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September 5, 2023

VIA ELECTRONIC FILING

Ms. A. Shonta Dunston
Chief Clerk
North Carolina Utilities Commission
4325 Mail Service Center
Raleigh, North Carolina 27699-4300

**RE: Duke Energy Carolinas, LLC and Duke Energy Progress, LLC's Joint Climate Risk and Resilience Study – Final Report
Docket Nos. E-7, Subs 1213, 1214 and 1187 and E-2, Subs 1219 and 1193**

Dear Ms. Dunston:

Pursuant to the North Carolina Utilities Commission's ("Commission") March 31, 2021 *Order Accepting Stipulations, Granting Partial Rate Increase, and Requiring Customer Notice* in Docket Nos. E-7, Subs 1213, 1214, and 1187, and the Commission's April 16, 2021 *Order Accepting Stipulations, Granting Partial Rate Increase, and Requiring Customer Notice* in Docket Nos. E-2, Subs 1219 and 1193 ("2019 Rate Case Orders"), enclosed for filing in the above-referenced dockets is the Joint Climate Risk and Resilience Study Final Report of Duke Energy Carolinas, LLC ("DEC"), and Duke Energy Progress, LLC ("DEP," together, "the Companies") ("CRRS Final Report").

As part of the Companies' 2019 Rate Case Orders, the Companies entered into a settlement agreement with Vote Solar to initiate a Climate Risk and Resilience Study ("CRRS") in North Carolina to study physical adaption risks to climate change in the Companies' Transmission and Distribution ("T&D") systems. Such study was to be conducted through an external stakeholder process and run by a third-party consultant. ICF Incorporated, LLC ("ICF") was selected as the third party consultant to lead this research and analysis.

The Companies established a Technical Working Group ("TWG") for the purpose of conducting and reporting on this study and stakeholder process. The CRRS study's scope includes: 1) assessing the vulnerability of the Companies' T&D assets and operations to current and projected physical impacts of climate change and 2) developing a flexible framework to improve the Carolinas' T&D system's resilience. The Companies in their scope with ICF included an optional Interim Report previously filed with the Commission and made public on the Duke Energy website that assessed the vulnerabilities. In this CRRS Final Report, ICF provides their flexible adaptation framework and recommendations for the Companies.

Throughout the process, the Companies' subject matter experts from across the company provided detailed input and feedback through ongoing discussions, interviews, workshops and comments. This CRRS Final Report has been shared with the external TWG stakeholders and discussed in the last TWG meeting held on June 8, 2023. The Companies are providing this CRRS Final Report as a final filing, which includes along with the previously shared climate projections for the Carolinas, the vulnerability assessment of T&D systems without mitigation, a summary of stakeholder engagement and feedback and details for an adaptation framework.

This CRRS Final Report will also be published on the Companies' website at [Climate Resilience and Adaptation - Duke Energy (duke-energy.com)] on or after September 8, 2023.

Thank you for your attention to this matter. If you have any questions, please let me know.

Sincerely,

Jack E. Jirak

Enclosure

cc: Parties of Record

CERTIFICATE OF SERVICE

I certify that a copy of Duke Energy Carolinas, LLC's and Duke Energy Progress, LLC's Joint Climate Risk and Resilience Study – Final Report, filed today in Docket Nos. E-7, Subs 1213, 1214, and 1187 and E-2, Subs 1219 and 1193, has been served by electronic mail, hand delivery or by depositing a copy in the United States mail, postage prepaid to parties of record.

This the 5th day of September, 2023.

Jack E. Jirak
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DUKE ENERGY | ICF

DEC/DEP T&D Climate Resilience and Adaptation Report

September 2023

Docket Nos. E-7, Subs 1213, 1214, and 1187 and E-2, Subs 1219 and 1193

DEC/DEP T&D Climate Resilience and Adaptation Report

Prepared by:

DUKE ENERGY

ICF

Table of Contents

Executive Summary

Duke Energy's service area in North Carolina and South Carolina comprises Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP), which deliver electricity to customers through a grid of transmission lines, distribution lines and substations. Duke Energy has been increasing the resilience of its energy system for the last decade through storm hardening, smart grid technologies, capacity and reliability projects. To build on this work, Duke Energy initiated a Climate Risk and Resilience Study (CRRS) of the North Carolina and South Carolina transmission and distribution (T&D) systems in 2021 to (1) systematically assess the vulnerability of its T&D assets and operations to the projected physical impacts of climate change and (2) develop a flexible framework to inform continued investments in North Carolina and South Carolina's T&D system's resilience. ICF led the research and analysis, and throughout the process, Duke Energy subject matter experts (SMEs) from across the company provided detailed input and feedback through ongoing discussions, interviews, workshops, and comments.

