Energy Markets & Policy
BERKELEY LAB

Grid Resilience Plans:

State Requirements, Utility Practices, and Utility Plan Template

Josh Schellenberg[1] and Lisa Schwartz

[1]Berkeley Lab affiliate

July 2024

This work was supported by the the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

Grid Resilience Plans: State Requirements, Utility Practices, and Utility Plan Template

Prepared for the
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Authors
Josh Schellenberg
Lisa Schwartz

Ernest Orlando Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 90R4000
Berkeley CA 94720-8136

July 2024

Acknowledgements

The work described in this study was conducted at Lawrence Berkeley National Laboratory and supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, under Contract No. DE-AC02-05CH11231.

The authors thank Paul Spitsen, U.S. Department of Energy, for supporting our work, and the following experts for reviewing this report (affiliations do not imply that their organizations support or endorse this work):

Anna Brockway and Roderick Dela Cruz, Southern California Edison
Judsen Bruzgul, ICF
Paul De Martini, Newport Consulting, Inc.
Joe Eto, Berkeley Lab
Gerad Freeman, U.S. Department of Energy, Grid Deployment Office
Anish Gaikwad, Jared Green and Robert Sheridan, Electric Power Research Institute
Cynthia Klein and Ryan Boyle, Duke Energy
Gayathri Krishnamoorthy, National Renewable Energy Laboratory
Jeff Loiter, National Association of Regulatory Utility Commissioners
Roshanak Nateghi and Joe Paladino, U.S. Department of Energy, Office of Electricity
Nick Sayen, Oregon Public Utility Commission
David Springe, National Association of State Utility Consumer Advocates
Kirsten Verclas, National Association of State Energy Officials
Tom Wall, Argonne National Laboratory
Stephanie Weisenbach and Rick Olesen (consultant), Iowa Economic Development Authority

Table of Contents

List of Figures

List of Tables

Executive Summary

Electricity is critical to providing many essential services, from water supply to health care and industry.[1] To effectively serve growing power needs, electricity grids must be resilient to natural and human-caused hazards — storms, floods, droughts, extreme temperatures, freezes, hurricanes, sea level rise, wildfires, seismic events, and cyber and physical attacks. In particular, increasing frequency and severity of extreme weather events pose unprecedented challenges to grid resilience – the ability to prepare for, adapt to, withstand, and recover rapidly from disruptions to mitigate impacts.[2] More billion-dollar disasters occurred in 2023 than any other year on record. All 50 states have been impacted by at least one of these events in the past 10 years (NOAA 2024).

State regulators throughout the United States are focusing on utility resilience strategies and proposed investments. The four largest states – California, Texas, Florida and New York, accounting for a third of the U.S. population – and 10 other states have adopted resilience plan requirements for regulated utilities (Figure E-1).[3]

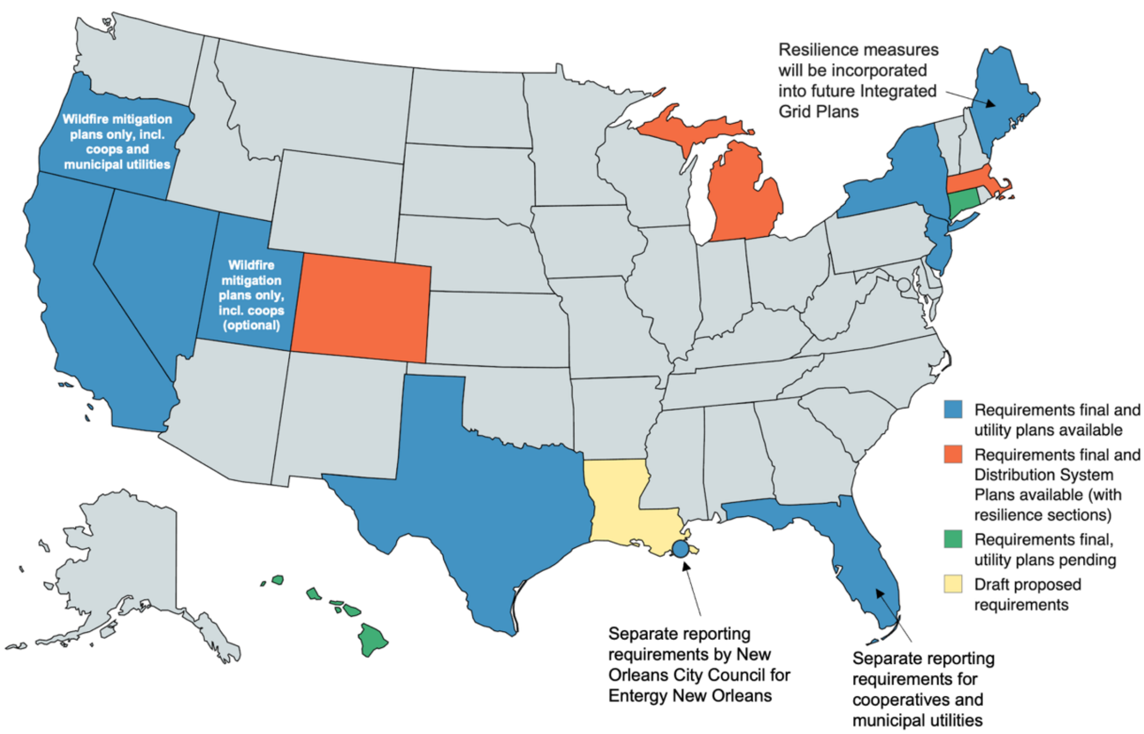


Figure E-1. Resilience Planning Requirements for Regulated Utilities

[1] De Martini et al. (2015); NASEO (2021); Homer et al. (2021); Skaggs and Hibbard (n.d.)
[2] Presidential Policy Directive 21 (2013)
[3] As used in this report, "regulated utilities" refers to investor-owned utilities and any other utilities overseen by state public utility commissions with respect to resilience planning.

From May 2022 to June 2024, at least 30 utilities filed one or more resilience plans under requirements that Berkeley Lab identified. These plans apply to over 47 million utility customers, with the aim to *improve grid resilience for roughly 130 million people, or 39% of the U.S. population.*

Drawing from emerging best practices that Berkeley Lab identified in these requirements and filings, this report offers a standard template for grid resilience plans that state regulators can adapt to:

- Develop or update resilience plan filing requirements for jurisdictional electric utilities, either as part of a distribution system plan or as a separate filing[4]
- Support review of filed plans by providing a checklist of needed information
- Establish a standard plan format across the state's utilities, reducing the burden of regulatory review and facilitating stakeholder feedback

Table ES-1 summarizes the key elements. While many requirements and plans focus on extreme weather hazards, the template also can be used to address additional threats, including cyber and physical attacks and seismic events. Utilities can use the template even in the absence of state resilience planning requirements.[5]

Table ES-1. Key Elements of the Grid Resilience Plan Template

Section	Description
1. Executive Summary	Overview of utility's resilience plan, including key objectives, definitions, resilience measures, proposed programs (including hazards in focus), cost-effectiveness evaluation, metrics, alignment with other plans, and status of state and federal resilience funding support
2. Vulnerability Assessment	Stakeholder-informed approach to threat-based risk assessment: • Identification of communities, infrastructure, facilities and processes that are vulnerable to specific hazards • Prioritization of vulnerabilities that are most important to mitigate with a utility resilience program, based on potential economic impacts
3. Description of Proposed Resilience Programs	Description of how the utility prioritized and will deliver each selected resilience measure, for each proposed resilience program: • Specific resilience measures that mitigate a certain vulnerability, based on the jurisdiction's definition of a resilience event • Estimated costs and benefits (avoided economic impacts for the utility, customers and society) that informed prioritization
4. Projected Costs and Rate Impacts	• Projections of project costs, annual revenue requirements, and retail rate impacts for each year of the resilience plan • Summary of key cost drivers and options that the utility considered to mitigate rate impacts, including state and federal funding support

[4] Grid resilience plans may include the transmission system, if applicable in the jurisdiction.

[5] State Energy Offices develop State Energy Security Plans and may participate in regulatory and stakeholder processes on utility resilience planning. State Energy Offices can use the template as a tool for these processes. Other stakeholders can consider the template as they seek to improve grid resilience plan filings in their state.

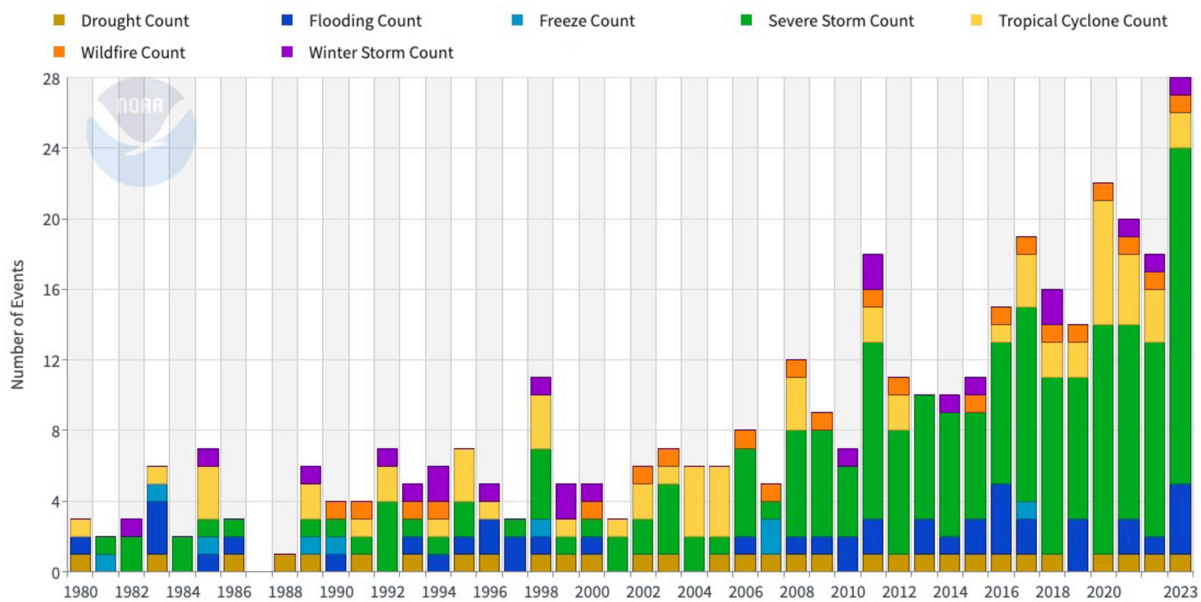
This report provides context and motivation for offering a standard template for grid resilience plans (Chapter 1), a section-by-section overview of the template and guide for adapting it to meet state needs (Chapter 2), and a summary of emerging best planning practices (Chapter 3). States can adapt the plan template (Chapter 4) to meet their own needs – based on policy objectives; hazards, utility infrastructure and processes in scope; and other factors – to proactively prepare for, adapt to, withstand, and recover rapidly from resilience events to mitigate impacts. The template includes several example definitions for key terms used throughout the report. The report concludes with suggested areas for future research (Chapter 5).

1. Introduction

Electricity is critical to providing many essential services, including water supply, wastewater treatment, irrigation, telecommunications, health care and manufacturing.[6] The Energy Information Administration (EIA) and many utilities are projecting surging electricity demand from data centers and new manufacturing facilities, leading to expected all-time highs in nationwide electricity consumption.[7] Electrification of transportation, buildings and industry will increase society's dependence on power grids.

To reliably serve growing electricity needs, grids must be resilient to natural and human-caused hazards — storms, floods, droughts, extreme temperatures, freezes, hurricanes, sea level rise, wildfires, seismic events, cybersecurity, and physical attacks. Significant progress has been made to improve grid resilience in the past decade. This report is a resource for states and utilities to continue to improve resilience planning processes in the context of rapidly changing risks and technologies to address them.

Since 2008, the United States has experienced a precipitous increase in the frequency and severity of extreme weather events, culminating in 28 billion-dollar disasters in 2023, more than any year on record and over three times higher than the 1980-2023 annual average number of events (Figure 1-1). In 2017, the worst year on record for damages, costs totaled nearly $384 billion, adjusted for inflation.



Source: NOAA (2024)

Figure 1-1. U.S. Billion-Dollar Weather and Climate Disasters: 1980-2023 (Adjusted for Inflation)

[6] De Martini et al. (2015); NASEO (2021); Homer et al. (2021); Skaggs and Hibbard (n.d.)
[7] EIA, Short Term Energy Outlook (June 2024); Kearney et al. (2024); Halper (2024)

All 50 states have been impacted by at least one billion-dollar event in the past 10 years.[8] For example, while Hawaii did not experience a disaster of this magnitude for over 30 years, the state was devastated by the 2023 firestorm that destroyed the historic town of Lahaina on Maui Island, causing $5.6 billion in damages and 100 deaths – the deadliest U.S. wildfire in over a century (NOAA 2024).

With the increasing magnitude and geographic scope of weather-related disasters, state regulators throughout the United States are focusing on utility resilience strategies and proposed investments to prepare for, adapt to, withstand, and recover rapidly from resilience events.[9] Many states also are developing resilience planning requirements for regulated utilities. The four largest states – California, Texas, Florida and New York, accounting for a third of the U.S. population – have adopted resilience plan requirements, as well as 10 other states (Figure 1-2). Requirements include filing utility plans related to storms, wildfires, climate change and other threats.[10] Regulated utilities in most of these jurisdictions have submitted at least one resilience plan under the established requirements, either as a standalone resilience plan (in blue) or as part of a distribution system plan (in orange). Two states (in green) have finalized requirements, but no utility plans have yet been filed. Louisiana (in yellow) developed a final proposed rule, but it has not yet been adopted.[11]

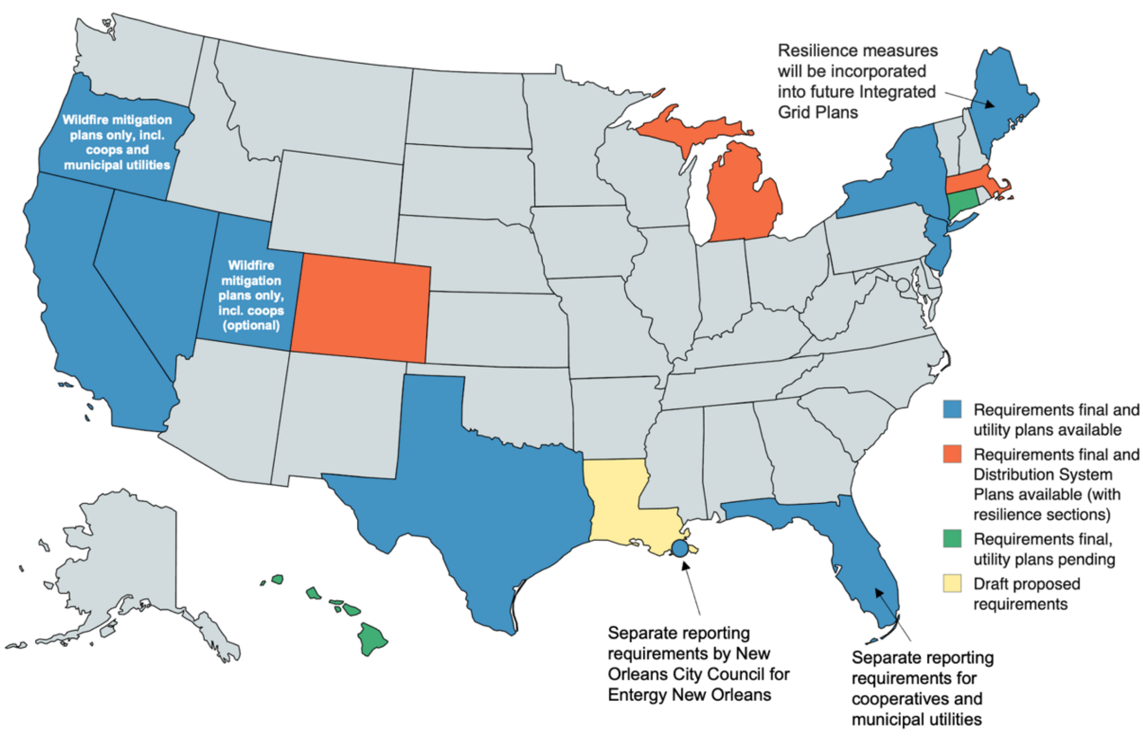


Figure 1-2. Resilience Planning Requirements for Regulated Utilities

[8] Except for Hawaii and Alaska, an impacted state may not have suffered at least $1 billion in inflation-adjusted losses on its own. Rather, the impacted state is within the footprint of the disaster (NOAA 2024).
[9] While "resilience event" is commonly used in the electricity industry, there is no standard industry definition. Each jurisdiction or utility develops its own based on hazards in scope. See Chapter 4 for an example definition.
[10] Other states may include some resilience-related reporting requirements as part of established reliability reporting processes, but this report focuses on resilience *plans*, either as standalone plans or part of distribution system plans.
[11] The New Orleans City Council adopted separate resilience planning requirements for Entergy New Orleans.

While best practices for resilience planning are still emerging (PNNL 2023, De Martini et al. 2022), initial state requirements and utility filings are beginning to point toward effective approaches. Drawing from Berkeley Lab's review of state planning requirements and filed utility plans, the template in Chapter 4 of this report can help states develop or improve resilience planning requirements to meet their own needs, assist with review of filed utility plans, and facilitate a standard format for filed plans across jurisdictional utilities.

