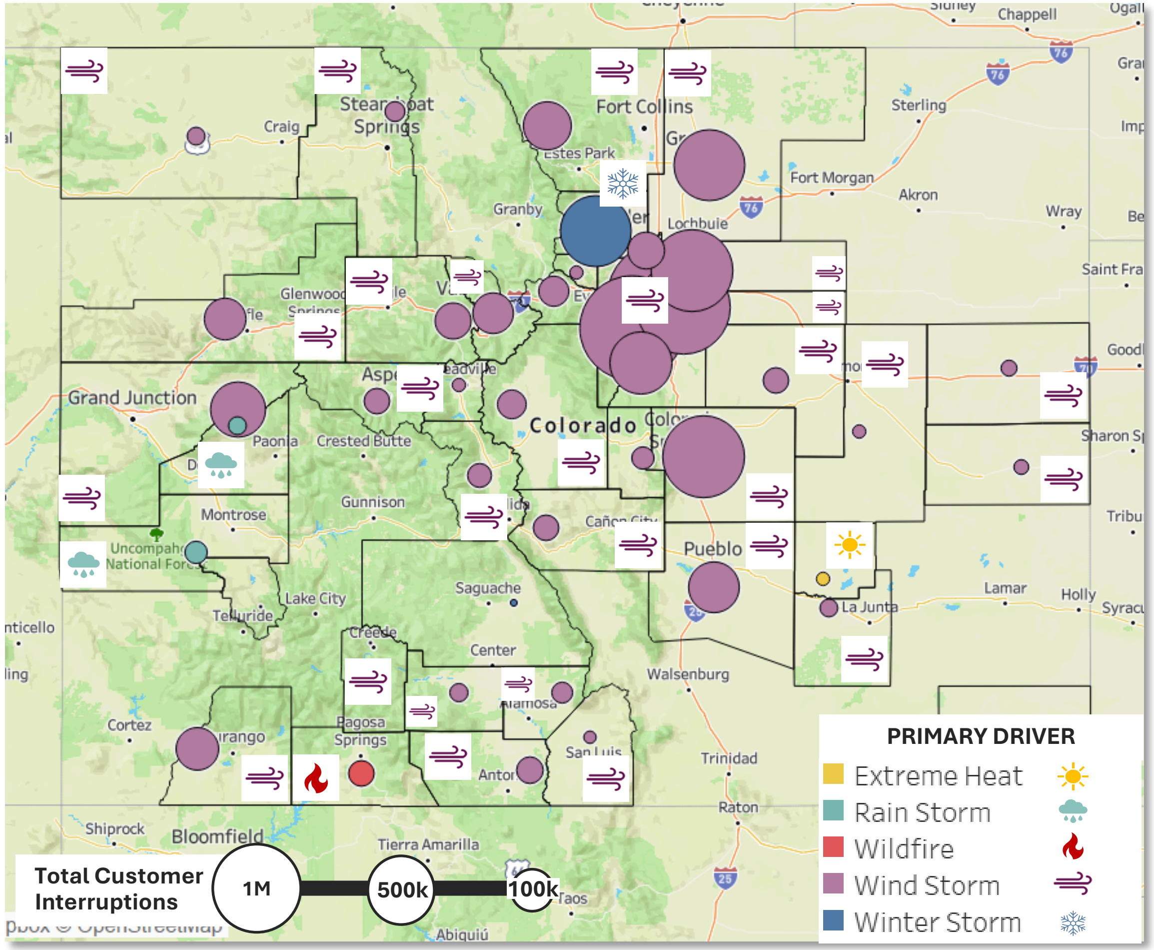
SEVERE OUTAGES* BY WEATHER EVENT & TOTAL CUSTOMER INTERRUPTIONS
(CO, 2018-2022)



*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

High wind speeds drive the majority of customer interruptions in the state, including a high volume in the Denver metropolitan area, followed by extreme temperatures and winter storms

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



Counties not shown on this map lacked sufficient outage data to determine the primary driver of customer interruptions

INSIGHTS

The highest volume of customer interruptions is concentrated in and around Denver County

- The majority of customer interruptions in the region are attributable to high wind speeds, but winter storms and extreme temperatures were also contributing factors

High wind speeds are the primary driver of customer interruptions across CO

- Wind is the leading cause of customer interruptions across the vast majority of counties, both rural and urban
- While wind ranks third in terms of customer interruptions resulting from severe outages, its predominance on this map (across all outage severities) indicates that it contributes to a higher volume of less severe outages than winter weather

Comparing customer interruptions to population reflects the reliability of different portions of the state's grid

- Logan County experienced a relatively high volume of customer interruptions given its low population, indicating a potential area for additional investment
- El Paso and Larimer Counties experienced fewer customer interruptions than would be expected given their population
- Larimer's high exposure to wind and extreme temperature suggests that the grid infrastructure in this portion of the state is relatively resilient to extreme weather

