NARUC
National Association of Regulatory Utility Commissioners

Energy Resilience Reference Guide

Chapter Two: Developing a Shared Framework to Value Resilience Investments

William McCurry & Elliott Nethercutt, NARUC
February 2023

U.S. DEPARTMENT OF ENERGY
Office of Cybersecurity, Energy Security, and Emergency Response

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Acknowledgments

The National Association of Regulatory Utility Commissioners (NARUC) wishes to thank the U.S. Department of Energy (DOE) Office of Cybersecurity, Energy Security and Emergency Response (CESER) for their generous support of this initiative under Award Number DE-CR0000009. In particular, Brandi Martin of DOE CESER, Megan Levy of DOE CESER, and Juan Gomez of DOE CESER have been key supporters of this effort, recognizing the unique role public utility commissions have to play in enhancing the resilience of critical energy infrastructure.

The authors would also like to thank Christian Pilarski, MPP Candidate ’23 at the University of Chicago’s Harris School of Public Policy for their various writing contributions. A special thanks to Andrew Bochman, Idaho National Laboratory and Tim Roxey, Eclectic Technologies for their contributions. Additional thanks to other NARUC staff and invited experts, for their review and comments to inform the best practices and key considerations contained within this reference guide.

Introduction to NARUC Resilience Reference Guide

The NARUC 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 resiliency. Several states have already established evaluative resilience criteria (via legislative statute or regulatory directive). This guide is intended to 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 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 second chapter of the NARUC Resilience Reference Guide is to highlight key themes pertaining to creating a value of resilience framework and share current efforts at the state-level at incorporating these frameworks into practice.

Table of Contents

Chapter 2: Developing a Shared Framework to Value Resilience Investments

Regulatory commissions in several states, along with other key state agency stakeholders have developed a shared framework to appropriately evaluate energy resilience investments into the utility systems they regulate. Working in close conjunction with regulated utilities, states could identify several different approaches to set specific energy resilience objectives to enhance system preparedness and reliability. A few of these approaches are summarized later in this chapter. This chapter focuses on what an energy resilience valuation framework is or could be and how state commissions and related state actors may appropriately value resilience investments. The chapter summarizes several leading metrics used currently to value energy resilience investments and track system performance over time. The intent of this chapter is to:

- Summarize key themes of current resilience frameworks;
- Facilitate robust sharing of approaches and frameworks for evaluating potential resilience investments; and
- Collate existing resilience valuation frameworks for consideration by state utility regulators to make informed decisions.

Similar to defining energy resilience, measuring resilience may also be a challenge. As noted by the Institute of Electrical and Electronics Engineers (IEEE), "it is not possible to have simple, industry-accepted resilience metrics addressing all possible events." [i] Therefore, adapting a framework to understand resilience, potential threats and hazards, and the metrics to measure resilience and the impacts of those threats and hazards can help regulators and utilities better plan and measure their path toward a more resilient system. [ii]

State PUCs generally have three types of authority when it comes to energy resilience:

1. Approving a regulated utility's investments into grid improvements via rate case filing for cost-recovery of various expenditures
2. Opening an investigatory docket or commission order to pursue energy resilience objectives (e.g., required filing of energy resilience plans, required utility assessment of vulnerabilities, data requests)
3. Establishing resiliency goals or targets for regulated utilities in the state

State policymakers and public utility commissions (PUCs) have considerable responsibility for implementing public and approving private investments for cost-recovery from ratepayers across the gas, water, electric, and telecommunication sectors. State utility regulators must carefully weigh the pros and cons of allowing utilities to develop resiliency improvements in their jurisdictions before determining whether they can recover funds from all ratepayers for these projects, particularly if those grid benefits are not universal to the system. Placing a value on grid resilience can aid in coordinating and prioritizing investments with the greatest benefit to ratepayers, taxpayers, and society at large. [iii]

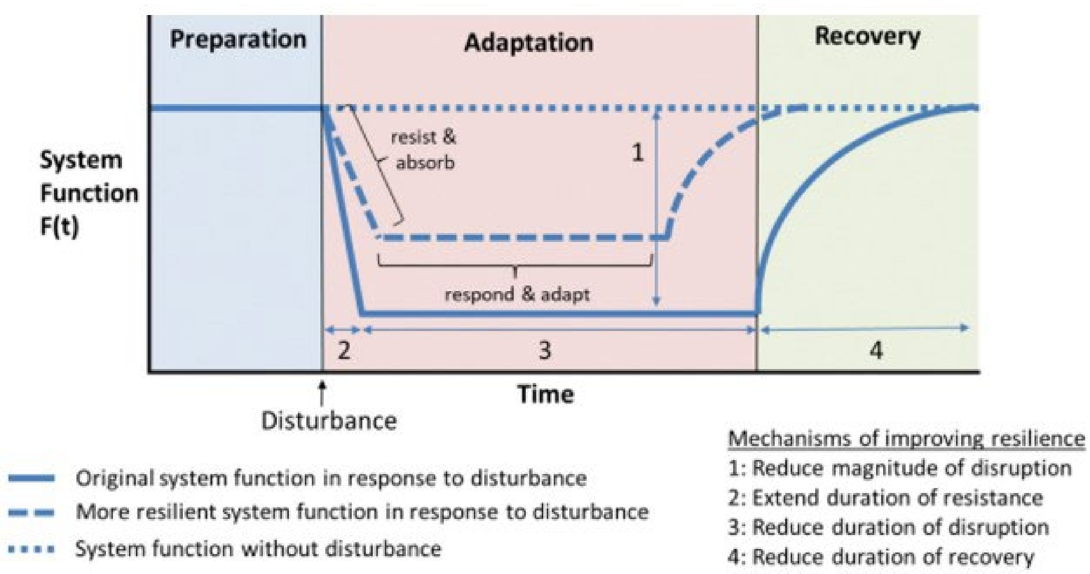
Each state has unique energy resilience needs based on several key indicators including, but not limited to, type of assessed risk to energy system, particular policies in place at the state-level for mitigation planning, robustness of state energy resilience planning to date, resource diversity mix, and identified system performance metrics. Several leading research institutions have developed recommendations for energy resilience frameworks and performance metrics that can be leveraged in state energy resilience planning, particularly around threat modeling, cost-benefit analysis of mitigation strategies, and ongoing performance assessment. These comparative measurements and metrics help inform regulators' understanding of different investment impacts in the system and allow for benchmarking of progress toward more resilient infrastructure systems. These inputs serve the broader objective of energy resilience planning and implementation that seek to ensure the energy system is better adapted to recover from extraordinary disruptive events.

What is a resilience valuation framework?

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 under consideration.

A resilience valuation framework attempts to quantify those two complex inputs to better weigh investment decisions and achieve the outcome of a more resilient energy system in an increased threat environment. Each state might have its own definition for energy resilience, but generally a more resilient energy system is one that can more rapidly recover from disruptive outages. Resilience assessment includes not only the analysis of potential disruptive events but also post-event analysis (e.g., recovery), covering the whole life cycle of a system.[iv] A frequently cited visualization of this objective is the 'resilience trapezoid' (**Figure 9**) that highlights the return to normal operations after a disturbance in a baseline system compared to a more resilient system.

Figure 9. Resilience Trapezoid [v]



States set energy resilience objectives through several different policy vehicles that may include an executive order from the governor's office, statutorily enforced rules and regulations passed by a state legislature, regulatory requirements from the state PUC, or voluntary benchmarking from a utility. Many states have created Chief Resilience Officer positions or dedicated state agencies to evaluate energy resilience criteria. Some states have programmatic funding and specific energy resilience interagency authorities, many of which are detailed in the National Association of State Energy Officials and National Governors Association's *State Governance, Planning, and Financing to Enhance Energy Resilience* report.[vi] This guide will primarily focus on authority granted to or implemented by the public utility commissions with some reference to specific state directives involving legislative or executive energy resilience policymaking.

Developing a state energy resilience framework requires input from diverse stakeholders including state government agencies, specific regulatory authorities, and the utility sector. However, the exact form that a state energy resilience framework takes is less important than each state recognizing that building a more resilient system is essential to ensuring reliable delivery of utility services in an increased threat environment. At a minimum, state PUCs or their designees should coordinate closely with other relevant state energy officials, key stakeholders in the utility sector, and executive leadership at governors' offices on energy resilience objectives. This convening of key energy stakeholders across sectors is instrumental to the success of a states' energy resilience framework.