Utilities, regulators, and stakeholders can consider how resilience planning fits into a broader planning framework across all levels of the electricity system (Figure 1-3). Berkeley Lab's interactive decision framework for integrated distribution system planning lays out the relationships and steps in greater detail.

1.1 Resilience Planning Requirements for Cooperatives and Municipal Utilities

While state requirements for resilience planning primarily focus on investor-owned utilities, requirements in some states (e.g., Florida, Maine and Oregon) also apply to rural electric cooperative and/or municipal utilities. However, these requirements differ in scope from requirements for regulated utilities and in some cases are optional, such as the Wildfire Mitigation Plans for cooperatives in Utah. In Florida, cooperatives and municipal utilities are subject to storm protection requirements, but the requirements focus on reporting instead of the detailed 10-year Storm Protection Plan that each investor-owned utility prepares every three years.[12]

1.2 State Energy Security Plans

State Energy Security Plans, required by the federal Infrastructure Investment and Jobs Act (IIJA) to receive State Energy Program funding, serve as the foundation of state resilience planning (NASEO and Berkeley Lab 2023). Under the Act, State Energy Security Plans must assess existing circumstances in the state and propose methods to strengthen its ability to:

- Secure energy infrastructure against all physical and cybersecurity threats
- Mitigate the risk of energy supply disruptions
- Enhance the response to, and recovery from, energy disruptions
- Ensure that the state has reliable, secure, and resilient energy infrastructure

The plans must address physical and cybersecurity threats and vulnerabilities, provide a risk assessment of energy infrastructure and cross-sector interdependencies, and develop a risk mitigation approach to enhance reliability and end-use resilience.

[12] Florida cooperatives and municipal utilities are not required to develop resilience plans at a specific cadence (e.g., every three to five years).

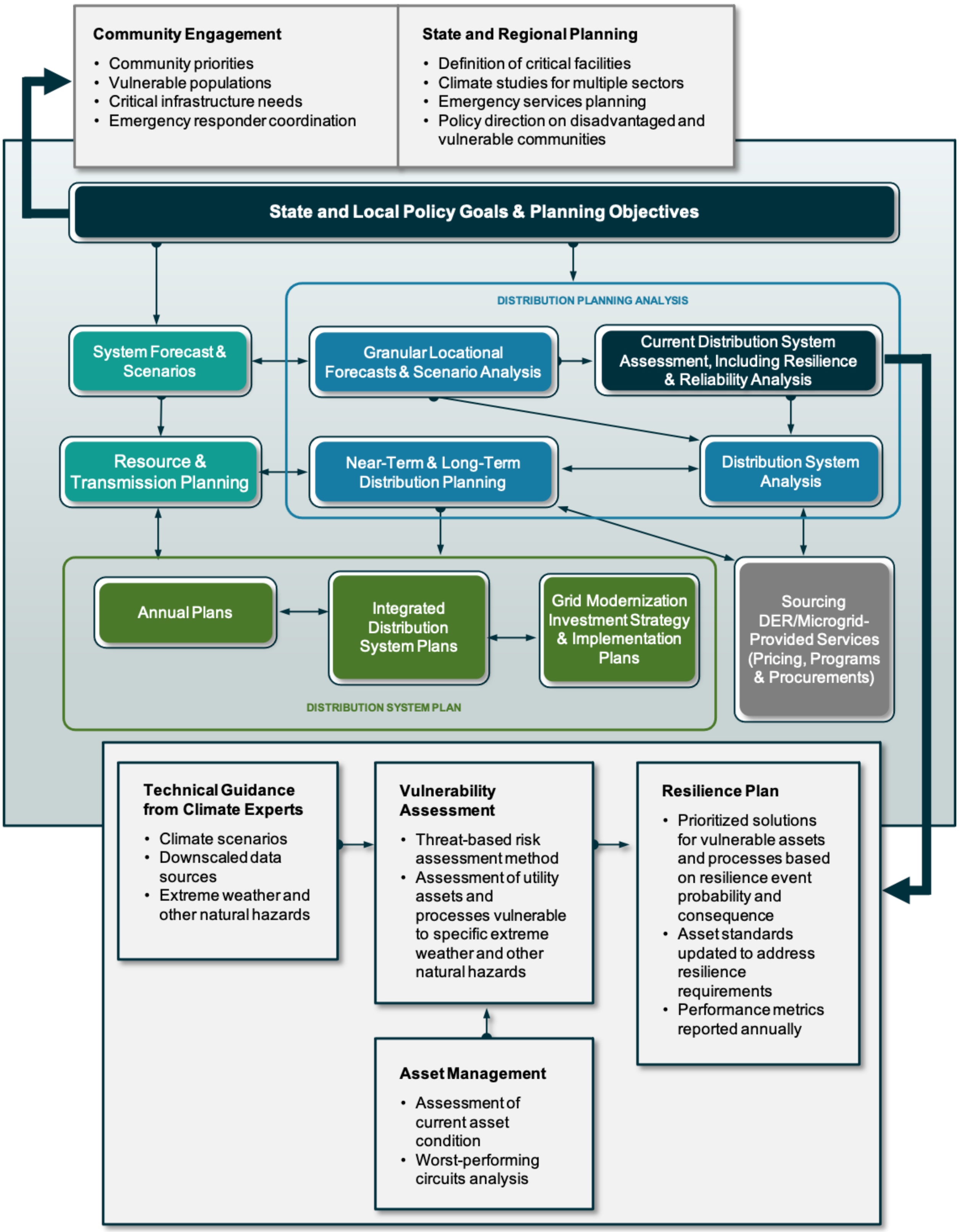


Figure 1-3. Resilience Planning in the Context of an Integrated Distribution Planning Framework

State Energy Security Plans highlight resilience risks, discuss investment priorities for enhancing grid resilience, and provide insights into potential priority investments by both consumer- and investor-owned utilities. Utility resilience plans can aim to align with methods, data sources and priorities in the State Energy Security Plan. While these plans are generally not publicly available due to sensitive information on critical infrastructure and emergency management, State Energy Offices and other responsible agencies have developed processes to share plans with utilities and regulators. States such as Idaho, Delaware and Kentucky have made redacted versions of the plans publicly available.

1.3 Resilience Planning Requirements for Regulated Utilities

As of June 2024, 14 states and one city require electric utilities to file resilience plans.[13] Table 1-1 summarizes the type of plan required, hazards in scope, plan frequency and planning horizon. Many of the planning requirements aim to mitigate adverse consequences related to certain types of hazards, such as storms (Florida and Connecticut) and wildfires (California, Oregon and Utah), and climate change comprehensively (California, Maine and New York). In other states, requirements aim to mitigate a broader range of hazards including cybersecurity and, for some states, any type of natural disaster (Colorado, Louisiana, Nevada, New Jersey and Texas). Requirements in Colorado, Louisiana and Texas also cover physical attacks.

Although requirements may include a broad range of hazards, extreme weather and its increasing frequency and severity due to climate change are a common impetus for establishing and continuously improving regulatory processes for resilience planning. For example:

- In Northern states (Connecticut, Michigan, New Jersey and New York), major storms from Superstorm Sandy in 2012 to Tropical Storm Isaias in 2020 led states to act due to rapidly increasing restoration costs, safety impacts, and extended outages for millions of utility customers.
- In Southern states (Florida, Louisiana and Texas), major storms — from Hurricane Matthew in 2016 to Winter Storms Uri in 2021 and Mara in 2023 — and their increasing impacts on electricity infrastructure were drivers for new resilience planning requirements.
- In Western states (California, Colorado, Nevada, Oregon and Utah), wildfires have been the primary focus for resilience planning after several catastrophes, most notably the 2017-2018 fires that led to the bankruptcy of Pacific Gas & Electric Company (PG&E) and devastating wildfires in Oregon in 2020.

In some states, resilience planning requirements originated from decisive legislative action, commonly after extreme weather events. For example, in 2022 the New York Legislature enacted a new law[14] requiring regulated utilities to submit climate change vulnerability studies that evaluate "infrastructure,

13 Statutory requirements in Texas apply to plans that regulated utilities file voluntarily for consideration of expedited cost recovery for resilience investments. U.S. island territories that are particularly vulnerable to climate change also have been active in resilience planning. Notable examples include the Puerto Rico Hazard Mitigation Plan and Guam Climate Change Resiliency Commission.

14 Subdivision 29 to Public Service Law §66 - Chapter 45 of the Laws of 2022 (effective March 22, 2022)

Table 1-1. Resilience Planning Requirements for Regulated Utilities (as of June 2024)

State	Name of Plan or Legislation	Hazards in Scope	Plan Frequency	Planning Horizon
California	Wildfire Mitigation Plan (Senate Bill 901)	Wildfires	Annual	3 years
California	Climate Change Vulnerability Assessment	Wildfires, extreme heat, extreme storms, drought, subsidence, sea level rise and other climate change hazards	4 years (part of general rate case – GRC)	10–50 years
California	Risk-based Decision-making Framework	All hazards	4 years (part of GRC)	4 years
Colorado	Distribution System Plan	Natural disasters and cyber/physical security threats	2 years	10 years
Connecticut	Resilience Plan	Tropical storms, hurricanes, ice storms	4 years (part of GRC)	10 years
Florida	Storm Protection Plan	Storms	3 years	10 years
Hawaii	Natural Hazard Mitigation Plan	Wildfires, tsunamis, hurricanes, floods, landslides, extreme heat, drought, seismic/volcanic activity	To be determined	5 years
Louisiana (excluding New Orleans)	Grid Resilience Plan	Any low-probability/high-consequence events, including cyber/physical security threats	5 years	10 years
Maine	Climate Change Protection Plan	Expected effects of climate change on utility assets	3 years	10 years
Michigan	Distribution System Plan	Storms	2 years	5 years
Massachusetts (Section 92B)	Electric-sector Modernization Plan (House Bill 5060)	Weather and disaster-related risks	5 years	5–10 years
Nevada	Natural Disaster Protection Plan	Wildfires are primary focus, other natural disasters also covered	3 years	3 years*
New Jersey	Infrastructure Investment Program	Any hazard that impacts safety, reliability, and/or resiliency, including cybersecurity	Voluntary	5 years
New Orleans	System Resiliency and Storm Hardening Plan	Storms	To be determined	5 years
New York	Climate Change Vulnerability Study and Resilience Plan	Increase in severe weather expected from climate change, including stronger storms and more flooding	5 years	10–20 years
Oregon	Wildfire Mitigation Plan	Wildfires	Annual	3 years*
Texas	T&D System Resiliency Plan (House Bill 2555)	Any event involving extreme weather conditions, wildfires, or cyber/ physical security threats that poses a material risk to safe and reliable operation of T&D systems	3 years (voluntary)	3 years (minimum)
Utah	Wildland Fire Protection Plan (House Bill 66)	Wildfires	3 years	3 years*

Source: Berkeley Lab

* While state requirements do not specify a planning horizon, utilities have filed three-year plans.

design specifications, and procedures to better understand the electric system's vulnerability to climate-driven risks." In 2023, the Texas Legislature passed House Bill 2555, directing the Public Utility Commission (PUC) to adopt utility filing requirements in January 2024.[15] Similarly, House Bill 66 in Utah led to Wildland Fire Protection Plan requirements.

State requirements typically specify a planning horizon of 10 years or more, with greater detail required for the first three to five years of the plan. California and New York require planning horizons of 20 to 50 years for Climate Change Vulnerability Assessments. Typically, states require plan updates every three to five years. Such updates allow for flexibility as the industry develops better data, projections, and resilience solutions. Due to the urgency of wildfire threats in Western states in recent years, wildfire mitigation plans are filed more frequently (every one to three years) and have a shorter planning horizon (three years).

Example Requirements for Grid Resilience Planning: California

Senate Bill 901 (2018) directed the California Public Utilities Commission (CPUC) to develop requirements for electric utilities to file Wildfire Mitigation Plan annually for review. Oversight under the CPUC's Wildfire Safety Division was later transferred to a new state agency, the Office of Energy Infrastructure Safety.[1] The Office has issued several revised guidelines and other new requirements for the plans. The most significant change from the initial CPUC decision was the introduction of a maturity model to identify emerging best practices and drive continuous improvement in wildfire mitigation. Other changes include greater detail required for input assumptions and more transparency for data, analysis and results, including trends and lessons learned.

The CPUC continues to oversee two other resilience planning requirements, tied to general rate cases that regulated utilities file every four years. The CPUC requires the utilities to apply a risk-based decision-making framework in the Risk Assessment and Mitigation Phase of each general rate case. In addition, similar to requirements in New York, each California utility must file Climate Change Vulnerability Assessments every four years, a rigorous assessment of vulnerabilities to a broad range of climate change-related hazards. The CPUC specifies a "key time frame" of 20 to 30 years for assessing climate vulnerabilities. Utilities also must assess vulnerabilities over the next 10 to 20 years and over 30 to 50 years. Although wildfires are in scope, these assessments complement Wildfire Mitigation Plans, which utilities file more frequently (annually) and have a shorter planning horizon (3 years).

[15] Under House Bill 2555 and the PUC's adopted rule, regulated utilities can submit resilience plans on a voluntary basis, but they must follow the PUC's requirements to apply for accelerated cost recovery for resilience investments.

1.4 Filed Utility Resilience Plans

Table 1-2 summarizes recent utility plans submitted under resilience planning requirements identified by Berkeley Lab. The resilience plan template in Chapter 4 draws from these filings. For example, the New York Climate Change Vulnerability Studies and Resilience Plans, particularly Con Edison filings (2023a, 2023b), demonstrate a two-phase approach for vulnerability assessment and prioritization of resilience solutions. The template also applies a program-by-program breakdown of resilience measures and costs, as in the storm protection plan filed by Florida Power & Light (2022). Chapter 3 provides additional details of emerging best practices drawn from filed utility plans.

From May 2022 to June 2024, at least 30 regulated utilities filed resilience plans under the requirements listed in Table 1-1. These plans apply to over 47 million utility customers, *potentially improving grid resilience for roughly 130 million people, or 39% of the U.S. population.* This includes two large utilities – Oncor and Centerpoint – that voluntarily submitted plans in May 2024 under the Public Utility Commission's recently finalized rule in Texas, following two catastrophic events.[16]

Where to Start?

Developing a comprehensive resilience plan that includes all items in the template in Chapter 4 may not be feasible for some utilities at this point. Further, best practices are in active development. (See text box in Chapter 3 about EPRI's Climate READi initiative, engaging over 40 utilities and 100 stakeholder organizations.) Instead of implementing the entire resilience template at once, it may be sufficient to start with a vulnerability assessment for one or two high priority hazards, learn from the process, and continue iterating as planning practices evolve, incorporating stakeholder input and state and local objectives.

A vulnerability assessment for one or two high priority hazards may help identify cost-effective resilience measures that address important community needs. Depending on utility size* and level of resilience investments, developing a detailed forecast of the costs and benefits of all potential investments for a 10-year planning horizon may not be warranted. However, an initial assessment of a limited set of hazards can help the utility and its stakeholders focus on the primary vulnerabilities for existing utility infrastructure and process areas. The resilience plan can then identify the least-cost, best-fit solutions for mitigating these primary vulnerabilities.

*The National Rural Utilities Cooperative Finance Corporation (2022) and National Rural Electric Cooperative Association (2019) prepared resources designed for coop members, including small utilities.

[16] The recent Smokehouse Creek Fire was the largest and most destructive wildfire in Texas history (Cohen 2024). Winter Storm Uri, in 2021, was one of the worst natural disasters in the state's history. Some 246 people died during that storm as power outages contributed to hypothermia and accidents with alternate heat sources (Svitek 2022).

Table 1-2. Utility Plans Submitted Under Resilience Planning Requirements

State	Plan Name	Utility Plans (Recent Examples)
California	Wildfire Mitigation Plan	• PG&E (2024a) • Southern California Edison (2023) • SDG&E (2023)
California	Climate Change Vulnerability Assessment	• PG&E (2024b) • Southern California Edison (2022)
Colorado	Distribution System Plan	• Xcel Energy (2022) Phase I • Xcel Energy (2023) Phase II
Florida	Storm Protection Plan	• Florida Power & Light (2022) • Duke Energy (2022) • Tampa Electric (2022) • Florida Public Utilities (2022)
Maine	Climate Protection Plan	• Central Maine Power (2023) • Versant (2023)
Massachusetts (Section 92B)	Electric-sector Modernization Plan	• Eversource (2024) • National Grid (2024) • Unitil (2024)
Michigan	Distribution System Plan	• DTE Electric (2023) • Consumers Energy (2023) • Indiana Michigan Power (2023)
Nevada	Natural Disaster Protection Plan	• NV Energy (2023a) Part 1 • NV Energy (2023b) Part 2
New Jersey	Infrastructure Investment Program	• PSE&G (2018)
New Orleans	System Resiliency and Storm Hardening Plan	• Entergy New Orleans (2023)
New York	Climate Change Vulnerability Study	• Con Edison (2023a) • Orange & Rockland (2023a) • RG&E and NYSEG (2023) • National Grid (2023a) • Central Hudson (2023a)
	Climate Change Resilience Plan	• Con Edison (2023b) • Orange & Rockland (2023b) • RG&E (2023) • NYSEG (2023) • National Grid (2023b) • Central Hudson (2023b)
Oregon	Wildfire Mitigation Plan	• Pacific Power (2023) • Portland General Electric (2023) • Idaho Power (2023)
Texas	T&D System Resiliency Plan	• Oncor (2024) • Centerpoint (2024)
Utah	Wildland Fire Protection Plan	• Rocky Mountain Power (2023)

1.5 Report Organization

The remainder of this report provides the following information:

- *Chapter 2. Guide for Resilience Plan Template* – A section-by-section description of Berkeley Lab's template, including considerations for states to adapt the template to meet their own needs
- *Chapter 3. Emerging Resilience Planning Practices* – Based on Berkeley Lab's review of initial state requirements for utility resilience plans as well as utility plans filed to date
- *Chapter 4. Resilience Plan Template* – A model document that states can adapt for resilience plan filings for jurisdictional electric utilities, also useful for utilities and stakeholders
- *Chapter 5. Areas for Future Research* – Tools, analysis and actionable examples to improve grid resilience planning
- *References* – Resources for more information

2. Guide for Resilience Plan Template

This chapter explains each section of Berkeley Lab's grid resilience plan template, in Chapter 4 of this report. A Word version of the template is available on [Berkeley Lab's website] to make it easy for states and utilities to adapt the template to account for jurisdiction-specific considerations, such as the following:

- State objectives and priorities
- Definitions of key terms (reliability, resilience, resilience event)
- Hazards, infrastructure, and processes in scope
- Size of utilities, scope of plan, planning horizon and expected level of investment
- Availability of downscaled climate data[17] for specific hazards
- Most viable resilience measures, including changes to infrastructure as well as planning and operational processes
- Specific, impact-oriented performance metrics and benchmarks
- Equity considerations, vulnerable populations, and third-party review and engagement processes
- Alignment with other applicable plans – for example, state energy security, transmission, distribution system, and emergency response plans

This chapter provides guidance on these considerations, while the next chapter provides examples of emerging best practices.