Stakeholder Engagement

Duke Energy understands that for climate resilience planning to be effective, it must include the perspectives of a broad range of stakeholders (including the communities that Duke Energy serves) and leverage expertise and insight beyond Duke Energy's own staff. Duke Energy is actively engaged with these groups throughout its company projects and initiatives. Its Government Community Relations team fosters direct relationships with staff from every community, and Duke Energy performs regular stakeholder engagement efforts with other community partners. The CRRS project was designed to build upon those efforts, ensuring that Duke Energy's resilience planning is informed by a broad range of perspectives and fulfills the utility's ultimate purpose of serving communities' and customers' energy needs into the future.

ICF convened a wide-ranging panel of stakeholders to serve on the CRRS Technical Working Group (TWG). The purpose of the TWG was to provide input and feedback to the study team throughout the study process, and to review interim study results ahead of key milestones. The TWG included representation from stakeholder segments including environmental organizations, customers, energy industry associations, government agencies, low-income advocates, academia and other utilities. The valuable input shared by the TWG informed the Vulnerability Assessment methodology, shaped the assessment goals and objectives and contributed recommendations and priorities for the flexible adaptation framework.

Vulnerability Assessment Findings

In September 2022, Duke Energy released an Interim Report that synthesized the exposure and vulnerability of the T&D system to the physical impacts of climate change. The report identified incremental vulnerabilities, through the 2050 time frame, by asset type (e.g., functional components such as transformers or conductors), by asset group (e.g., transmission, substations, distribution), and by planning and operations process areas (e.g., asset management, workforce safety). Without adaptation investments, substations are projected to be at the highest potential risk, with extreme heat and flooding likely being the greatest concerns for existing assets. The transmission and distribution systems face medium- or low-scoring risks for most climate hazards. In addition, Duke Energy's asset management practices were found to be at high risk, and load forecasting, capacity planning and reliability planning were found to have medium risks.

The adaptation recommendations in this report build upon the findings from the vulnerability study to outline a flexible framework to improve the resilience of Duke Energy Carolinas T&D system.

Overview of Climate Adaptation Flexible Framework

To inform continued resilience improvements at Duke Energy, the Climate Adaptation Flexible Framework is centered around four primary pillars, as shown in Figure 1. The framework includes monitoring climate science by using climate scenarios in planning and design and updating the foundational science over time, maintaining readiness by continuing to evolve T&D planning and operational practices, implementing selected T&D investments to improve resilience, and partnering with local communities to incorporate their priorities in resilience planning. Each of these pillars are briefly described below.

Monitor Climate Science

Monitoring climate science is the first pillar of the flexible adaptation framework. ICF assisted Duke Energy in reviewing climate science developed for the Vulnerability Assessment and selecting a climate change adaptation planning scenario, which provides standardized climate change projections to inform Duke Energy's adaptation efforts. While planning studies should look to a range of future climate scenarios, engineers ultimately need a number to use in their designs. The adaptation planning scenario is already being used to inform Duke Energy's work, such as its load forecasting process.

Moving forward, Duke Energy plans to continue to monitor and update its understanding of climate risks and its climate change adaptation planning scenario as climate science continues to improve.

Maintain Readiness

Maintaining readiness is the second pillar in Duke Energy's Climate Adaptation Flexible

Figure 1. Four pillars of Duke Energy's Climate Adaptation Flexible Framework.

Framework, and it arguably may be the most impactful and cost-effective way to increase climate resilience. Continuing to evolve Duke Energy's planning and operations capabilities to account for climate change sets the stage for continued long-term, incremental increases in resilience. Making these incremental updates ensures that capital investments and plans are informed by a forward-looking view of climate and allows assets to be gradually replaced with more robust designs (if needed) over time. For the majority of Duke Energy's T&D system, these incremental updates will be sufficient for keeping pace with the projected changes in climate given the gradual nature of the changes.