State PUCs routinely require their regulated utilities to address reliability with detailed plans for critical infrastructure improvements. Resilience planning takes those considerations further by suggesting that reliability in an increased hazards environment requires even greater attention to system improvements. Both resilience and reliability planning "may apply a cost-benefit analysis in evaluating which investments to make — i.e., both have processes by which utilities and regulators determine the kind and degree of investments they are willing to pay for and both address how quickly electric service is restored."[vii] Whereas reliability planning uses measurements of past restoration performance (such as SAIDI and CAIDI – see Chapter 1: Developing a Shared Definition of Energy Resilience[1]), resilience planning for restoration encompasses a broader array of policy actions for system adaptability.

Regulators can direct their regulated utilities to respond to state policy objectives or open dockets to investigate possible improvements in responding to a specific energy resilience criterion. For example, the Organization of MISO States in a recent report completed in conjunction with Lawrence Berkeley National Laboratory suggests that within the context of increased extreme weather threats, "commissions may ask utilities whether they have determined the elevation of each of their substations in relation to various flooding events — e.g., 100-year, 250-year and 500-year floods"[viii]

Although many existing resilience frameworks have varying levels of detail, there are key overarching themes that are advocated in nearly all framework proposals. Energy resilience planning and implementation generally address the following broad stages:

1. Risk-based Threat Assessment
2. Consequence Prioritization and Cost-Benefit Analysis
3. Mitigation Strategy Implementation
4. Continual Assessment of Performance

---

[1] The two primary metrics to assess the frequency (SAIFI) and duration (SAIDI) of outages has also been trending upward (Figure 2). These two metrics are defined as:

- **SAIFI**: SAIFI: System Average Interruption Frequency Index. It is the number of non-momentary electric interruptions, per year, the average customer experienced.
- **SAIDI**: System Average Interruption Duration Index. It is the minutes of non-momentary electric interruptions, per year, the average customer experienced.

The U.S. Climate Resilience Toolkit summarizes these main action steps (albeit with five steps instead of four) in this easily followed chart (see **Figure 10**). Identifying threats and particular vulnerabilities, prioritizing the effects that could have the biggest impact, allocating resources to an efficient mitigation strategy, and continuously evaluating your performance at each stage of the process using carefully selected resilience metrics and indicators are the main action steps that follow the same general sequential process.

Figure 10: U.S. Climate Resilience Toolkit Framework [ix]

At each stage of this process, there are ample opportunities for continual assessment of system performance and reassessment of identified indicators and metrics to track system progress. A sample of available resilience-based performance metrics are referenced in greater detail below and the National Laboratories have ample resources directed to improve collection of those data and analyses (included as Appendix A).

Resilience Frameworks in Practice

Risk-based Threat Assessment

This section will briefly summarize aspects of the four-step energy resilience planning and mitigation strategy implementation continuum (identified above) with samples of existing proposed resilience frameworks. 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 vulnerabilities, usually based on a wide range of scenarios. This may be informed by an examination of data on the economic and societal impacts that resulted in interruptions to various utility services. The Department of Energy has also developed Energy Risk Profiles for each U.S. state and FEMA region that offers additional insights into the energy infrastructure landscape, potential energy system disruptions, and the impact and frequency of those disruptions.[x]

Threat-based risk assessments directly tie probability and/or deterministic methodologies to inform resilience and reliability planning in an uncertain, but somewhat predictable future. These assessments can be conducted in a variety of spaces but most commonly are broken down by climate risks, cyber risks, and physical risks that might cause extended outages of utility services. New requirements under the Bipartisan Infrastructure Law (BIL), also referred to as the Infrastructure Investment and Jobs Act (IIJA), oblige states to submit State Energy Security Plans (SESP) to receive federal financial assistance. The following guidance from the Department of Energy on SESP define the following terminology:

- **Risk Assessment of Energy Infrastructure**: Risk is defined as the potential for loss, damage, or destruction of key resources or energy system assets resulting from exposure to a threat. Risk assessments consider the consequence of an asset's loss, the vulnerability of an asset to specific threats, and the likelihood that an asset will be exposed to a specific threat. Certain energy infrastructure assets may be especially important to ensuring energy infrastructure continuity. Being able to identify the assets that are most critical to the infrastructure or that provide significant support to other critical infrastructure systems helps to determine overall risk and prioritize mitigation strategies more effectively.

- Threat information includes anything that can expose a vulnerability and damage, destroy, or disrupt energy systems, including natural, technological, manmade/physical, and cybersecurity hazards.

- Vulnerabilities are weaknesses within infrastructure, processes, and systems, or the degree of susceptibility to various threats. Vulnerabilities may be specific to the threat, energy type, and infrastructure component.

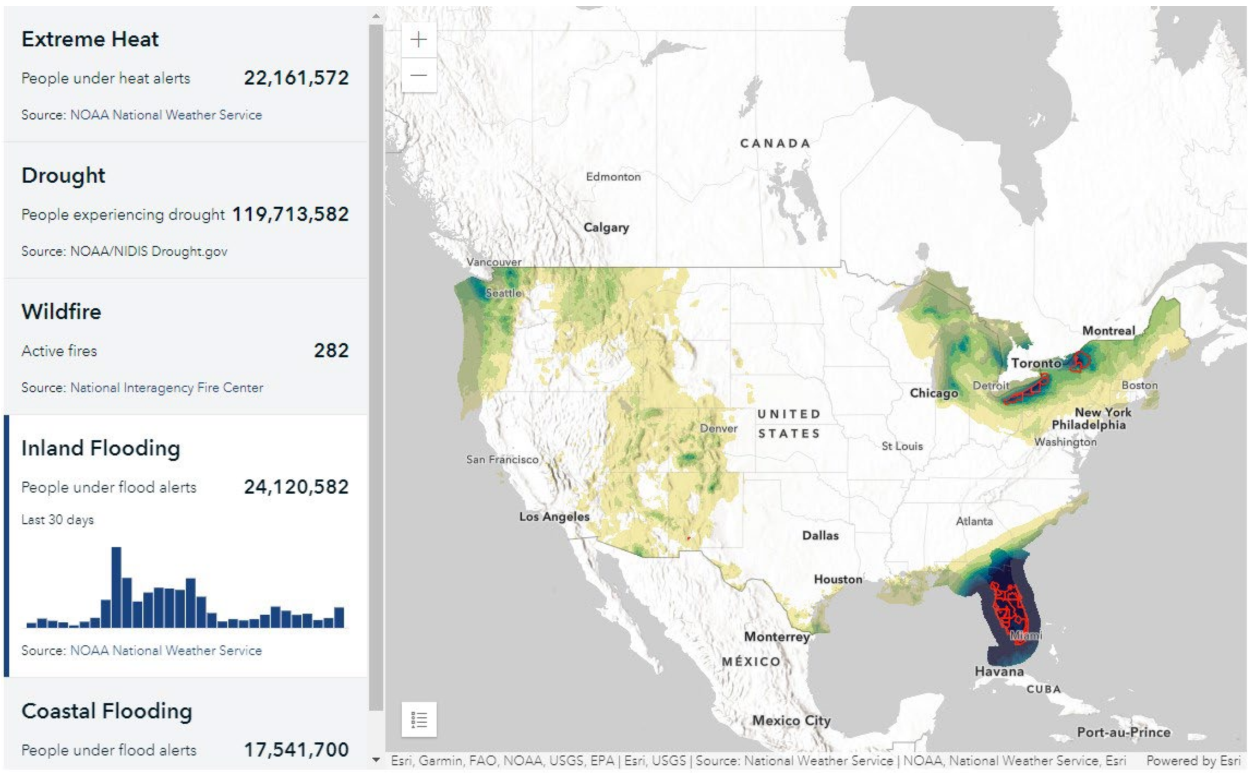
SESP are intended to provide a comprehensive threat assessment for critical energy infrastructure and are usually coordinated by State Energy Offices (SEO) and State Emergency Management Agencies. Information for can be drawn from several sources, including DOE state risk profiles, state hazard mitigation plans, state integrated resource plans, utility emergency plans, and after-action reports for previous incidents, and discussions with energy system operators and other stakeholders.[xi]

States and investor-owned utilities are expanding the time horizons to model system impacts from changing climate conditions. Although state PUC expertise typically does not extend to modeling of complex weather inputs or cybersecurity threats, state PUCs may work in close collaboration with regulated utilities to ensure those threats are adequately addressed. 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 (**Appendix A**).

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 based on the last 30 days of available data, a useful proxy for immediate emergency preparations during extreme weather events, prolonged heat waves, or extended rain events with flooding concerns. (**Figure 11**).