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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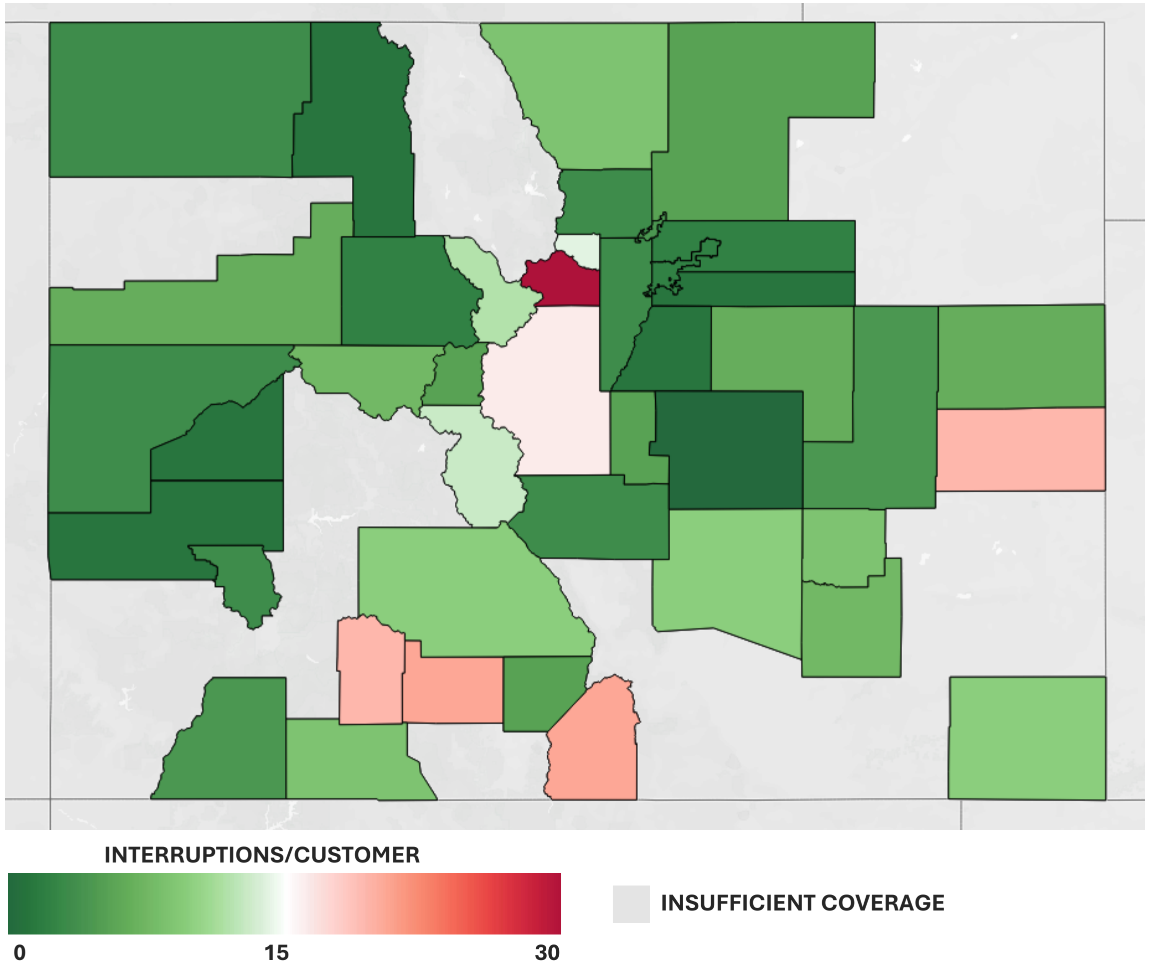
Population density appears to be a large driver of reliability in Colorado, with less-populated counties throughout the state experiencing a higher volume of interruptions per customer

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



INSIGHTS

Sparsely-populated counties throughout the state tend to experience the greatest number of customer interruptions per capita

- 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
- Among the more populous counties along the central-east corridor of the state, Larimer County experiences the highest volume of interruptions per customer (10), and could also be prioritized for additional investment

High winds generally drive outages across the least reliable sections of the Colorado grid

- The group of less reliable counties along the central corridor of the state are generally heavily forested and fall in an area of high wind exposure identified in Baringa's Grid Resilience Report
- Wind was identified as the primary driver of customer interruptions in all counties with below average reliability (see slide 19)

Reliability issues span across multiple utility types

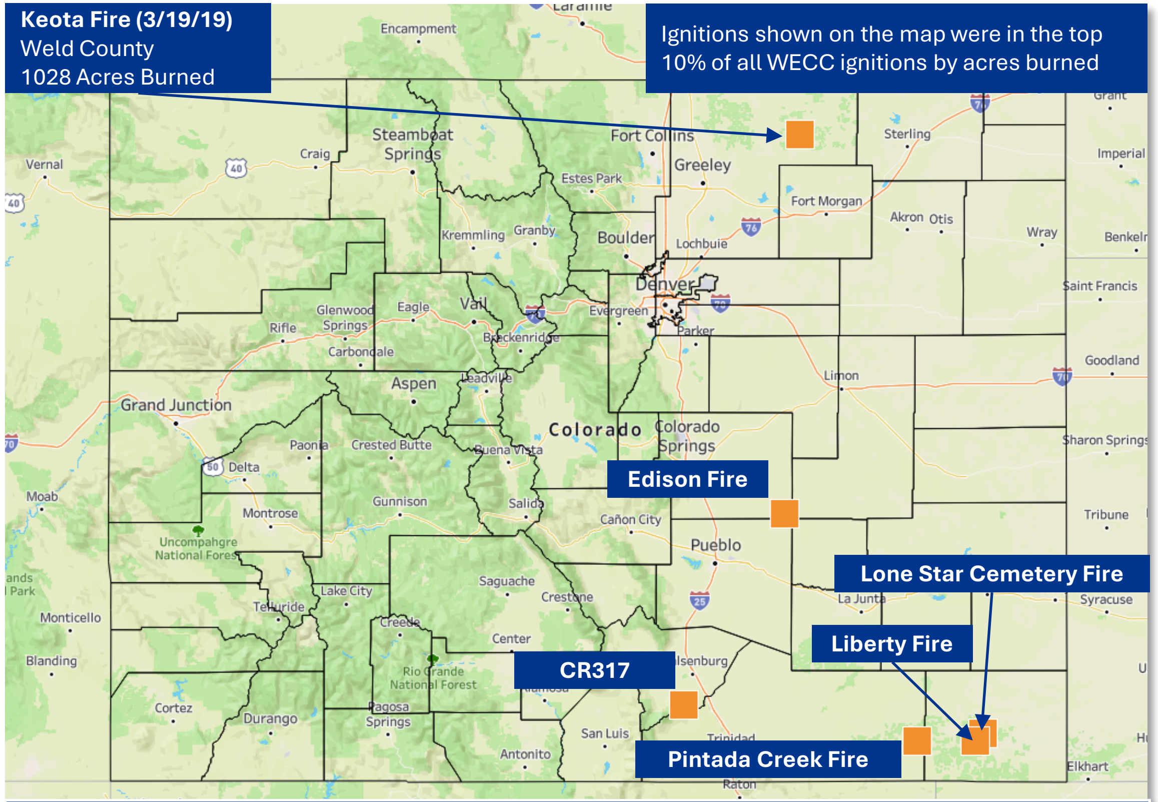
- Both IOUs and cooperatives serves counties with a high volume of interruptions per customer
- This indicates that population density and climate exposure are better indicators of reliability than utility type, although a clearer correlation with utility type may become apparent with improved outage data

