NARUC
National Association of Regulatory Utility Commissioners

Energy Resilience Reference Guide

Chapter Three: Climate Resilience Strategies for Regulators

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Introduction to NARUC Energy Resilience Reference Guide

The NARUC Energy Resilience Reference Guide is envisioned as a one-stop primer for state public utility commissions (PUCs) to assist in the development of a shared language, valuation framework, and educational tool on the topic of energy resilience. The resilience of the energy system has increasingly become part of commissions' regulatory scope so informed decisions are made regarding how to best enhance system resilience. Several states have already established evaluative resilience criteria (via legislative statute or regulatory directive). This guide is intended to succinctly summarize many of the critical topic areas within energy resilience and to facilitate adoption of resilience valuation frameworks by which PUCs can weigh investment decisions regarding energy system resiliency. This guide is intended to encourage state public utility commissions to develop their own definitional frameworks that align with existing resources and to provide topical information related to enhancing system resilience to extreme weather, cyber-attacks, a changing energy landscape and other threats to critical infrastructure. This guide will also assist in continual assessment of new policies and regulations that seek to enhance energy system resilience.

This primer attempts to synthesize key takeaways on energy resilience topics. Individual chapters will highlight emerging best practices on a variety of topics, profile individual state efforts at enhancing system resilience, solicit contributions from subject matter experts, and summarize key regulatory considerations for energy system resilience.

The objective of this third chapter of the NARUC Resilience Reference Guide is to highlight key themes and regulatory considerations for addressing energy system resilience for specific climate-related threats. Content in this chapter includes general information on climate resilience modeling, climate security planning, investment opportunities, and regulatory mandates around climate resilience. The chapter details specific state case studies for various hazard adaptation strategies that are climate-informed, including a review of equity-informed hazard adaptation strategy for historically disadvantaged communities bearing the brunt of climate change hazards.

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Chapter 3: Climate Resilience Strategies for Regulators

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The previous chapter of the Energy Resilience Reference Guide detailed how state commissions might adopt or adapt a framework by which to incorporate and appropriately evaluate energy resilience investments into the utility systems they regulate. This chapter builds on those concepts to more exclusively focus on resilience investments, strategies, and processes that address and mitigate the impacts from climate-related threats.

This chapter serves as a reference guide for state utility regulators to quickly familiarize themselves with climate resilience terminology, emerging challenges with the clean energy transition, and regulatory considerations for enhancing resilience to climate-related threats.

Climate resilient utility system investments are not exclusive to mitigating impacts from extreme weather. Chronic stressors like longer-duration heating or cooling seasons and increased flooding risk areas will have tangible impacts on utility planning and operations, particularly on future load forecasting. State public utility regulators are tasked with assessing regulated utility's proposed investments and may also require utilities to specifically file climate-related threat mitigation or adaptation plans.

For clarification, here are brief definitions of "mitigation" and "adaptation".

1. Mitigation, in a climate context, is the reduction of emissions and stabilizing the levels of heat-trapping greenhouse gases into the atmosphere.
2. Adaptation, in a climate context, is changing how or when a process is conducted in light of previously unexperienced environmental conditions in given geography.

Each state has unique energy resilience needs based on several key indicators including, but not limited to, risks to energy systems, state-level adaptation planning policies, robustness of state energy resilience planning, resource diversity mix, and identified system performance metrics. Implicit in this characterization is that climate threats differ across state jurisdictions and regulated utilities service territory based on a variety of complex climate inputs – geography, weather, temperature levels, flooding zones, etc.

A joint report from Sandia National Laboratories and Synapse Energy Economics (Synapse) notes that "the probability of recurrence and severity for some climate threat types, such as those exacerbated by climate change, like hurricanes and forest fires, is increasing. As a result, historical probabilities may not accurately predict future probabilities."[1] State utility regulators should be keenly aware of what impacts current and future climate conditions may have on utility operations to best adjudicate state policy objectives and utility investment strategies to moderate the impacts of climate change.

Additionally, many states are grappling with state decarbonization mandates for the electricity sector to alleviate potential future climate shocks.[2] President Biden's Executive Order 14057 requires the federal government to use 100 percent carbon pollution-free electricity by 2035.[3] State PUCs are working to integrate large amounts of distributed energy resources (DERs) and other clean energy sources into regulated utility system planning and operations. State utility regulators are closely following the variability of these new renewable resources and balancing the need to ensure the continued reliability of the power system. While this chapter is not directly focused on the clean energy transition or related challenges with intermittent DERs, the context for climate-related impacts on a more distributed system as well as reliability considerations in a climate-resilient system are important considerations for state utility regulators.

Ultimately, state utility regulators are tasked with approving a utility's investments and strategies to mitigate the impacts of climate change. These resilience investment decisions require an understanding of two complex inputs: 1) the direct and indirect costs of a long-duration outage in the absence of the investment; and 2) the potential benefits of the infrastructure investment. A climate resilience framework or model can better quantify those two complex inputs so regulators can better weigh utility investment decisions and achieve the outcome of a more resilient energy system in an increased climate-related threat environment. Recognizing that exiting reliability metrics like SAIDI/SAIFI capture shorter duration interruptions of service, this chapter discussion/criteria will be focused on more high-impact, low frequency events (HILF). However, these criteria are incredibly difficult to ascertain when considering climate data inputs because of the infrequency and unpredictability of extreme weather events.

This chapter is organized into two distinct 'Pillars' to describe some of the challenges with adapting to a climate resilient power system.

1. Climate Related-Threat Assessments
2. Climate-Related Threat Adaptation Strategies

A third Pillar on 'Climate Resilience Preparedness' will be developed in the coming year with the introduction of a tool to assist regulators with assessing the maturity of a regulated utility's resilience posture and investment strategy.

There are many interconnected state policies that address climate resilience, but this guide specifically is targeted for an audience of public utility commissioners and commission staff. The types of resources and hazard adaptation strategies outlined here will closely reflect existing PUC activity on these subjects or highlight publicly available tools that could be adopted for utility climate threat assessment modeling.

How to Read an Action

Action at a Glance
Readers can begin reading here, where a brief overview of the action is provided.

Themes Addressed
(5) consistent themes relevant to the particular action. See next page for *Themed Addressed Legend*

Continued Action Items
This section further elaborates on the topic or provides specific details.

Why/How?
This section provides context for the action's origins or purpose.

Themes Addressed

Graphic	Theme	Description
	**Risk Assessment**	This theme testifies to the power of risk assessment in energy resilience and extreme weather preparedness.
	**Extreme Weather Preparation**	This theme demonstrates practical measures for readying the state against severe weather conditions.
	**Innovative Technology**	As technology develops in the energy sector, this theme utilizes innovative technology to achieve energy resilience goals.
	**Legislative Actions**	This theme illustrates the role of legislation is effective energy resilience policies, for both democratic and effective results.
	**Interagency Collaboration**	This theme exemplifies the power of collaboration across agencies, to leverage resources and achieve common goals.

I. PILLAR ONE – Climate-Related Threat Assessments

To effectively navigate the complexities of climate change, some public utility commissions are requiring regulated utilities to include data-driven, analytical approaches for assessments of climate-related threats in their filings. This approach involves evaluating, modeling, and forecasting the threats posed by climate change to utility infrastructure and the communities they serve. Many utility companies and state PUC expertise typically does not extend to the computing of complex weather inputs or climate-related threats.

The inclusion of climate vulnerability assessments and climate mapping into these utility justifications for rate cases or other commission proceedings is becoming an increasingly common practice. Utilities in New York and California are required by commission order to file climate vulnerability assessments that particularly account for impacts to energy justice communities. The Pacific Northwest National Laboratory compiled a list of states (Figure 1.) with climate-planning related requirements.

Figure 1. List of State Requirements for Climate-Related Processes[4]

Climate-Related Process	California	Connecticut	D.C.	Florida	Hawaii	Louisiana	Maryland	Massachusetts	Michigan	Nevada	New Hampshire	New York	New Jersey	North Carolina	Oklahoma	Oregon	Pennsylvania	Rhode Island	Texas	Utah	Washington
State-level planning requirements																					
Requirement for climate vulnerability assessment and mitigation plans	•											•									
Requirement for storm management plans				•																	
Requirement for wildfire mitigation plan[1]	•									•						•				•	o
Requirement to consider climate change in distribution system planning									o												
Settlement agreement requires climate vulnerability assessment														•							
Resilience actions tied to cost recovery																					
Grid hardening or storm management actions tied to cost recovery surcharge		•	•		•	•	•	•			•		•	o	•		•	•	•		

• is used to indicate the statutory or legislative requirement exists, or utilities voluntarily developed the plans indicated.
o is used to indicate that dockets are open in which the objective would apply.
[1]States apply several names, e.g., resource protection plans, but wildfire mitigation is a major part of such alternative plans.