For several years, Duke Energy has been working to maintain readiness by identifying and revising its design and operations specifications to address emerging extreme weather risks. Examples include building new substations to updated standards that consider flood risk, installing permanent flood protection at selected substations and increasing overhead distribution conductor ambient temperature assumptions.

Specific recommendations are provided in Section VI for continuing to evolve Duke Energy's asset management, load forecasting, capacity planning, and reliability planning processes.

Incorporate New Factors in T&D Investments

Incorporating new factors in T&D investments is the third pillar in Duke Energy's Climate Adaptation Flexible Framework. Climate change is increasing the severity and frequency of some climate hazards across Duke Energy's territory, which may create the need for additional T&D system investments to maintain consistent, affordable, and reliable service. As determined through the Vulnerability Assessment, hazards such as flooding, extreme heat, high winds, and wildfire can pose risks to the T&D system (particularly to substations), potentially resulting in power outages, grid damage, operational disruptions and higher costs.

Duke Energy has already begun investing to build resilience to extreme weather impacts and preparing for the future. Duke Energy's investments in resilience include capacity upgrades, self-optimizing grid technologies, substation and distribution hardening and improvements in vegetation management. Continued proactive investment to address future changes in climate hazards will use an informed

Investment Prioritization Framework

What

- Additional T&D resilience investments could include traditional and non-traditional solutions
- Solution prioritization could include decision-support tools that consider a range of possible cost effectiveness approaches

Where

- Prioritized locations for adaptation solutions can be based primarily on the vulnerability of assets, drawing from the Vulnerability Assessment results
- Siting considerations may include how vulnerable the local community is to outage events; this is already used in some program criteria

When

- Risks to consider when determining adaptation solution timing
  - ✓ Climate adaptation planning scenario
  - ✓ Acceptable level of risk
  - ✓ Life span of assets
  - ✓ Asset-specific capital investment plans
  - ✓ Regulatory filings
  - ✓ Other entities' investment plans

Figure 2. Duke Energy investment prioritization framework considerations.

investment prioritization framework that specifies how adaptation solutions should be selected, as well as where and when solutions should be implemented. Figure 2 summarizes the key "what, where, when" considerations for T&D system investment prioritization. These prioritization considerations should be married with Duke Energy's broader project prioritization process moving forward, which may result in the acceleration or delay of certain investments. As a reminder, this framework is meant to be flexible and to evolve over time as Duke Energy works toward implementation.

Partner with Local Communities

Partnering with local communities is the fourth pillar in Duke Energy's Climate Adaptation Framework. Duke Energy already has very robust partnerships with local communities and recognizes that partnerships are particularly critical when extreme events cause extended power outages. Duke Energy's current T&D system is both robust and resilient; however, not all risks can be designed out of the system. On occasion, extreme events may lead to extended power outages, and it is Duke Energy's intention to put measures in place to protect communities when outages happen. Almost all of the recommendations in this section are for incremental enhancements or additional areas of focus within existing practices and programs.

Duke Energy's three-pronged approach to community support (pictured to the right in Figure 3) includes:

Proactive planning and coordination – Collaboration throughout the year to ensure that Duke Energy and its community partners are prepared for major events.

Real-time coordination during emergencies – Duke Energy partners with communities to respond to major outages, to safeguard community residents, an to accelerate system restoration.

Funding and grant support – Duke Energy's efforts to support the research and programs that support community resilience.

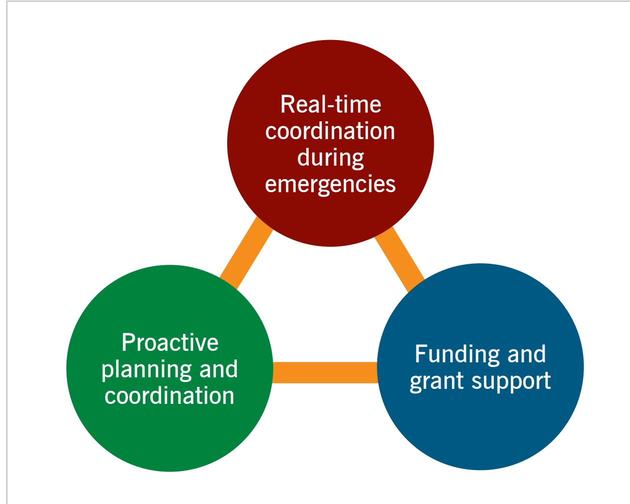


Figure 3. Three elements of Duke Energy community resilience support.

