Grid Resilience Data, Metrics and Analyses

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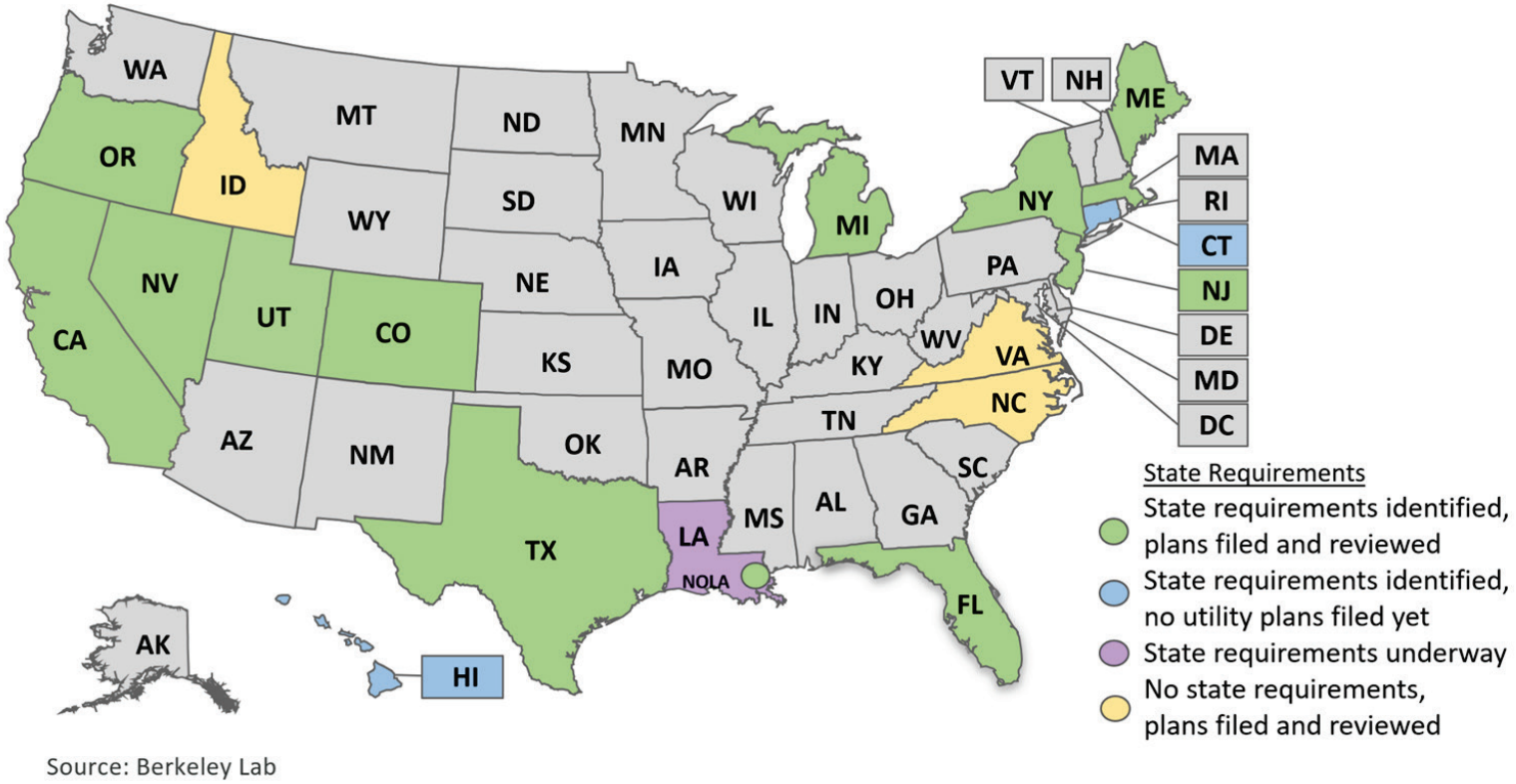
Background

- A growing number of states are establishing requirements for electric utilities to file grid resilience plans to meet a variety of objectives.
  - Many planning requirements focus on extreme weather hazards, given increasing frequency and severity of extreme weather events. (Schellenberg and Schwartz, 2024)
  - State objectives and expected plan outcomes drive needs for data, metrics and analysis.
- Many state utility regulators are not familiar with the types of available data they can request and why it is useful in the context of grid resilience planning.
- Utility regulators may not be aware of what metrics are effective and approaches in use in other jurisdictions for measuring grid resilience performance.
  - The use of resilience-related metrics is relatively nascent.
  - Different states use different data sources and metrics, in part because they face different climate hazards.