By integrating climate data and projections into resilience planning, PUCs can enhance their ability to prioritize resources, and thoroughly evaluate the potential impacts of climate change on utility infrastructure, operations, and service reliability.

Many utility companies and state PUC expertise typically does not extend to the computing of complex weather inputs or climate-related threats. States like California, Michigan, New York, Louisiana, and Texas have required or are considering incentives for regulated utilities to leverage advanced climate modeling techniques and better understand their vulnerabilities (see Table 1). Utilities and state PUCs have utilized outside consultant assistance to conduct these types of assessments where that expertise does not exist within their own organizations.

Table 1: Sample of State Requirements for Climate Vulnerability Assessments

State	Proceeding	Description
California	R1804019 (2018) Rulemaking on Climate Change Adaptation: - Decision 20-08-046 on Disadvantaged Vulnerable Communities and Utility Vulnerability Assessments - CPUC Guidance: Phase 1 Topics 1 &2 / Phase 1 Topics 4&5	The California Public Utilities Commission (CPUC) requires investor-owned utilities to file climate adaptation and vulnerability assessments with particular attention to climate impacts in historically disadvantaged communities.
Michigan	Case No. U-20464-0063 - Final Report - Michigan Statewide Energy Assessment	In response to a request from Governor Whitmer to review state energy emergency preparedness, the Michigan Public Service Commission opened this case to evaluate whether the electric distribution system is designed to account for changing climate conditions and extreme weather events. The resulting report developed into several proceedings under the auspice of the Michigan Statewide Energy Assessment.
New York	22-00184 Proceeding on Motion of the Commission Concerning Electric Utility Climate Vulnerability Studies and Plans - 13-00197: Filing 625 Order Adopting Storm Hardening and Resiliency Collaborative Phase Three Report Subject to Modifications - ConEdison 2019 Climate Vulnerability Study	In 2022, Governor Hochul signed into law an act requiring utility corporations to submit a climate vulnerability study to evaluate each electric corporation's infrastructure exposure to climate risks. The act also requires each utility to file a subsequent climate vulnerability and resiliency plan to address the results and conclusions of the study.

Louisiana	R-36227: Draft Proposed Rule Regarding Electric Utility Grid Resilience Plans *NOTE: Draft rulemaking	Louisiana Public Service Commission staff proposed rulemaking on requiring electric utilities to file a 'Grid Resilience Plan' with the commission that contain an all-hazard risk assessment, including climate risks.
Texas	Case 53401-39 - House Bill 2555	In the aftermath of Winter Storm Uri – February 2021, the Public Utility Commission of Texas (PUCT) required development of robust weather emergency preparedness reliability standards to ensure continued reliable operations in extreme weather conditions. The Texas legislature subsequently passed a law requiring electric utilities to file a 'resiliency plan' with the PUCT that addresses at least one of climate-related threats.

The key components of a data driven, analytical approach include climate-related threat identification, exposure assessment, vulnerability analysis, and risk evaluation. Through scenario-based projections and probabilistic assessments, public utility commissions can prioritize investments and infrastructure improvements to effectively allocate resources and minimize potential disruptions. The results from the methodologies involved in threat assessments provide PUCs with informed insight for regulatory oversight to ensure the provision of reliable service.

There are other resources and tools that are publicly available or in development that state PUCs may consider, in close collaboration with regulated utilities, to ensure those threats are adequately identified so they can be addressed. Incorporating climate data into utility system planning and analysis allows public utility commissions to gain critical insights into the potential impacts of climate change on critical infrastructure and empower public utility commissions to make informed decisions and develop robust adaptation strategies. Additionally, many of these climate vulnerability assessments can be layered into energy justice mapping tools to better direct investments and system upgrades to historically disadvantaged communities.

The CPUC has required their utilities to include an iteration of climate vulnerability mapping as one of their ten categories of potential adaptation strategies included as a guideline for their utilities' required Wildfire Mitigation Plans.[5] In California, utilities are also required to specifically consider climate impacts on historically disadvantaged communities in their system planning and investment strategies.

Following the theme of risk-specific plans, that incorporate a climate vulnerability, Florida Public Service Commission, requires utilities to develop and implement storm protection plans (SPPs) to evaluate the ability of the electric grid to withstand and recover from hurricanes and tropical storms.[6] These approaches to planning, strategically including climate change address cost recovery concerns and forecast priority investments.

State Profile: Michigan Public Service Commission's Michigan Statewide Energy Assessment

(See next page)

Actions Commissions Can Take:
MPSC's Michigan Statewide Energy Assessment

Action At Glance:

The Michigan Public Service Commission (MPSC) in 2019 issued the "Michigan Statewide Energy Assessment", to assess risks during disruptive outage events. The report contains a thorough risk and vulnerabilities assessment for the Michigan electricity grid.

Why?

The report was prompted by the January 2019 Polar Vortex 19, or PV19, wherein the extreme cold and a subsequent natural gas facility fire caused unprecedented stress on both electricity and natural gas deployment statewide. In response, Governor Whitmer issued Executive Order 2019-06, asking MPSC to evaluate the adequacy of electric, natural gas, and propane delivery systems during extreme weather events.

The Assessment Includes:

- asset performance and conditions,
- capital investments,
- operations and maintenance,
- clean energy requirements and drivers,
- aging distribution infrastructure,
- supply and operations
- considerations across seasons,
- natural gas and electric coordination
- local geographic nuances,
- electric distribution risk- based planning models,
- changing consumer behavior and technological adoption,
- Forecasting challenges,
- MPSC closing recommendations given the aforementioned challenges

Themes Addressed

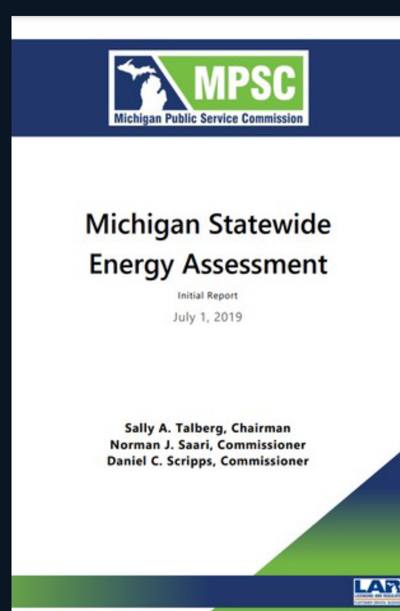
Legislative Actions

Risk Assessment

On Asset conditions and performance,

MPSC identifies extreme wind and/or ice as the most detrimental climate impacts for its regulated utility electric distribution systems.

Tree trimming and line clearance operations and upgrading equipment in accordance with National Electrical Safety Code design requirements are identified mitigation strategies. MPSC warns that as the energy market shifts towards newer renewable energy, companies may not update nonrenewable energy plants equipment. Outdated equipment yields higher outage rates, particularly since aging plants may have a limited resiliency budget if the plant is on route to retirement.



In addition to specific investigatory proceedings to address climate-related threats, public utility commissions in states with an Integrated Resource Planning (IRPs) or integrated distribution system planning (IDSP) process as a state regulatory planning framework may consider specifically calling out climate vulnerability assessments as integral to utility system planning.

Climate Data and Mapping Tools

This section will briefly summarize aspects of the existing climate impact modeling and vulnerability assessments tools that are currently available in the public sphere (see Table 2). It is important to note that these tools are not 100% accurate, particularly with regards to predicting singular extreme event days. However, general trends observed in climate data are relevant for utility system planning and should be considered. Consistent trends like higher temperatures or wetter conditions can impact future load forecasts as well as inform opportunities to prioritize consequence-based resilience investments. This type of information can be extrapolated from climate data inputs when utilized by utility system planners.

Current commonly utilized threat-based risk assessments directly tie probability and/or deterministic methodologies to inform resilience and reliability planning in an uncertain, but somewhat predictable future. Climate risks are inherently unpredictable. Any resilience value for high-impact, low frequency (HILF) events associated with changing weather patterns and other natural hazards, require careful tracking of new forms of data and metrics. Regulators and utilities must ask themselves the following questions when considering any specific investment or adaptation strategy:

- Does the cost of this investment outweigh the societal and/or specific grid benefit?
- Is the next best alternative a better value for the cost-benefit calculus?

Utility system planners considering climate vulnerability assessments should be aware that climate data is typically gathered and analyzed as a large-scale model dealing with global impacts. Any helpful analysis for state or utility service territory impacts will require a 'downscaling' of existing climate models to translate large-scale general circulation models (GCMs) into more localized results.[7] Downscaling allows scientists, regulators, and utility system planners to understand how climate change will impact local and regional climates. As noted in a recent report from Pacific Northwest National Laboratory on 'Emerging Best Practices for Electric Utility Planning with Climate Variability: A Resource for Utilities and Regulators' "downscaling GCMs can be time consuming and expensive. For this reason, utilities often team up with regional organizations and university partners to perform downscaling or otherwise apply GCM data to their service territory".[8] PUCs or utilities considering climate vulnerability assessment requirements might consider partnering with national laboratories, universities, or other third-party experts to conduct these types of assessments.