2.1 Executive Summary

The executive summary provides an overview of the utility's resilience plan, with a focus on the following topics.

2.1.1 Plan objectives and motivation

The executive summary begins with the primary objectives and motivations driving the development of the resilience plan. This includes objectives identified in state legislation and regulatory proceedings and by utilities, as well as specific resilience events and trends — such as increasing restoration costs — that are motivating the need to improve grid resilience.

2.1.2 Definitions of key terms

Clear and concise definitions of key terms[18] are critical to establish a common understanding of the grid resilience plan, as well as a description of what is and is not in scope. Clarity in terminology and the plan's scope is important for effective communication and collaboration with stakeholders. The

---

[17] According to the Intergovernmental Panel on Climate Change (IPCC), *Downscaling is a method that derives local- to regional-scale (up to 100 km) information from larger-scale models or data analyses*. See https://archive.ipcc.ch/pdf/special-reports/srex/SREX-Annex_Glossary.pdf.

[18] Grid resilience planning requirements commonly apply or adapt definitions from other industries.

template includes example definitions for three key terms – resilience, resilience event and reliability.[19] At a high level, reliability refers to maintaining the delivery of power under all operating conditions (Eto et al. 2020), whereas resilience refers to preparing for, adapting to, withstanding, and recovering rapidly from large disruptions such as those resulting from extreme natural hazards (Presidential Policy Directive 2013). Regulators can adapt the example definitions to their jurisdiction based on hazards in scope, market structure, state legislation and other factors.

Definitions for resilience, resilience event, and reliability are important to define upfront so that all stakeholders can understand what types of hazards and measures apply to the resilience plan. These definitions also help determine how the resilience plan differs from, or how it is coordinated with, other planning processes, including State Energy Security Plans under IIJA, transmission and distribution plans, and transportation and building electrification plans. In addition, consideration of local government infrastructure plans and emergency response plans is critical.

For example, Texas law defines a resilience event as "an event involving extreme weather conditions, wildfires, cybersecurity threats, or physical security threats that poses a material risk to the safe and reliable operation of an electric utility's transmission and distribution systems. A resiliency event is not primarily associated with resource adequacy or an electric utility's ability to deliver power to load under normal operating conditions." This definition makes it clear which hazards are in scope and how resilience events are distinct from reliability or resource adequacy events. Other definitions related to asset classes, utility processes or jurisdiction-specific circumstances may apply.

2.1.3 Hazards in scope

Each proposed resilience program in the plan involves specific measures that mitigate the impacts of one or more hazards in scope, based on the definition of a resilience event. Depending on the jurisdiction, hazards in scope for the resilience plan may focus on storms (specifically, high winds and floods), wildfires, freezes, heat waves, seismic events, cybersecurity threats, or physical security threats. Alternatively, state requirements may specify multiple specific hazards or an all-hazards approach.[20] To facilitate stakeholder alignment on the resilience plan scope, the template includes a summary of all hazards that may be considered, including a brief explanation for any hazards that the state or utility ultimately did not select for the vulnerability assessment.

2.1.4 Summary progress report

The template includes a summary progress report on programs included in the utility's most recently filed plan, if applicable, taking into consideration any action on the plan by the regulatory commission. The summary progress report is a program-by-program update on delivery of measures in the prior plan, in addition to updates on progress toward mitigating specific vulnerabilities for utility infrastructure and processes. Effective resilience plans clearly communicate changes in key

[19] The IPCC Glossary provides generally accepted definitions for many key terms, including risk, hazard (similar to threat), vulnerability, impacts (similar to consequence), exposure, sensitivity and adaptive capacity.

[20] See National Renewable Energy Laboratory's Resilience Roadmap.

performance metrics, particularly during any resilience events, as well as metrics related to delivery of measures included in the prior plan.

2.1.5 Measures considered and selected

The types of resilience measures the utility considered are important to include in the plan's executive summary. The template lists many common resilience measures as a starting point. States and utilities can adapt the list based on potential viable solutions for a given region. Resilience measures may include enhancements to utility processes such as vegetation management, as well as capital investments such as hardening or undergrounding. In particular, best practice resilience plans consider lower-cost process-related improvements that also may be faster to implement and summarize all measures the utility considered, in addition to those ultimately selected.

2.1.6 Proposed resilience programs

The executive summary briefly describes how the utility will deliver each selected resilience measure as part of a program. Each program involves specific resilience measures that mitigate vulnerabilities to one or more hazards in scope.

2.1.7 Summary of costs, benefits and metrics

This section is a program-by-program summary of rate impacts, costs, and benefits and a description of the metrics the utility intends to use for reporting on the plan's performance. Subsequent sections of the template provide greater detail.

2.1.8 Alignment with other utility plans and state plans

Ideally, priorities, data, and methodology in the grid resilience plan are aligned with other types of utility planning processes to prioritize capital investments and other expenditures across multiple objectives, reveal how investments fit together over time and avoid redundancy. Examples include transmission and distribution plans and transportation and building electrification plans. In addition, states can coordinate with utilities with respect to State Energy Security Plans under IIJA.

Priorities for vulnerable communities and local government infrastructure plans also are important to consider. Utility coordination with emergency responders is critical, most notably to identify changes in processes during an emergency to prioritize critical needs such as roads blocked by downed trees, high priority grid circuits, safety hazards, and communication protocols. This section of the executive summary can clearly explain how the utility's resilience plan is coordinated with these other planning processes.

2.1.9 Status of state and federal resilience funding support

The level of government funding may have a significant impact on resilience programs. Some state regulatory commissions are requiring utilities to seek state and federal funding support for resilience investments for applicable measures and report regularly on progress. The executive summary can summarize the status of such support, including applications under review. Regulators also can require updates of this information during the plan review and approval process and in reporting on plan implementation.

2.1.10 How the resilience plan serves the public interest

The executive summary concludes with a description of how the plan serves the public interest, including utility customers that will pay for approved investments. Among the important factors to summarize are costs, benefits – most notably avoided adverse consequences of resilience events, vulnerable infrastructure and processes, stakeholder priorities, funding support, and alignment with other plans to avoid redundant investments.

2.2 Vulnerability Assessment

The grid resilience plan template applies a phased approach to threat-based risk assessment. Utilities initially focus on identifying vulnerabilities with input from stakeholders and then work toward developing in a transparent and collaborative manner a prioritized portfolio of solutions to reduce or fully mitigate the risks.

The first phase involves identifying communities, infrastructure, facilities, and processes that are vulnerable to specific hazards such as high winds or floods. In some regions, both of these hazards are tied to hurricanes, which may be increasing in frequency and severity due to climate change. The additional specificity in this initial phase allows planners, subject matter experts, and stakeholders to more effectively assess the vulnerabilities and potential adverse consequences. It also allows for assessing compound hazards.[21]

The second phase identifies and prioritizes cost-effective resilience solutions that mitigate vulnerabilities. While most solutions will not completely eliminate a vulnerability (even a steel utility pole may fall in high winds), the utility assesses expected benefits in terms of reduced likelihood or magnitude of adverse impacts relative to the cost of the measure. Importantly, a utility process such as vegetation management may be vulnerable to a hazard in a similar manner to a utility asset. For example, a utility's existing vegetation management process could be vulnerable to high winds and may require significant enhancements to avoid outages, such as more frequent and aggressive trim cycles, while an aging wooden utility pole may require an upgrade to reduce vulnerability to high winds and the potential for adverse societal impacts (i.e., outages). As discussed further in Chapter 3, cost-effective resilience measures include enhancements to planning and operational processes.

[21] An example compound hazard is high winds following a period of heavy rains, which saturate the soil and increase the likelihood that a tree falls on a utility asset.

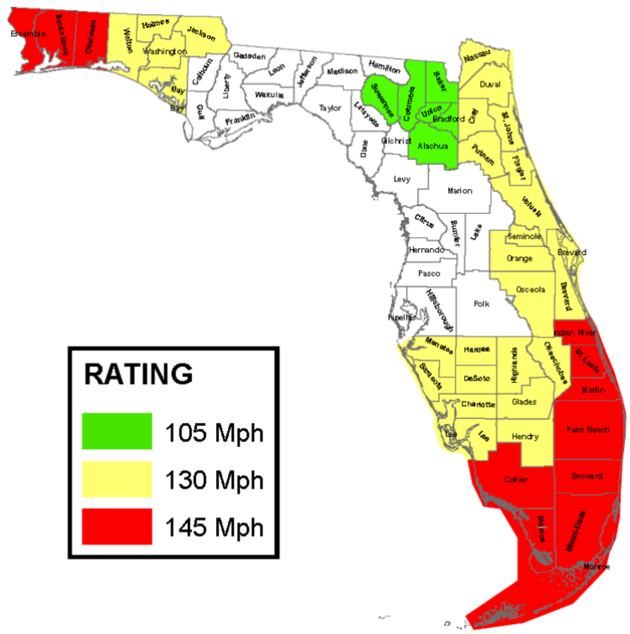
Stakeholder Involvement in Vulnerability Assessments

Stakeholder involvement is important throughout the vulnerability assessment and prioritization process. Communities (including local government agencies, representatives of other critical facilities, and community-based organizations) can be engaged at the beginning of the process to provide input on objectives, metrics, and priorities with respect to vulnerable populations and critical and essential facilities. This input is essential to properly assess the impact of power interruptions due to climate and other threats. Stakeholders may be convened through technical workshops, typically facilitated by the utility or regulatory commission. Stakeholders also may directly participate in regulatory proceedings, providing comments on draft proposed rules and plans related to vulnerability assessments.

2.2.1 Description of service territory

This section of the template includes a description of the utility's service territory, including key utility system characteristics (i.e., overhead or underground, urban or rural) and a map that relates to hazards in scope. For example, Florida Power & Light's 2022 Storm Protection Plan segments the utility's service territory based on the National Electrical Safety Code extreme wind map for the state (Figure 2-1). To develop transmission and distribution hardening solutions, the utility divided its service territory into three wind regions, corresponding to expected extreme wind speeds of 105, 130 and 145 miles per hour.[22] These types of maps and analyses help illuminate how the utility plans to target certain resilience measures in particular geographic areas to improve cost-effectiveness. Investing in such measures throughout the service territory may be cost-prohibitive and yield limited benefits.

[22] Best practice for breaking down extreme weather hazards into distinct regions within the utility's service area is to factor in climate projections to keep the boundaries and intensities up to date as they change over time.



Source: Florida Power & Light (2022). Note: White portion of map is outside the utility's service territory.

Figure 2-1. Florida Power & Light Extreme Wind Regions

2.2.2 History of resilience events

The next section of the template covers the history of resilience events in the utility's service territory in the past five to 10 years, including storms, wildfires, floods, freezes, heat waves, cyber and physical security incidents, seismic events and other hazards. This may include restoration costs, outage times and, if available, customer interruption costs. For example, Table 2-1 summarizes the restoration costs for historical storm events that Eversource provided to its Connecticut regulator. The table shows the largest storms over several years, including the precipitous increase in costs for mutual aid and external contractors for Tropical Storm Isaias ($206 million). Highlighting such trends in resilience events and impacts, including solutions previously implemented that have proven effective (or ineffective), helps identify high priority issues that the plan can address.

Table 2-1. Eversource's Summary of Storm Costs for Historical Events (in thousands)

	Storms				
	October 2017	**March 2, 2018**	**March 7, 2018**	**May 15, 2018**	**Tropical Storm Isaias**
Event Level	Level 4	Level 5	Level 4	Level 5	Level 2
Labor – Internal	$4,028.5	$3,947.8	$4,652.8	$6,799.1	$13,618.9
Labor - Affiliate	$1,299.1	$1,145.1	$1,983.7	$6,311.0	$16,342.0
Payroll-Related Overheads	$795.6	$415.8	$802.4	$3,830.7	$7,160.2
Mutual Aid and External Contractors	$26,979.1	$17,864.6	$26,247.6	$48,346.2	$206,256.8
Vehicles	$129.6	$73.6	$107.0	$241.8	$1,293.6
Material	$366.1	$694.1	$873.3	$2,887.3	$6,292.2
Food and Lodging	$1,246.3	$1,021.7	$1,662.7	$4,031.9	$13,275.4
Employee Expenses/Other	$196.9	$180.1	$243.0	$446.6	$880.1
Total Incremental Storm Restoration Costs	**$35,041.2**	**$25,342.8**	**$36,572.6**	**$72,894.7**	**$265,875.0**

Source: Connecticut Public Utilities Regulatory Authority (2022)

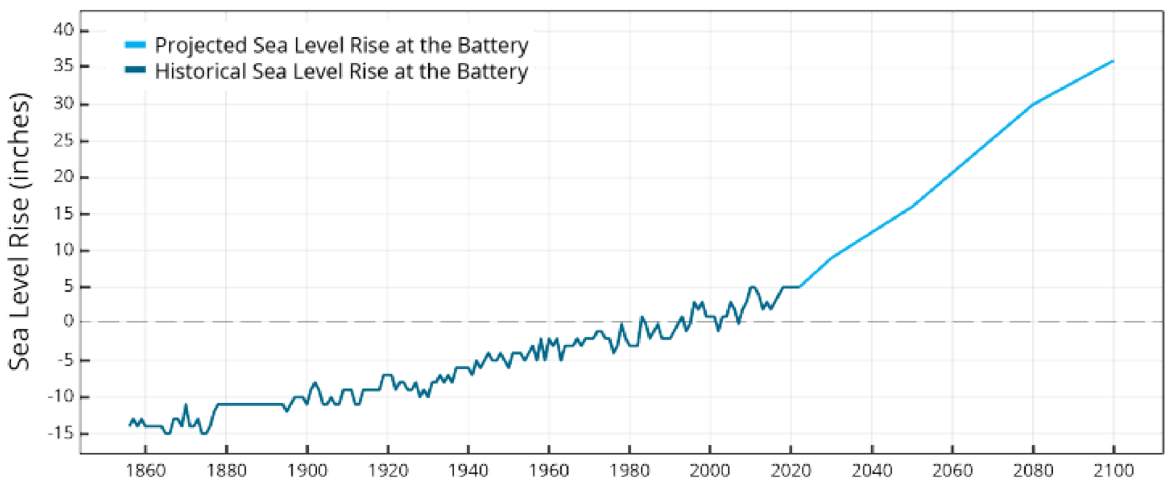
2.2.3 Summary of approach for projecting frequency and severity of resilience events

This section of the template provides a summary of the utility's approach to projecting the frequency and severity of resilience events. Developing these projections is complex. They may not produce highly precise estimates and will most likely require updates as part of each planning cycle. Argonne National Laboratory's Climate Risk and Resilience Portal (ClimRR) is a tool that utilities can use to develop local climate projections. Utilities can upload a GIS shapefile of their service territory to ClimRR and receive a summary of projections.

The plan can indicate how resilience events are expected to evolve in the next 10 years or more throughout the utility's service territory, especially for hazards that are increasing in frequency and severity. That includes compound events involving multiple hazards within a short time period. For example, high winds and floods can have a compounding effect if the utility cannot re-energize flooded critical infrastructure due to safety issues. Further, a cyber or physical attack may occur while another resilience event is ongoing, exacerbating the consequences.

The plan also can provide sufficient detail to explain how the utility developed projections at a granular geographic level to identify specific areas and infrastructure vulnerable to each type of hazard. The plan can specify years and extreme weather events analyzed and provide a transparent summary of the methodology used, including how climate experts contributed input, and explain the extent to which each resilience event or historical year factors into the projections. If the projections assume that the frequency and severity of extreme weather will remain similar to historical data, the utility can explain why. An appendix to the plan can provide further details on the utility's methodology.