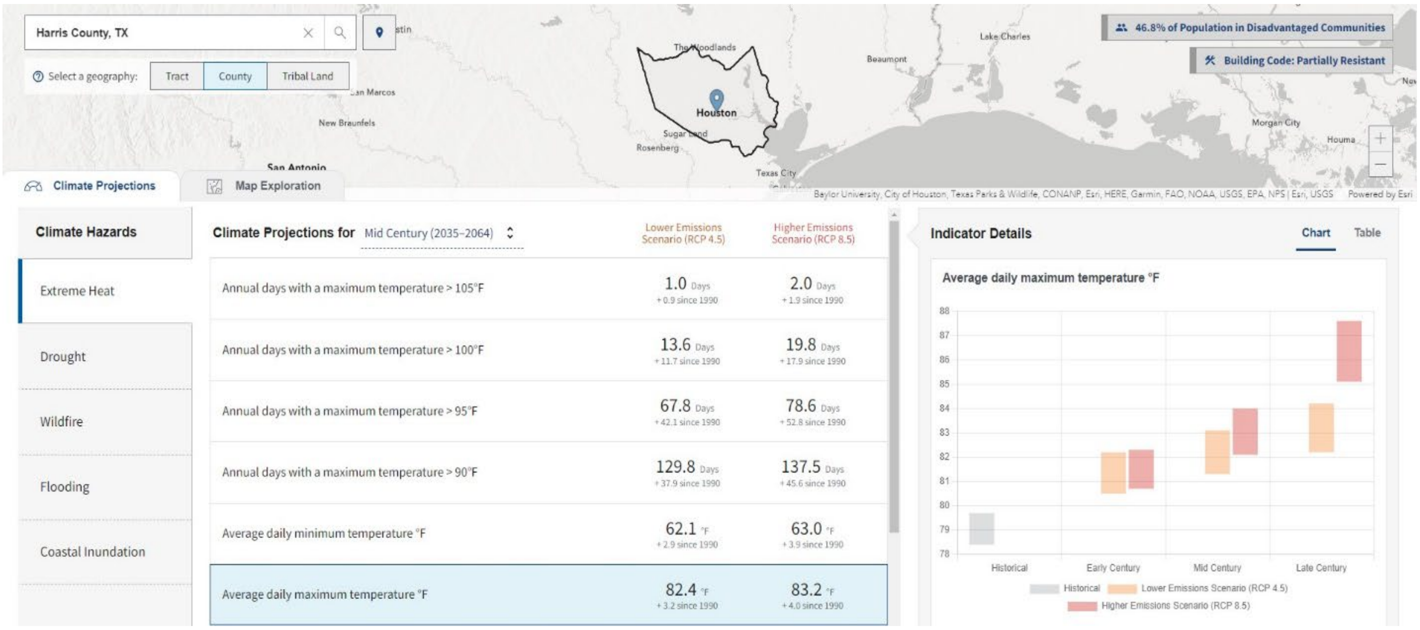
Figure 11: Climate Mapping for Resilience and Adaptation in Real-Time



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

Additionally, the tool allows for climate predictions on specific time horizons throughout the 21st century. The categories Extreme Heat; Drought; Wildfire; Flooding; and Coastal Inundation are each modeled. Narrowing in on a specific locale (Houston, Texas, chosen at random), the model can predict how many annual days are expected to be at a maximum temperature of over 100 degrees Fahrenheit compared to a baseline rate in 1990 (see **Figure 12**). This tool is representative of the type of analysis a utility might be expected to conduct and report to its state public utility commission as it makes investment decisions into enhancing grid reliability and resilience over time horizons that stretch into decades. Commissions might also reference these materials as one source to project the potential climate threats and impacts in the coming decades.

Figure 12: Climate Mapping for Resilience and Adaptation Climate Projections



Snapshot of climate projections for Houston, TX from September 26, 2022. Climate projections on the Climate Mapping for Resilience & Adaptation tool project to the end of this century.

Planning for resilience may identify opportunities for strategic infrastructure investment that is not identified during traditional reliability planning. As climate change impacts the increased frequency of extreme weather events, planning horizons for resilience may differ from traditional planning for reliability, which may not be adequate for the future threat environment. Events historically understood to occur once every 50 or 100 years may occur on a more regular basis (every 20 to 35 years for example), thus necessitating more frequent or different types of utility investments in maintenance and mitigation. For example, if a commission or its regulated utility decides to protect against a 500-year flood, it would identify critical infrastructure that would be submerged by a 500-year flood and may choose to elevate or move those components. Reliability planning, exclusive of a resilience component, may not address this question and, therefore, would not likely result in the same recommendation.[xii] While climate models may be an imperfect proxy to predict specific future weather conditions, there is a benefit for commissions to understand that extreme weather events are increasing in frequency, and utilities should be incentivized to incorporate climate vulnerabilities into their threat assessments. No model can predict a specific extreme weather event like a Winter Storm Uri but understanding that climate models are pointing to significant events happening with more regularity and intensity. These considerations should inform utility system planning and where appropriate, encourage regulated utilities to make investments to harden their system against climate impacts from the next big event.

Consequence Prioritization and Cost-Benefit Analysis

Once a state PUC and its regulated utilities have identified the specific types of threats they face and the probable impact from those threats, they can begin to prioritize investments based on level of consequences. Cost-benefit analysis plays into both determining which consequences represent the greatest threat to system reliability and societal impact but also in determining the type of mitigation strategy to pursue to rectify those consequences. In this section, several different existing frameworks are referenced to highlight how consequence prioritization and cost-benefit analysis of those impacts can be factored into a larger energy resilience framework.

Throughout the process of consequence prioritization, the interdependencies among critical infrastructure sectors should be considered. DOE and the Federal Emergency Management Agency provide detailed examples of interdependencies between disparate critical infrastructure sectors including water, electricity, natural gas, telecommunications, oil, and transportation. Disruption in one regulated sector may have far-reaching consequences throughout adjacent critical infrastructure sectors (see **Figure 13**). The Department of Energy's Office of Cybersecurity, Energy Security, and Emergency Response (CESER) has publicly available graphics that detail the interdependency links between the electric and natural gas sectors with other critical infrastructure sectors as part of its resources for SESP development.[xiii]

Figure 13: Examples of Interdependencies Between Critical Infrastructure Sectors and Electricity[xiv]