Several institutions have highly advanced modeling capabilities that commissions might consider encouraging or requiring their utilities to utilize in developing their own threat-based risk assessments. State resilience initiatives often involve examining risks and potential impacts of man-made and natural hazards to identify which investments will have the largest impact on either protecting or more aptly responding to climate vulnerabilities, usually based on a wide range of scenarios. The Department of Energy has also developed Energy Risk Profiles for each U.S. state and FEMA Region that offers insights into the energy infrastructure landscape, potential energy system disruptions, and the impact and frequency of those disruptions.[9]

Table 2: Sample of Publicly Available Climate Modeling Tools*

Organization/Tool(s)	Description
National Oceanic and Atmospheric Administration **U.S. Climate Resilience Toolkit** **Climate Mapping for Resilience and Adaptation (CMRA) tool**	As previously discussed in Chapter 2, the U.S. Climate Resilience Toolkit attempts to collate several interagency efforts across the federal government's array of scientific institutions to deliver a highly localized climate mapping tool. Synchronized with NOAA's current weather forecasting capabilities, the tool can provide immediate information on predicted weather impacts for the based on the last 30 days of available data. [10]
Argonne National Laboratory's Center for Climate Resilience and Decision Science **Climate Risk & Resilience Portal (ClimRR)**	Argonne National Laboratory's Climate Risk & Resilience Portal (ClimRR) is a tool to simulate future climate conditions at mid- and end-of-century for a range of climate threats. ClimRR provides free access to peer-reviewed climate datasets for climate vulnerability analysis. Some layers in the climate mapping portal allow for various equity-related criteria to overlay climate risks with census tract data on demographics, housing, income, and a community resilience challenge index.
Pacific Northwest National Laboratory (PNNL) **Climate Research Portal**	PNNL has made public their research into climate science including available datasets, models, and various publications. Users can also contact relevant PNNL staff for specific interests across drought research, hydropower modeling, water management, and Western U.S. climate simulations.
U.S. Environmental Protection Agency (EPA) **Climate Change Adaptation Resource Center (ARC-X)**	EPA has several tools primarily geared towards assessing climate risks to water utilities with their climate vulnerability assessments and adaptation strategies. For example, CREAT is a tool that specifically assists water sector utilities in assessing climate-related risks to utility assets and operations.

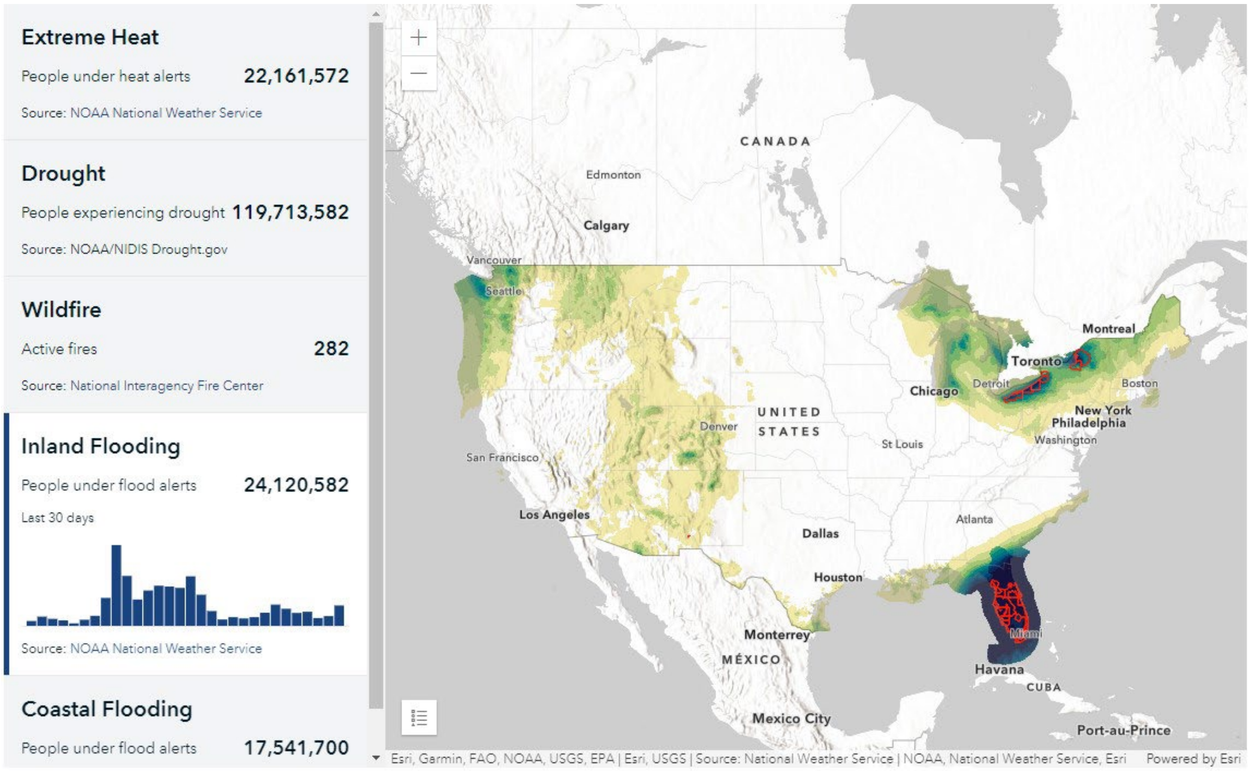
Climate Resilience Evaluation and Awareness Tool (CREAT): Risk Assessment Application for Water Utilities **Vulnerability Self-Assessment Tool:** Water or Wastewater Utility Risk Assessment	The ARC-X tool is a comprehensive interactive tool to help state and local governments effectively deliver services to communities even as the climate changes. Information in the toolkit contains risk assessments for climate-related threats, relevant adaptation strategies, and case studies illustrating how states and communities have successfully adapted to those risks.
Federal Emergency Management Agency (FEMA) **Risk Mapping, Assessment, and Planning (Risk MAP)**	FEMA has several tools available to accurately map flooding risk in the United States. The Risk MAP process is a framework by which to evaluate flood risk and associated costs due to flooding. FEMA's publicly available tools could be utilized to map potential flooding risk for a utility's assets.
Cal-Adapt	While the mapping and datasets are specific to California, the Cal-Adapt tool provides the public, researchers, government agencies, and industry stakeholders with essential data and tools for climate adaptation planning, building resiliency, and fostering community engagement. Cal-Adapt is funded by the California Energy Commission and California Strategic Growth Council to provide publicly available datasets and climate mapping capabilities.

***NOTE: This list is not intended to be an exhaustive list of publicly available tools.**

U.S. Climate Resilience Toolkit

As previously discussed in Chapter 2, the U.S. Climate Resilience Toolkit attempts to collate several interagency efforts across the federal government's array of scientific institutions to deliver a highly localized climate mapping tool. Synchronized with NOAA's current weather forecasting capabilities, the tool can provide immediate information on predicted weather impacts for the based on the last 30 days of available data (Figure 3). [11]

Figure 3: Climate Mapping for Resilience and Adaptation in Real-Time

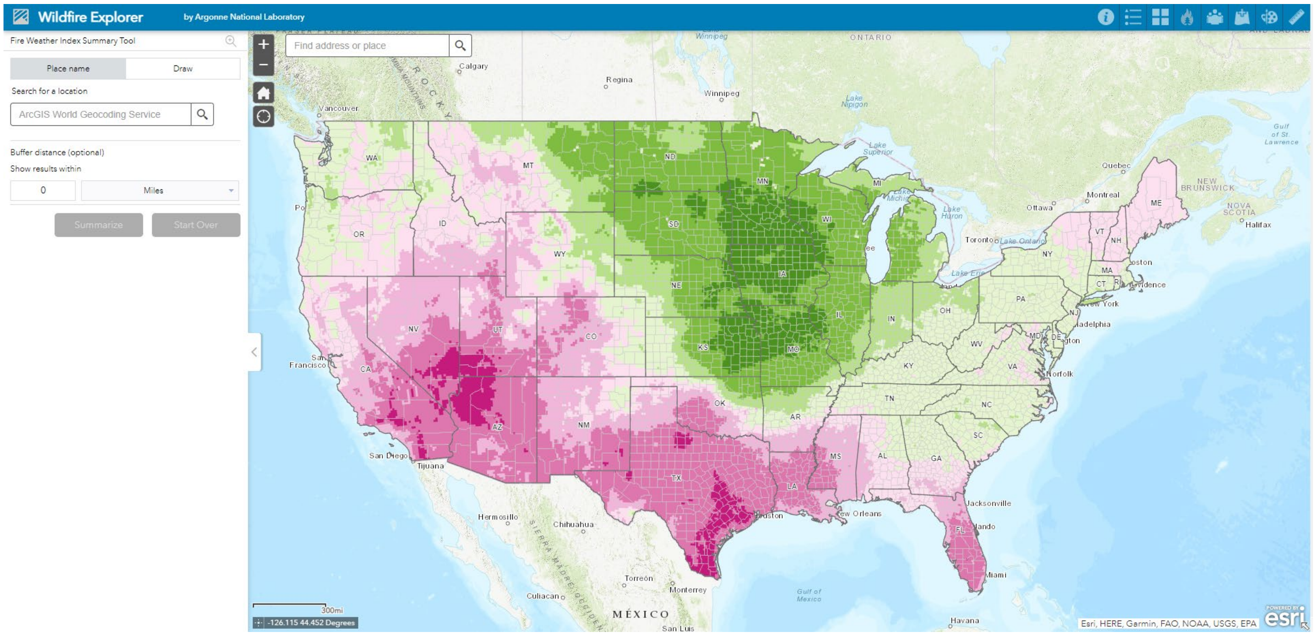


Snapshot of Inland Flooding alerts from September 26, 2022. Florida is receiving significant warnings based on approaching Hurricane Ian.