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

Ignitions associated with utility infrastructure are concentrated in the eastern portion of the state, potentially due to high winds in the region and inadequate wildfire mitigation strategies

IGNITIONS ASSOCIATED WITH UTILITY EQUIPTMENT (CO, 2018-2022)



IGNITION STATS (2018-2024)			
Ignitions in WECC Top 10%:	635	**Average Fire Size (acres burned)**	220.33
Total Ignitions	13,336	**Utility-related extreme ignitions**	6

INSIGHTS

Ignitions from utility equipment are generally concentrated in the eastern portion of the state

- This contrasts Baringa's findings from the Grid Resilience Report which showed elevated wildfire exposure in the western counties
- High wind exposure in this SE could be driving ignitions in the region
- These types of ignitions generally occurred in the service territories of small electric cooperatives, which may have less robust wildfire mitigation strategies and own a higher percentage of overhead transmission and distribution lines

Wildfire mitigation efforts could be expanded in Baca County

- A cluster of 3 ignitions associated with utility equipment in Baca County indicates a need for wildfire mitigation investment

IGNTIONS METHODOLOGY

- Historical ignition data was collected from the FPA-FOD and the WFIGS Interagency Fire Perimeter Database
- We filtered out 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

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

UNDERSTANDING THE DATA

Extreme outages (>50% of customers out) are more likely to be coincident with >47 mph wind speeds than non-extreme outages

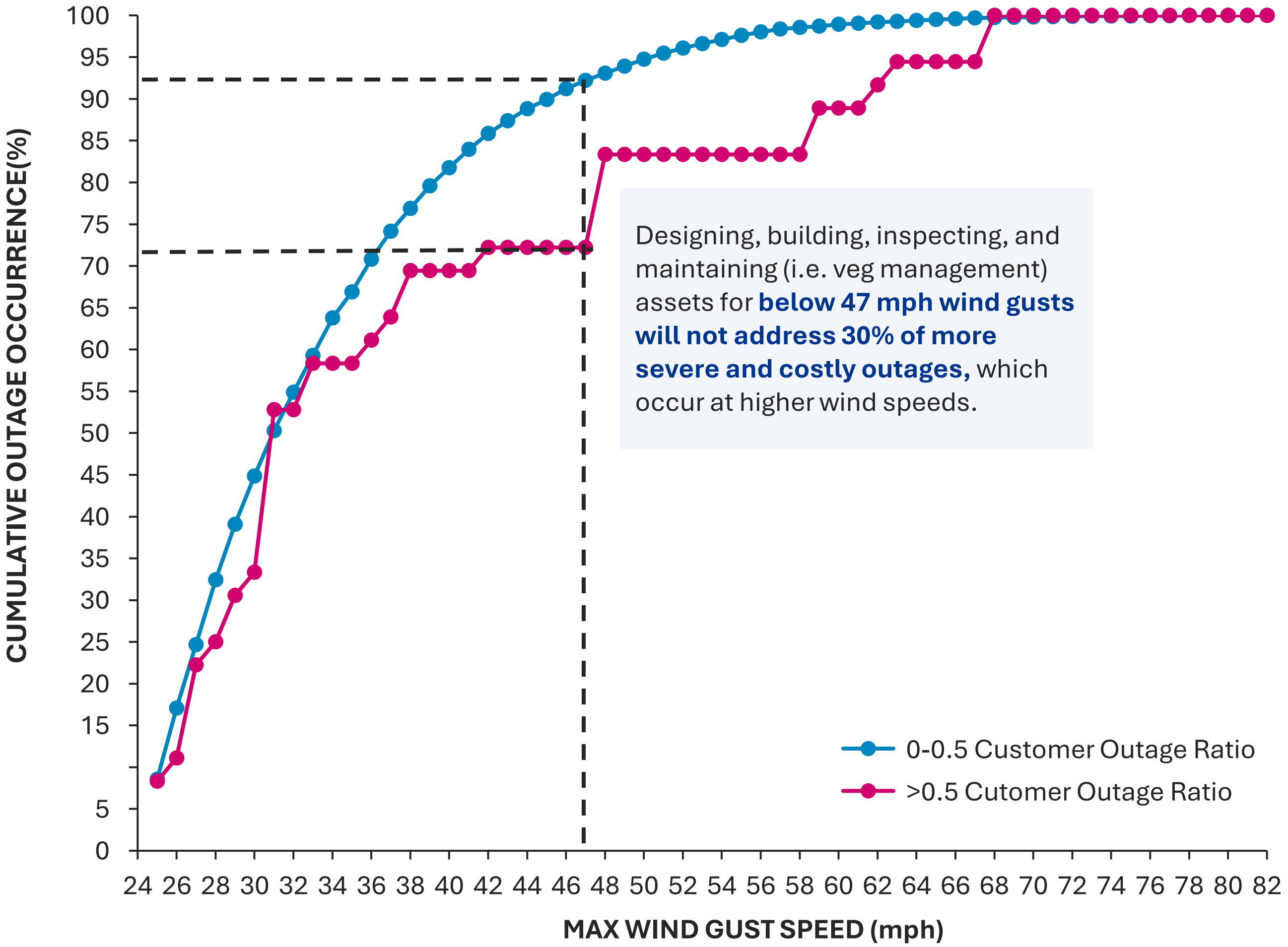
- About 30% of extreme outages are attributable to wind speeds above 47 mph, compared to under 10% of non-extreme outages
- The gap between the curves indicates that extreme outages are generally more likely to be coincident with higher wind speeds than non-extreme outages