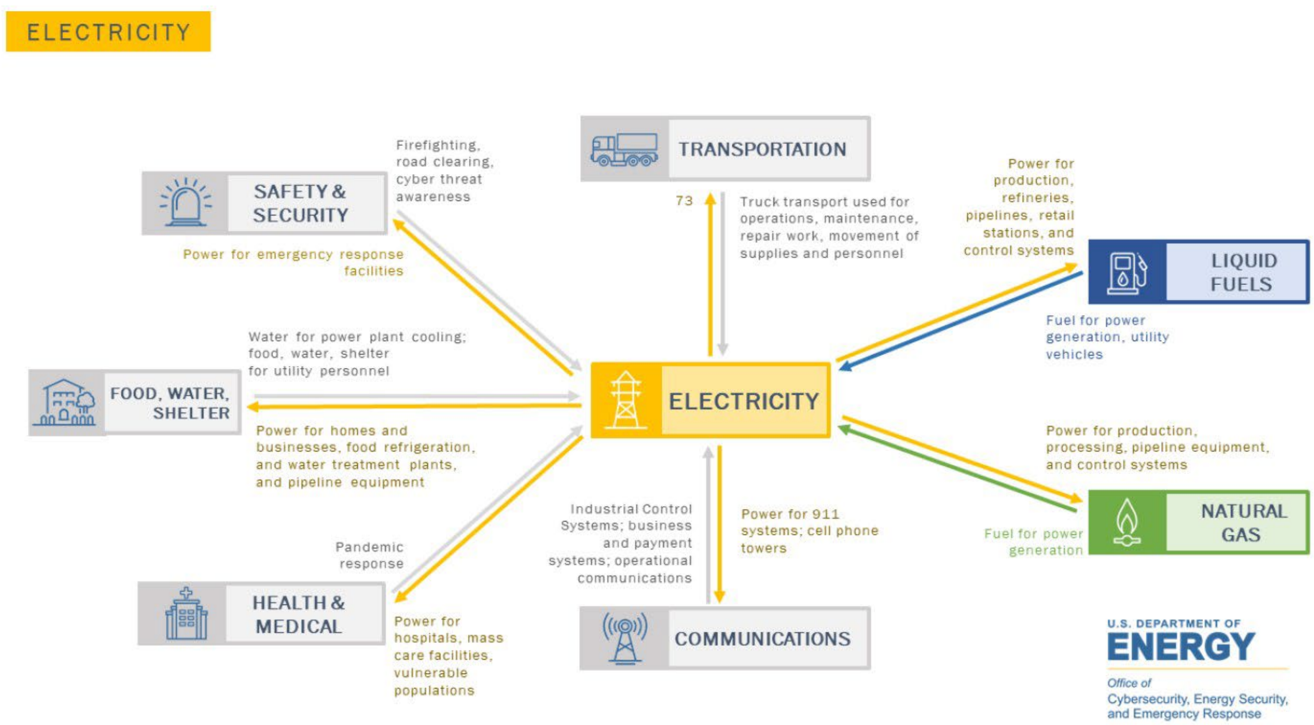
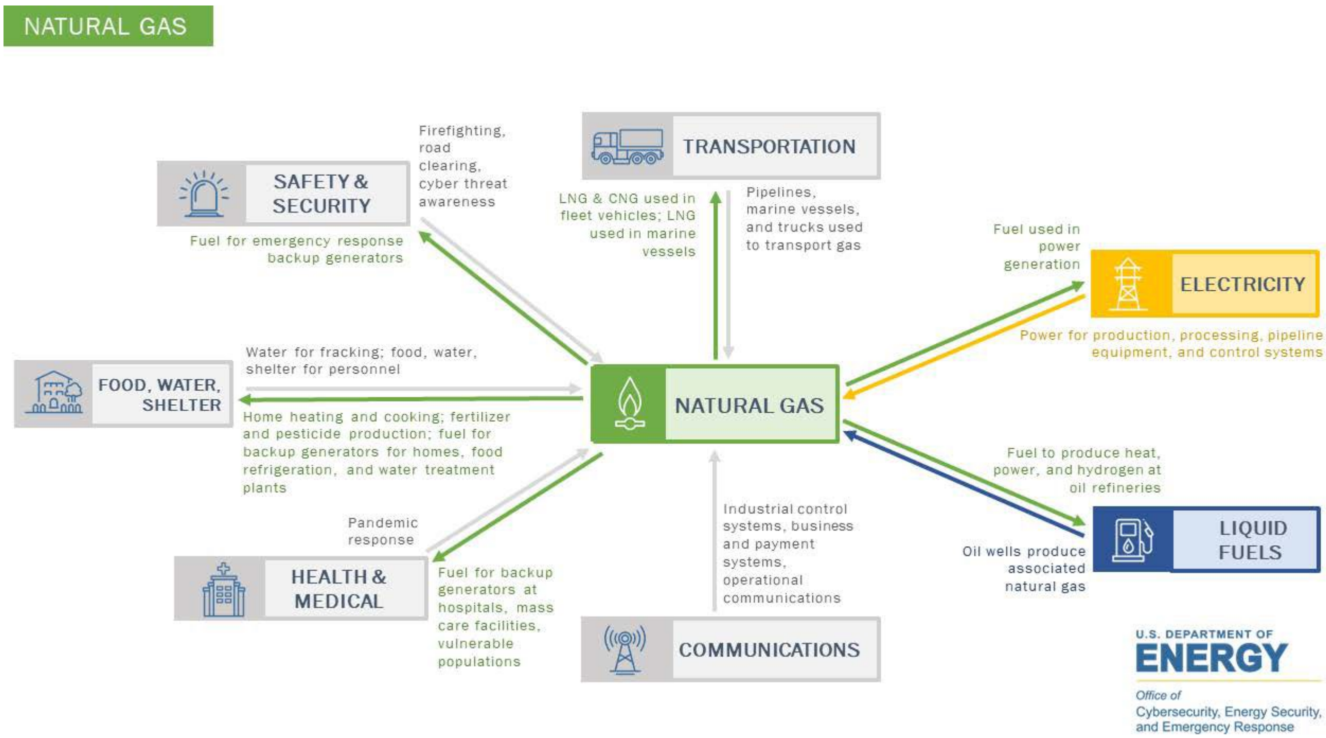


Figure 14: Examples of Interdependencies Between Critical Infrastructure Sectors and Natural Gas[xv]



Sandia National Laboratory (SNL) described a "Resilience Analysis Process" that incorporates a series of 7 steps but effectively meets the same four criteria outlined earlier in this chapter (see **Figure 15**). There is an explicit 'Calculate Consequences' step that encourages users to develop a system model that incorporates larger social benefits from continued operation of the energy system.[xvi] Consequence analysis generally falls into two categories informed by specific identifiable metrics. A sampling of potential costs used to calculate the impact of consequences follow:

- *Direct Costs*
  - Electrical service (cumulative customer-hours of service)
  - Critical electrical service (cumulative critical customer-hours of service)
  - Restoration (time to recovery)
  - Monetary (loss of utility revenue)

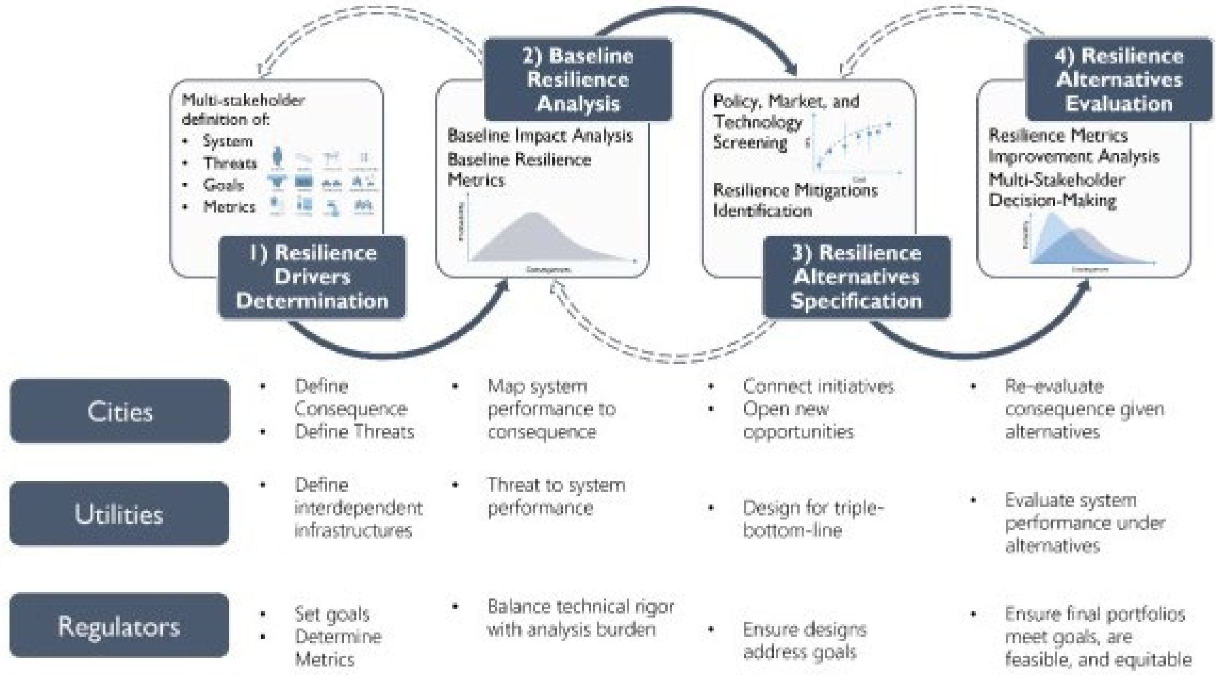
- *Indirect Costs*
  - Community function (hospitals and fire and police stations without power)
  - Monetary (business interruption costs)
  - Other critical assets (key military facilities without power)[xvii]
  - Cascading impacts to other sectors (loss of power disrupting water treatment)

Figure 15: Resilience Analysis Process [xviii]

In SNL's resilience framework starts with level-setting around defined resilience objectives, goals, and metrics. Then, users consider the threats with which they are concerned, followed by a baseline analysis with the performance-based analysis in mind, and consider the threats they are likely to experience. Then, the users would evaluate their alternatives for improving their resilience including policy, market, and technology options. Finally, the groups would evaluate and implement from the suite of alternatives based on which identified input provided the most advantageous benefit-cost ratio. This resilience framework process is based on SNL's 'Designing Resilient Communities' project maps with detailed phases for integrated planning (see **Figure 16**).