Argonne National Laboratory's Climate Risk and Resilience Portal (ClimRR)

Argonne National Laboratory has developed a similar mapping tool called ClimRR which simulates future climate conditions at mid- and end-of-century for a range of climate-related threats, including wildfire risk, precipitation amounts, expected wind, and temperature impacts. The tool also allows additional mapping layers for community impacts by layering in census tract data on demographics. The tool can also produce a 'resilience report' that summarizes impacts to critical infrastructure and community assets that give detailed vulnerability assessments.

Figure 4: Percent Change between Mid-Century and Historical Fire Weather Index Risk Average



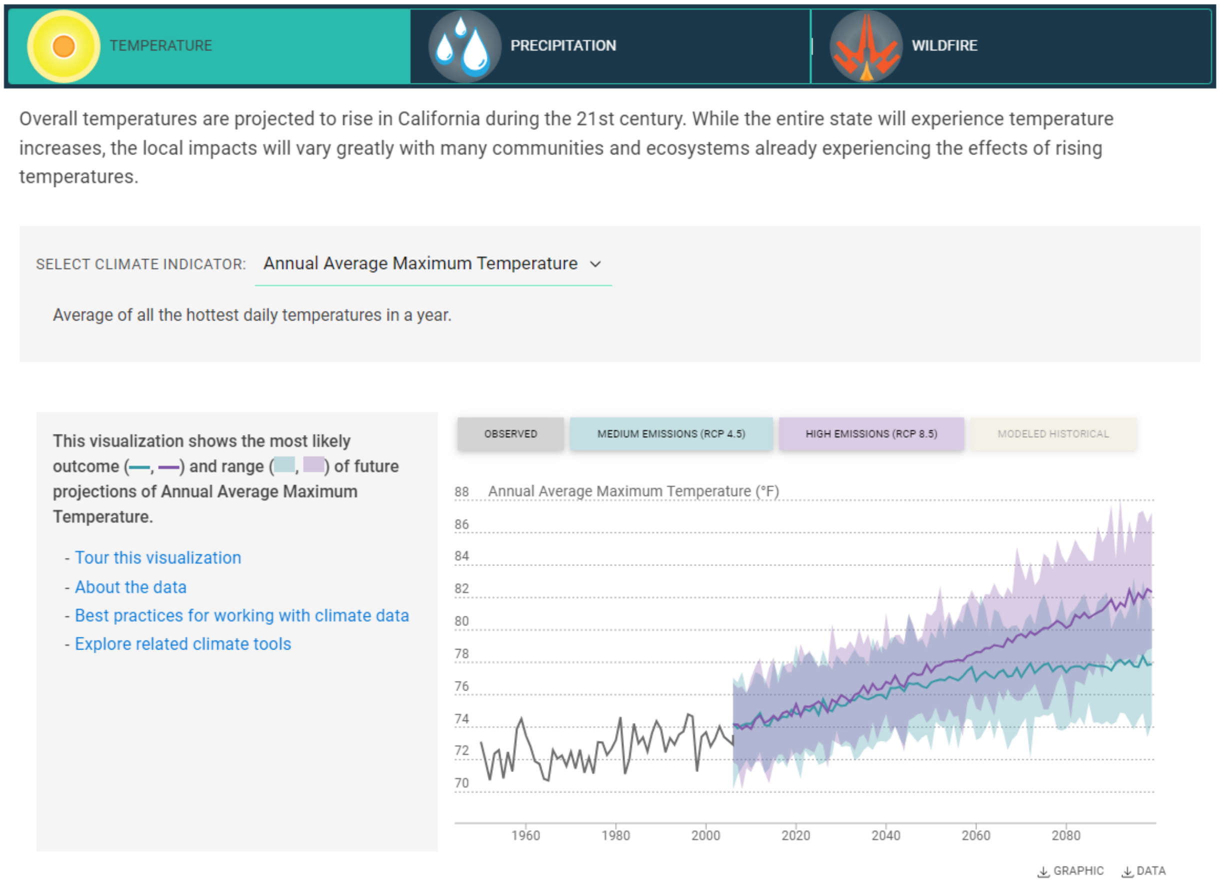
Snapshot of Fire Weather Index Summary tool from August 2023. The percent change in wildfire risk into the mid-century is mapped where the darker shades of red indicate higher risk areas and the shades of green are lower risk areas (see Figure 4).

Cal-Adapt – A State Approach to Climate Resilience

California state regulators required regulated utilities in the state to file climate vulnerability assessments for their utility operations. Utilities were directed to use the studies, models, data and tools from the most recent California Statewide Climate Change Assessment.[12] Data for these assessments is publicly available via an online web portal called Cal-Adapt which allows for granular downscale modeling of climate impacts to communities and infrastructure. Cal-Adapt is used as a central information sharing platform with climate data, models, and projections for California that are available and accessible across multiple industry sectors.

One aspect of the tool utilizes available climate data to project predicted average temperatures under a medium emissions and high emissions future (see Figure 5). In Los Angeles County, average annual maximum temperatures through mid-century and beyond are expected to rise. This has obvious implications for utility system planning with longer duration cooling seasons.

Figure 5: Snapshot of Projected Temperature Increase in Los Angeles County



Climate-Informed Resilience Strategies for Load Forecasting

When state regulators review a utility's proposed rate case filings involving resource procurement or other regulatory proceedings impacting resource adequacy, they are often tasked with analyzing whether a utility has sufficient resources to meet expected demand. This planning reserve margin metric for resource adequacy is informed by two primary inputs – **resources** and **load**. Of these inputs, there are several variables that can be considered (see Table 2). In an uncertain climate future, these secondary variables that inform both resources and load are both difficult to predict and difficult to incorporate into existing planning frameworks.

Climatologists and current observed trends in extreme weather and climate have indicated that these events are both increasing in frequency and severity. EPRI notes that the "uncertainty in future climate hazards, grid technologies, policies, populations, and societal response will require that we move beyond relying on a backward-looking approach to planning, as historical climate records are no longer as reliable at adequately representing future climate conditions"[13]. To date, regulators and utility planners have used historical conditions to characterize the current hazard landscape and inform the planning for utility system operations. But if those historical conditions are no longer reliable predictors of future climate conditions, “expected [climate] changes are likely to increase risk [to] infrastructure designs”. State regulators need a better valuation and analytical process to fully understand the impact from extreme weather events while enhancing the resilience of the power system against such threats to minimize damage costs, outages, and the often-disproportionate impact to historically disadvantaged communities.