For extreme weather hazards, states may specify climate scenarios for the utility's vulnerability assessment and designate a source for downscaled climate data based on expert input (see emerging best practices in Chapter 3). The impact of climate change on certain extreme weather hazards such as ice storms and tornadoes in a specific area may be more challenging to accurately predict, whereas general trends such as extreme heat generally have lower uncertainty. Therefore, the plan ideally aligns with climate analysis conducted by the state, local experts and consensus estimates. For example, Con Edison's Climate Change Vulnerability Assessment uses projections of sea level rise at the Battery Tide Gauge (Figure 2-2) provided by the New York State Energy Research and Development Authority, in partnership with Columbia University. States can consider available data and opportunities for collaboration with government agencies and researchers when considering requirements for utility resilience plans.



Source: Con Edison (2023a)

Figure 2-2. Historical and Projected Sea Level Rise at Battery Tide Gauge in New York City

Intergovernmental Panel on Climate Change (IPCC) Planning Scenarios

States may specify climate scenarios for the utility's vulnerability assessment and designate a source for downscaled climate data based on expert input. Climate experts typically develop the scenarios and downscaled data based on a range of IPCC planning scenarios.

IPCC Representative Concentration Pathways (RCPs) are scenarios that represent varying levels of greenhouse gas concentration trajectories adopted by the IPCC. RCPs are labeled with a number that represents the net radiative forcing (i.e., net energy into the earth system from the sun) under that scenario in the year 2100, measured in watts/meter $(m)^2$. The RCP scenarios range from 1.9 to 8.5 watts/m^2, depending on the amount of global greenhouse gas emissions. For example, based on expert input and projections from the Fourth Statewide Climate Change Assessment, California requires that Climate Change Vulnerability Assessments filed by investor-owned utilities use IPCC RCP 8.5 to simulate historical and projected temperatures, precipitation, and other climate parameters such as relative humidity and soil moisture.

The RCP trajectories are tied to Shared Socioeconomic Pathways (SSPs). These pathways forecast global economic, demographic and technological changes to the year 2100, informing greenhouse gas concentrations under various policy interventions.

Each scenario has a range of global climate models, resulting in different percentiles for the projections. For example, Con Edison (2023a) uses the 75th percentile of the SSP5-8.5 emissions scenario – considered a high emissions scenario because it assumes that global growth through 2100 will be driven by fossil fuels. For resilience plan requirements, a state may choose the SSP5-8.5 scenario and 75th percentile projection for a high emissions scenario, as well as a medium emissions scenario such as SSP2-4.5 and 50th percentile projection. Such analysis indicates which proposed investments are cost-effective in both scenarios and could be prioritized in the plan.

States can consider requiring utilities to plan for one or more scenarios that are tied to choices of a specific IPCC SSP, RCP, and global climate model percentile. Climate experts can support the development of reasonable scenarios to consistently apply across utility resilience plans.

2.2.4 Summary of community and stakeholder engagement

States may require certain community and stakeholder engagement processes for resilience plans.[23] Given the scope of most resilience events, priorities, responsibilities, and actions of many external stakeholders can be considered in a utility's resilience plan, such as state and local emergency response agencies. This section of the plan calls out these parties, how the utility's resilience plan addresses their interests, and how the utility will coordinate with these parties as it implements the plan.

Information about community and stakeholder engagement has become increasingly detailed in utility resilience plans as a result of state requirements. This part of the plan can explain priorities and viewpoints expressed by stakeholders, including vulnerable populations and disadvantaged communities. Importantly, the state can develop clear guidance for the utility on how to identify these groups and critical facilities and provide this information in maps or databases. Stakeholder engagement processes can identify additional facilities that are essential to prioritize for resilience investments, such as certain grocery stores or community centers that the community identifies as particularly important for continued operations during a resilience event.

The plan's summary of stakeholder engagement can distinguish among types of stakeholders and ways the utility engaged with each group. Engagement with communities may include local workshops and outreach to community-based organizations. Engagement with regulators and other government entities may include technical workshops and coordination at the state level.

The summary can describe engagement activities, community and stakeholder input received throughout the vulnerability assessment and solution prioritization processes, how input influenced the utility's plan, and continuing engagement activities during plan implementation. To the extent possible, utilities can use community input to develop metrics related to community resilience and impact to inform prioritization of resilience solutions and locations. For example, Southern California Edison (2022) developed a community resilience metric that measures the sensitivity and adaptive capacity of communities during a power outage and a community impact metric that measures the effects of adaptation actions (Table 2-2).

[23] Stakeholder engagement processes vary depending on the nature of the hazards analyzed. In particular, cybersecurity and physical security threats are not conducive to an open stakeholder-driven process for identifying vulnerabilities and prioritizing solutions, given the sensitivity of this information. An independent third-party review of the plan may be appropriate in such cases.

Table 2-2. Southern California Edison Overview of Metrics for Community Resilience and Impact

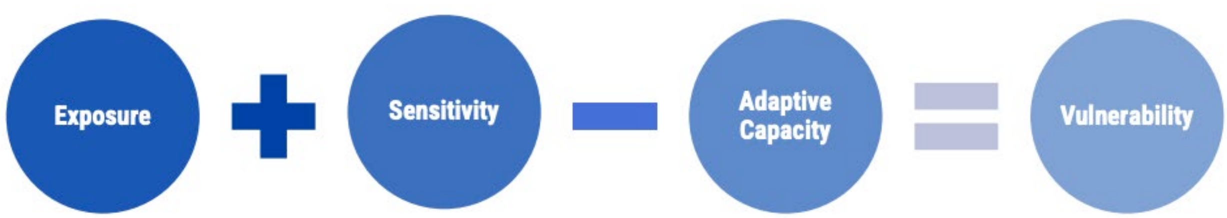
Metric	What it is	How it can potentially be used	How it was informed by community feedback
Community Resilience Metric	A set of scores measuring the sensitivity and corresponding adaptive capacity of a partcular community to potential loss of utility service	Inform locational priotritation of adaptation action, in conjunction with other planning and operational considerations	Based on a series of workshops with environmental and social justice subject matter experts as well as SCE's Community Resilinece Leadership Group (CRLG)
Community Impact Metric	Set of indicators mesauring the positive, negative or neutral effect of an adaptation action on the community it is deployed in	One of the factors used to evaluate adaption alternatives for a given community	Indicators determined using a combination of research, benchmarking and community input. SCE proposes using feedback from surveys co-developed and administered by CRLG member organizations during actual alternative evaluation

Source: Southern California Edison (2022)

These types of metrics that account for varying levels of sensitivity and adaptive capacity across communities are key inputs for a vulnerability assessment (Figure 2-3). The IPCC defines these terms as follows:

- *Sensitivity* - "The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change."
- *Adaptive capacity* - "The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences."

When combined with exposure to a specific hazard for a given community, asset, critical infrastructure facility, service or process, the vulnerability assessment and associated vulnerability rating follow a common framework that many utilities (electric, water and gas) and government agencies have used in resilience plans and for other infrastructure, processes and services.



Source: City of Seattle (2023)

Figure 2-3. Vulnerability Assessment Framework

2.2.5 Vulnerabilities and their impact on customers and communities

This part of the plan begins by detailing how the utility incorporates criteria for critical and essential facilities and vulnerable populations. The vulnerability assessment culminates in a matrix that summarizes all hazards relative to utility infrastructure and process areas analyzed (see emerging best practice examples in Chapter 3, the example matrix in Table I in Chapter 4, and DOE guidance). Importantly, this process clearly defines the vulnerability rating that applies to each infrastructure-hazard and process-hazard pair.

For vulnerabilities with a medium to high rating, the plan can estimate the economic impacts (adverse consequences), including utility, customer and broader societal costs, assuming that a resilience event occurs and exposes the vulnerability to a given hazard. Projections of the economic impacts, weighted by the likelihood that a resilience event occurs during the planning horizon, also can inform prioritization of which vulnerabilities to mitigate in the current cycle of the resilience plan. An appendix to the resilience plan can provide more detailed results of this assessment.

2.3 Description of Each Proposed Resilience Program

This section of the plan details the resilience programs the utility prioritized within the planning horizon. The plan also may discuss programs that would mitigate longer term vulnerabilities, but are not included in the current plan, given the planning horizon or other factors. Depending on the size of a utility, scope of the plan and investment time horizon, resilience plans vary widely in terms of the level of investment, from millions to billions of dollars. The level of detail in the plan typically varies with the magnitude of investment.

2.3.1 Proposed resilience programs

For each resilience program, this section provides the actual or estimated start and completion dates, the cost estimate broken down by the projects and resilience measures within the program, and the vulnerabilities that the program is designed to mitigate. In addition, this section describes how each program impacts the prevention of, response to, or recovery from resilience events, including the expected improvement to the utility's existing infrastructure and processes.

Importantly, this section also describes how each resilience measure within the program is targeted. For example, many utilities have considered undergrounding portions of their system to mitigate the vulnerability of power lines to wildfires, high winds and other hazards. A program that proposes undergrounding all power lines may be less cost-effective than a program that targets undergrounding certain power lines and includes other measures such as enhanced equipment inspections and vegetation management. Targeting each resilience measures based on characteristics of the grid, climate, geography or community can increase cost-effectiveness. Undergrounding may be the most cost-effective option in a remote area with extremely high wildfire risk, whereas enhanced vegetation management may be sufficient in urban areas with a lower likelihood of wildfires. Put simply, there may be a variety of measures within the program that together can cost-effectively achieve an objective to mitigate a given vulnerability.

2.3.2 Rationale for selecting and prioritizing the proposed program

This section of the template summarizes why the utility prioritized the proposed resilience programs, including the affected utility infrastructure and processes and specific vulnerabilities mitigated. The description for each program can summarize mitigation alternatives considered and demonstrate why the utility selected the program as the most cost-effective option, including results of prioritization analyses. Details important for prioritization include the number and types of customers impacted by the program, projections used, and expected performance improvement under varying severities of extreme weather conditions and other hazards, particularly for parts of the grid with low historical performance. Estimates of expected performance can be incorporated into metrics that track how well the program performs during resilience events of varying severities. Coordination with key stakeholders is an important element for documenting the basis for investment priorities.

This section concludes with a description of options that the utility considered to mitigate the resulting rate impact for each program. First, the plan can summarize efforts the utility made to offset ratepayer costs through state and federal funding support. If the utility already reports federal funding efforts in other regulatory dockets,[24] the resilience plan can summarize applicable information reported in those proceedings. Second, cost efficiencies may be achieved by aligning the resilience program with other planned distribution upgrades and operations and maintenance. Third, the utility can coordinate with municipalities to avoid redundant investments. For example, a utility that plans to mitigate flood risk by moving critical infrastructure may find that the municipality is planning flood mitigation measures that may significantly reduce the risk to the grid.

2.3.3 Estimated benefits

This section estimates the benefits of the resilience program to the utility, its customers and society more broadly,[25] including how the resilience program impacts the prevention of, response to, and recovery from events, relative to the counterfactual scenario in which the program is not implemented. Benefits ideally are monetized in terms of present value (dollars) to directly compare to costs as part of a benefit-cost analysis. Alternative approaches such as Value-spend Efficiency may be preferred in some cases (De Martini et al. 2022), especially to identify a least-cost investment to most effectively mitigate a given vulnerability.

States can specify the approach for estimating benefits and measuring plan performance. For example, states may provide guidance that utilities use certain tools and analytical methods to estimate

---

[24] For example, Duke Energy reports federal funding efforts on a semi-annual basis in South Carolina Docket No. 2023-319-A and North Carolina Docket No. M-100, Sub 164.

[25] Utility benefits include avoided operation and maintenance (O&M) and capital costs. Customer benefits include avoided damages, spoilage, and other costs for the customers that directly benefit from a reduction in outage frequency and/or duration for their own electric service. Societal benefits include the "spillover" benefits for other entities that indirectly benefit from the customers with improved resilience, even though the resilience program does not impact their own electric service. For example, a business in a neighboring, unaffected region benefits from being able to continue delivering goods to a grocery store that does not lose power during a major storm.

resilience program benefits. Chapter 3 of this report summarizes emerging best practices that may inform such guidance. Further, there may be certain "no-regrets" solutions, such as those informed by state and local emergency response agencies, that utilities can clearly prioritize. Stakeholder-informed prioritization can start with the "Bowtie" approach described in Chapter 3.

2.3.4 Performance metrics

This section provides details on proposed performance metrics to measure benefits, including underlying assumptions, and ways to track costs and performance timelines relative to expectations. Many states that have adopted grid resilience planning requirements for regulated electric utilities have not provided detailed guidance on reporting performance, other than requiring utilities to report budgets and spending by year. States also can consider requiring specific, impact-oriented metrics that measure how well the utility's investments mitigate the consequences of resilience events. For example, California's requirements for Wildfire Mitigation Plans state, "Metrics should focus on the success of mitigation at lowering the risk of catastrophic wildfires and not simply program targets such as the number of trees removed or wires replaced."[26] These types of metrics can complement other types of performance reporting. See the example emerging best practices for resilience metrics and performance reporting in Chapter 3 of this report.

2.4 Projected Costs and Rate Impacts

This section of the template includes elements such as the estimated number and costs of projects under each resilience program, annual revenue requirements, and rate impacts for each year of the plan. Following are other components included in this part of the template, which can be adapted to any state-specific considerations for estimating and summarizing rate impacts.

2.4.1 Reconciliation of resilience-related investments

Utilities make substantial ongoing investments that improve resilience, including many common reliability-related measures that are not included in a resilience plan. Therefore, this section includes a reconciliation that summarizes how the proposed program is incremental to other resilience-related investments that the utility has proposed, planned, and implemented as part of other planning processes or a general rate case.

2.4.2 Cost drivers for each program

This section specifies key cost drivers (if applicable) for each resilience program. For example, the frequency of trim cycles is a primary driver of costs for an enhanced vegetation management program. The number of line miles is a primary cost driver for an undergrounding program. The utility can benchmark its costs against similar solutions that other utilities have implemented, taking into consideration cost differences based on service territory characteristics, such as labor costs, urban versus rural customers, and terrain (e.g., mountainous, forested).

[26] Utilities may not be able to estimate such impact metrics unless events occur that test resilience measures implemented.

3. Emerging Resilience Planning Practices

This chapter summarizes emerging best practices for state resilience planning requirements and utility resilience plan filings and provides examples and references for more information. While many requirements focus on extreme weather hazards, several states require utilities to cover other threats, including cybersecurity, physical attacks, and seismic events.[27] Resilience planning practices are continually evolving and improving as regulators and utilities gain more experience and the industry collaborates on common challenges and opportunities for improvement (see text box on EPRI's Climate READi initiative). An emerging best practice today may be superseded by a superior approach that becomes the new best practice as resilience experts and practitioners identify improvements.

3.1 Planning Horizon and Frequency

Given the long-term nature of capital investments in grid infrastructure, and potential longer-term changes in extreme weather and other hazards, state requirements (Table 1-1) typically specify a planning horizon of 10 years or more, with greater detail required for the first three to five years of the plan. California and New York require planning horizons of 20 to 50 years for Climate Change Vulnerability Assessments, given the long-term nature of sea level rise, extreme heat and other climate trends. For example, coastal areas are exposed to sea level rise, which could produce catastrophic storm surges and floods in 20 years or more. Utilities in coastal areas can consider sea level rise and associated extreme weather hazards when making large capital investments that may have a long useful life.

Typically, utilities must file grid resilience plan updates every three to five years. Given the uncertainty in hazards, vulnerabilities and climate change impacts (PNNL 2023), this frequency enables future plans to make use of better data for critical infrastructure, vulnerable populations, climate projections and resilience solutions as they develop over time. Importantly, the plan template in Chapter 4 of this report includes programs that are under consideration, not just firmly planned, providing flexibility for the utility to further review program investments between planning cycles. While utility reporting on plan implementation can keep the regulator and stakeholders informed about changes, states may wish to consider providing guidance for filing a plan update out of cycle when significant new information is available, such as a new climate assessment, that may lead the utility to significantly deviate from its last filed plan.

Due to the urgency of wildfire threats in Western states in recent years, wildfire mitigation plans are filed more frequently (every one to three years) and have a shorter planning horizon (three years). These plans identify improvements to emergency response processes, such as communications during de-energization events, that utilities can implement relatively quickly and improve continuously.

[27] For an example plan that covers resilience of critical infrastructure and utilities (gas, water and electric) to earthquakes and tsunamis, see Oregon Seismic Safety Policy Advisory Commission (2013).

Climate READi (REsilience and ADaptation initiative)

Climate READi (REsilience and ADaptation initiative) is a three-year initiative convened by the Electric Power Research Institute engaging more than 40 power companies and 100 stakeholder organizations. The initiative is intended to develop a broadly accepted, comprehensive framework for assessing risk to the power system from extreme weather and long-term climactic trends. The framework can inform how an organization applies appropriate climate data throughout the planning, design and operation of a resilient power system.

There has been tremendous growth in publicly available and location-specific climate and weather information, including historical trends and projections of future weather due to increasing demand for climate-informed decision support and advances in earth and data sciences. As a result, new priorities have emerged for practitioners. For example, confidence and uncertainty in future trends vary by weather variable and source, and often necessitate additional interpretation for power system analysis and insights. Climate READi has developed tools such as the Climate Data Users Guide, the Climate Data Inventory, and the Climate 101 Training Series to help the power industry better tackle challenges for selection and application of climate data.