This proposed framework for the Resilience Analysis Process as well as suggested inputs for a Resilient Community Design Framework closely mirror the aspects of resilience planning. There is an assessment of current threat environments, followed by robust analysis of policy-based interventions into the system, with continual analysis of alternatives and performance relative to the status quo. This is a resilience framework analysis and can be adapted to suit the needs of a specific state or utility based on their unique requirements.

Figure 16: Resilient Community Design Framework



(Source: Jeffers, Robert "Bobby," Sandia National Labs. 2021, "A Performance Based Approach to Equitable Resilience Planning," PowerPoint, NARUC webinar on Regulators' Financial Toolbox: Resilience Technologies, https://pubs.naruc.org/pub/5236710E-1866-DAAC-99FB-C9D14F045395, August 25, 2021.)

Mitigation Strategy Implementation

After a robust analysis of threat-based risk assessments and prioritizing which consequences ought to be mitigated, state resilience planners and utilities can agree to a mitigation strategy. This usually results in preventive policy measures and investments to minimize the frequency and consequences of significant disruptions. Throughout the process of determining a mitigation strategy, state PUCs and utilities should work closely with SEOs and governors' offices to determine the appropriate strategic approach to mitigate identified consequences. These types of mitigation strategies, technologies, and investments will be detailed in a later chapter of this *Energy Resilience Reference Guide*.

It takes rigorous monitoring of new types of data and metrics to determine a resilience value for high-impact, low frequency (HILF) events linked to changing weather patterns, other natural hazards, and human threats. The strategy also needs to be able to gather site-specific information on risks, weaknesses (in terms of resistance and damage), and the costs incurred by asset repair.[xix] When contemplating any given investment or mitigation option, regulators and utilities must ask themselves the following questions:

- 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?

States and utilities must accept that they operate within limited financial constraints and that investment in resilience measures reach a point of diminishing returns to value of dollars invested. State regulators are tasked with avoiding 'gold-plating' the system or approving unnecessarily expensive investments that are not reasonable nor prudent for ratepayers. State PUCs have a duty to set 'just and reasonable' rates through regulatory cost-recovery decisions. The alternative is that costs are borne by customers who are disproportionate to the benefits they provide.

An additional framework to help think through the prioritization of investment strategies comes from Idaho National Laboratory's Resilience Optimization Center. The Infrastructure Climate Adaptation and Resilience (ICAR) framework is designed to "help users ingest downscaled climate model data, that when paired with adaptive engineering decision support tools and other filters, will identify the highest confidence candidate adaptation and resilience options for given critical infrastructure assets" (see **Figure 17**).[xx] The process follows a similar trajectory to other identified resilience frameworks except in this framework the consequence prioritization phase and risk assessment phase are swapped. However, the end result is the same, the framework is a tool to direct investments for enhancing grid resilience based on specific identified needs that are responsive to relevant threats. These visualizations are useful guidelines for state planners in the early stages of conceptualizing a resilience framework.

Figure 17: Infrastructure Climate Adaptation and Resilience Framework Workflow

Implementation of specific mitigation strategies should closely address the unique threat environment that a state or utility territory operates within. Although some physical investments into improved reliability (i.e., vegetation management, replacement of aging infrastructure, automated distribution components, etc.[xxi]) generally bolster resilience, a resilience valuation framework helps to prioritize those investments. State utility regulators 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.

Process to Value Resilience

Continual Assessment of Performance

Continual assessment of system performance at each stage of the resilience valuation process is essential to understanding the effectiveness of your mitigation strategies and investments. States and utilities should work toward developing transparent and repeatable methodologies that prioritize investment options for improving the resilience of any infrastructure. Several of the national laboratories are developing more robust metrics to prioritize resilience investments beyond SAIDI and SAIFI, which have traditionally been used to measure system reliability. There is no universal consensus on the exact proper way to quantify the value of resilience. Each state has pursued its own definition and metrics and, in some cases, has not updated their cost-benefit calculations to include newer forms of resilience metrics. A resilience valuation framework is predicated on the notion that quantitative analysis of grid investments for enhanced resilience requires some form of data collection and performance tracking. The following section summarizes some of the most recent efforts into putting a value on energy resilience.

The Grid Modernization Laboratory Consortium (GLMC) categorizes resilience metrics into two broad categories: multi-criteria decision analysis and performance based. These can be used in conjunction to quantify the resilience of grid infrastructures. Multi-criteria decision analysis (MCDA) takes a qualitative approach to gathering information from customers about baseline expectations for 'the current state of resilience for the energy system' and 'expectations around enhancing resilience over time?' GLMC notes that this process "typically requires that analysts follow a process to review their system and determine the degree to which the properties are present within the system. These determinations are usually made by collecting survey responses, developing a set of weighting values that represent the relative importance of the survey responses, and performing a series of calculations that result in numerical scores for the resilience attributes."[xxii] The baseline can then be used to conduct "what if" analysis to understand the impacts of targeted investments or actions to improve the resilience posture of one or more of the attributes.

In contrast, performance-based metrics generally try to answer the question: "how can regulators align utility incentives with state policy goals?" These measures are more easily assessed based on specific performance indicators from the overall system. GLMC notes that performance metrics are "used to quantitatively describe how the grid has been impacted or compromised in the event of a specified disruption (such as a natural disaster). The required data can be gathered from historical events, subject-matter estimates, or computational infrastructure models. Because the metrics can often be used to measure the potential benefits and costs associated with proposed resilience enhancements and investments, performance-based methods are often ideal for cost-benefit and planning analyses"[xxiii]. Some examples of the specific performance measures a utility might track are as follows:

Table 5: Performance-Based Metrics

Consequence Category	Resilience Metric
Direct	
Electrical Service	Cumulative customer-hours of outages Cumulative customer energy demand not served Average number (or percentage) of customers experiencing an outage during a specified time period
Critical Electrical Service	Cumulative critical customer-hours of outages Critical customer energy demand not served Average number (or percentage) of critical loads that experience an outage
Restoration	Time to recovery Cost of recovery
Monetary	Loss of utility revenue Cost of grid damages (e.g., repair or replace lines, transformers) Cost of recovery Avoided outage cost
Indirect	
Community Function	Critical services without power (e.g., hospitals, fire stations, police stations) Critical services without power for more than *N* hours (e.g., *N* > hours of backup fuel requirement)
Monetary	Loss of assets and perishables Business interruption costs Impact on Gross Municipal Product or Gross Regional Product
Other Critical Assets	Key production facilities without power Key military facilities without power

The barriers to incorporating resilience benefits into decision-making include the lack of standardized or widely accepted valuation practices and the limitations of currently available valuation methods. Working toward standardization of core valuation processes with flexibility for specific case-by-case investments might be an objective that state PUCs develop with each of their regulated utilities. At present, states are wrestling with a variety of different performance-based metrics and whether they are appropriate to include as benchmarks for various state policy goals and as incentives for regulated utilities to achieve certain policy objectives.

Another consideration with development of valuation methods for resilience investments is that state PUCs share jurisdiction and interest in accounting for resilience in decision-making with other stakeholders such as the State Energy Offices. However, these two agencies typically have differing considerations as economic regulators and policymakers, respectively.[xxiv] State PUCs are generally limited in authority to consider the economic impacts of utility investments in resilience beyond assuring just and reasonable rates, with some statutorily defined and relatively narrow exceptions.[xxv] Whether and how beneficiaries that lie outside of the utility footprint or sector should contribute to the cost of resilience improvements may need to be considered by regulators and other governmental entities. State regulators may be hesitant to consider the impact of social burden and broader societal costs outside of the direct economic costs from rates.