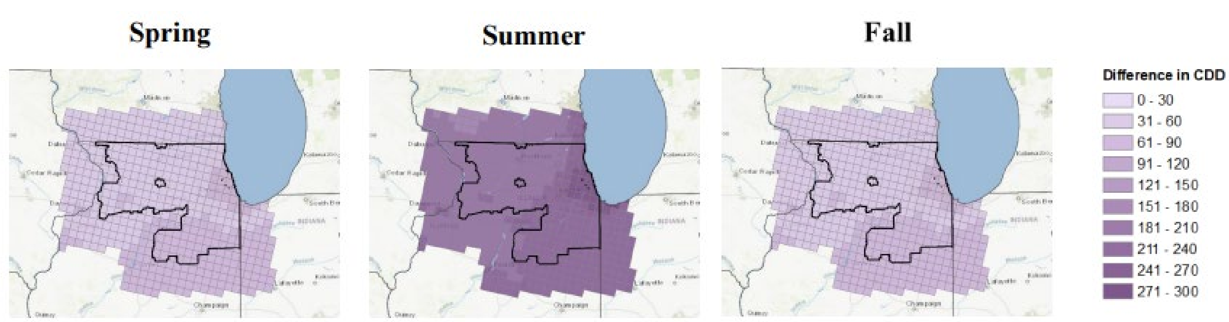
Table 2: Reserve Margin Inputs[14]

Primary Inputs	Additional Considerations	Description and Examples
Resources	Availability/Performance	Forced-outages; fuel supply (all resources); environmental policy restrictions (e.g., run time limitations); minimal operating reserves (NERC Standard)
	Imports/Exports	Imports with firm delivery contracts are usually treated the same as available resources within the area; firm exports committed to neighboring areas are subtracted from total resources
	Variability	Utility-scale wind and solar; run-of-river hydro (seasonal)
	Demand Response	Varying programs; controllable vs. non controllable; industrial customer contracts, limitations
	Deliverability	Transmission limitations; constraints; reactive-power limitations; under voltage load shedding; under frequency load shedding; protection devices
Load	Forecasting Models	Load forecasting error, weather uncertainty, extreme conditions (heat waves & polar vortex); coincident vs. non-coincident
	Distributed Resource (Behind-the-Meter) Impacts	Rooftop photovoltaic serves the end-use customer and reduces system load; impacted by cloud cover; customer must use on-site storage or utility supply after sunset
	Local Load Growth	Rapid commercial and industry growth (North Dakota oil sands, data centers)

In some instances, the utility has taken the initiative to conduct detailed climate vulnerability assessments for their service territories to better understand and predict expected hazards in future conditions. In Illinois, the utility ComEd study was produced with computational analysis and assistance from Argonne National Laboratory's Center for Climate Resilience and Decision Science (CCRDS) to better understand three primary climate inputs "of immediate interest to ComEd for infrastructure and operations planning: surface temperature, wind, and humidity (represented via heat index)".[15] Argonne's CCRDS projected future climate impacts for both medium-emissions and high-emissions climate scenarios for mid-century to better understand the range of possible outcomes. In their analysis, "ComEd's service territory are likely to be substantially warmer and more humid than historical (1995 – 2004) conditions".[16]

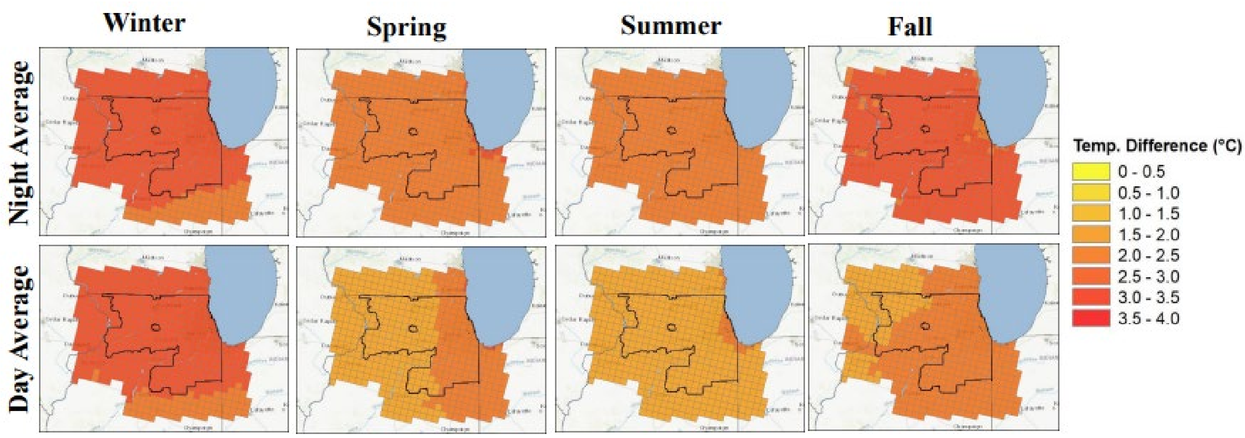
ComEd recognized that these hotter and wetter conditions would have dramatic impact on their future load forecasting. Hotter and more humid days increase demand for space cooling while simultaneously reducing the distribution capacity of power lines (See Figure 1). Additionally, higher temperatures create multiple stress points within the system with the potential to overheat lines and equipment and cause equipment to deteriorate and fail at greater rates (see Figure 2). [17] These identified impacts from future climate conditions have dramatic implications for ComEd's SAIDI reporting requirements where reliability may suffer absent specific climate-related investments to mitigate these hazards.

Figure 1: Change in the seasonal count of cooling degree days (CDD) between the baseline and mid-century periods. [18]



***NOTE: Maps in Figures 1 & 2 represent ComEd's service territory in Northern Illinois**

Figure 2: Change in the average seasonal daytime/nighttime maximum temperature between baseline and mid-century periods. [19]



What emerges from ComEd and Argonne's CCRDS's report is that climate impacts, while uncertain, have clearly defined trends that will impact reliability and service in the future. The shifts in load patterns from longer space cooling seasons and other related impacts to utility service have clear implications for utility resource procurement and planning. State regulators who adjudicate rate cases must make determinations about whether utility investment strategies are just and reasonable expenses for ratepayers.

Consequence Prioritization and Cost-Benefit Analysis in a Climate Resilience Context

Chapter 2 of this guide discusses how once a state PUC and its regulated utilities have identified the specific climate threats they face and the probable impact from those threats, they can begin to prioritize investments based on level of consequences. Consequence is essentially the "other half" of the simple risk equation (Risk = Probability x Consequence) . Regulators can look to changing probabilities of extreme events (the above section) and be explicit about decreasing the consequences (Chapter 2). Traditional cost-benefit analysis from both utilities and regulatory commissions will play into determining which consequences represent the greatest threat to system reliability and societal impact.

Consequence prioritization can help utilities understand and make informed decisions and develop appropriate resilience strategies. In a climate-resilience context, this includes evaluating specific climate risks to power generation and transmission, water supply and treatment facilities, communication networks, and other critical infrastructure.

By systematically assessing and prioritizing consequences, utilities can allocate investments and resources towards the most critical areas of concern. This includes weatherizing infrastructure upgrades, establishing redundancy measures, enhancing monitoring and early warning systems, developing emergency response plans, and integrating climate resilience into long-term planning. Consequence prioritization enables utilities to proactively address climate-related risks, minimize service disruptions, protect public safety, and enhance the overall resilience of utility systems in the face of evolving climate hazards.

II. PILLAR TWO: Climate-Related Threat Adaptation Strategies

There are various weather or climate-related threats that are intensified by climate change, that directly affect the utility sectors and authorities of which public utility commissions have jurisdiction. These threats include but are not limited to, hurricanes, floods, droughts, heatwaves, polar vortexes, wildfires, coastal erosion, and extreme shifts in precipitation patterns. In this section, we will explore five specific hazard adaptation strategies currently employed by either regulated utilities or via regulatory commission action that mobilize effective solutions to abate climate impacts.

Central to the discussion on climate resilience, climate change induces various threats that can lead to devastating consequences such as property loss, loss of life, disruption of essential services, and economic setbacks. Climate-related threat adaptation in the context of the electric power grid involves taking proactive measures to minimize vulnerability and increase the resilience of electric systems and critical infrastructure.

Following a robust analysis of threat-based risk assessments and prioritizing which consequences to take preemptive measures with, state resilience planners and utilities can agree to an adaptation strategy. This usually results in preventive policy measures and investments to minimize the frequency and consequences of significant disruptions, and not to mention, buy down risk. Throughout the process of determining an adaptation strategy, state PUCs and utilities should work closely with State Energy Offices and Governors Offices to determine the appropriate strategic approach to further prevent identified consequences.

States and utilities operate within limited financial constraints and investments in resilience measures reach a point of diminishing returns to value of dollars invested. State regulators are tasked with avoidance of ‘gold-plating’ the system (approving financially beneficial infrastructure investments above and beyond what is prudent) in their duty to set ‘just and reasonable’ rates through regulatory cost-recovery decisions. The alternative is that costs are borne by customers that are disproportionate to the benefits they provide.

Implementation of specific adaptation strategies should closely address the unique threat environment that a state or utility territory operates within. While some physical investments into improved reliability (i.e. vegetation management, replacement of aging infrastructure, automated distribution components, etc[20]) generally bolster resilience, a resilience valuation framework helps to prioritize those investments. Also recognizing that particular investments that have a low impact on addressing direct reliability, may improve those aforementioned low frequency, high impact events. State regulators, in conjunction with other key state agency stakeholders, are tasked with the final approval of those investments for cost-recovery and should endeavor to be intimately involved with the process by which those investments are justified. Many states have developed statewide climate or resilience plans that are a good starting point for a specific PUC climate resilience plan.

A. Enabling Microgrids Deployment to Minimize Critical Infrastructure Outages and Enhance Customer and System Resilience

NARUC and NASEO jointly manage the Microgrids State Working Group to improve the ability of states to plan for and develop microgrid projects, regulations, and policies.[21] Several reports including papers on valuing resilience, user objectives and design approaches, funding and financing options, and clean energy microgrids explain in greater detail state energy office and regulatory considerations for microgrids. The NASEO-NARUC Microgrids State Working Group is planning to publish a comprehensive framework for state microgrid policy, programmatic, and regulatory frameworks in 2023 that will assist states with supporting regulatory environments that support the deployment of microgrid technologies.