ASSET PLANNING INSIGHTS

Prioritizing vegetation management and active inspection could address a significant portion of wind-driven outages

- Over 80% of extreme outages and 95% of non-extreme outages occur at wind speeds < 50 mph, which are more likely attributable to vegetation contact or aging equipment rather than direct failure
- Designing to 67 mph wind speeds would historically address most extreme outages, including those caused by direct failure
- **Low-Cost:** Pole Reinforcement (Trussing, Guy Cables, Concrete Base, etc.), Pole Material Upgrades, Decreased Spans, Vegetation Management
- **High-Cost:** Undergrounding

GUST SPEED & POWER OUTAGES



Designing, building, inspecting, and maintaining (i.e. veg management) assets for **below 47 mph wind gusts will not address 30% of more severe and costly outages,** which occur at higher wind speeds.

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Extreme outages are concentrated above the 99th percentile weather hazards, particularly wind, necessitating additional investment to avoid the costliest outage events

UNDERSTANDING THE DATA

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

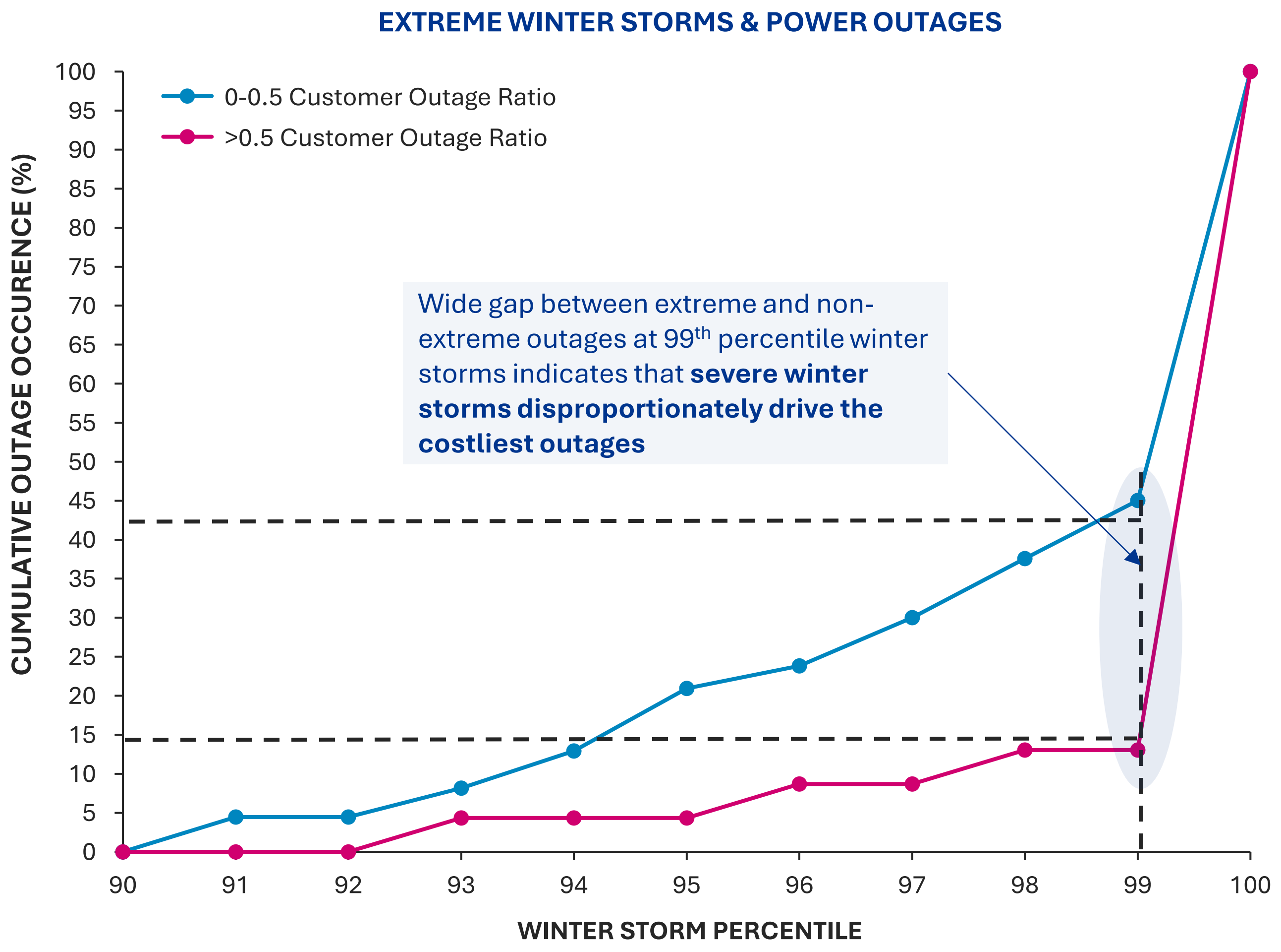
- About 85% of extreme outages are coincident with winter storms in the 99th percentile or greater, compared to about 55% of non-extreme outages
- The gap between the curves at the 99th percentile shrinks to about 10% when wind is excluded from the percentile mapping, indicating that it is the key drivers of extreme outages among the components of winter storms