CLIMATIC IMPACT-DRIVER	OBSERVED TREND	FUTURE CHANGES
Extreme heat	Upward trend	High confidence of increase
Cold spell	Downward trend	High confidence of decrease
Snow and glaciers	Downward trend	High confidence of decrease
Heavy precipitation	Upward trend	High confidence of increase
Drought	No assessment given	Medium confidence of increase
Fire weather	Upward trend	High confidence of increase in Western NA, medium confidence of increase in Central and Eastern NA
Coastal and river flooding	Upward trend	High confidence of increase
Tropical cyclone, severe wind	No assessment given	Medium confidence of increase

The table above shows IPCC-assessed observed trends and future changes for select weather extremes (known as climate impact drivers) for North America (NA). The science of attribution is a rapidly developing area of research; it is important to recognize that non-climate factors are contributors to risk, as well as important considerations for managing extreme weather risk. In addition, despite consensus around the direction of future trends for certain climate variables, extremes at the opposite direction may still occur. This table was constructed from IPCC (2021) Interactive Atlas results for IPCC WGI's four NA regions, and further adapted from EPRI (2021).

References

EPRI (2021). "IPCC's 2021 Climate Science Assessment Report: High-Level Technical Summary and Perspectives" https://www.epri.com/research/products/3002023094

IPCC (2021). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press.

Source: EPRI (2022). A Starting Point for Physical Climate Risk Assessment and Mitigation: Future Resilience and Adaptation Planning

3.2 Summary of Hazards Analyzed

The urgency of planning for hazards that regions currently face may lead to single hazard plans, such as for wildfires or storms. On the other end of the spectrum, some states require or allow utilities to use an all-hazards approach to resilience planning.[28] Such an approach allows the utility to identify the most pressing threats and associated resilience needs. In practice, however, if state requirements do not specify which hazards the utility must analyze, some hazards may get little attention in the plan. At a minimum, requirements can specify that resilience plans provide a clear summary of all hazards analyzed and resulting vulnerability assessments.

3.3 Measures in Scope

Some state requirements list resilience measures that regulated utilities must analyze and report on as part of the potential programs in grid resilience plans, including why the utility does or does not plan to implement each measure. Importantly, potential viable and cost-effective resilience measures include changes to planning and operational processes for distribution systems and, where relevant, bulk power systems — as well as capital investments.

Following are example resilience measures specifically called out in grid resilience planning requirements, along with the state that requires reporting and analysis for these measures:

- Undergrounding (California, New York, Michigan and Texas)
- Vegetation management (most plan requirements)
- De-energization events, including protocols and emergency communications (Wildfire Mitigation Plans in several states)
- Lineworker staffing and storm severity forecasting (Connecticut)
- Measures that mitigate gas-electric dependencies during winter storms (Louisiana)
- Microgrids and distributed energy resources (Colorado)

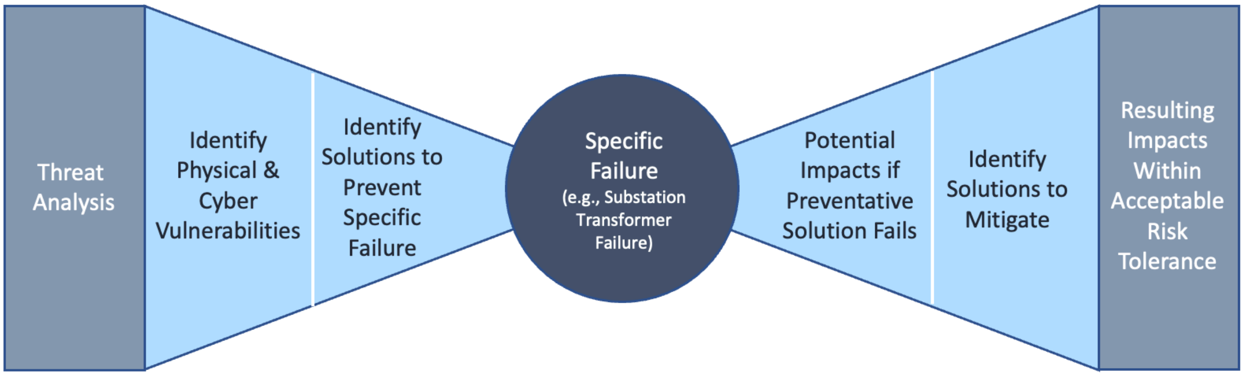
States can identify these and other promising resilience measures to include in planning requirements by reviewing assessments of vulnerabilities in utility infrastructure and processes during past resilience events and vulnerability assessments for future scenarios. When a resilience event occurs, utilities can submit to the regulatory commission a narrative summary, including a detailed description of the root cause and particular hazard that exposed vulnerabilities in utility infrastructure and processes and performance metrics for the event (see section 3.7). With this information in hand, states can discuss with the utility the particular resilience measures that would have improved performance.

In addition, using a “Bowtie" method (Figure 3-1) to identify viable resilience solutions helps stakeholders understand the specific threat and failure scenario and then focuses efforts on identifying potential resilience solutions. This method uses a collaborative process with subject matter experts and stakeholders to develop proposed resilience measures for identified vulnerabilities, distinguishing

---

28 See NREL’s resilience roadmap.

between preventative and mitigative solution options.[29] The approach “helps identify where and how solutions would have the greatest impact for customers and communities.”[30]



Source: De Martini et al. (2022)

Figure 3-1. Bowtie Method for Resilience Solution Identification

3.4 Vulnerability Matrix

The resilience plan template in Chapter 4 applies a two-phase approach for vulnerability assessment and prioritization of solutions. The first phase involves identifying communities, infrastructure, facilities and processes that are vulnerable to specific hazards. Several states require resilience plans to include a matrix that summarizes all hazards relative to infrastructure and process areas analyzed, with a clearly defined vulnerability rating that applies to each infrastructure-hazard and process-hazard pair. The second phase identifies and prioritizes resilience solutions for each infrastructure or process-hazard pair that the assessment identifies as highly vulnerable.

For example, the Climate Change Vulnerability Assessments that New York utilities file must propose storm hardening and other resilience measures for the next 10 years and 20 years and detail how the utility incorporates climate change into its planning, design, operations and emergency response, among other requirements. Table 3-1 summarizes the vulnerability assessment that Con Edison conducted to meet these requirements. Table 3-2 provides the rubric that planners used to rate vulnerabilities as Primary, Secondary and Low. The company’s subsequent Climate Change Resilience Plan proposes measures to mitigate certain vulnerabilities, based on further analysis of the specific assets within the broader infrastructure categories.

[29] As described in De Martini et al. (2022, page 30), “Preventive solutions are shown on the left side of the bowtie. Preventative solutions involve those that can either avoid (e.g., undergrounding) or withstand (e.g., pole hardening) a specific risk. Mitigation solutions can reduce the scope or duration of a resulting outage caused by a major event. Mitigation solutions are shown on the right side of the bowtie.”
[30] De Martini et al. (2022, page 30).

Table 3-1. Con Edison Climate Change Vulnerability Study (2023) – Summary of Vulnerabilities

	Temperature and Temperature Variable (TV)	Flooding	Wind and Ice
Area and Unit Substations	Primary	Primary	Low
Transmission Substations	Primary	Primary	Low
Overhead Transmission	Primary	Low	Secondary
Overhead Distribution	Secondary	Low	Primary
Underground Transmission	Secondary	Secondary	Low
Underground Distribution	Primary	Secondary	Low
Key Company Facilities	Secondary	Secondary	Low

Source: Con Edison (2023a)

Table 3-2. Con Edison Climate Change Vulnerability Study (2023) – Vulnerability Scoring Rubric

Low	• Asset/system has low vulnerability to the given climate hazard. – There are minimal or no negative outcomes or effects associated with asset/system exposure to this climate hazard.
Secondary	• Asset/system is moderately vulnerable to the given climate hazard. • Vulnerability is influenced by one or more of the following factors: – Asset is expected to experience increased degradation over time. – Asset is moderately sensitive but expected to experience a limited increase in magnitude for the given climate hazard within the evaluated time horizon. – Asset has limited sensitivity, but the increase in magnitude for the given climate hazard is moderate.
Primary	• Asset/system is highly vulnerable to the given climate hazard. • Vulnerability is influenced by one or more of the following factors: – Asset is highly sensitive, and the increase in magnitude for the given climate hazard is high, resulting in a high risk of major individual failure or severe degradation of service. – Asset is only moderately sensitive to the given climate hazard but is expected to experience a large magnitude of change in the given climate hazard. – Asset is highly sensitive to the given hazard but will experience only moderate changes in the magnitude of the given hazard.

Source: Con Edison (2023a)

Resilience plans can include the same type of matrix for planning and operational processes. For example, Duke Energy Carolinas (2022) provides a summary of climate change vulnerabilities by process area (Table 3-3), along with a vulnerability priority category rating scale for assets as well as planning and operational processes (Table 3-4). According to the study, "Risks to Duke Energy's asset management include accelerated equipment aging; a potential need to adjust design criteria to address the risk of changing precipitation, flooding and heat patterns; an incomplete understanding of the pole fleet's weather readiness; and limited insight into failure data and impact of climate on failure rates." As this citation makes clear, utilities can identify data- and process-related resilience improvements to mitigate vulnerabilities, complementing capital-intensive solutions.

Table 3-3. Duke Energy Carolinas (2022) Vulnerability Ratings by Process Area

Asset Management	High
Load Forecasting	Medium
Capacity Planning	Medium
Reliability Planning	Medium
Emergency Response	Low
Workforce Safety	Low
Vegetation Management	Low

Source: Duke Energy Carolinas (2022)

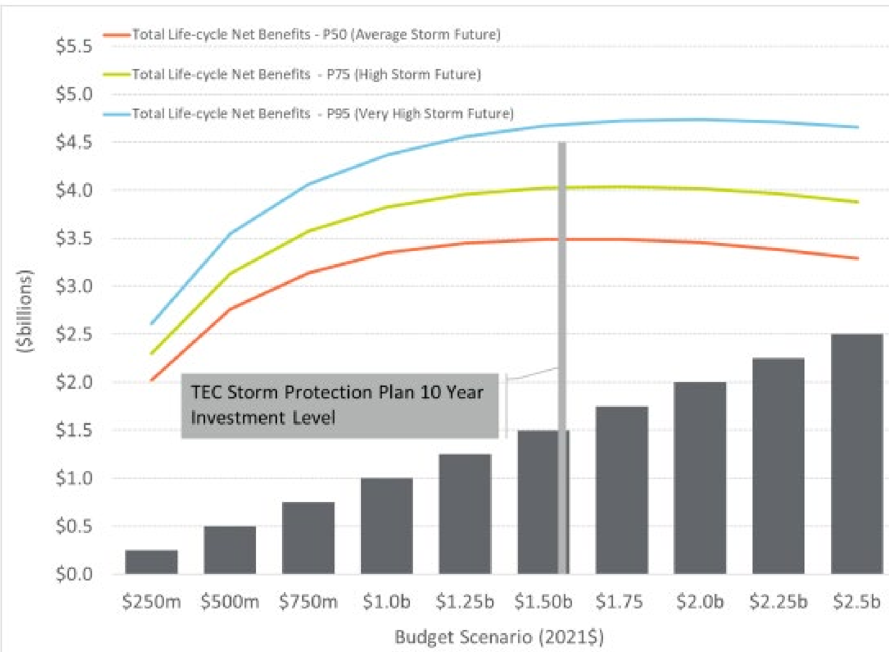
Table 3-4. Duke Energy Carolinas (2022) Vulnerability Priority Category Rating Scale

Vulnerability Category		
	Assets	Planning & Operational
Low	Limited sensitivity to projected levels of change in exposure, accounting for existing risk mitigations.	No process vulnerabilities to climate change are identified.
Medium	Potential for increased impacts that could result in reliability, cost, or other consequences. Moderated by existing adaptive capacity or risk mitigations, concentration of risks in high-end climate scenarios only, or other factors.	Vulnerabilities to climate change are identified in one or two process components.
High	High sensitivity/consequence associated with potential change in exposure. Could result in increased potential for highly significant outages, risks, and/or costs.	Vulnerabilities to climate change are identified in several process components.

Source: Duke Energy Carolinas (2022)

3.5 Prioritization

Best practices for prioritizing resilience projects and programs are evolving. Figure 3-2 provides an example from the Tampa Electric (2022) Storm Protection Plan, developed under Florida resilience planning requirements. Budget optimization, which estimates the optimal investment level for storm protection based on total lifecycle net benefits under various storm scenarios, led to a proposed spend of $1.59 billion over the 10-year plan. Tampa Electric used Berkeley Lab's Interruption Cost Estimate (ICE) Calculator[31] and other tools to quantify the value of these improvements as part of a benefit-cost analysis.



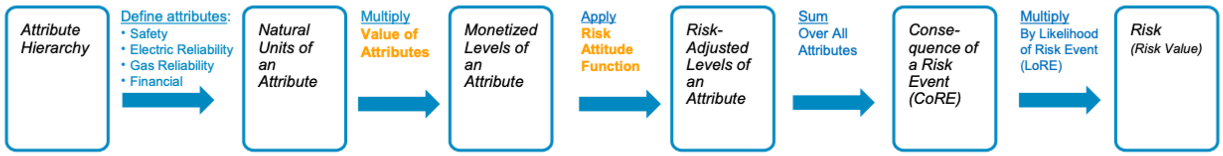
Source: Tampa Electric (2022)

Figure 3-2. Tampa Electric Storm Protection Plan Budget Optimization Results (2022)

For prioritization of risk mitigation investments more broadly, the CPUC required regulated utilities to apply a risk-based decision-making framework in the Risk Assessment and Mitigation Phase of the four-year general rate case cycle. PG&E is the first utility to implement this framework, summarized in Figure 3-3. The framework adds standardized measures of safety and reliability[32] risks to prioritize grid solutions. It addresses gaps in measurements and impact assessments and ensures consistent metrics across utilities. Implementation of this resilience framework is still in progress and subject to ongoing questions related to aligning resilience investments identified in Wildfire Mitigation Plans, Climate

31 See https://icecalculator.com/home. Berkeley Lab is updating its studies on the value of reliability and resilience.

32 The CPUC decision requires each utility to use the most current version of Berkeley Lab's ICE Calculator – or justify its choice of an alternative model – to determine a standard dollar valuation of electric reliability risk for the Reliability Attribute. CPUC Staff comments refer to Berkeley Lab's Power Outage Economics Tool (POET). POET estimates the direct and indirect economic impacts of more widespread, long duration outages. The utilities are not required to use POET at this time. A study would need to be conducted to collect important assumptions, calibrate the tool, and then deploy POET in California jurisdictions.



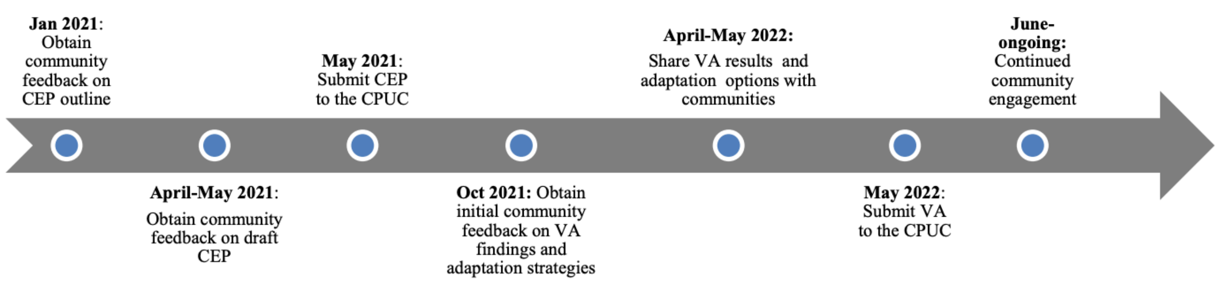
Source: PG&E (2024).[33]

Figure 3-3. PG&E Implementation of CPUC Risk-based Decision-making Framework (2024)

Change Vulnerability Assessments and General Rate Cases, highlighting the importance of coordinating resilience investment plans to limit redundant proposals that may cause confusion among stakeholders.

3.6 Stakeholder Engagement

State requirements are increasingly reflecting the importance of stakeholder involvement in resilience planning. For example, California requires utilities to undertake a multi-step community engagement strategy. One year before the utility files its vulnerability assessment, it must develop and submit a plan describing its community engagement processes and promoting equity in disadvantaged vulnerable communities. One year after filing a vulnerability assessment, the utility must survey these communities and community-based organizations to assess the effectiveness of their outreach and engagement and file the results with the PUC. Figure 3-4 summarizes Southern California Edison's (2021) Community Engagement Plan for its Climate Change Vulnerability Assessment, in accordance with California requirements. Stakeholder engagement also is important in development and execution of climate adaptation strategies, including performance targets, models and analyses.



Source: Southern California Edison (2021)

Figure 3-4. Southern California Edison Community Engagement Plan (CEP) for Climate Change Vulnerability Assessment (VA)

Similarly, each New York utility must establish a climate resilience working group to inform the development and implementation of climate change resilience plans, pursuant to Public Service Law §66(29). Con Edison's (2023b) Climate Change Resilience Plan details the stakeholder input process, building on previous efforts with organizations participating in these planning processes since 2012.

[33] PG&E presentation from 2024 Risk Assessment and Mitigation Phase Workshop #1.