State Requirements and Resilience Plans Reviewed

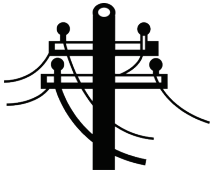


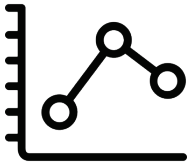
Source: Berkeley Lab

Resilience Information Provided by Utilities

Data, metrics, and analyses in resilience planning documents can be split into five categories

1. Exposure Data and Metrics	2. Attribute Data and Metrics	3. Performance Metrics	4. Analyses	5. Prioritization Metrics
Where and to what degree utility assets are exposed to hazards	System characteristics beneficial to resilience	Consequences of climate hazards on utility system / performance of resilience measures	Methods for assessing risk and prioritizing investments across multiple criteria	Metrics for prioritizing investments





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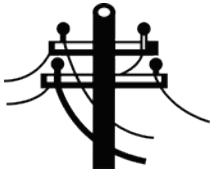
1. Exposure Data and Metrics

- Hazard characteristics generally cover climate conditions and severe weather events at different levels of geographic granularity
  - Includes historical information and projections
- Exposure to hazards covers data reflecting which assets, locations, and customers may experience a climate hazard and the degree to which they may experience that hazard

Examples of Hazard Characteristics	Examples of Exposure to a Hazard	Data Sources
• Coastal flooding extent and depth • Heating and Cooling Degree Days • High heat / temperature • High wind speeds • Inland flood extent and depth • Total number of major events days per year • Winter storms and ice	• Asset exposure to: - High heat - Inland flooding - Rising seas - Storms - Wildfire - High wind • Wildfire Ignition Potential • Customers affected by catastrophic storms	• State and federal agencies manage geospatial datasets that utilities can obtain and overlay with service territory maps of assets and customers • Examples: NOAA flood and storm surge potential maps,[1] FEMA Digital Flood Insurance Rate Maps,[2] U.S. Forest Service/Cal Fire map of high hazard zones[3]

2. Attribute Data and Metrics

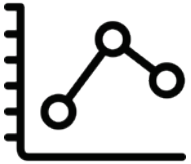


- Data and metrics that characterize whether assets or communities are sensitive to damage from a particular hazard
  - Asset design specification or condition
  - Extent to which assets have been hardened

Examples of Attribute Data and Metrics for Assets
• Asset condition (age, inspection data) • Transformers meeting latest temperature specification • Circuit miles undergrounded • Annual probability of asset-caused ignition • Covered conductor miles • Average time for vegetation clearance permissions from local agencies

Examples of Calculated Metrics for Communities	Description
Community Impact Metric[2]	Set of indicators that capture various impacts an adaptation action can have on the community it takes place in. Objective is to factor in equity when selecting adaptation options and/or prioritizing and refining these options.
Community Resilience Metric[2]	Set of scores measuring the sensitivity and corresponding adaptive capacity of a particular community to potential loss of utility service

3. Performance Metrics (1) – Power Interruptions



Outage Events and Causes	Number of outages
	Outage cause
Outage Frequency	SAIFI (with and without MEDs)
	MAIFI (with and without MEDs)
Outage Duration	SAIDI (with and without MEDs)
	CAIDI (with and without MEDs)
	Percent of outages longer than 5 hours
Customer Outages	Customer outages (outages weighted by customers affected)
	Customer minutes interrupted (CMI)
	Customers Experiencing Multiple Interruptions (CEMI)
	Customers Experiencing Long Interruption Duration (CELID)

- Outage metrics should only reflect outages applicable to the analysis
- Metrics can target a specific time period and location where an extreme weather event was occurring

Metrics Targeted to Specific Time, Location, and/or Outage Type
• All-weather circuit-level SAIDI[4] • Outage events caused by contact with vegetation in Tier 3 High Fire Threat District during high wind warning[5] • SAIFI by circuit during a storm

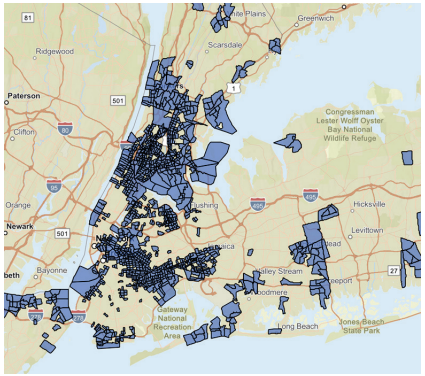
Poll

Think back to the last outage you experienced. How long did it last?

a) 0-5 minutes
b) 5 minutes to 1 hour
c) 1 – 4 hours
d) 4 – 8 hours
e) 8 – 24 hours
f) Longer than 24 hours