For each of these areas, this report presents current Duke Energy activities and proposed areas for potential expansion of these efforts.

Next Steps

While the four pillars of the Climate Adaptation Flexible Framework outlined in this report set the groundwork for future climate resilience efforts at Duke Energy, the Framework does not dictate a specific set of investments, nor does it specify how this work will happen. Rather, it is another step on a path toward climate resilience—one that will require continued development, refinement and collaboration. Key next steps to help advance the recommendations included in this report from a framework to practice include:

- Set expectations and assign responsibility
- Continue implementation of process changes to maintain readiness
- Develop an actionable resilience plan to address evolving potential impacts from climate change
- Determine a funding approach
- Conduct regular engagement with stakeholders
- Establish performance metrics
- Implement, monitor, revise

Introduction

Overview of Duke Energy Climate Risk and Resilience Study

Through the Climate Risk and Resilience Study (CRRS), Duke Energy has developed an improved understanding of the physical vulnerabilities[1] and risks that climate change could pose to its transmission and distribution (T&D) assets, operations and customers in the Carolinas, and developed a flexible Climate Adaptation Flexible Framework to improve the company's resilience. Duke Energy selected ICF's climate adaptation and resilience experts to conduct the technical analysis supporting the study. ICF's experts, along with Duke Energy internal SMEs, make up the project team for the CRRS.

The Climate Adaptation Flexible Framework reflects the recommendations of the project's Technical Working Group (TWG), which is composed of representatives from Duke Energy's external stakeholders, and ICF in their capacity as an expert advisor on utility resilience planning. The CRRS and this framework are the natural continuation of ongoing work on reliability and resilience, but it is not the end of the road—Duke Energy acknowledges that additional modifications to its processes and work plans remain to be completed to fully implement the framework and ideas discussed in this report.

Figure 4 summarizes the work that has been completed under the CRRS and future implementation activities.

Duke Energy's September 2022 Climate Risk and Resilience Study Interim Report[2] summarizes the climate change vulnerability and risk analysis findings for Duke Energy Carolinas T&D assets. It includes a robust presentation of climate change projections and analysis on how those changes may impact Duke Energy's T&D assets and planning practices. In short, the study found that, by 2050, rising temperatures and flooding pose the greatest risks to substations, though the scope and scale of those risks vary across the range of future climate projections. In addition, Duke Energy's asset management practices may require multiple adjustments to account for future changes in climate. More details on the methodology for this phase of the project can be found in the Overview of the Vulnerability Assessment. Applicable findings from the Vulnerability Assessment are woven throughout this report.

This report focuses on the overarching Climate Adaptation Flexible Framework, which identifies the suite of potential adaptations and outlines considerations for future project prioritization and implementation. The framework will inform Duke Energy's continued work to consider and address climate change in Duke Energy's T&D system planning and operations as it moves into the future implementation phase.

1 This report is only focused on physical climate change risks, but Duke Energy is also a leader in climate change mitigation efforts to help reduce the likelihood that the physical risks come to pass. Duke Energy has set ambitious climate mitigation goals, striving toward at least a 50% reduction in CO2 emissions from electricity generation in 2030, and are on the way to net-zero CO[2] by 2050. Find more information at https://www.duke-energy.com/our-company/environment/global-climate-change#:~:text=We've%20set%20ambitious%20climate,gas%20distribution%20business%20by%202030.

2 Duke Energy. 2022. Climate Risk and Resilience Study Interim Report. https://www.duke-energy.com/-/media/pdfs/our-company/carolinasresiliencetransmissiondistributionstudy.pdf?rev=817f65188d5a4667a054ecc85137b135