ASSET PLANNING INSIGHTS

Utilities could consider pole reinforcement or undergrounding to address snow and ice loading, line galloping, and high wind speeds associated with winter storms

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

HAZARD	PRECIP	GUST SPEED	MIN TEMP
99TH PERCENTILE	0.04 (in.)	40 (mph)	8°F



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Extreme and non-extreme outages are equally sensitive to increasingly cold temperatures, as these outages are more likely driven by generator failures than transmission and distribution

UNDERSTANDING THE DATA

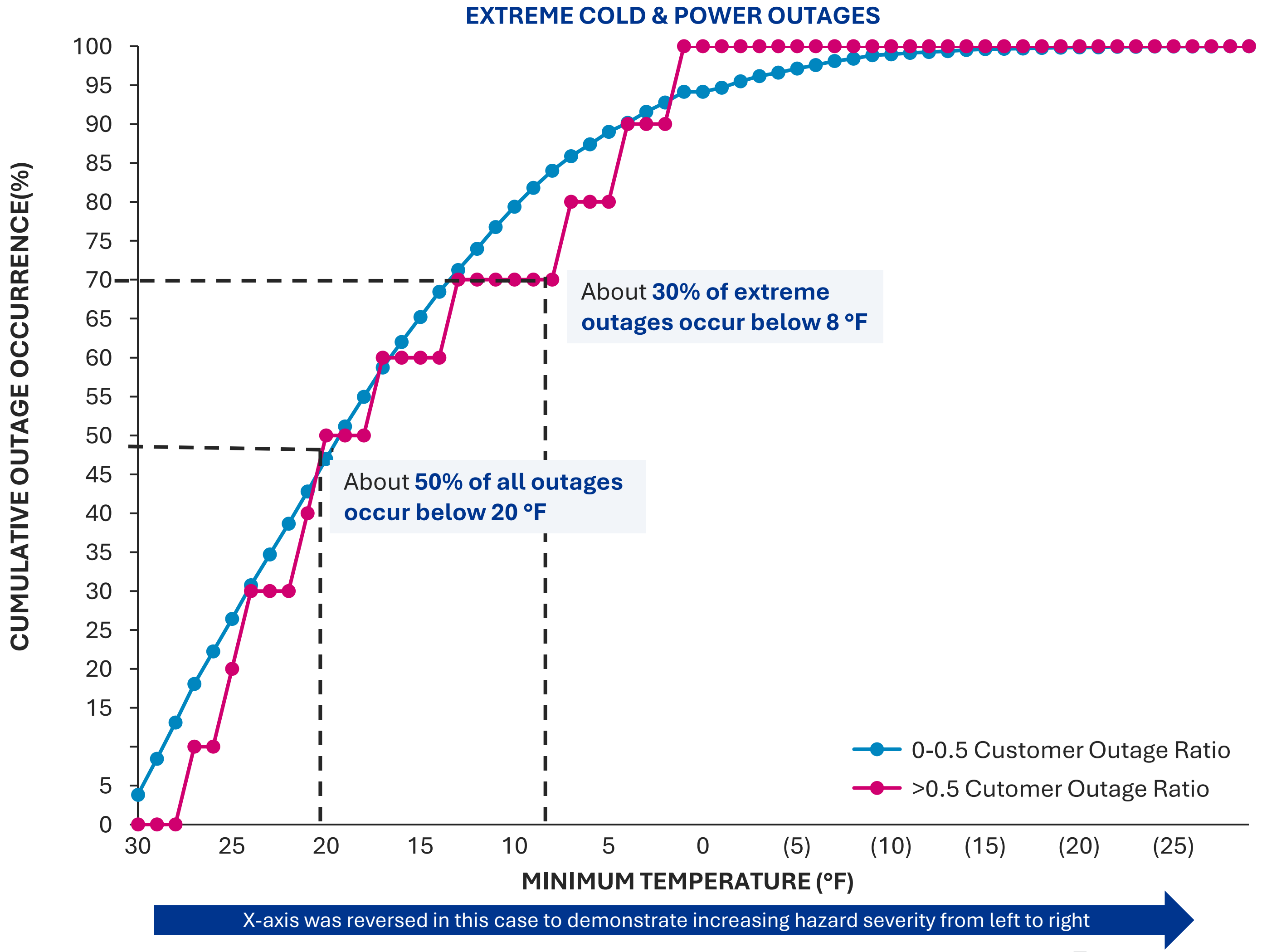
Regardless of severity, outages driven by extreme cold are generally concentrated below 20 °F

- Over 50% of outages attributable to extreme cold occurred coincidentally with minimum temperatures below 20 °F
- Over 50% of extreme cold outages are coincident with extreme precipitation, indicating that snow/icing is driving outages rather than temperature along
- Of purely temperature-driven outages, >50% are concentrated in Costilla County

ASSET PLANNING INSIGHTS

Extreme cold without accompanying wind or precipitation is more likely to cause power plant failure than distribution and transmission issues

- Designing and maintaining assets to a 5 °F threshold would address about 90% of all cold-related outages
- Smaller utilities could coordinate with generation owners and update emergency plans to prepare in advance for potential cold-related outages
- **Low-Cost:** Contingency planning, monitoring and sensors, demand response
- **High-Cost:** Undergrounding, backup power systems, upgrade transformers and switchgear