3.7 Metrics and Performance Reporting

Best practices for resilience performance reporting are evolving. Currently, states typically require quarterly to annual reporting of specific, impact-oriented metrics (relative to key benchmarks and forecasts, if applicable). For example, California requirements for Wildfire Mitigation Plans state the following:

> *Metrics should focus on the success of mitigation at lowering the risk of catastrophic wildfires and not simply program targets such as the number of trees removed or wires replaced.*

Planning requirements can go beyond basic metrics such as dollars spent relative to the original spending plan. In addition to specific, impact-oriented metrics (*ex post*), states may consider forecasted (*ex ante*) reliability metrics and benchmarks for varying levels of resilience events.[34] Further, utilities can map planned system investments against metrics to better understand expected impacts. For example, the Michigan Public Service Commission indicates the following in its requirements for distribution system plans:

> *[T]he Commission is particularly interested in the utilities' expectations with their metrics moving forward and would like to see utilities' projections of these metrics mapped to planned system investments to be able to directly understand the benefits that anticipated investments will bring to customers' reliability. Therefore, future distribution plans should include expected measurable improvements resulting from the proposed distribution investments.*

While forecasted metrics are subject to significant uncertainty, particularly for frequency and severity of extreme weather, projections could be helpful to understand anticipated benefits customers will experience from improved reliability and resilience, with the caveat that differences relative to the forecast could be due to statistical error as opposed to resilience performance.

Utilities also can report major storm data for outages, blocked roads, critical facility impacts, and life-threatening emergency response events by storm intensity and level of resilience investment. For example, the Connecticut Public Utilities Regulatory Authority developed a framework for reporting these types of metrics for each major storm, including event level (Table 3-5). The Authority directs the utilities to present these metrics annually for stakeholder review, including separate results for "Resilience Zones," for which the utility has implemented projects in accordance with the resilience requirements. This framework allows for benchmarking over time by comparable storm intensity levels for Resilience Zones relative to: (1) "Non-hardened Zones," for which the utility has not implemented resilience solutions and (2) "VM-only Zones," for which the utility has only implemented vegetation management.

---

[34] These metrics could be segmented by storm category levels, such as "Event Level" (Table 3-5). This type of reporting for major storms allows for benchmarking performance of comparable events over time. However, it also may be important to account for the percentage of the service territory that is impacted by a given extreme weather event. Given that some utilities cover large regions, and a storm can change course unexpectedly, performance benchmarking may combine the storm category level with metrics related to the percentage of the service territory that the storm impacted.

Table 3-5. Reporting Metrics Framework for Major Storms

	Non-hardened Zones	Resilience Zone	VM-only Zone
Event Type			
Event Level			
Event Start Date			
Event End Date			
Event Duration			
Total Customer Min. Interrupted			
No. of Customer Outages			
Total Customers			
% of Customers Out			
Estimate of Lost Load			
No. of C&I Outages			
Total C&I Customers			
% of C&I Outages			
Estimate of Lost Load			
No. of Critical Facility Outages			
Total Critical Facilities			
% of Critical Facility Outages			
No. of Life Support Outages			
Total Life Support Customers			
% of Life Support Outages			
Time to Restore 50% customers			
Time to Restore 90% customers			
No. of Cust. Outages Exceeding 96 hr.			
No. of Cust. Outages Exceeding 120 hr.			
No. of Distribution Miles			
No. of Pole Failures			
No of Blocked Roads			
No. of Fire Police (FPS) Priority 1			
Average time to respond FPS1			
No. of Fire Police Priority 2			
Average time to respond FPS2			
No. of Fire Police Priority 3			
Average time to respond FPS2			

Source: Connecticut Public Utilities Regulatory Authority (2022)

Table 3-6 lists selected reliability and resilience metrics that states can consider for resilience planning and reporting requirements.[35] While there is overlap in the two sets of metrics, the distinction is tied to definitions. Reliability metrics focus on all operating conditions, whereas resilience metrics focus on large disruptions and their outsized impacts, including extended restoration times, critical infrastructure outages, and injuries or deaths. Utilities and regulators increasingly recognize that traditional measures of reliability are insufficient to fully characterize and measure resilience and new tools and approaches are needed, particularly for performance under extreme weather conditions. In addition, hazard-specific metrics, such as wind speeds and wildfire ignition, require new data collection processes that map risks throughout the service territory, as well as expertise to understand the key risk drivers.

[35] IEEE Standard 1366-2022 is a detailed guide for typical reliability metrics, including calculation methodologies.

Table 3-6. Selected Performance Metrics for Reliability and Resilience

Metric	Description	Interpretation / Considerations
Reliability		
SAIFI	System Average Interruption Frequency Index	Total number of sustained interruptions that an average customer experiences over some time period
SAIDI	System Average Interruption Duration Index	Total number of minutes that an average customer is without power over some time period
CAIFI	Customer Average Interruption Frequency Index	Average number of interruptions per customer interrupted over some time period
CAIDI	Customer Average Interruption Duration Index	Time required to restore service for an average customer over some time period
MAIFI	Momentary Average Interruption Frequency Index	Total number of momentary interruptions (< 5 minutes) that an average customer experiences over some time period
MED	Major Event Day	Any day with a daily reliability metric that exceeds a statistically-defined threshold based on the previous five years of daily data (e.g., IEEE 1366 standard)
Resilience (normalized based on the severity of the resilience events if applicable)		
Major Storm-only SAIFI	SAIFI specifically for major storms (or MEDs in general)	Utilities can report these metrics for storm events and on an annual basis by storm category level. These metrics also can be specific to life support customers or other types of vulnerable customers and communities.
Customers Interrupted (CI)	Total number of customers interrupted for major storms (or MEDs in general)	
Major Storm-only SAIDI	SAIDI specifically for major storms (or MEDs in general)	
Customer Minutes of Interruption (CMI)	Aggregate duration of all customer interruptions for major storms (or MEDs in general)	
Time to Restore X% of Customers	Hours from outage onset time to restore a certain percentage of customers impacted (usually 50%, 90%, or 100%)	
% of Customers Restored within 24 Hours of a major storm	Among customers impacted by a major storm (or MEDs in general), the percent that are restored within 24 hours of the outage onset time	
Average Time to Respond to Safety and Critical Infrastructure Needs	Minutes elapsed from the time the issue is reported to when the utility resolves it	Safety and critical infrastructure needs include blocked roads, downed power lines and other emergency responder priorities.

Metric	Description	Interpretation / Considerations
Number of Critical Assets without Power for More than N Hours	Number of critical assets without power for longer than a chosen time threshold (from one to 24 hours)	Critical assets include substations or feeders that serve critical infrastructure such as hospitals, police stations and water treatment plants.
Service Restoration Cost	Total O&M cost for outage restoration, including external lineworkers from mutual aid agreements	Utilities can report these metrics for specific storm events and on an annual basis by storm category level.
Number of Injuries or Deaths	Number of injuries or deaths during storm restoration or due to a lack of electric power	Utilities can report these metrics for utility workers, other emergency responders, or the public at large (due to a lack of electric power).
Total Damages ($)	Estimated value of damages due to a lack of electric power	Utility customers experience substantial costs due to major power interruptions.

Source: California Public Utilities Commission (2021)[36] and Larsen (2023).[37]

While there is no standard practice for measuring resilience performance, utilities, regulators, and other industry experts have started to focus on metrics for Major Event Days (MEDs) under varying levels of extreme weather conditions, such as storm categories based on wind speeds. Utilities can report many of these metrics for specific storm events, on an annual basis by storm category level and specifically for vulnerable customers, to better assess resilience performance and investment strategies. Metrics for individual catastrophic events can be established, and utilities can provide a narrative summary for each resilience event, including a detailed description of the root cause.

3.8 Funding Support

Resilience planning requirements can include a requirement to seek government funding support, if applicable for a given measure, and report progress. The Connecticut and proposed Louisiana requirements include almost identical language: "Every effort must be made, both now and in the future, to identify non-ratepayer funds to offset the costs associated with implementing the Reliability and Resilience Frameworks required herein. Specifically, it is incumbent on each EDC, the Authority, and stakeholders, to continuously review the Frameworks for alignment and potential leveraging of existing and future federal funding opportunities, particularly those included in the Federal Infrastructure Investment and Jobs Act (IIJA)."[38] Connecticut requires detailed funding status updates on a quarterly basis.

36 Adapted reliability metrics from California Public Utilities Commission (CPUC). 2021. "Electric System Reliability." Presentation by Julian Enis, CPUC - Energy Division, February 17. https://www.cpuc.ca.gov/-/media/cpuc-website/transparency/commissioner-committees/emerging-trends/2021/2021-02-17-electric-system-reliability-presentation---final.pdf.

37 Selected resilience metrics from Connecticut Public Utilities Regulatory Authority (PURA), Consumers Energy, Synapse/Sandia, and Larsen (2023, drawing from several states and utilities).

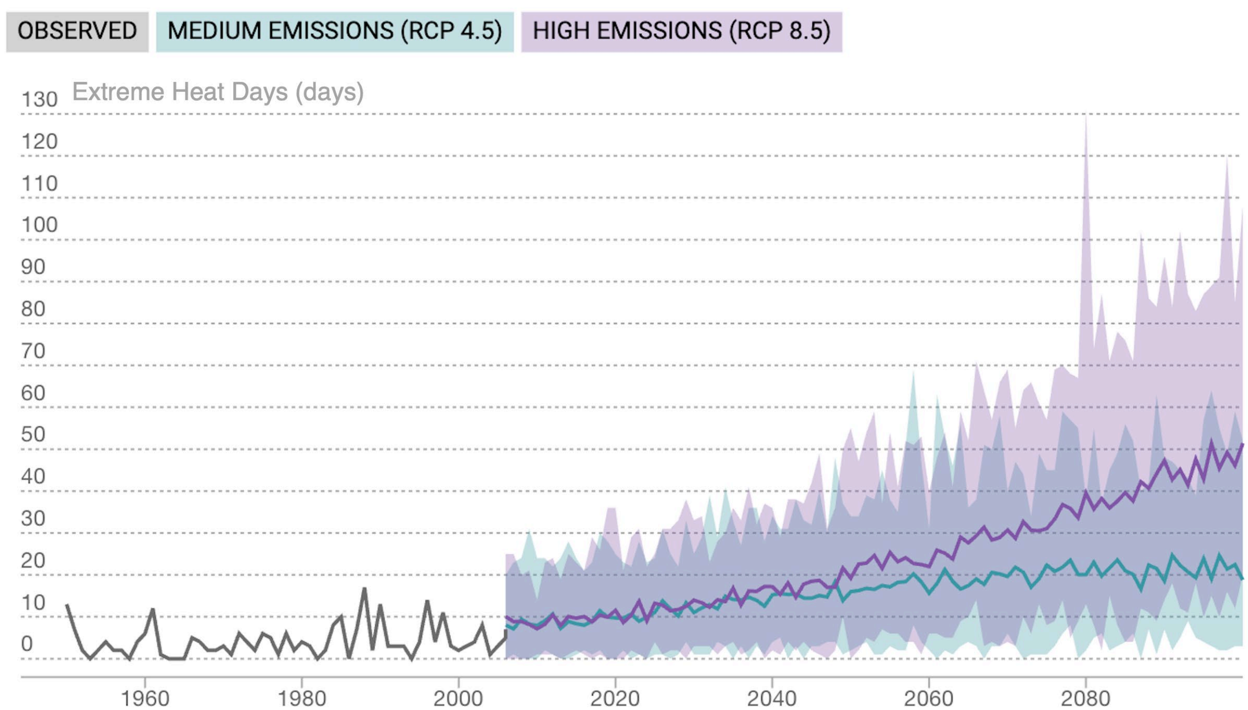
38 Connecticut Public Utilities Regulatory Authority (2022), page 76.

Other jurisdictions can consider this language and frequency of updates. Taxpayer support may have a significant impact on the decision-making process for utilities and regulators.

3.9 Climate Scenarios and Data

Resilience planning requirements can specify climate scenarios for vulnerability assessments and sources for downscaled climate data based on expert input. In California and New York, State Energy Offices worked with climate experts at leading universities in their states to develop and downscale extreme weather projections for a variety of climate hazards. For example, Figure 3-5 shows projections of extreme heat days for downtown Sacramento, using a state-funded tool called Cal-Adapt. The tool provides granular projections and underlying data at a ZIP code level, through the end of the 21st century, readily available to California utilities for a variety of climate hazards and scenarios.

Making such downscaled projections readily available in other states is an important step for consistency of utility data sources and scenarios.[39] With the increasing frequency and severity of extreme weather events, past weather data may lead to misguided resilience investment decisions. A focus on projections of extreme weather hazards is critical for exposing grid infrastructure vulnerabilities.



Source: Cal-Adapt (2024)[40]

Figure 3-5. Cal-Adapt Projections of Extreme Heat Days for Downtown Sacramento

---

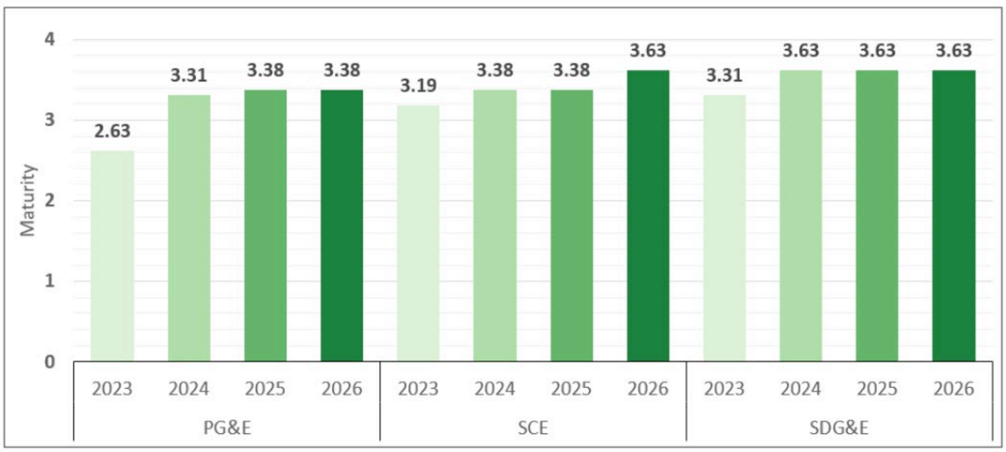
[39] Municipal utilities and rural electric cooperatives also can opt to use these scenarios and sources.

[40] Cal-adapt.org, Local Climate Change Snapshot for Downtown Sacramento (ZIP Code 95814). The California Energy Commission provides funding and oversight.

3.10 Continuous Improvement

Grid resilience planning is still nascent. States and utilities are applying learnings for each new planning cycle. For example, the California Office of Energy Infrastructure Safety issued a series of guidelines and new requirements over time for utility Wildfire Mitigation Plans. The most significant change from the original 2019 CPUC decision was the introduction of a maturity model to surface emerging best practices and drive continuous improvement in wildfire mitigation. Other changes include greater detail required for input assumptions and more transparency on analysis data and results, including trends and lessons learned.

The maturity model scores each utility on level of maturity, from zero to four (Figure 3-6), for 52 capabilities organized into 10 categories (Table 3-7). Within each category, the Office of Energy Infrastructure Safety compares current and projected maturity levels across utilities to identify areas of improvement and improve capabilities over time. For example, Figure 3-6 shows cross-utility maturity for vegetation management and inspections.[41] States also can consider this approach for grid resilience plans focused on other hazards, especially when there is an urgent need for sharing emerging best practices across utilities to drive continuous improvement.



Source: Office of Energy Infrastructure Safety Decision on PG&E's 2023-2025 Wildfire Mitigation Plan

Figure 3-6. Cross-Utility Maturity for Vegetation Management and Inspections (Average Values)

[41] These types of maturity assessments are common for cybersecurity for utilities and other industries.

Table 3-7. California Wildfire Mitigation Maturity Model

Category	I. Capability	II. Capability	III. Capability	IV. Capability
A. Risk assessment and mapping	1. Climate scenario modeling	2. Ignition risk estimation	3. Estimation of wildfire consequences for communities	4. Estimation of wildfire and PSPS risk-reduction impact
B. Situational awareness and forecasting	6. Weather variables collected	7. Weather data resolution	8. Weather forecasting ability	9. External sources used in weather forecasting
C. Grid design and system hardening	11. Approach to prioritizing initiatives across territory	12. Grid design for minimizing ignition risk	13. Grid design for resiliency and minimizing PSPS	14. Risk-based grid hardening and cost efficiency
D. Asset management and inspections	16. Asset inventory and condition assessments	17. Asset inspection cycle	18. Asset inspection effectiveness	19. Asset maintenance and repair
E. Vegetation management and inspections	21. Vegetation inventory and condition assessments	22. Vegetation inspection cycle	23. Vegetation inspection effectiveness	24. Vegetation grow-in mitigation
F. Grid operations and protocols	27. Protective equipment and device settings	28. Incorporating ignition risk factors in grid control	29. PSPS op. model and consequence mitigation	30. Protocols for PSPS initiation
G. Data governance	33. Data collection and curation	34. Data transparency and analytics	35. Near-miss tracking	36. Data sharing with research community
H. Resource allocation methodology	37. Scenario analysis across different risk levels	38. Presentation of relative risk spend efficiency for portfolio of initiatives	39. Process for determining risk spend efficiency of vegetation management initiatives	40. Process for determining risk spend efficiency of system hardening initiatives
I. Emergency planning and preparedness	43. Wildfire plan integrated with overall disaster/ emergency plan	44. Plan to restore service after wildfire related outage	45. Emergency community engagement during and after wildfire	46. Protocols in place to learn from wildfire events
J. Stakeholder cooperation and community engagement	48. Cooperation and best practice sharing with other utilities	49. Engagement with communities on utility wildfire mitigation initiatives	50. Engagement with LEP and AFN populations	51. Collaboration with emergency response agencies

Source: California Office of Energy Infrastructure Safety (2020). Note: Final two columns excluded to improve readability.