There are a broad range of tools and methods available or in development that state regulators may consider using as a basis for resilience evaluation assessments. NARUC has summarized these tools and their unique characteristics in its recent report on *Valuing Resilience for Microgrids: Challenges, Innovative Approaches, and State Needs*.[xxvi]

Table 6: New and Pending Resilience Valuation Approaches[xxvii]

Method / Tool	Developers	Advantages / New Additions	Available
Interruption Cost Estimator 2.0 Tool	• Lawrence Berkeley National Laboratory • Edison Electric Institute	• Updated calculations of power interruption costs. • New willingness-to-pay surveys that will populate the tool with more recent data and more geographic specificity for power interruption cost estimates. • New data on customer responses to longer-duration power interruptions	2023
Customer Damage Function Calculator Tool	• National Renewable Energy Laboratory	• Helps individual facilities (or groups of similar facilities) calculate power interruption costs, based on the specific losses that they project will occur. • Guided questions lead facilities through their own assessments. • Graphical summary of initial damage costs, and costs over time.	2021
Social Burden Method	• Sandia National Laboratories • University of Buffalo	• Provides a metric for the social burden of power outages that emphasizes the needs of communities during power outages, instead of emphasizing protecting critical infrastructure for its own sake. • Adopts a more neutral treatment of the willingness to pay vs. the ability to pay for resilience.	Pilot 2021-2022
FEMA Benefit-Cost Analysis Tool	• Federal Emergency Management Agency	• Provides quantitative values for lost emergency services, such as police, fire, and emergency medical response. • New pre-calculated values specifically for hospitals published in 2021. • The use of FEMA values aligns with the application requirements of FEMA grant programs.	2021
Power Outage Economics Tool (POET)	• Lawrence Berkeley National Laboratory • ComEd	• Estimates the economic impacts of longer-duration power outages. • Takes into account how utility customers adapt their behavior during longer duration power interruptions. • Uses surveys of utility customers to collect data on how they would actually behave during a power outage.	Pilot 2021-2022

Regardless of what tools state regulators consider using, requiring reporting of utility resilience assessments and relevant data collection used by the utilities is a good basis for tracking resilience improvements. Additionally, recovery funding from federal sources after a natural disaster may require some prior resilience assessment as part of the request for recovery funding.[xxviii]

State Energy Resilience Spotlights

The following states have been identified as interesting case studies in resilience planning and mitigation strategy implementation. The level of comprehensive resilience framework differs across each example but provides context into how a state might begin incorporating a resilience valuation framework into its decision-making processes.

Oregon: The Oregon Public Utility Commission is an example of a comprehensive Resilience Framework, inclusive of legislative mandates, PUC directive, programmatic funding, and executive action.
The Oregon Department of Energy developed the Oregon Guidebook for Local Energy Resilience for consumer-owned utilities (COUs), which provides a high-level overview of resiliency. The Resilience Guidebook uses current research from Electric Power Research Institute (EPRI) to define resilience as a concept and distinguish it from reliability.[xxix] With the understanding that standardized metrics for resilience are still in development, the guidebook also provides a framework for how COUs can conduct risk assessments and links to national resources.[xxx] The Oregon Department of Energy also has a web page with high-level discussions on resiliency topics, such as advancements in DER technologies, resilient microgrid solutions, FEMA, Federal Cybersecurity Resources, state emergency planning, and state resilience planning.[xxxi] The OPUC requires the three investor-owned electric utilities – PGE, PacifiCorp, and Idaho Power – to file Smart Grid Reports every two years.[xxxii] The Smart Grid Reports from 2019 all demonstrate resilience as a foundational principle of the Smart Grid, and each developed a system of investing in resiliency. For example, Idaho Power's most recent report from 2019 highlights plans for the Jordan Valley Microgrid for the stated purpose of being a resilience improvement to the distribution system. The final report was published in 2018 and it offers some guidance on resiliency objectives, particularly the future penetration of DERs into Oregon's energy market.[xxxv]

Mississippi: The Mississippi Public Service Commission (MPSC) uses the resilience framework of a state PUC directive, combining event-specific dockets within its Integrated Resource Planning (IRP) processes.
The IRP process integrates the concept of "resiliency" into its process of annual reporting from utility companies. MPSC Docket No. 2018-AD-64 addresses the development of Rule 29 – Integrated Resource Planning and Reporting. It requires that regulated utilities will complete an Annual Energy Delivery Plan, which reports "efforts to improve energy delivery."[xxxvi] This Annual Energy Delivery Plan

includes a "discussion of the adequacy of its transmission and distribution systems, including reliability, resiliency and storm hardened condition."[xxxvii]

The MPSC allows alternative cost recovery mechanisms for resiliency costs for transmission systems. Transmissions system resiliency costs were associated with "North American Electric Reliability Corporation (NERC) compliance rules, plans, programs or requirements, including costs associated with critical infrastructure protection plans (NERC CIP)."[xxxviii] The alternative cost recovery mechanism specified is to "remove these NERC costs from base rates" and utilities "may choose to defer and amortize any such costs over five years."

The MPSC also allows alternative cost recovery mechanisms for resiliency costs for distribution systems. The goal was to empower utilities to "effectively manage vegetation growth and to more quickly improve grid resiliency at the distribution level."[xl] Similar to resiliency costs for transmission systems, MPSC specifies that "utilities may remove all vegetation management costs and Commission-approved grid resiliency costs from base rates" and utilities may "choose to defer and amortize such costs over five years."[xli]

The MPSC also commissioned a review of the "condition and resiliency of the state's public utility infrastructure"[xlii] in 2021, which was completed in February 2022 by titled the Public Utility Infrastructure Review Report. This was in response to the February 2021 Winter Storm Uri to determine the strengths and weaknesses of public utilities infrastructure and emergency planning. The final section outlines recommendations for improved resiliency with four overarching recommendations:

1. Formalize a Forum for Ongoing Preparedness Planning and Information Sharing
    a. Recommends a formal, semiannual forum for key personnel in the utilities sector to discuss severe weather and cybersecurity preparedness to facilitate information sharing of best practices in mitigation.[xliii]
2. Strengthen Cybersecurity Defenses
    a. Recommends partnerships with the cybersecurity industry to provide ongoing education on new and emerging threats and actors, build cybersecurity capacity (both infrastructure and personnel), and simulate grid attack exercises[xliv]
3. Establish and Maintain Emergency Response Plans
    a. Recommends that each utility should establish and maintain an emergency response plan, that should be considered a living document, and conduct post-event action evaluations to update emergency operating procedures[xlv]
4. Create Fuel Supply Redundancy and Diversification
    a. Recommends actions be taken to address heavy dependence on natural gas, including expanding to multiple supply sources for utilities relying on a single pipeline, increasing natural gas storage capacity, and researching alternative fuel sources[xlvi]

Michigan: The Michigan Public Service Commission (MPSC) pursued a type of resilience framework following an event-specific docket that opened a PUC investigation into the resilience of Michigan's energy system. After the January 2019 polar vortex storm and Ray Compressor station fire, which created an energy emergency, Governor Whitmer directed the MPSC to conduct a Statewide Energy Assessment (SEA) to evaluate the resiliency of Michigan's public utilities, particularly for HILF events.[xlvii] The final report for SEA was completed in September 2019.

SEA made a total of 37 recommendations in its initial report, including integrated electricity system planning, valuing resource diversity and resilience, gas-electric interdependencies, demand response, emergency drills, cybersecurity standards for natural gas distribution utilities, propane contingency planning, and risk-based integrated natural gas planning.[xlviii]

In September 2021, the MPSC issued a 2021 Progress Report on the implementation of SEA's recommendations.[xlix] The 2021 Progress Report outlines that the recommendations have expanded to 59 action items, of which 18 were complete, 39 were in progress or ongoing, and two were scheduled to begin work on in 2022.[l] Many of the recommendations are addressed though the MI Power Grid Initiative. The SEA action plan outlines the key areas of electricity systems, natural gas systems, propane access, cyber and physical security, and emergency management. Notable work by the MPSC was done for Demand Response Tariffs, Distributed Energy Resources considerations in Integrated Resource Plans, Mutual Assistance Agreements, and Cybersecurity Standards.

Regarding Demand Response Tariffs (DRTs), the MPSC opened docket Case No. U-20628 to establish a stakeholder workgroup whose recommendations were adopted in an October 2020 Commission Order. Utilities were directed to file updated DRTs by April 1, 2021, and the MPSC opened dockets for each utility company (Case No. U-21037, U-20628, U-21042, U-21038, and U-21036).[li]

Regarding Distributed Energy Resources (DERs) in IRPs, the MPSC opened docket Case No. U-20633 to establish a stakeholder workgroup to review generation diversity and resilience issues, including finding ways to quantify value of resilience for DERs and quantify value of generation diversity in IRPs. A staff report was completed in May 2021, and a Commission Order adopting the recommendations was filed in September 2021.[lii]

Regarding Mutual Assistance Agreements, the MPSC opened docket Case No. U-20631 to establish a stakeholder workgroup and published a report with recommendations on mutual assistance for gas utilities and recommendations on transmission contingency planning in March 2021, which were accepted by a MPSC Order in May 2021.[liii]

Regarding cybersecurity standards, the MPSC issued a Commission Order revising the Technical Standards for Gas Service in 2020, specifically Rule 460.2324 on Security Reporting. This requires an annual report by utilities to the MPSC on a utility's cybersecurity plan on threat assessment and preparedness strategy, including an overview of the utilities approach to cybersecurity, specialized training, organizational diagram, and a description of risk assessment tools and methods to evaluate, prioritize, and improve cybersecurity resiliency.[liv]

California: The California Public Utility Commission (CPUC) is an example of a comprehensive Resilience Framework, inclusive of legislative mandates, PUC directive, programmatic funding, and executive action.