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Baringa

Utility Capital Plan Analysis

Project Overview

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

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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
- SYSTEM UPGRADES
- ... 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
- SYSTEM UPGRADES
- ... additional spend categories in slide 34

WILDFIRE

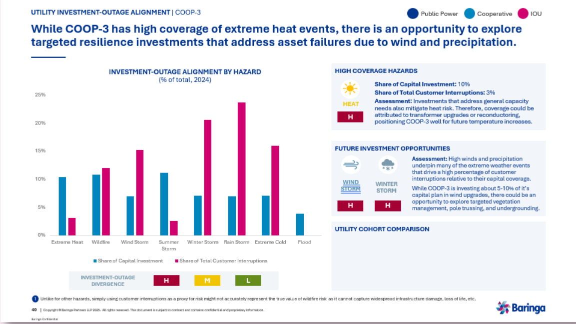
EXTREME HEAT

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
WILDFIRE MITIGATION	Investments in system upgrades, adaptations, mitigations, that lower the likelihood of wildfire ignition and prevent damage to assets.	Investments that explicitly address wildfire risk.

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Baringa estimated the share of utility capital spending related to specific hazards by assigning a probability that each upgrade addressed a particular event

Capital Investment

Capital Expenditure	Amount
Distribution Undergrounding	$2,000,000
Distribution Pole Replacement	$1,000,000

Allocation to Weather Events

Upgrade	Heat	Wildfire	Summer Storm	Windstorm	Rainstorm	Winter Storm	Cold
Undergrounding	10%	30%	12%	12%	12%	12%	12%
Pole Replacement	10%	10%	16%	16%	16%	16%	16%

Mapped $

Upgrade	Heat	Wildfire	Summer Storm	Windstorm	Rainstorm	Winter Storm	Cold
Undergrounding	$200,000	$600,000	$240,000	$240,000	$240,000	$240,000	$240,000
Pole Replacement	$100,000	$100,000	$160,000	$160,000	$160,000	$160,000	$160,000

Coverage Calculation

Metric	Heat	Wildfire	Summer Storm	Windstorm	Rainstorm	Winter Storm	Cold
Hazard Total	$300,000	$700,000	$400,000	$400,000	$400,000	$400,000	$400,000
% of Total Spend	10%	23%	13%	13%	13%	13%	13%

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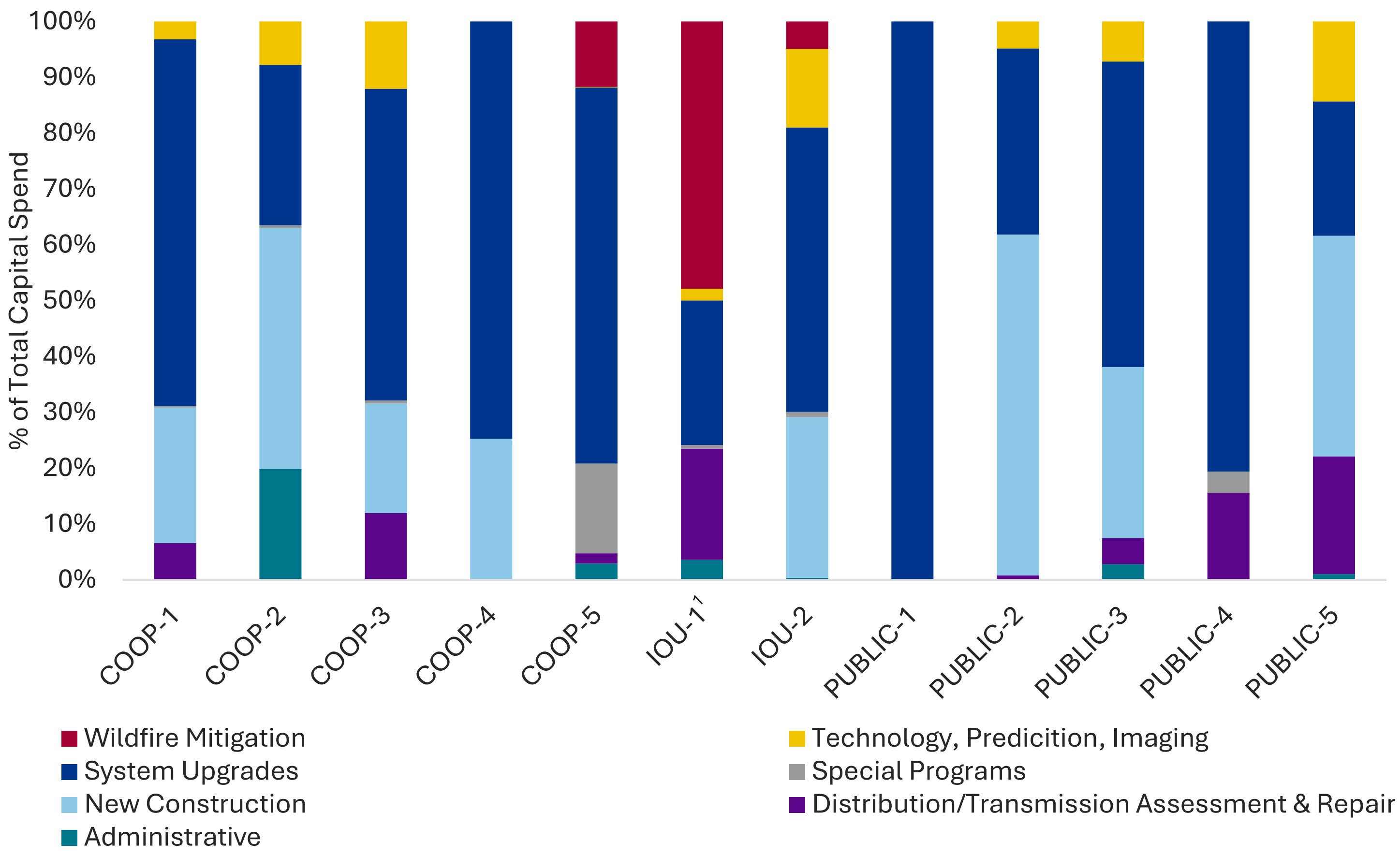
Capital Plan Review