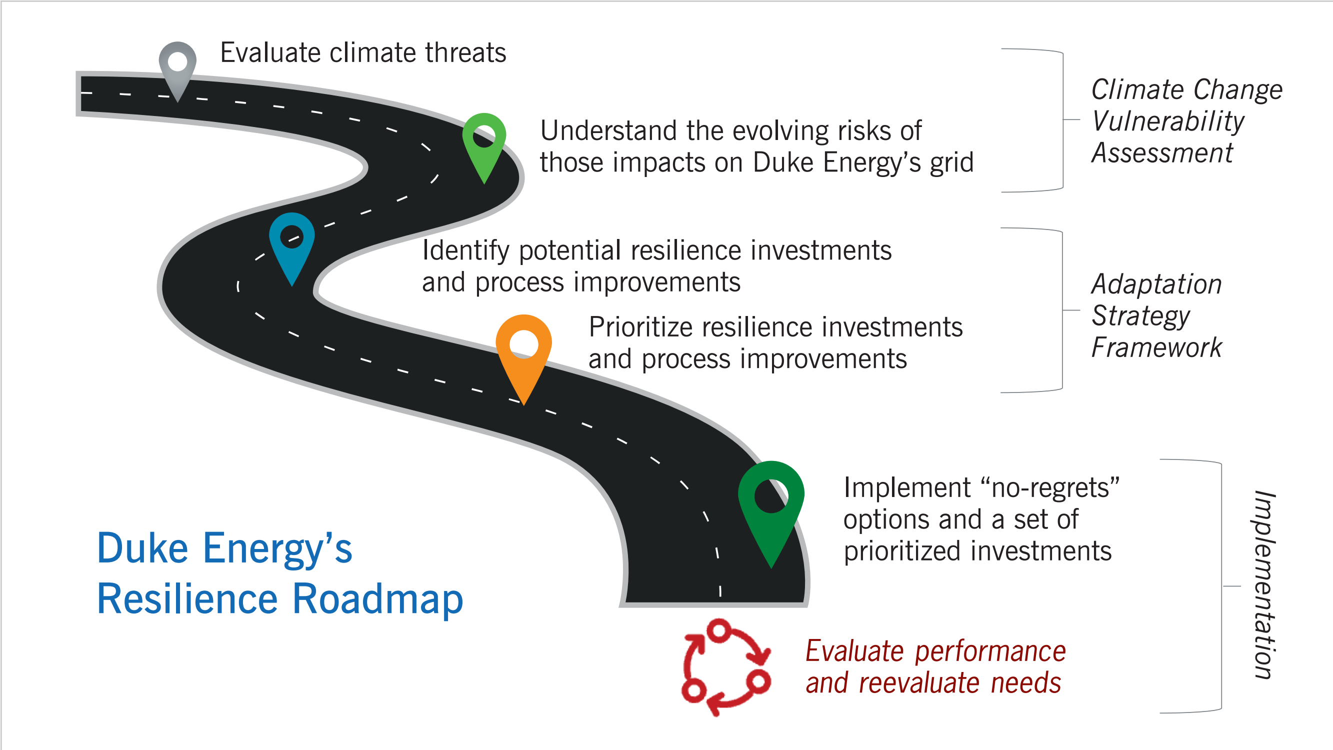


Figure 4. Duke Energy's Climate Adaptation Road Map.

Discussion with Duke Energy stakeholders (via the TWG) indicated that the flexible framework should:

- Consider stakeholder priorities and mutual resilience objectives
- Be flexible to allow for change over time as climate information evolves
- Identify potential adaptation options
- Address both gradual changes in climate and extreme weather events
- Balance costs and benefits
- Consider the life cycle of equipment versus when climate risk is realized
- Consider evolving industry standards and regulations
- Consider the needs of populations that may be differentially vulnerable to or impacted by outages (e.g., due to factors such as energy burden, environmental and climate hazards, socioeconomic vulnerabilities or fossil dependence).[3]

Based on Duke Energy's and ICF's work over the past two years and stakeholder input, the framework is organized into four key pillars:

- **Monitor climate science** – Use adaptation planning scenarios to inform planning and design; update the scenarios as science evolves.
- **Maintain readiness** – Continue to evolve T&D planning and operational practices to be ready for changing climate risks.
- **Incorporate new factors in T&D investments** – Identify and prioritize selective T&D investments, when and where appropriate, that will reduce climate risk for Duke Energy's grid and customers.
- **Partner with local communities** – Continue to support community resilience planning efforts and have community priorities inform resilience planning.

[3] The four factors contributing to differential vulnerability included in the parenthetical are aligned with the factors the Department of Energy considered when developing their Energy Justice Mapping Tool.