3.11 Planning for Other Threats

Many states that have enacted resilience planning requirements focus on extreme weather hazards, given their increasing frequency and severity. Several states also require utilities to address other resilience threats, such as cybersecurity, physical attacks and seismic activity.[42] Following are examples of these state requirements.

Resources for Planning for Cybersecurity

The National Association of Regulatory Utility Commissioners and National Association of State Energy Officials provide cybersecurity training and publications for their members.
A presentation by Lawrence Livermore National Laboratory summarizes cybersecurity threats and mitigation measures.[1] DOE C2M2, a Cybersecurity Capability Maturity Model, is a useful tool to help organizations evaluate their cybersecurity capabilities and optimize security investments. DOE initially developed C2M2 in 2012 and released a version specifically for the electricity sector in 2014. Utilities can use the latest C2M2 release from June 2022 – Version 2.1 – to measure cybersecurity capabilities across planning cycles, determine target maturity levels based on a risk assessment, and prioritize investments that achieve target maturity levels. As with the California Wildfire Mitigation Maturity Model, states can use C2M2 results to compare capabilities and share emerging best practices across utilities to drive continuous improvement and monitor how investments are improving specific capabilities over time.

Colorado Distribution System Plan requirements include analysis of cybersecurity and physical security threats and efforts the utility is taking to ensure distribution system security. The requirements include:

- A list of major outages, including cause and duration, over the past three years
- Analysis of cybersecurity issues or other threats to the distribution system
- Efforts the utility is taking to ensure the security of the distribution system

These requirements, specifically rule 3539 (Security Assessment), cover a broad range of hazards, including cybersecurity, wildfires, floods, severe storms and other threats. The rule specifies that the Distribution System Plan provides a narrative assessment of the reliability and resilience of the distribution grid with respect to these threats.

New York requires Distributed System Implementation Plans to include specific information on cyber security, including:

- Utility policies, procedures, and assets that address the security, resilience and recoverability of data stored

[42] For the bulk power system, all jurisdictions are subject to federal requirements for addressing vulnerabilities to threats. NERC Critical Infrastructure Protection standards focus on cyber-security. There also is a specific standard for physical attacks (https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-014-3.pdf).

- Processes running in interacting systems
- Devices owned and operated by third parties

In California, PG&E's 2020 Risk Assessment Mitigation Phase (RAMP) report constituted the initial phase of the company's 2023 General Rate Case. The report identifies and describes a wide variety of safety risks, including 12 primary RAMP risks and eight cross-cutting factors, which are drivers or consequences that may affect more than one event-based risk. These cross-cutting factors include cyber attacks, physical attacks and seismic activity. Table 3-8 maps the eight cross-cutting factors for the 12 RAMP risks in terms of impact on the likelihood of the risk event occurring. PG&E conducted a similar analysis related to the impact on the consequence of a risk event and incorporated the applicable cross-cutting factors directly into Bowtie assessments for the 12 RAMP risks.

Table 3-8. PG&E RAMP Cross-Cutting Factors Impact on the Likelihood of the Risk Event

		Cross-Cutting Factor							
Line No.	RAMP Risk	Climate Change	Cyber Attack	EP&R	IT Asset Failure	Physical Attack	RIM	Seismic	SQWF
1	Contractor Safety Incident								
2	Employee Safety Incident	(b)				X	X		X
3	Failure of Electric Distribution Overhead Assets	X				X	X	X	X
4	Failure of Electric Distribution Network Assets	(b)				X	X	X	X
5	Large Overpressure Event Downstream of Gas Measurement and Control Facility						X		X
6	Large Uncontrolled Water Release (Dam Failure)	(b)	X		X	X		X	
7	Loss of Containment on Gas Distribution Main or Service	(b)				X	X	X	X
8	Loss of Containment on Gas Transmission Pipeline	(b)				X	X	X	X
9	Motor Vehicle Safety (MVS) Incident								
10	Real Estate and Facilities Failure	(b)				X		X	
11	Third-Party Safety Incident								
12	Wildfire	(b)						X	

(a) Given historical data, this cross-cutting factor impacts the RAMP risk, but was not extracted from the data and considered or modeled separately. This is referred to in Section B.1 as "Embedded."

(b) This cross-cutting factor is considered by PG&E to impact the RAMP risk, but data limitations precluded a statistically meaningful quantification of its impact. See Attachment A, Section A for more information.

Source: PG&E's 2020 Risk Assessment Mitigation Phase (RAMP) report

PG&E detailed the analysis of cross-cutting factors in Chapter 20, attachment A, of the RAMP report. For cyber attacks, PG&E proposed a series of mitigations aligned with the four pillars of the National Institute of Standards and Technology's Cybersecurity Framework. For physical attacks, PG&E reported consideration of a program to mitigate identified risks through the Security Defined Protection Levels, an internally developed process. Using this framework, PG&E Corporate Security assigned risk levels to 2,600 facilities and enhanced security protocols at high-risk locations. For seismic activity, the PG&E

Geosciences team collaborated with line of business asset owners and risk managers[43] to quantify seismic risk and propose mitigations tailored to assets.

Although RAMP reports do not explicitly serve as utility resilience plans, they are extensive assessments of various hazards that present risks to electric utility grids and the mitigations needed. The S-MAP Settlement Agreement requires utilities to provide Risk Spend Efficiency calculations for all mitigations in the RAMP filings. Ranking mitigations using this metric allows the California PUC and stakeholders to compare the cost-effectiveness of utilities' mitigations during rate case proceedings. The utilities discuss both ongoing, compliance-based mitigations and new mitigations based on modeling. The robust modeling that utilities are required to perform, and the Risk Spend Efficiency calculations for mitigations, comprise a data-driven approach for resilience planning of multiple hazards.

Hawaiian Electric Companies (HECO) laid out an action plan in its Integrated Grid Plan for meeting grid needs through 2050, including resilience. The process included a Resilience Working Group comprised of state and national agencies, commercial and industrial customers, and not-for-profit interest groups. The Resilience Working Group brought together expertise from a wide range of sectors, including:

- Defense
- Telecommunications
- Transportation (including energy)
- Water and wastewater
- Hospitals and health care
- Emergency management and first responders
- Hospitality industry

Hazards in scope include:

- Hurricane/Flood/Wind
- Tsunami/Earthquake
- Wildfire
- Physical/Cyber Attack
- Volcanic activity (Hawaiʻi Island only)

As described in the utility's filed plan, "For each threat, the working group considered moderate and severe reference scenarios to provide a range of potential impacts to consider when assessing proposed solution options. Our initial resilience plans focus largely on the working group's consensus top-priority threat: Hurricane/Flood/Wind, with a secondary focus on preventing and mitigating utility-caused wildfires." Table 3-9 summarizes the severe events considered and prioritized by the Resilience Working Group.

[43] A line of business (LOB) is a department within PG&E, such as Electric Operations and Power Generation, that owns specific assets and is responsible for identifying, evaluating, mitigating, and monitoring risks for those assets. As detailed in the RAMP report (page 2-7), "Dedicated Risk Managers in each LOB manage all risk-related activities within that LOB, which includes: risk assessments and quantification, reporting and governance, and tracking metrics and mitigations."

Table 3-9. Severe Events Considered and Prioritized by HECO's Resilience Working Group

Natural	C	P	Technological	C	P	Attack	C	P
Avalanche			Dam failure			Physical (shooter)	X	X
Drought						Physical (explosive)	X	
Earthquake	X	X				Cyber	X	
Epidemic						Chemical		
Flood	X	X	Mine Accident			Improvised nuke		
Hurricane	X	X				Terrorist nuke		
High wind	X	X				Radiological		
Space weather								
Tornado								
Tsunami	X	X						
Volcano	X	X						
Wildfire	X	X		X				
Landslides	X			X				
Greenhouse gas	X					**C - Considered**		
Lightning	X					**P – Prioritized**		

Source: Hawaiian Electric (2022).

4. Resilience Plan Template

States and utilities can adapt this template to account for jurisdiction-specific considerations. A Word document version is available on [Berkeley Lab's website](#) for this purpose.

Section 1. Executive Summary

- Resilience plan objectives and motivation
  - Legislative and regulatory requirements
  - Extreme weather events, increasing restoration costs, availability of government funding support, data sources and solutions, technological changes, and other jurisdiction-specific items
- Definition of resilience, resilience event, and reliability – for example:
  - *Resilience* – "[A]bility to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."[44]
  - *Resilience event* – "[A]n event involving extreme weather conditions, wildfires, cybersecurity threats, or physical security threats that poses a material risk to the safe and reliable operation of an electric utility's transmission and distribution systems. A resiliency event is not primarily associated with resource adequacy or an electric utility's ability to deliver power to load under normal operating conditions."[45]
  - *Reliability* – "The ability to maintain the delivery of electric power to customers in the face of routine uncertainty in operating conditions."[46]
- Definitions of other key terms,[47] including those that define what the plan does (and does not) cover in terms of the service territory, infrastructure areas, etc.
- Hazards in scope
  - Summary of all hazards considered and ultimately selected during plan development

---

44 Presidential Policy Directive (2013)

45 This illustrative definition is from Texas, based on hazards in scope in that state. The electricity industry does not have a standard definition for "resilience event." Each jurisdiction develops its own definition based on hazards in scope. The definition may indicate the range of normal operating conditions as well as the degrees of severity for resilience events.

46 Eto et al. (2020). Other definitions of reliability may simply refer to "normal operating conditions," as in the resilience event definition.

47 The IPCC Glossary provides generally accepted definitions for many key terms, including risk, hazard (similar to threat), vulnerability, impacts (similar to consequence), exposure, sensitivity and adaptive capacity.

  - Brief rationale for any hazards that were not included in the vulnerability assessment
- Summary progress report on programs included in the most recently filed resilience plan (if appliable) to clearly communicate advancement or completion of:
  - Resilience program delivery
  - Changes in key performance metrics, particularly during any resilience events
  - Progress toward mitigation of specific vulnerabilities for the applicable utility infrastructure and processes
- Summary of measures considered and ultimately selected during plan development to enhance resilience of the utility's infrastructure and processes,[48] including:
  - Hardening electrical transmission and distribution (T&D) facilities
  - Modernizing electrical T&D facilities
  - Undergrounding certain electrical distribution lines
  - Lightning mitigation measures
  - Flood mitigation measures
  - Information technology (IT)
  - Cybersecurity measures
  - Physical security measures
  - Vegetation management
  - Wildfire mitigation and response
  - Emergency planning and response
  - Design criteria and standards
  - Other eligible resilience measures
- Proposed resilience programs in plan
  - Name of each resilience program[49]
  - Category of resilience measure(s) (from list of measure types above)
  - How program is expected to mitigate impacts for identified vulnerabilities in utility infrastructure and/or processes for specific hazard(s), including high winds, wildfires, floods, freezes, heat waves, cyber and physical security threats, and other hazards

[48] While the focus of many resilience plans is the T&D system, utilities may consider measures that improve resilience under bulk system emergency alerts and fuel supply shortages, such as IT investments to optimize load shedding, improve energy efficiency (PNNL et al. 2023), and control microgrids and distributed energy resources (PNNL 2022).
[49] For example, Florida Power & Light (2022) calls resilience programs the "Distribution Inspection Program," "Transmission Hardening Program," "Substation Storm Surge/Flood Mitigation Program," etc.

- Summary of overall costs and benefits by resilience program, including:
  - Cost summary
  - Rate impacts
  - Expected benefit streams (such as reduced restoration costs, shorter outage duration, avoided resilience events, lower unserved energy, avoided customer interruption costs and increased safety)
  - Summary of quantitative and qualitative benefits[50]
  - How the program prioritizes vulnerable populations, critical infrastructure and worst-performing circuits during resilience events
- Summary of performance metrics
  - Description of metrics the utility plans to use to report on the plan's progress and performance
  - Underlying assumptions for calculating metrics
  - Expected performance results by category of resilience event severity (such as storm category levels based on wind speeds for extreme weather)
- Description of how the utility's resilience plan aligns with the State Energy Security Plan under the federal Infrastructure Investment and Jobs Act (IIJA)
- Summary of how the resilience plan fits into other utility planning processes, including transmission and distribution plans, transportation and building electrification plans, and climate vulnerability and adaptation plans, as well as local government infrastructure plans and emergency response plans
- Status of applications and approvals for state and federal resilience funding support
- Summary of how the overall resilience plan serves the public interest

Section 2. Vulnerability Assessment[51]

- Description of utility service territory
- History of resilience events in the service territory in the past five to 10 years, including storms, wildfires, floods, freezes, heat waves, cyber and physical security incidents, seismic events, and

[50] Planners can use Berkeley Lab's Power Outage Economics Tool (POET) to estimate the impacts of longer duration and consecutive outages. However, a study would need to be conducted to provide the necessary data to use the tool.
[51] For examples of in-depth vulnerability and hazard assessment approaches, see Con Edison's Climate Change Vulnerability Study (2023a), Southern California Edison's Climate Change Vulnerability Assessment (2022), and PG&E's wildfire mitigation plan (2024).

other hazards[52] (include estimated restoration costs and times and, if available, customer interruption costs)

- Summary of approach for projecting frequency and severity of resilience events (include detailed analysis methodology in an appendix)
  - Methodology for projecting resilience events at a granular geographic level in the service territory to identify specific areas and infrastructure vulnerable to each type of hazard, factoring in how frequency and severity of extreme weather will be different from prior years due to climate change (recommended approach)[53]
  - Alignment of projections with analysis conducted or sponsored by the state (if available)
  - Climate scenarios considered, including scenarios with compounding of extreme event impacts (such as high winds and flooding)[54]
  - If the projections assume that the frequency and severity of extreme weather will remain similar to prior years (not recommended), provide the specific time period, with a preference for more recent years, and extreme weather events analyzed (including weighting of years and events in the projections, if not a simple average)
- Summary of community and stakeholder engagement
  - How the plan's priorities considered the viewpoints expressed by key stakeholders
  - For extreme weather hazards,[55] provide summary of the stakeholder engagement process to date, including local communities, vulnerable populations, critical and essential facilities, and government entities, most notably emergency responders
  - Outcomes and changes in plan based on stakeholder engagement process
  - Future stakeholder engagement included in resilience plan
- Vulnerabilities and their impact on customers and communities

[52] Depending on the jurisdiction-specific definition of "resilience event."

[53] Argonne National Laboratory developed a tool called the Climate Risk and Resilience Portal (ClimRR) that utilities can use to support development of local climate projections. Also see PNNL (2023) for a review of emerging best practices for projecting extreme weather events at a granular geographic level.

[54] Resilience plans may use two or more scenarios to assess the range of potential impacts under varying frequencies and severities of resilience events. With this information, utilities can identify "no regrets" measures that are cost-effective under all scenarios, in addition to measures that may only be cost-effective under a worst-case scenario.

[55] For cyber and physical security threats, the plan can summarize any independent third-party review and standards employed – for example, see NERC (2015). This step may take place later in the plan development process.

- How the plan incorporates criteria for critical and essential facilities[56] and vulnerable populations (including method employed — e.g., state guidance, maps or data, community engagement, worst-performing circuits during prior resilience events)
- Methodology for identifying utility infrastructure and processes that are highly vulnerable to resilience events
- Matrix that summarizes all hazards relative to infrastructure and process areas, analyzed with a clearly defined vulnerability rating[57] that applies to each infrastructure-hazard and process-hazard pair (see example matrix in Table I)
- Estimated economic impacts (adverse consequences), including utility, customer and societal costs, if a resilience event were to occur and expose a vulnerability
- Projections of economic impacts that result from extreme weather events, or cyber or physical security incidents, weighted by the likelihood that a resilience event occurs during the planning horizon
- Any areas where the utility has determined that enhancement of its existing infrastructure and processes would not be feasible, reasonable or practical at this time
- Appendix with more detailed results of the vulnerability assessment, including how projections of frequency and severity of resilience events inform prioritization of which vulnerabilities are most important to mitigate through a resilience program

---

[56] FEMA defines "critical facilities" as structures from which essential services and functions for victim survival, continuation of public safety actions, and disaster recovery are performed or provided. Shelters, emergency operation centers, public health, public drinking water, and sewer and wastewater facilities are examples of critical facilities. “Essential facilities” may include certain grocery stores, community centers, or other facilities that the community deems are particularly important to access during a resilience event.

[57] The vulnerability rating typically accounts for exposure, sensitivity and adaptive capacity. IPCC defines sensitivity as “The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change.” The IPCC defines adaptive capacity as “The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences.” See IPCC Glossary. When combined with exposure of a community, asset, critical infrastructure facility, service or process to a specific hazard, the vulnerability assessment and associated rating follow a common framework that many utilities and government agencies have used for resilience plans (including for electric, water and gas systems) and other infrastructure, processes and services.

Table I. Example Vulnerability Matrix*

Category of Utility Infrastructure or Processes	Hazards Included in Vulnerability Assessment (Vulnerability Rating)			
	High Winds	Floods	Heat Waves	Cybersecurity
Substations				
Transmission lines				
Transmission towers				
Distribution lines				
Distribution poles				
Distribution transformers				
Key company facilities				
Asset management				
Load forecasting				
Workforce safety				
Emergency response				
Vegetation management				

* Add rows and columns as needed.