Performance Metrics (2) - Specific Groups of Interest

- Critical facilities: Infrastructure which is essential for the health, safety, and economic well-being of a population (e.g., hospitals, fire stations, emergency operation centers, public drinking water facilities, sewer and wastewater facilities)
  - Examples of resilience plans that incorporate consideration of critical facilities: O&R (2023),[6] NYSEG and RG&E (2023),[7,8] National Grid (2023)[9]
- Disadvantaged communities: Census tracts designated by state governments for meeting a certain set of criteria
  - Examples of resilience plans that incorporate consideration of disadvantaged communities: SCE (2022),[2] PG&E (2024),[10] DTE (2023)[11]



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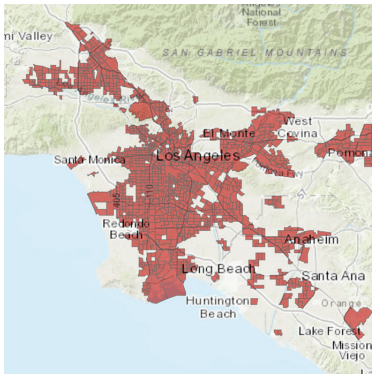
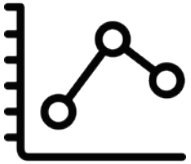


Source: OEHHA

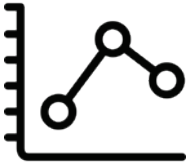
Performance Metrics (3)



- Measures of utility performance in improving resilience to hazards
  - Implementing resilience measures avoids future impacts from similar hazards

Asset Damage or Failure	Restoration Costs	Customer Interruption Costs	Customer Communications / Customer Experience	Response and Recovery
• Distribution poles replaced • Transformer failures during storm • Facilities requiring repair after storm • Value of assets and structures destroyed by ignition events[12]	• Restoration costs (operations and maintenance portion) [4, 13, 14] • Cost of grid damage from extreme weather	• Cost per event • Cost per average kW • Cost per unserved kWh • Cost per CMI	• Customer emails sent and opened • Customer recall of wildfire preparedness communications • Count of customer complaints	• Downed wire response • Post-outage time needed to restore service to 90% of customers • Restoration construction staff hours after storm

Performance Metrics (4) - Public Safety Power Shutoffs



- Public Safety Power Shutoffs (PSPS) are temporary events where the utility shuts off power to certain customers to reduce the risk of wildfires
- PSPS events are both a mitigation measure for improving community resilience to wildfires and also a negative impact of severe climate conditions (wind and heat)
- Utilities use a number of metrics for tracking PSPS activity specifically

Examples[5]

Outage Metrics	Specific Customers	Customer Communications	Response and Recovery
• SAIDI and SAIFI – including and excluding PSPS • Frequency of events during different wind warning statuses	• Critical infrastructure impacted by PSPS • Medical Baseline customers impacted by PSPS	• Number of customers notified prior to public safety outage event • Number of Medical Baseline customers notified prior to PSPS event	• Median and 95th percentile of time between de-energization, due to PSPS, and inspection of a circuit segment

4. Analyses in Resilience Plans

Analysis Example	Explanation	Examples
Benefit-Cost Analysis	Compares monetized benefits and costs	Consolidated Edison (2019),[15] PG&E (2024)16
Multi-Criteria Assessment	Allows comparison of benefits that are difficult to quantify or monetize, or that may not be effectively highlighted in financial analysis	Duke Energy (2023),[17] Consolidated Edison (2019)[15]
Pre/post Analysis	Estimates impact of resilience measures by tracking metrics pre- and post-implementation	FPL (2022),[13] Idaho Power (2023),[18] National Grid[9]
Business Case Justification Framework	Characterizes benefits of resilience projects at specific locations. Based on system reliability, community resilience, and safety	National Grid (2023),[9] NYSEG (2023)[7]
Wildfire Risk	Employs various methods to calculate wildfire risk using fire probability and consequence	Rocky Mountain Power (2023),[19] Idaho Power (2023)[18]

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5. Prioritization Metrics

- Scoring mechanisms to assess risk and/or prioritize investments across multiple criteria

Metric Example	Explanation	Examples
Benefit-Cost Ratio	Present value of monetized benefits divided by present value of monetized costs	Tampa Electric (2022),[20] Duke (2022)[21]
Risk Spend Efficiency	Estimation of cost-effectiveness based on risk-reduction benefits (calculated by probability and associated consequences) and costs for a specific solution	Pacific Power (2023)[2,2] Duke Energy (2023)[17]
Value Spend Efficiency	Quantified measure of risk, adjusted for qualitative impacts not easily measured in dollars	PGE (2023)[23]
Circuit Performance Indicator	Index with weighted SAIDI, SAIFI, MAIFI, and breaker lockouts	Rocky Mountain Power (2023)[19]

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