Introduction to Duke Energy's System

Duke Energy's service area in North Carolina and South Carolina comprises Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP), which deliver electricity to customers through a grid of transmission lines, distribution lines and substations. This study focuses on these portions of Duke Energy's assets and operations. It does not include Duke Energy's generation assets. Figure 5 depicts Duke Energy's service area for DEC and DEP.

Infrastructure in the DEC service area serves approximately 2.7 million industrial, commercial, and residential customer accounts, and spans nearly 24,000 square miles. The DEP service area serves nearly 1.6 million industrial, commercial and residential customer accounts, and spans nearly 32,000 square miles.

Within Duke Energy's service territory in North Carolina and South Carolina, approximately 1.5 million customer accounts are served by local distribution cooperatives or municipal utilities. These entities resell energy (supplied by wholesale electricity generators, such as Duke Energy) to end-use customers using distribution assets owned and operated by the cooperative or municipal utility. These non-Duke Energy assets are considered out of scope for the current study, though the climate analysis in this study does encompass those utilities' service territories.

Overview of the Vulnerability Assessment Methodology

The Vulnerability Assessment (as summarized in the Interim Report) reviewed exposure and the potential impacts of climate change at the individual asset level (discrete, existing physical T&D assets) and provided granular data to support Duke Energy's assessment of adaptation options that would improve the system's resilience amid future potential risks. The study used the best available climate science, but the science will continue to evolve over time. The study's findings were organized by asset type (e.g., functional components such as transformers or conductors), by asset group (i.e., transmission, substations, distribution), and by

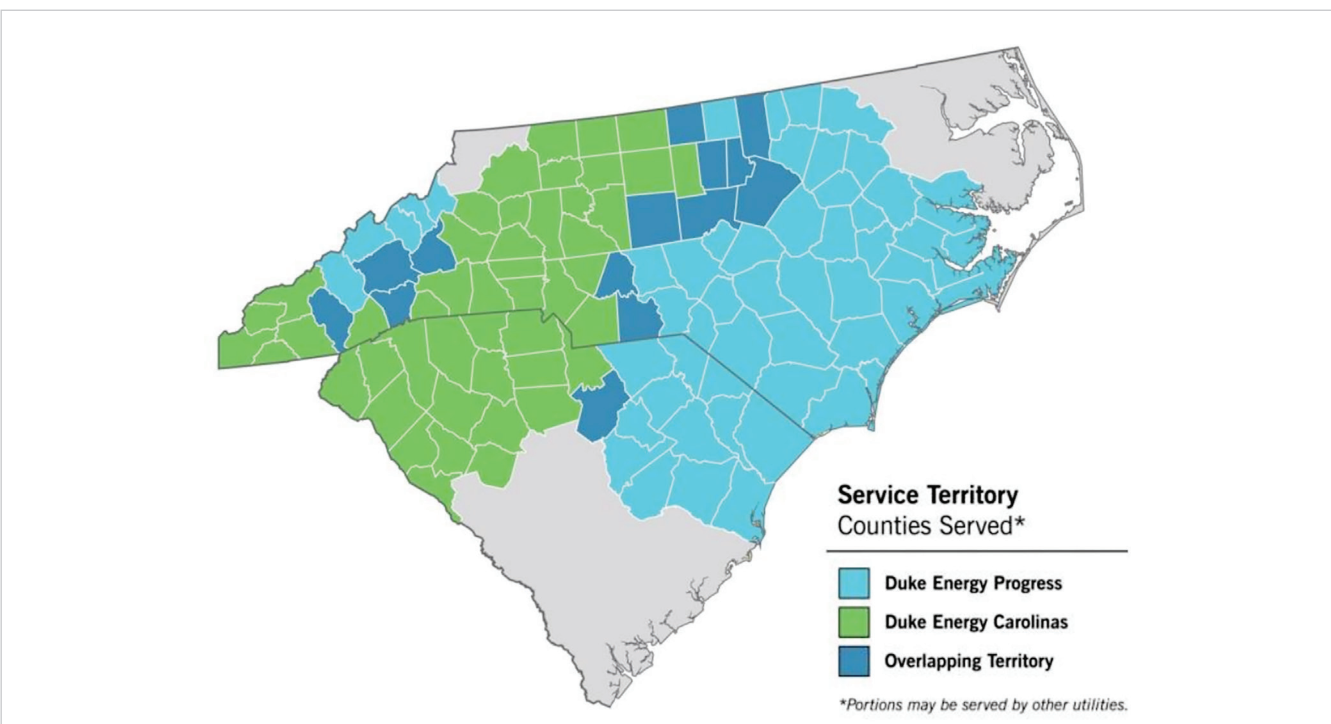


Figure 5. Map of DEC & DEP service territory.