Section 3. Description of Each Proposed Resilience Program

- Proposed resilience programs, including:
  - Time period (actual or estimated start and completion dates)[58]
  - Cost estimate, including capital and operating and maintenance (O&M) expenses broken down by the projects and resilience measures within the program
  - Vulnerabilities in utility infrastructure or processes for a specific hazard that the program is designed to mitigate
  - How each resilience measure within the program is targeted based on system, climate, geographic or community characteristics[59]
  - Description of how the program impacts the prevention of, response to and recovery from resilience events

58 This section may include programs that are designed to mitigate longer term vulnerabilities, but are not included in the budget for the current plan, given the planning horizon or other factors.

59 For example, consider a program designed to mitigate vulnerability of transmission lines to wildfires. A program that proposes undergrounding all transmission lines may be less cost-effective than a program that also considers measures such as enhanced inspections and vegetation management. Targeting each resilience measure based on system, geographic or community characteristics can increase cost-effectiveness.

    - Expected improvement to utility's existing infrastructure and processes[60]
- Rationale for selecting and prioritizing the proposed program, including the following:
    - Description of the affected utility infrastructure and processes and specific vulnerability mitigated
    - Alternatives considered for mitigating the vulnerability, including results of prioritization analyses that compared different options
    - Number and type(s) of customers impacted by the program
    - Expected performance improvement under varying severities of extreme weather conditions (or under cyber or physical security threats or seismic events, if applicable)
    - How the utility used stakeholder input and projections of performance during resilience events to prioritize the proposed program
    - How the program prioritizes areas of lower historical performance
    - Options considered to mitigate resulting rate impacts, including:
        - State and federal funding support
        - Cost efficiencies by aligning program with capital upgrades and O&M in the utility's distribution plan and other applicable plans
        - Coordination with local municipalities that plan to mitigate certain vulnerabilities to extreme weather hazards (such as investments in flood management)
- Estimated benefits,[61] including but not limited to:
    - Reduced restoration costs (to restore power and replace damaged equipment)
    - Shorter outage duration
    - Avoided resilience events
    - Lower unserved energy
    - Avoided customer interruption costs
    - Increased safety during extreme weather conditions (or under cyber or physical security threats, if applicable)
    - Comparison of costs and benefits for the proposed resilience program

---

[60] While the plan focuses on improving performance during resilience events, many programs also may deliver reliability improvements under normal operating conditions. These types of "co-benefits" are important to consider.
[61] For a comprehensive analysis framework to estimate costs and benefits of undergrounding T&D lines, see Larsen (2016). Sandia's ReNCAT tool applies a benefit-cost analysis framework for microgrids (Sandia National Laboratories 2023).

- Performance metrics
    - Description of metrics the utility plans to use to evaluate the program's performance
    - Assumptions that underlie the use of those metrics
    - Scope of reporting on progress of program implementation and effectiveness

Section 4. Projected Costs and Rate Impacts

- Estimated number and cost of projects under each specific program
- Reconciliation that summarizes how each program is incremental to other resilience-related investments that the utility has proposed, planned, and implemented as part of a General Rate Case or other planning process
- Cost drivers for each program, such as:
    - Frequency of inspections (T&D assets)
    - Frequency of trim cycles (vegetation management)
    - Projected miles of affected T&D lines
    - Estimated annual labor and equipment costs for both utility and contractor personnel
- Estimated annual revenue requirements for each year of the plan (Table II)

Table II. Estimated Annual Revenue Requirements by Year

Year	Resilience Plan Annual Revenue Requirement ($ millions)
2024	
2025	
2026	
2027	
2028	
2029	
...	

- Estimated impacts for each year of the plan
- Estimated rate impacts for each of the first three years of the plan for the utility's average residential, commercial and industrial customer (Table III)

Table III. Estimated Rate Impacts by Customer Class (years 1-3 of resilience plan)

Customer Class	Estimated Rate Impacts		
	2024	2025	2026
Residential ($/kWh)			
Commercial ($/kW and $/kWh)			
Industrial ($/kW and $/kWh)			

5. Areas for Future Research

Our research identified 14 states that adopted requirements for grid resilience plans and 30 utilities that filed plans with regulators. Best practices are still emerging. States and utilities seek tools, analyss, and actionable examples to improve grid resilience planning, including valuing and prioritizing resilience solutions and measuring performance. The following are suggested areas for further research:

- **Estimating resilience benefits.** Berkeley Lab and partners piloted a prototype Power Outage Economics Tool (POET) that estimates the economic impact of widespread, long-duration power interruptions. As discussed in Larsen et al. 2024, POET could be deployed in other parts of the country to estimate the economic value of investments in power system resilience. This tool fills an important gap related to estimating resilience benefits for the utility and its customers as part of broader benefit-cost analysis (BCA) that informs prioritization of resilience solutions.
- **BCA alternatives for investment prioritization.** While in-depth BCA that quantifies the monetary value of benefits is generally preferable for prioritizing among investment options, this approach may not be feasible for all utilities. Some jurisdictions may approve alternative prioritization approaches including least-cost best-fit, multi-criteria analysis, and value-spend efficiency. Alternative approaches are typically undertaken when it is difficult to monetize the benefits or when planning under deep uncertainty involving the impact of resilience events and performance of resilience solutions (PNNL 2023 and De Martini et al. 2022). Additional research, tools, examples, and guidance related to BCA alternatives in the context of resilience planning could fill an important gap for states and utilities that have conducted a climate change vulnerability assessment, but are challenged with prioritizing and targeting resilience solutions in the context of deep uncertainty.
- **Resilience metrics and performance reporting.** Practices related to resilience metrics and performance reporting are rapidly evolving. Many more utilities will be filing resilience plans and plan updates in the near future. Further guidance on resilience metrics and performance reporting could specify how to calculate and report resilience metrics that (1) measure impact of resilience programs and (2) effectively benchmark performance against a baseline by leveraging data that many utilities routinely collect through Outage Management Systems. Such guidance would address a key gap that states and utilities have identified in Berkeley Lab trainings and the external peer review process for this report.

6. References

Centerpoint (2024). System Resiliency Plan. https://interchange.puc.texas.gov/search/documents/?controlNumber=56548&itemNumber=2

Central Hudson (2023a). Climate Change Vulnerability Study. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b9083CC8A-0000-C237-8C20-372E1BF8AA27%7d

Central Hudson (2023b). Climate Change Resilience Plan. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7bA0A9F38B-0000-C413-A90B-C446A75DC3C0%7d

City of Seattle (2023). Climate Vulnerability Assessment. https://seattle.gov/documents/departments/opcd/seattleplan/seattleclimatevulnerabilityassessmentjuly2023.pdf

Cohen, Li (2024). Smokehouse Creek Fire, second-largest in U.S. history, merges with another to stretch across huge swath of Texas Panhandle. https://www.cbsnews.com/news/smokehouse-creek-fire-texas-panhandle-second-largest-state-history

Con Edison (2023a). Climate Change Vulnerability Study. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b40F8BC8A-0000-C237-B92D-FF39630B3E8D%7d

Con Edison (2023b). Climate Change Resilience Plan. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7bC05CF38B-0000-CC16-ABC2-A376526F5B14%7d

Consumers Energy (2023). Electric Distribution Infrastructure Investment Plan (2024-2028). https://mi-psc.my.site.com/sfc/servlet.shepherd/version/download/0688y00000A3A9WAAV

De Martini, Paul, Lorenzo Kristov, and Lisa C. Schwartz (ed.) (2015). Distribution Systems in a High Distributed Energy Resources Future. https://emp.lbl.gov/publications/distribution-systems-high-distributed

De Martini et al. (2022). Integrated Resilient Distribution Planning. https://gridarchitecture.pnnl.gov/media/advanced/Integrated_Resilient_Distibution_Planning.pdf

DTE Electric (2023). 2023 Distribution Grid Plan. https://mi-psc.my.site.com/sfc/servlet.shepherd/version/download/0688y00000A4YUXAA3

Duke Energy (2022). Storm Protection Plan. https://www.floridapsc.com/library/filings/2022/11327-2022/11327-2022.pdf

Duke Energy Carolinas (2022). Climate Risk and Resilience Study. https://www.duke-energy.com/-/media/pdfs/our-company/carolinasresiliencetransmissiondistributionstudy.pdf?rev=0c58199ed32d466d89795a3bf2dc353b

Entergy New Orleans (2023). System Resiliency and Storm Hardening Plan. https://cdn.entergy.com/userfiles/content/future/ENO-resilience-filing-4-17-2023.pdf

Eto et al. (2020). Grid Modernization: Metrics Analysis (GMLC1.1) Reliability. https://gmlc.doe.gov/sites/default/files/2021-08/GMLC1.1_Vol2_Reliability.pdf

Eversource (2024). Electric Sector Modernization Plan. https://www.eversource.com/content/docs/default-source/default-document-library/eversource-esmp%20.pdf

Florida Power & Light (2022). Storm Protection Plan 2023-2032. https://www.floridapsc.com/library/filings/2022/11240-2022/11240-2022.pdf

Florida Public Utilities (2022). Storm Protection Plan 2022–2031. https://www.floridapsc.com/library/filings/2022/11316-2022/11316-2022.pdf

Halper, Evan (2024). Amid explosive demand, America is running out of power. https://www.washingtonpost.com/business/2024/03/07/ai-data-centers-power

Hawaiian Electric Company, Maui Electric Company, and Hawaiʻi Electric Light Company (2020). Resilience Working Group Report for Integrated Grid Planning. https://www.hawaiianelectric.com/a/7883

Homer, Juliet S., Jennie S. Rice, Kendall Mongird, and Kostantinos Oikonomou (2021). Coordination and Planning for Water and Power System Resilience. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-31880.pdf

Idaho Power (2023). 2024 Wildfire Mitigation Plan. https://docs.idahopower.com/pdfs/Safety/WildfireMitigationPlan.pdf

Indiana Michigan Power (2023). Michigan Five-year Distribution Plan 2023-2027. https://mi-psc.my.site.com/sfc/servlet.shepherd/version/download/0688y00000A4XSxAAN

Kearney, Laila, Seher Dareen, and Deep Kaushik Vakil (2024). US electric utilities brace for surge in power demand from data centers. https://www.reuters.com/business/energy/us-electric-utilities-brace-surge-power-demand-data-centers-2024-04-10

Larsen, Peter H. (2016). A Method to Estimate the Costs and Benefits of Undergrounding Electricity Transmission and Distribution lines. https://eta-publications.lbl.gov/sites/default/files/lbnl-1006394_pre-publication.pdf

NASA (2024). NASA Analysis Confirms 2023 as Warmest Year on Record. https://www.nasa.gov/news-release/nasa-analysis-confirms-2023-as-warmest-year-on-record

NASEO (2021). Electricity-Water Critical Infrastructure Interdependencies: How States Can Enhance Resilience and Reduce Risks. https://naseo.org/data/sites/1/documents/publications/NASEO%20Electricity-Water%20Critical%20Infrastructure%20Interdependencies%20December%202021%20FINAL.pdf

NASEO and Berkeley Lab (2023). State Energy Offices' Engagement in Electric Distribution Planning to Meet State Policy Goals. https://naseo.org/Data/Sites/1/documents/tk-news/naseo_electric-distribution-planning-final.pdf

National Grid (2023a). Climate Change Vulnerability Study. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7bD001CD8A-0000-CC39-BDF3-FE8300353FF9%7d

National Grid (2023b). Climate Change Resilience Plan. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b107AF38B-0000-C79C-90B4-B7A8DDC4B15E%7d

National Grid (2024). Future Grid Plan. https://www.nationalgridus.com/media/pdfs/our-company/massachusetts-grid-modernization/future-grid-full-plan.pdf

NOAA (2024). Billion-Dollar Weather and Climate Disasters (as of January 9, 2024). https://www.ncei.noaa.gov/access/billions/state-summary/US

NERC (2013). Reliability Terminology. https://www.nerc.com/AboutNERC/Documents/Terms%20AUG13.pdf

NERC (2015). Standard CIP-014-2 – Physical Security. https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-014-2.pdf

NV Energy (2023a). 2024 Triennial Natural Disaster Protection Plan Part 1. https://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2020_THRU_PRESENT/2023-3/24369.pdf

NV Energy (2023b). 2024 Triennial Natural Disaster Protection Plan Part 2. https://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2020_THRU_PRESENT/2023-3/24370.pdf

NYSEG (2023). Climate Change Resilience Plan. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7bD030F38B-0000-C116-9CC6-FE546E842502%7d

Oncor (2024). System Resiliency Plan. https://interchange.puc.texas.gov/search/documents/?controlNumber=56545&itemNumber=3

Orange & Rockland (2023a). Climate Change Vulnerability Study. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b8046BD8A-0000-C81D-9CA2-5E1857AF2CFD%7d

Orange & Rockland (2023b). Climate Change Resilience Plan. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b00C7F38B-0000-C913-BC7A-2E9ADAC51421%7d

Oregon Seismic Safety Policy Advisory Commission (2013). The Oregon Resilience Plan: Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami. https://www.oregon.gov/oem/documents/oregon_resilience_plan_final.pdf

Pacific Power (2023). Oregon Wildfire Mitigation Plan. https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/wildfire-mitigation/PacifiCorp_2024_WMP_12-29-23.pdf

Portland General Electric (2023). 2024 Wildfire Mitigation Plan. https://edocs.puc.state.or.us/efdocs/HAQ/um2208haq325939023.pdf

PG&E (2024a). 2023-2025 Wildfire Mitigation Plan R4. https://www.pge.com/assets/pge/docs/outages-and-safety/outage-preparedness-and-support/pge-wmp-r4-010824.pdf

PG&E (2024b). Climate Adaptation and Vulnerability Assessment. https://www.pge.com/tariffs/assets/pdf/adviceletter/GAS_4914-G.pdf

PNNL (2022). Considerations for Resilience Guidelines for Clean Energy Plans. https://edocs.puc.state.or.us/efdocs/HAH/um2225hah113046.pdf

PNNL (2023). Emerging Best Practices for Electric Utility Planning with Climate Variability. https://www.pnnl.gov/sites/3efault/files/media/file/Final%20Report%206_7_2023.pdf

PNNL et al. (2023). Enhancing Resilience in Buildings through Energy Efficiency. https://www.energycodes.gov/sites/default/files/2023-07/Efficiency_for_Building_Resilience_PNNL-32727_Rev1.pdf

Presidential Policy Directive (2013). Critical Infrastructure Security and Resilience. https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil

PSE&G (2018). Energy Strong II Program Filing. https://s24.q4cdn.com/601515617/files/doc_downloads/energy_strong/2018-06-08_-_Energy_Strong_II_-_Filing.pdf

RG&E and NYSEG (2023). Climate Change Vulnerability Study. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7bE015BE8A-0000-C315-BFDF-32186365C7B0%7d

RG&E (2023). Climate Change Resilience Plan. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b7034F38B-0000-C01D-813A-A73CEBB821BA%7d

Rocky Mountain Power (2023). Utah Wildfire Mitigation Plan. https://pscdocs.utah.gov/electric/23docs/2303544/329969UTWldfrMtgtnPln202320259-25-2023.pdf

Sandia National Laboratories (2023). Sandia's Resilient Node Cluster Analysis Tool (ReNCAT). https://energy.sandia.gov/download-sandias-resilient-node-cluster-analysis-tool-rencat

Skaggs, Richard, and Kathy Hibbard (n.d.). Climate and Energy-Water-Land System Interactions: Technical Report to the U.S. Department of Energy in Support of the National Climate Assessment https://climatemodeling.science.energy.gov/system/files/private/publications/attachments/PNNL-21185.pdf

Southern California Edison (2021). Climate Adaptation Community Engagement Plan. https://www.sce.com/sites/default/files/custom-files/R1804019-SCE%20Community%20Engagement%20Plan.pdf

Southern California Edison (2022). Climate Change Vulnerability Assessment. https://edisonintl.sharepoint.com/:b:/t/Public/TM2/EY7Wy9MCrcVGl7XKg_tczQoBM0k8RKtJhwvWlf6qxlJvbg?e=ptXS0i

Southern California Edison (2023). 2023-2025 Wildfire Mitigation Plan. https://www.sce.com/sites/default/files/AEM/Wildfire%20Mitigation%20Plan/2023-2025/2023-10-26_SCE_2023_WMP_R1.pdf

SDG&E (2023). 2023-2025 Wildfire Mitigation Plan. https://www.sdge.com/sites/default/files/regulatory/2023-2025%20SDGE%20WMP%20with%20Attachments_Errata_10-23-23.pdf

Svitek, P. (2022). Texas puts final estimate of winter storm death toll at 246. https://www.texastribune.org/2022/01/02/texas-winter-storm-final-death-toll-246/

Tampa Electric (2022). 2022–2031 Storm Protection Plan. https://www.floridapsc.com/library/filings/2022/11038-2022/11038-2022.pdf

Unitil (2024). Electric Sector Modernization Plan. https://unitil.com/sites/default/files/2024-01/Unitil-ESMP-2025-2050-DPU-FINAL.pdf

Xcel Energy (2022). Distribution System Plan. http://www.dora.state.co.us/pls/efi/efi.show_document?p_dms_document_id=971602&p_session_id=

Xcel Energy (2023). Phase II Distribution System Plan Report. http://www.dora.state.co.us/pls/efi/efi.show_document?p_dms_document_id=1004191&p_session_id=