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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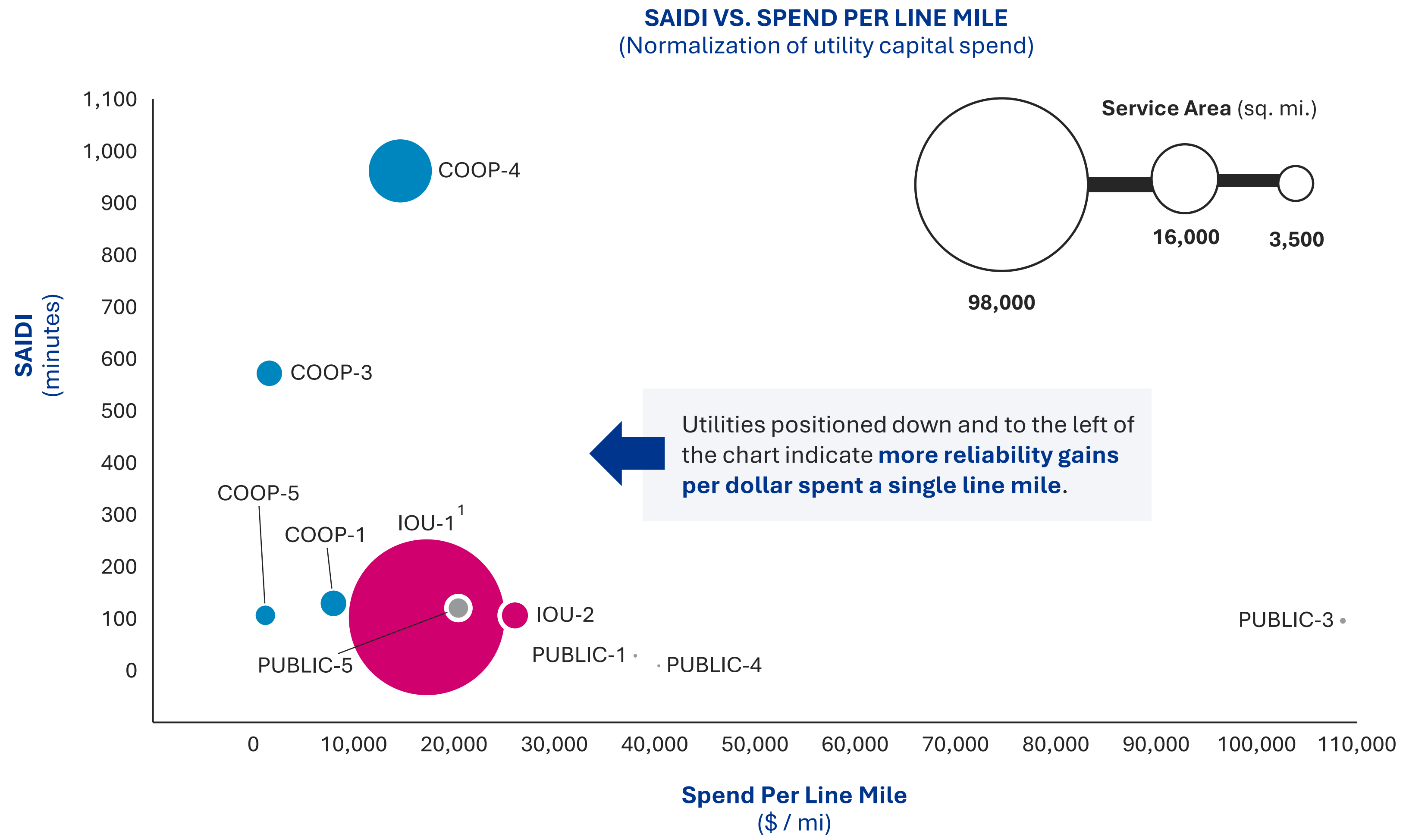
Public Power Cooperative IOU