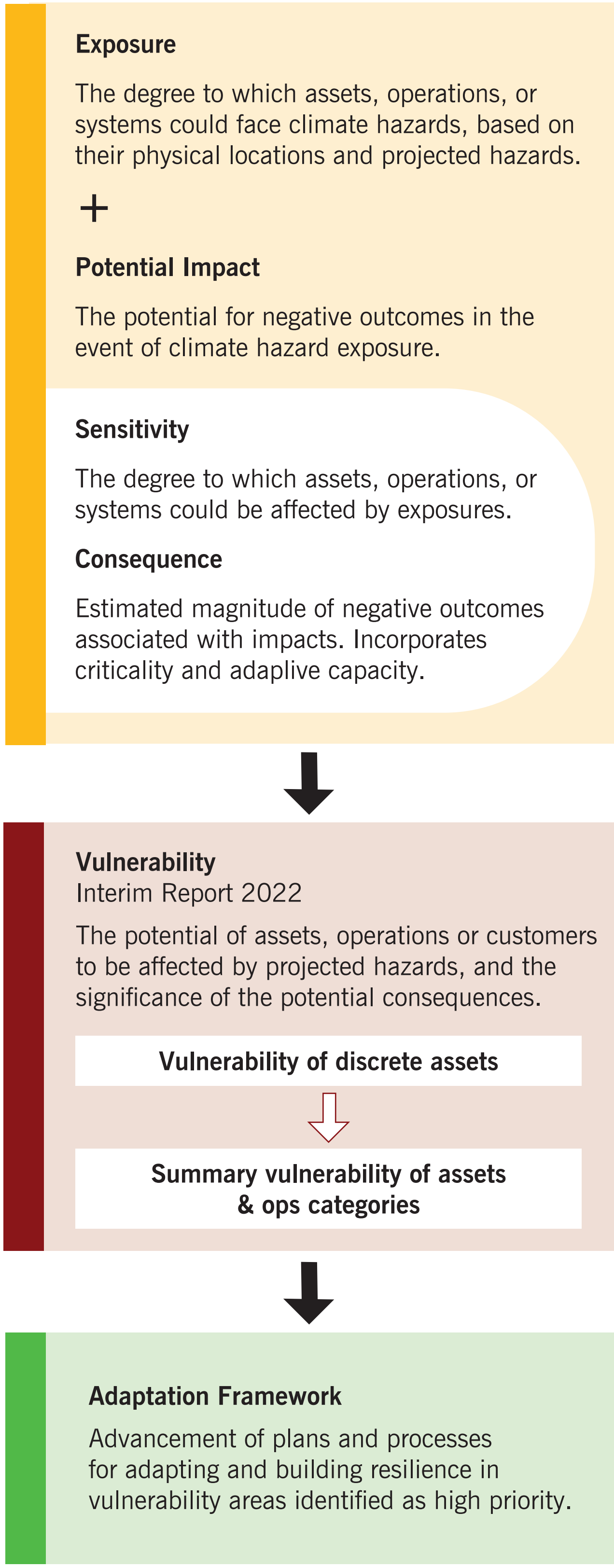


Figure 6. Vulnerability assessment framework.

planning and operations process areas (e.g., asset management, workforce safety). The **vulnerability ratings** were summarized as **low**, **medium** or **high**, with supporting documentation. Importantly, these ratings reflect incremental risk associated with plausible climate change effects, focusing on the 2050 time frame, and are not intended to indicate current or cumulative risk levels. Figure 6 illustrates the framework for assessing and characterizing vulnerability.

The key findings from the Vulnerability Assessment are woven throughout this report.