Microgrids provide resilience benefits by enhancing grid resilience, improving energy security, enabling rapid recovery and restoration, and offering flexibility and adaptability to changing energy landscapes. Their decentralized nature, diversified energy sources, and ability to operate independently from the main grid contribute to a more resilient and reliable energy infrastructure, ensuring the availability of power even in challenging circumstances.

Microgrids are combinations of generation, storage, load management, and advanced controls, representing novel areas for state PUCs to regulate. A paramount consideration for PUCs is safety of the electric distribution system with affordability, resource adequacy, and system reliability.

Enhanced Grid Resilience: Microgrids provide enhanced grid resilience by incorporating localized generation, energy storage, and intelligent control systems. In the event of a grid outage or natural disaster, microgrids have ‘islanding capabilities’ that can continue to supply reliable electricity to critical infrastructure, such as hospitals, emergency response centers, and community shelters. This capability helps minimize disruptions and enables faster recovery in affected areas.

Energy Security: Microgrids enhance energy security by reducing dependence on centralized power generation and transmission systems. They also can help states achieve their decarbonization policy goals by incorporating distributed energy resources like solar photovoltaic panels, wind turbines, or combined heat and power (CHP) units, microgrids diversify the energy sources and increase local control over energy supply.[22] This decreases vulnerability to external disruptions, such as fuel supply disruptions or cyber-attacks on centralized infrastructure.

Demand Response and Load Management: Microgrids enable effective demand response and load management strategies. By leveraging advanced monitoring and control systems, microgrids can optimize energy consumption patterns, balance supply and demand, and manage peak loads more efficiently. This capability allows for demand-side management, load shedding, and load shifting, contributing to overall grid stability and resilience.

Integration of Renewable Energy: Microgrids facilitate the integration of renewable energy sources into the energy mix. By coupling distributed generation from renewables with energy storage technologies, microgrids enable increased renewable energy penetration and reduce greenhouse gas emissions. This supports environmental sustainability goals while providing a reliable and resilient energy supply to connected communities.

Rapid Deployment and Scalability: Microgrids offer rapid deployment and scalability, making them suitable for disaster response and recovery efforts. Their modular design allows for quick installation and expansion, providing immediate access to electricity in emergency situations or remote areas. This flexibility enables targeted deployment and can facilitate the restoration of critical services in a timely manner.

These specific resilience benefits that enhance grid stability, promote energy security, and support efficient management of electricity supply make microgrids a particularly intriguing resilience investment strategy that state PUCs should consider.

California Public Utilities Commission in consultation with he California Energy Commission and California Independent System Operator, has undertaken a number of activities to develop policies related to microgrids under SB 1339, on leveraging implementing microgrids strategically, preventing the creation of large amounts of additional cost. For example, The Microgrid Incentive Program, funding for community, local and tribal government-driven, reliability and resilience projects.

Case Study: Hawaii Microgrid Services Tariff

The Hawaii Public Utilities Commission was tasked with developing a specific services tariff for microgrids by the Hawaii Legislature in 2018 - **Act 200 "Relating to Resiliency".** In 2018, the Hawaii Legislature passed Act 200 directing the Hawaii Public Utilities Commission (PUC) to establish a microgrids services tariff to encourage and facilitate the development and use of energy resilient microgrids.

(See next page)

Actions Commissions Can Take:
Hawaii Microgrid Services Tariff

Action at a Glance:

In 2018, the Hawaii Legislature passed Act 200 directing the Hawaii Public Utilities Commission (PUC) to establish a microgrids services tariff to encourage and facilitate the development and use of energy resilient microgrids. Priorities for the program include islanding of microgrids during extreme events and outages to improve grid resiliency, standardizing interconnection language to facilitate broader adoption of microgrids, and exploring multiple market opportunities for customers to pursue microgrid projects. The Hawaii PUC opened an investigatory docket (Docket No. 2018- 0163) to investigate establishment of a microgrid services tariff alongside prominent state IOUs.

Themes Addressed

Interagency Coordination

Risk Assessment

Legislative Actions

How?

The Hawaii PUC created two working groups: Market Facilitation and Interconnection Standards, with participants granted intervenor status. They addressed microgrid tariff language, DER programs, and new initiatives for microgrid development. Co-chaired by Hawaiian Electric and Consumer Advocacy, other intervenors and interested parties were included as working group members. In February 2020, the two working groups submitted their Phase 1 report, complying with Order No. 36514, outlining microgrid definitions within the tariff scope and initiating discussions on compensation for eligible microgrid projects.

The Results

In May 2021, the Hawaii PUC approved the microgrid services tariff for Hawaiian Electric Company, defining two types of microgrids: customer microgrid and hybrid microgrid. They also accepted a Microgrid Participants Bill of Rights submitted by the Division of Consumer Advocacy, providing protections for program participants. In April 2022, the PUC issued Order No. 38293, outlining priorities, and establishing the Working Group process for Phase 2, with the Phase 2 Working Group report expected in November 2022.

B. 'Tiger Dams' for Flood Mitigation and Control

Tiger Dams are a type of temporary flood control system designed to provide rapid response and protection against flooding. They are portable, flexible, and designed to be easily deployed and an effective solution in emergency flood situations.

A 'tiger dam' consists of a long, tubular, water-filled barriers made from high-strength geotextile materials, ranging from tens to hundreds of feet and can be interconnected to form continuous barriers of any desired length and can be stacked in multiple layers to increase the height of the barrier if necessary. Once in place, the tubes are filled with water, causing them to expand and create a solid barrier against flood waters. Like the widely used sandbag, the weight and stability anchors the barrier in place.

There are effective resilience benefits to deploying Tiger Dams in a flood control situation. Tiger Dams have the ability to conform to uneven terrain providing a flexible design to be configured in various ways, such as around utility substations, riverbanks, or commercial property. Due to their capabilities of being stacked upon one another, they adapt to the changing water levels. Tiger Dams are also reusable, reducing the concerns of not being as cost-effective as other flood control methods.

Although Tiger Dams are a specific, temporary solution for flood control, there are federal funding opportunities that can address that climate-hazard of flooding in the context of hazard adaptation and resiliency for critical infrastructure. Outlined in NARUC's *Guidebook for Federal Funding Opportunities: BIL, IRA, and Disaster Resilience*, you will find funding streams that can be applicable.

Case Study: Duke Energy's Tiger Dam Deployment in North Carolina

(See next page)

Actions Commissions Can Take: North Carolina's Tiger Dam Deployment for Flooding Risk

Action at a Glance:

Duke Energy, a major electric power holding company in the United States, in the state of North Carolina must routinely prepare for major hurricanes and tropical storms, such as Hurricanes Dorian, Matthew and Florence. Duke Energy has categorized precipitation-driven flooding due to extreme weather patterns as a significant risk to their operations. Many of Duke Energy's existing substations that are in identified flood zones are protected by permanent flood walls and temporary modular flood walls, Tiger Dams, in the event of an adverse weather event. The North Carolina Utilities Commission has approved these investments.

Themes Addressed

Extreme Weather Preparation

Innovative Technology

Why?

Tiger Dams are deployed around substations constructed before Duke Energy's Design Flood Elevation (DFE) Standard which requires equipment elevations at or above 100-year storms levels plus 2 feet, the 500- year flood level plus 1 foot or local ordinances, whichever is greater.

Ana Gibbs
@DE_AnaGibbs

.@DukeEnergy is proactively protecting its substations against floodwaters by using the Tiger Dam System. This substation is located just outside of Nichols, SC. These orange tubes are used to keep the water and the power on.

9:10 PM · Sep 16, 2018

C. Commission Approval of Vegetation Management Plans in Context of Wildfire Prevention

Wildfires are increasingly recognized as a climate hazard exacerbated by the effects of climate change. Wildfire occurrence have increased in frequency, intensity, and have resulted in altered vegetation patterns.[23] As temperature and precipitation patterns shift, new regions of the country might experience more favorable conditions for vegetation growth, which increase fuel availability and fire risk.[24]

Vegetation management, as it relates to wildfire prevention, is the strategic and deliberate management or removal of grasses, shrubs, and trees to restore and maintain ecosystems and limit the negative impacts of wildfires.[25] Controlled burning, fuel reduction (thinning), and forest management are among the many techniques of vegetation management, yet vegetation removal remains the most popular.

By integrating effective vegetation management into wildfire prevention or hazard adaptation strategies, utilities can strengthen community resilience to wildfires. Removing highly flammable vegetation located in critical areas reduces the likelihood of ignition and faster-paced wildfire spread. This practice is usually implemented along roadways, powerlines, critical infrastructure, and utility corridors to create fire breaks.[26] A robust utility plan for vegetation management will also mitigate outage impacts during summer or winter storms by reducing the amount of potential tree falls that knock down or damage power lines.