Executive Order B-30-15 from April 2015 identified three critical actions to advance adaptation and resilience.[lv] First, preparation of Implementation Action Plans to identify steps to realize goals from *Safeguarding California,* which is California's Climate Adaptation Strategy.[lvi] This was developed first in 2009 as the first state-level, multi-sector climate adaptation strategy. It is updated every three years by the California Natural Resources Agency. Second, direction to state agencies to consider climate change in all planning and investment, particularly infrastructure investment.[lvii] Lastly, the Governor's Office of Planning and Research established a Technical Advisory Group (TAG) to provide state agencies with guidance on how to integrate climate change into planning and investment. The TAG developed a guidebook called "Planning and Investing for a Resilient California: A Guidebook for State Agencies," which provides a high-level four-step planning and investment process to address resilience.[lix]

1. Identify how climate change could affect a project or plan.
2. Conduct an analysis of climate risks.
3. Make a climate-informed decision.
4. Track and monitor progress.

This guidebook also defines resilience as "Resilience is the capacity of any entity – an individual, a community, an organization, or a natural system – to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience."[lx] Also, the guidebook provides a scientific foundation for the importance of prioritizing resilience and climate-change-aware investments in infrastructure.

California chose to focus on a specific type of resilience-based technology, state support for microgrids, to achieve several of its energy resilience objectives. SB 1339, a bill enacted in 2018, directs CPUC to undertake activities to develop policies related to microgrids.[lxi] In September 2019, CPUC voted to initiate a new rulemaking to implement the requirements of SB 1339, and formally launched an Order Instituting Rulemaking (OIR) to address the issues codified under Section 8371, with eight distinct tracks.[lxii]

1. Develop microgrid service standards necessary to meet state and local permitting requirements.[lxiii]
2. Develop methods to reduce barriers for microgrid deployment.
3. Develop guidelines to determine what impact studies are necessary for microgrids to connect to the electrical corporation grid.
4. Develop separate rates and tariffs, that are just and reasonable, to support microgrids.
5. Facilitate the formation of a working group to codify standards and protocols needed to meet California electrical corporation and CAISO microgrid requirements.
6. Develop a standard for direct current metering in Electric Rule 21 to streamline the interconnection process and lower interconnection costs for direct current microgrid applications.

7. Ensure that the actions taken by the Commission to fulfill the requirements of SB 1339 do not discourage or prohibit the development or ownership of a microgrid by an electrical corporation.
8. Ensure that any microgrid programs, rules, or rates developed to implement the requirements of SB 1339 are consistent with relevant state policy goals and are coordinated with existing Commission responsibilities.[lxiv]

Currently, CPUC has completed work in Track 4 through the work of the CPUC Resiliency and Microgrids Working Group (RMWG), whose charter prioritizes work on standardizing metrics for measuring resiliency and reliability values, CAISO wholesale market, critical facilities, and other topics.[lxv]

In January 2021, CPUC authorized the Microgrid Incentive Program, which has a $200 million budget.[lxvi] The purpose of the Microgrid Incentive Program is to fund clean energy microgrids to support the critical needs to vulnerable communities impacted by grid outages and to test new technologies or regulatory approaches to inform future action and is anticipated to be launched in 2022.

Questions Facing the Regulatory Community for Developing an Energy Resilience Framework

- Who should be involved in setting objectives for energy resilience at the state level? Who will represent the private sector? What other key stakeholders need to be involved?
- What type of specific threats to critical infrastructure exist in your state?
- How are you factoring in climate change forecasts for your service area and consumer base into planning approaches for siting new assets?
- How are you factoring in cybersecurity threats in your state energy resilience planning?
- How did you determine those threats exist?
- How did your state quantify the consequences for damage to specific critical infrastructure? What decision tools and metrics were used to justify those prioritizations?
- How can regulators measure preventative investments under consideration through the states' Energy Resilience Plan?
- What types of mitigation strategies and technologies does your state find the most effective? How did you determine that level of cost-benefit analysis?
- Can existing reliability metrics be adjusted or enhanced to improve system resilience?
- What type of new data requests are needed to make resilience investment decisions?

APPENDIX A: Sample of Research Institutions Involved with Threat-Based Risk Assessment & Resilience Frameworks

Institution	Program Description
National Oceanic and Atmospheric Administration (NOAA): U.S. Climate Resilience Toolkit [lxvii]	The Steps to Resilience framework describes a methodical approach communities can use to identify their valuable assets, determine which climate-related hazards could harm them, and then identify and take effective actions to reduce their risk. Inclusive in these resources are extraordinarily detailed predictive climate mapping for extreme heat, wildfire, drought, flooding, and coastal inundation on an early-century (2015–2044), mid-century (2035–2064), and late century (2070–2099) time horizon.
DOE's Office of Cybersecurity, Energy Security, and Emergency Response (CESER): State Risk Profiles	The Office of Cybersecurity, Energy Security, and Emergency Response (CESER) has developed a series of **State** and **Regional** Energy Risk Profiles that examine the relative magnitude of risks at a regional and State level highlighting energy infrastructure trends and impacts. The profiles present both natural and man-made hazards with the potential to cause disruption of the electric, petroleum, and natural gas infrastructures. CESER also keeps a program resource library with several helpful resources produced by NARUC, the National Governors Association, National Association of State Energy Officials, National Association of Emergency Management Agencies, and National Council of State Legislatures.
Argonne National Laboratory: Center for Climate Resilience and Decision Science	Argonne National Laboratory's (ANL) Center for Climate Resilience and Decision Science uses advanced climate modeling and data analytics to assess present and future risks to critical infrastructure. ANL has recently released its 'Climate Risk & Resilience Portal (ClimRR) which is intended to provide non-technical individuals, organizations, and decision-makers with tools to gain awareness of future climate conditions and conduct climate risk-informed analyses to support decision-making and adaptation efforts. The ClimRR tool can detail climate modeling capabilities down to individual communities and recently conducted a study with ComEd on the impacts of future climate conditions to ComEd's Northern Illinois service territory. ANL also offers a Regional Resilience Assessment Program to understand security and resilience gaps in regionally significant infrastructure systems as well as identify strategies to manage those risks.
Idaho National Laboratory: Resilience Optimization Center	Idaho National Laboratory's (INL) Resilience Optimization Center conducts voluntary, nonregulatory, cooperative assessments of critical infrastructure and can address a range of infrastructure resilience issues that may have regionally or nationally significant consequences. INL provides expertise in vulnerability and risk analysis, as well as probabilistic risk assessments for a variety of industries and public-sector agencies. Their Storm Damage Estimate Prediction and Recovery tool (Storm-DEPART) is one resource in INL's extensive resource catalogue that can be applied to a state's resilience valuation frameworks.

Cybersecurity & Infrastructure Security Agency (CISA): Shields Up initiative	The Department of Homeland Security's Cybersecurity & Infrastructure Security Agency is the federal agency responsible for strengthening cybersecurity and infrastructure protection across all levels of government. They are specifically responsible for coordinating cybersecurity programs with U.S. states and have a Shields Up initiative that identify, mitigate, and respond to cyber threats from malicious actors.

[i] "Resilience Framework, Methods, and Metrics for the Electricity Sector," Technical Report PES-TR83, IEEE Power & Energy Society Industry Technical Support Leadership Committee Task Force at 1, October 2020. https://resourcecenter.ieee-pes.org/publications/technical-reports/PES_TP_TR83_ITSLC_102920.html

[ii] Chris Villarreal and Kerry Worthington, Plugged In Strategies on behalf of the National Association of Regulatory Utility Commissioners, *Regulator's Financial Toolbox: Resilience Technologies Brief*, August 2021, https://pubs.naruc.org/pub/5236710E-1866-DAAC-99FB-C9D14F045395.

[iii] J. Kallay et al., The Resilience Planning Landscape for Communities and Electric Utilities, Prepared for Sandia National Laboratories, Synapse Energy Economics, 2021a, April, https://www.synapse-energy.com/sites/default/files/Resilience_Planning_Landscape_for_Communities_%20Electric_Utilities_SAND2021-4171_19-007.pdf

[iv] Patrick Gasser et al, A review on resilience assessment of energy systems, Sustainable and Resilient Infrastructure, 2021, 6:5, 273-299, DOI: 10.1080/23789689.2019.1610600.