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

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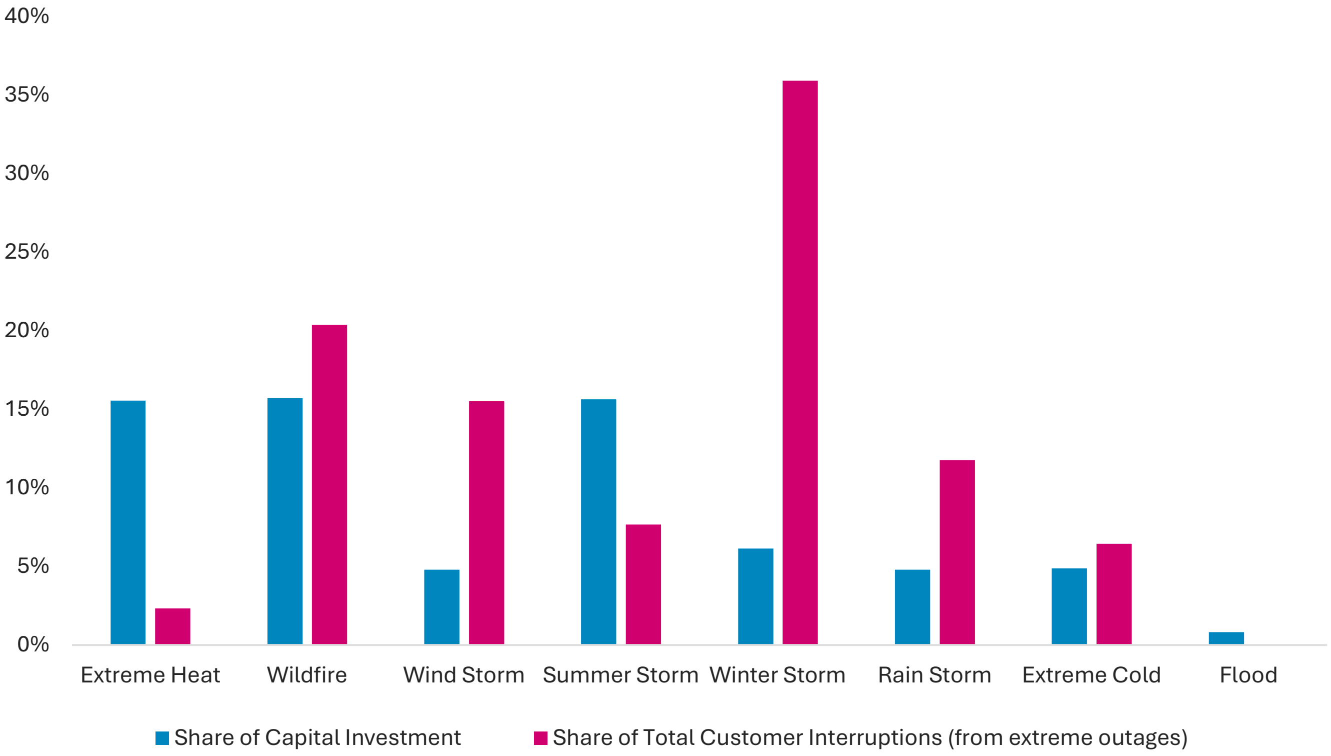
Utility Investment-Outage Alignment

Public Power Cooperative IOU

While COOP-1 is well-positioned to weather future extreme heat and summer storm events, there is an opportunity to expand investment addressing winter storms and high winds

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



INVESTMENT-OUTAGE DIVERGENCE: H | M | L

HIGH COVERAGE HAZARDS

HEAT: M

SUMMER STORM: L

Assessment: Investments that address general capacity needs also mitigate heat risk. Therefore, coverage could be attributed to voltage/phase upgrades or reconductoring, positioning COOP-1 well for future temperature increases.

COOP-1 could consider expanded monitoring and grid analytics to ensure heat-related investment is targeting the most at-risk equipment.

FUTURE INVESTMENT OPPORTUNITIES

WIND STORM: M

WINTER STORM: H

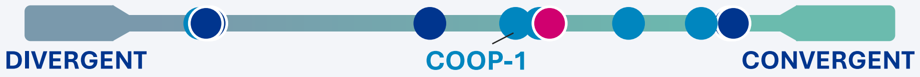
Assessment: Winter storms account for over 35% of customer interruptions that occur during extreme outages, making them a priority hazard to address.

Windstorm's larger coverage gap than extreme cold indicates that wind is the primary driver of interruptions from winter storms, and could be addressed through targeted vegetation management, pole trussing, and undergrounding.

UTILITY COHORT COMPARISON

UNCERTAIN COVERAGE

Assessment: COOP-1's capital expenditures exhibit roughly average alignment with climate exposure compared to other utilities in WECC. The utility could consider conducting an asset-level risk assessment using future weather data to clarify future exposure.



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

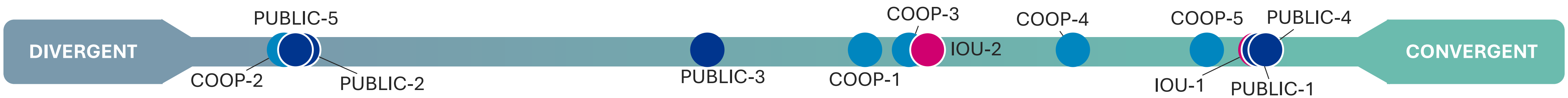
Utilities with convergent coverage are investing in upgrades that address hazards that have been historically responsible for the most severe outages in their service territory

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

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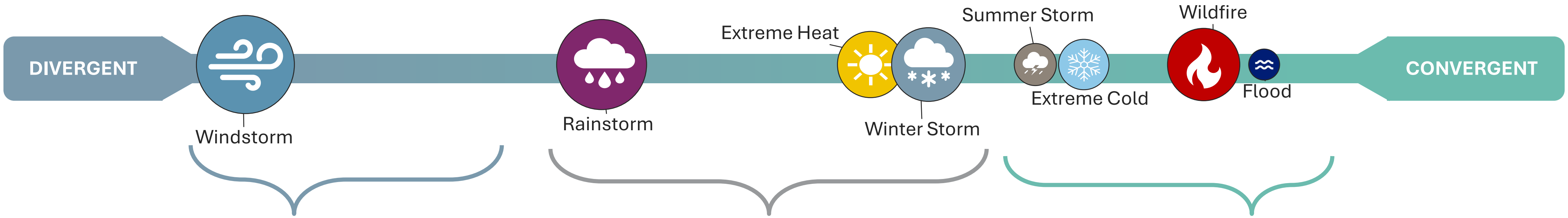
Utilities in WECC generally underinvest in windstorms given their widespread severity over utility service territories. Wildfire remains a highlight hazard for continued investment.

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

*The size of each bubble represents the relative volume of customer interruptions attributable to that hazard across WECC

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