Case Study: Oregon Public Utilities Commission Wildfire Mitigation Plan Requirements

(See next page)

Actions Commissions Can Take: PGE's Advanced Wildfire Risk Reduction (AWRR) Program

Themes Addressed

Extreme Weather Preparation

Risk Assessment

Action at a Glance:

As a response to the Oregon Senate Bill 762 request for the Oregon Public Utility Commission to implement wildfire preparedness, Portland General Electric Company (PGE) introduced the 2022 Wildfire Mitigation Plan, featuring the Advanced Wildfire Risk Reduction (AWRR) program, alongside the Routine Vegetation Management program. AWRR primarily targets High Risk Fire Zones (HRFZs), conducting annual inspections, QA/QC measures, and communication with external entities. The program adheres to ORS 758.280-758.286 and employs insights from PGE's Wildfire Risk Assessment modeling to focus on targeted prevention and mitigation.

How?

PGE's Advanced Wildfire Risk Reduction (AWRR) program encompasses key components addressing HRFZs. The program conducts annual vegetation inspections for overhead lines in these zones, implementing quality assurance and quality control measures, while also collaborating with counties, municipalities, and external agencies. Additionally, the AWRR program actively pursues hardening specific lines within HRFZs to enhance resilience. It operates independently of routine vegetation management, prioritizing findings from PGE's Wildfire Risk Assessment modeling program to prompt informed decision-making. Furthermore, AWRR adheres to the operational framework of ORS 758.280-758.286 and ensures the removal of trees within striking distance of power lines, regardless of their health status, to bolster wildfire preparedness and safeguard against potential hazards.

PGE identifies three AWRR Mitigation strategies:

- Vegetation Inspection: PGE confirms clearance compliance and catches vegetation growth in between inspections, occurring annually outside of the three-year vegetation cycle.
- Cycle Buster Tree Trimming: PGE addresses "cycle -buster" vegetation through the AWRR program, occurring annually prior to fire season declaration.
- Enhanced Vegetation Management (EVM) Techniques: Annually, PGE prescribed these techniques for vegetation cases which exceed standard clearance procedures, such as greater clearances or partial to whole tree removal.

D. Developing Reliability Standards for Extreme Cold Weather & Related Winterization Efforts

Winterization is the process of preparing and protecting critical infrastructure, equipment, and systems to withstand the challenges posed by cold weather conditions. This is particularly important for utilities that provide essential services like electricity, natural gas, water, and telecommunications, as extreme cold can lead to equipment failures, service disruptions, and potential safety hazards. By minimizing these disruptions, the grid can maintain a more consistent power supply during cold weather.

Several commissions in the wake of recent extreme winter storm events opened investigatory dockets to assess the resilience of the electric grid to extreme cold conditions.[27][28][29] PUCs have a vital role in enforcing cold weather reliability standards and overseeing winterization efforts within the utility industry. PUCs might be tasked with establishing regulations and enforcing standards that a utility must adhere to for cold weather preparedness. A PUC will also approve a utility's winterization plans and investments. In the aftermath of Winter Storm Uri, the Governor of Texas charged the PUCT with developing winterization standards for regulated utilities in the state.

Case Study: Texas Winterization Standards in the Aftermath of Winter Storm Uri

(See next page)

Actions Commissions Can Take: Texas Winterization Standards in the Aftermath of Winter Storm Uri

Action at a Glance:

In 2021 the Texas legislature passed Senate Bill 3 which directed the Public Utility Commission of Texas (PUCT) to develop and enforce winterization standards for emergency preparedness. The PUCT adopted rules later that year that compels generator and utility compliance with winter weather readiness recommendations derived from a 2012 Quanta Report. [ii] These rules were subsequently updated the following year in 2022 to include new standards applicable during both summer and winter events. Failure to comply with these standards results in hefty fines levied by the PUCT.

Themes Addressed

Legislative Actions

Extreme Weather Preparation

Why?

Winter Storm Uri in 2021 triggered the worst energy infrastructure failure in Texas state history and nearly caused a complete catastrophic failure of the entire Electric Reliability Council of Texas (ERCOT) power grid. [i] The series of winter storms caused many billions of dollars in damages, millions of customer outages, and intense human suffering. The impact from one extreme weather event spurred multiple and ongoing efforts to address systemic climate risks in Texas, particularly threats from extreme cold weather.

Looking ahead:

The example of Texas in the wake of devastation caused by Winter Storm Uri reflects the realities of an uncertain future climate in Texas. Efforts to winterize assets are essential where climate uncertainties can cause freezing temperatures in regions that are not used to those extremes. Regulators have a responsibility to ensure safe and reliable utility service. The threat of grid failure from inadequately preparing for winter extremes should be an utmost consideration for state utility regulators. PUCs may consider developing their own winterization or related climate mitigation standards for generator, transmission, and/or distribution assets.

E. Equity-informed Climate Resilience Strategies at State PUCs

To address the needs of energy justice communities and promote equity in utility resilience investments, several state-level strategies have emerged. These strategies recognize the disproportionate impacts of climate change and utility disruptions on marginalized and low-income communities, aiming to ensure their inclusion and resilience in the energy sector.

States are implementing programs that provide targeted funding and incentives for utility resilience projects in energy justice communities. These initiatives prioritize investments in infrastructure, such as microgrids, renewable energy systems, and energy storage, to enhance resilience and reduce vulnerabilities. By leveraging data on socio-economic indicators, energy usage patterns, and environmental justice metrics, policymakers can prioritize resilience investments based on an accurate understanding of the communities most in need.

Another consideration for climate-informed resilience strategies is to actively engage community-based organizations and energy justice communities in decision-making processes related to utility system planning. Commissions are working to establish advisory boards or task forces composed of community representatives, utilities, and state representatives with the goal of fostering community-led investment prioritization.

State PUCs are revisiting their policies and regulations to remove barriers and promote equity, including developing intervenor compensation programs that encourage community-based organization participation in regulatory proceedings and implementing specific performance metrics to track progress in achieving energy justice goals.

Case Study: CPUC's Environmental and Social Justice Action Plan

(See next page)

Actions Commissions Can Take: CPUC's Environmental and Social Justice Action Plan

Action at a Glance:

CPUC's ESJ Action Plan will guide CPUC policy and programs addressing Disadvantaged communities, All Tribal lands, Low-income households, and Low- income census tracts.
Within the updated ESJ Version 2.0 goals is Goal 4: Increased Climate Resiliency in ESJ Communities.

Why?

Winter Storm Uri in 2021 triggered the worst energy infrastructure failure in Texas state history and nearly caused a complete catastrophic failure of the entire Electric Reliability Council of Texas (ERCOT) power grid. [i] The series of winter storms caused many billions of dollars in damages, millions of customer outages, and intense human suffering. The impact from one extreme weather event spurred multiple and ongoing efforts to address systemic climate risks in Texas, particularly threats from extreme cold weather.

Themes Addressed

Risk Assessment

Goal 4 Includes These Action Items:

1) Initiate Climate Change Adaptation Planning with Emphasis on Disadvantaged Vulnerable Communities

2) Consider Safety Policy Responses to Climate Change

3) Framework for Integrating Resiliency Planning and Evaluation into Current Grid Planning Policy

4) Propose new RAMP requirement in the SMAPOIR proceeding to address ESJ in the RAMP reports.

The tentative work plans, corresponding to the preceding action items, include:

1) CPUC clearly addressing the specific needs of disadvantaged and vulnerable communities in climate change adaptive planning through community engagement plans and climate change vulnerability assessments with community engagement

2) CPUC created a GIS visual tool to accessibly educate the public on climate change utility infrastructure impacts in both California largely and ESJ communities specifically.

3) CPUC standardizing definitions and measurements of resiliency and adaptive capacity by developing tools to guide resilience planning for energy providers.

4)CPUC requiring IOU's to identify and quantify the percentage of planned infrastructure mitigations occur within disadvantaged communities.

Questions Facing the Regulatory Community for Addressing Climate Resilience

- What stakeholders should be involved in setting objectives for climate resilience at the state level?
- How can stakeholder engagement strategies be equity-informed? How are climate-vulnerable communities assessed or mapped?
    - Are equity-informed resilience metrics being considered when evaluating cost-benefits methodologies?
- What type of specific climate threats to critical infrastructure exist in your state?
- How are you encouraging utilities to factor in climate change forecasts for your service area and consumer base into planning approaches for siting new assets?
- Have you determined as a commission which types of climate threats you want your utility to investigate?
- How can regulators measure preventative investments under consideration through a states' Energy Resilience Plan?
- What types of climate adaptation strategies and technologies does your state find the most effective? How did you determine that level of effectiveness?
- Can existing reliability metrics be adjusted or enhanced to improve system resilience?
- What type of new data requests are needed to make climate resilience investment decisions?