[v] Wilson Rickerson, Kiera Zitelman, and Kelsey Jones, Converge Strategies on behalf of the National Association of Regulatory Utility Commissioners & the National Association of State Energy Officials, February 2022, https://pubs.naruc.org/pub/1B571AB6-1866-DAAC-99FB-2509F05E4A67?_gl=1*1rp0viq*_ga*MTAwMzU1NTQyMi4xNTk3ODQ4Njg3*_ga_QLH1N3Q1NF*MTY2NDE0MTk3OS45Ny4xLjE2NjQxNDIwMDIuMC4wLjA.

[vi] https://naseo.org/data/sites/1/documents/publications/NASEO%20NGA%20Resilience_Guide_21Dec20212.pdf

[vii] 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.
[viii] Ibid.
[ix] National Oceanic and Atmospheric Administration, U.S. Climate Resilience Toolkit, https://toolkit.climate.gov/steps-to-resilience/steps-resilience-overview.
[x] Department of Energy Office of Cybersecurity, Energy Security, and Emergency Response, https://www.energy.gov/ceser/state-and-regional-energy-risk-profiles.
[xi] Department of Energy Office of Cybersecurity, Energy Security, and Emergency Response, State Energy Security Plan Guidance, 2022, https://www.energy.gov/sites/default/files/2022-09/State%20Energy%20Security%20Plan%20Framework%20and%20Guidance.pdf.
[xii] 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.
[xiii] Department of Energy' Office of Cybersecurity, Energy Security, and Emergency Response, State Energy Security Plan Resources, 2022, https://www.energy.gov/sites/default/files/2022-06/DOE%20CESER%20SESP%20Drop-In_Cross-Sector%20Interdependency%20Diagrams_FINAL_508.pdf
[xiv] Ibid.
[xv] Ibid.
[xvi] Jean-Paul Watson, Ross Guttromson, Cesar Silva-Monroy, et al., *Conceptual Framework for Developing Resilience Metrics for the Electricity, Oil and Gas Sectors in the United States*, Sandia National Laboratories, September 2015, http://energy.gov/sites/prod/files/2015/09/f26/EnergyResilienceReport_Final_SAND2014-18019.pdf.
[xvii] 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
[xviii] Watson, Jean-Paul, Ross Guttromson, Cesar Silva-Monroy, et al. (2015) Conceptual Framework for Developing Resilience Metrics for the Electricity, Oil and Gas Sectors in the United States. Sandia National Laboratories. (September 2015). http://energy.gov/sites/prod/files/2015/09/f26/EnergyResilienceReport_Final_SAND2014-18019.pdf
[xix] Mark Weimar, "Framework for Quantitative Evaluation of Resilience Solutions: An Approach to Determine the Value of Resilience for a Particular Site" Pacific Northwest National Laboratory, March 2022. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-28776.pdf
[xx] Andrew Bochman, *Protecting Energy Infrastructure from Extreme Weather and other Physical Climate Risks: An introduction to an Infrastructure Climate Adaptation and Resilience Conceptual Framework for Decision Makers*, Idaho National Laboratory, September 2022.
[xxi] 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.
[xxii] Frederic Petit, Vanessa Vargas, and James Kavicky, *Grid Modernization: Metrics Analysis (GLMC1.1) – Resilience*, Reference Document Volume 3, Grid Modernization Laboratory Consortium, Pacific Northwest National Laboratory, April 2020, https://gmlc.doe.gov/sites/default/files/resources/GMLC1.1_Vol3_Resilience.pdf.
[xxiii] Ibid.
[xxiv] Wilson Rickerson, Kiera Zitelman, Kelsey Jones, Converge Strategies on behalf of the National Association of Regulatory Utility Commissioners & the National Association of State Energy Officials, February 2022, https://pubs.naruc.org/pub/1B571AB6-1866-DAAC-99FB-2509F05E4A67?_gl=1*1rp0viq*_ga*MTAwMzU1NTQyMi4xNTk3ODQ4Njg3*_ga_QLH1N3Q1NF*MTY2NDE0MTk3OS45Ny4xLjE2NjQxNDIwMDIuMC4wLjA.
[xxv] Kiera Zitelman and Jasmine McAdams, *The Role of State Regulators in a Just and Reasonable Energy Transition: Examining Regulatory Approaches to the Economic Impacts of Coal Retirements*, National Association of Regulatory Utility Commissioners, September 2021,https://pubs.naruc.org/pub/952CF0F2-1866-DAAC-99FB-0C6352BF7CB0.
[xxvi] Wilson Rickerson, Kiera Zitelman, and Kelsey Jones, Converge Strategies on behalf of the National Association of Regulatory Utility Commissioners & the National Association of State Energy Officials, February 2022, https://pubs.naruc.org/pub/1B571AB6-1866-DAAC-99FB-2509F05E4A67?_gl=1*1rp0viq*_ga*MTAwMzU1NTQyMi4xNTk3ODQ4Njg3*_ga_QLH1N3Q1NF*MTY2NDE0MTk3OS45Ny4xLjE2NjQxNDIwMDIuMC4wLjA.
[xxvii]Ibid.

[xxviii] [xxviii] Frederic Petit, Vanessa Vargas, James Kavicky. "Grid Modernization: Metrics Analysis (GLMC1.1) – Resilience" Reference Document Volume 3. Grid Modernization Laboratory Consortium. Pacific Northwest National Laboratory. (April 2020). https://gmlc.doe.gov/sites/default/files/resources/GMLC1.1_Vol3_Resilience.pdf
[xxix] *Oregon Guidebook for Local Energy Resilience* (Oregon Department of Energy, 2019), 3.
[xxx] *Oregon Guidebook for Local Energy Resilience,* 6 and 39-41.
[xxxi] *Resilience Guidebook Deep Dives*, Oregon Department of Energy, n.d., State of Oregon: Safety & Resilience - Resilience Guidebook Deep Dives.
[xxxii] *Grid Modernization*, Oregon Public Utility Commission, n.d., Public Utility Commission : Grid Modernization: Utility Regulation : State of Oregon.
[xxxiii] Andy Macklin, *Smart Grid Report*, Portland General Electric Company, 2019, 31.
[xxxiv] Lisa Nordstrom, *Smart Grid Report,* Idaho Power Company, 2019, 695.
[xxxv] *SB 978 Actively Adapting to the Changing Electricity Sector*, Oregon Public Utility Commission, 2018, 57.
[xxxvi] *Integrated Resource Planning and Reporting*, (Mississippi Public Service Commission, 2019), 8.
[xxxvii] *Integrated Resource Planning and Reporting,* 12.
[xxxviii] Ibid
[xxxix] Ibid
[xl] Ibid
[xli] Ibid.
[xlii] *Public Utility Infrastructure Review Report,* (Del Sol Consulting, Inc., 2022), 3.
[xliii] *Public Utility Infrastructure Review Report,* 33.
[xliv] Ibid.
[xlv] Ibid.
[xlvi] Ibid.
[xlvii] *Michigan Statewide Energy Assessment* (Michigan Public Service Commission, 2019), i.
[xlviii] *Michigan Statewide Energy Assessment, ii-iii.*
[xlix] *2021 Annual Report,* Michigan Public Service Commission, 2022, 14-15.
[l] *2021 Annual Report,* 14-15.
[li] *Statewide Energy Assessment 2021 Progress Report* (Michigan Public Service Commission, 2021), 2.
[lii] *Statewide Energy Assessment 2021 Progress Report,* 2-3.
[liii] Ibid., 5.
[liv] Ibid., 8.
[lv] Louise Bedsworth and Greta Soos, *Planning and Investing for a Resilient California* (Governor's Office of Planning and Research, 2017), 1.
[lvi] Bedsworth and Soos, *Planning and Investing for a Resilient California, 1.*
[lvii] Ibid.
[lviii] Ibid.
[lix] Ibid., 2.
[lx] Ibid., 6.
[lxi] *Resiliency and Microgrids*, California Public Utility Commission, n.d., Resiliency and Microgrids (ca.gov).
[lxii] *Order Instituting Rulemaking Regarding Microgrids Pursuant to Senate Bill 1339* (California Public Utilities Commission, 2019), 1.
[lxiii] *Order Instituting Rulemaking Regarding Microgrids,* 6.
[lxiv] Ibid., 7.
[lxv] *Resiliency and Microgrids*, California Public Utility Commission, n.d., Resiliency and Microgrids (ca.gov).
[lxvi] Ibid.
[lxvii] National Oceanic and Atmospheric Administration, *U.S. Climate Resilience Toolkit*, https://toolkit.climate.gov/.