APPENDIX 1:

Additional considerations for Climate-Informed Resilience Strategies for Load Forecasting—

- Climate Migration
    - While utilities have always factored in anticipated changes in the size and type of customers served, some population dynamics experts are projecting a significant increase in climate change-driven relocations inside the US in coming years. Factors prompting moves include sea level rise in coastal areas, prolonged high heat events, wildfires, drought and repeated flooding.

      Arguably underway already, this phenomenon is poised to accelerate, with significant implications for utilities serving the communities that people to, as well as those they leave behind. It should be noted that only those with the resources to move will be able to move, leaving the disadvantaged disproportionately behind in more hazardous locations. See: https://projects.propublica.org/climate-migration/

Additional considerations for Climate-Related Threat Adaptation Strategies

- Public Power Safety Shutdowns
    - In the wake of the devastating Hawaiian Electric Company (HECO)-sparked fires in Lahaina, West Maui, Hawaii, and the discussions and lawsuits that followed, Public Safety Power Shutdowns (PSPS) are back in the spotlight. This consequence minimization technique was pioneered in California in response to the several deadly and costly wildfires that states have experienced over the past two decades, and the litigation that followed. Wildfire threats are rising and threaten the financial stability and even viability of the utilities they visit.

      As there's much more to wildfire defense than vegetation management, it's likely that in the near-midterm future more PUCs will explore the policy and technical actions (e.g., networks of pole-mounted weather sensors, grid segmentation, increased use of drones for situational awareness, etc.), necessary to get PSPS programs in place before their catastrophic fires arrive. With lessons learned from CPUC's experiences, educational outreach to their state's business and residential customers explaining why PSPS actions are sometimes necessary should accompany these activities.

- Planning for Extreme Heat Events and other Extreme Weather Events
    - A technical report produced by the Pacific Northwest National Laboratory (PNNL), intended to provide support to electric utilities and regulators for resilience plannings with best practices and examples of;
        - Utility forecasting
        - Resource planning
        - Contingency planning
        - Data development and Access
        - Pathways for decision making under deep uncertainty
        - Regulatory considerations
        - Coordination and cost-sharing approaches

        Report available here: https://www.osti.gov/biblio/1985294

- Electric System Hardening
    - Resilience has taken on a variety of definitions, and as we learned, implemented differently depending on numerous of factors. Universally, we understand that proactively taking steps to ensure that your most critical functions and the assets that enable them are able to withstand, "operate through," and rapidly recover from extreme weather events. This is often called "hardening," which sometimes literally means to make an asset stronger, for example, retrofitting a transformer to be able to withstand projectiles hitting it from storms at higher rates of speed than previously

specified. But also figuratively, as in undergrounding power lines in fire prone areas, or elevating substation equipment in case of flooding, or fireproofing distribution poles, or insulating previously uninsulated wires, or in a coastal location, building a barrier wall around a grid system to reduce the risk of inundation from storm surge.

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[1] Jennifer Kallay, Steve Letendre, Tim Woolf, Ben Havumaki, Shelley Kwok, Asa Hopkins, Robert Broderick, Robert Jeffers, Katherine Jones, Mercy DeMenno (2021) "Application of a Standard Approach to Benefit-Cost Analysis for Electric Grid Resilience Investments | Designing Resilient Communities: A Consequence-Based Approach for Grid Investment Report Series". Sandia National Laboratories. https://www.synapse-energy.com/sites/default/files/Standard_Approach_to_Benefit-Cost_Analysis_for__Electric_Grid_Resilience_Investments_19-007.pdf

[2] "Table of 100% Clean Energy States" (2023). Clean Energy States Alliance. https://www.cesa.org/projects/100-clean-energy-collaborative/guide/table-of-100-clean-energy-states/

[3] Executive Order No. 14057 "Executive Order on Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability" (December 08, 2021). The White House. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/

[4] Emerging Best Practices for Electric Utility Planning with Climate Variability: A Resource for Utilities and Regulators. May 2023. Pg. 45. https://www.pnnl.gov/sites/default/files/media/file/Final%20Report%206_7_2023.pdf

[5] 2022 Wildfire Mitigation Plan Guidelines Template, Attachment 2.7.3, p. 74 (accessed June 6, 2023): https://efiling.energysafety.ca.gov/eFiling/Getfile.aspx?fileid=51912&shareable=true

[6] Florida Public Service Commission (FPSC). 2018. Memorandum: Docket No. 20170215-EU – Review of Electric Utility Hurricane Preparedness and Restoration Actions. From Division of Engineering, Office of Industry Development, Office of Consumer Assistance & Outreach, Office of the General Council, to Braulio L. Baez, Executive Director. Tallahassee, FL.

[7] Emerging Best Practices for Electric Utility Planning with Climate Variability: A Resource for Utilities and Regulators. May 2023. Pg. 37. https://www.pnnl.gov/sites/default/files/media/file/Final%20Report%206_7_2023.pdf

[8] *Ibid*. Page. 33

[9] Department of Energy's Office of Cybersecurity, Energy Security, and Emergency Response (CESER). https://www.energy.gov/ceser/state-and-regional-energy-risk-profiles.

[10] National Oceanic and Atmospheric Administration, U.S. Climate Resilience Toolkit, https://toolkit.climate.gov/steps-to-resilience/steps-resilience-overview

[11] National Oceanic and Atmospheric Administration, U.S. Climate Resilience Toolkit, https://toolkit.climate.gov/steps-to-resilience/steps-resilience-overview

[12] California's Fourth Climate Change Assessment. State of California (2023). https://climateassessment.ca.gov/

[13] Electric Power Research Institute (EPRI): Climate READi Resilience and Adaptation Initiative. "Climate-Informed Planning and Adaptation for Power Sector Resilience" (May 2023). https://www.epri.com/research/programs/116584/results/3002026317

[14] National Association of Regulatory Utility Commissioners. "Resource Adequacy Primer for State Regulators (July 2021). https://pubs.naruc.org/pub/752088A2-1866-DAAC-99FB-6EB5FEA73042

[15] R. Burg, R. Kartheiser, M. Mondello, M. Blaise, M. Altinakar, J. Branham, C. Burdi, M. Cuadra, B. Gamelin, V.R. Kotamarthi, K.B Pfieffer, V. Ramalingam, A. Raffety, A. Ruiz, T.A. Wall, E. Yan. "ComEd Climate Risk and Adaptation Outlook, Phase 1: Temperature, Heat Index, and Average Wind" (November 2022). https://publications.anl.gov/anlpubs/2022/12/180058.pdf

[16] *Ibid*

[17] *Ibid*

[18] *Ibid*

[19] *Ibid*

[20] Lisa Schwartz. "Utility Investments in Resilience of Electric Systems: Report No. 11" Lawrence Berkeley National Lab. (April 2019). https://eta-publications.lbl.gov/sites/default/files/feur_11_resilience_final_20190401v2.pdf

[21] NASEO-NARUC Microgrids State Working Group. https://www.naseo.org/issues/electricity/microgrids

[22] Kirsten Verclas & Kelsey Jones. "Clean Energy Microgrids: Considerations for State Energy Offices and Public Utility Commissions to Increase Resilience, Reduce Emissions, and Improve Affordability" (May 2023). https://pubs.naruc.org/pub/87CE4278-F947-EB1E-8337-1DD6799E6A5C

[23] Heidari, Hadi; Arabi, Mazdak; Warziniack, Travis (August 2021). "Effects of Climate Change on Natural-Caused Fire Activity in Western U.S. National Forests".

[24] (n.d.). *How Does Wildfire Impact Wildlife and Forests?* U.S. Fish & Wildlife Service

[25] (n.d) *Fuels Management*. Department of Interior.

[26] U.S. Department of Agriculture, Forest Service. Confronting the Wildfire Crisis: Expanding Efforts to Deliver on the Wildfire Crisis Strategy. January 2023.

[27] Arkansas Public Service Commission. 2022. Docket No. 21-036-U. *In the Matter of an Investigation into the Operations, Procedures, and Performances of the Regulated Utilities During the Winter Weather Event February 2021*. https://apps.apsc.arkansas.gov/olsv2/docket_search_results.asp?casenumber=21-036-U

[28] South Carolina Public Service Commission. 2021. Docket No. 2021-66-A. *Motion to Solicit Comments from Utilities and Other Interested Stakeholders Regarding Measures to be Taken to Mitigate Impact of Threats to Safe and Reliable Utility Service.* https://dms.psc.sc.gov/Web/Dockets/Detail/117700

[29] North Carolina Utilities Commission. 2022. Docket No. M-100 Sub 163. *In the Matter of Investigation Regarding Ability of North Carolina Electricity, Natural Gas, Water, and Wastewater Systems to Operate Reliably During Extreme Cold Weather*. https://starw1.ncuc.gov/NCUC/PSC/DocketDetails.aspx?