Stakeholder Engagement

Duke Energy understands that, for climate resilience planning to be effective, it must include the perspectives of a broad range of stakeholders, including the communities that DEC and DEP serve, and leverage expertise beyond Duke Energy's own staff. Duke Energy is actively engaged with these groups and has been working with them for decades. Its Government & Community Relations team fosters direct relationships with staff from every community, and Duke Energy performs regular stakeholder engagement with other community partners. This project was designed to build upon those efforts, ensuring that Duke Energy's resilience planning is informed by a broad range of perspectives and fulfills the utility's ultimate purpose of serving communities' and customers' energy needs into the future.

Therefore, this project involved a robust stakeholder engagement effort designed to:

- Identify stakeholders' key goals, challenges and concerns
- Collect and consider best practices and expertise offered from third-party resources
- Integrate stakeholder feedback in Duke Energy's evolving resilience planning
- Provide transparency on the climate study process and outcomes

ICF convened a wide-ranging panel of stakeholders to serve on the CRRS TWG. The purpose of the TWG was to provide input and feedback to the study team throughout the study process, and to review interim study results ahead of key milestones. The TWG includes a wide range of stakeholder segments. A full list of TWG organizations that participated in the Vulnerability Assessment work is provided in Table 1. ICF and Duke Energy are grateful to TWG stakeholders for providing their time and insights in support of this effort.

ICF recognizes this initial stakeholder feedback focused on technical aspects important to develop a framework for additional community-based organizations' (CBOs) input and expertise in the next phase of the work. Duke Energy may consider opportunities to closely partner with representatives familiar with local community needs and perspectives, particularly to support populations that may be differentially vulnerable to or impacted by outages (e.g., due to factors such as energy burden, environmental and climate hazards, socioeconomic vulnerabilities or fossil dependence). These may include representatives from CBOs or networks, for example. Notably, this form of engagement would hinge on such representatives' availability and interest, which may be affected by their existing trust in Duke Energy, or a belief that their contributions will be meaningfully taken into account.

Duke Energy gathers input from external stakeholders through many venues. For example, external feedback on equity-related issues has been solicited from industry benchmarking and peer groups, state regulatory agencies, and community groups. This input has informed Duke Energy's efforts including the development of Environmental Justice Principles, their federal grant application process, their contracting process, their resource planning, and their philanthropic giving.

The participation of these organizations in this effort does not imply, suggest, signify, or in any way reflect their position concerning the issues discussed in the stakeholder meetings. The input from the TWG in this report does not necessarily reflect the positions of all member organizations and their contributions to these meetings do not reflect any sort of endorsement for this report.

Table 1. Technical Working Group Member Organizations.

Organization Type	TWG Member Organization
Clean Energy/ Environmental Organizations	Advanced Energy
	Interfaith Power & Light, NC
	NC Sustainable Energy Association
	Sierra Club
	Southern Alliance for Clean Energy
	Southern Environmental Law Center
	Vote Solar
Customers – Large	CIGFUR
	Corning Incorporated
	Gerdau
	Google
	Walmart
Energy Industry Association	Electric Power Research Institute
	Research Triangle Cleantech Cluster
	Smart Electric Power Alliance
Governmental	City of Asheville
	Durham County
	NC Department of Environmental Quality
	NC Department of Justice
	NC Utilities Commission Public Staff
	New Hanover County
	SC Department of Natural Resources
	SC Office of Regulatory Staff
	SC Office of Resilience
	Town of Chapel Hill
Low-Income Advocates	NC Justice Center
Universities & Other Educational Organizations	Clemson University
	Duke University
	Institute for Policy Integrity at NYU School of Law
	Nicholas Institute for Energy, Environment & Sustainability (Duke University)
	North Carolina State University/NC State Climate Office
	UNCC EPIC Center
	NC Clean Energy Technology Center
	NC Institute for Climate Studies
Utilities & Related Organizations	Dominion
	Dominion SC
	ElectriCities of NC, Inc.
	Lockhart Power Company
	NC Electric Membership Corporation

Stakeholder Engagement Activities

ICF engaged TWG members in the climate study through multiple channels, including interviews, meetings, email updates and surveys. Much of the feedback informed the development of the flexible adaptation framework created for this project.

Interviews

To inform the study plan, ICF interviewed 12 individuals across 11 organizations in fall 2021 to gain insights into stakeholders' key climate resilience priorities. The concept of "community resilience" emerged as the top concern voiced by stakeholders. More specifically, stakeholders urged the project team to:

- Consider how climate stressors will not impact all communities and populations equally; some may be differentially vulnerable to or impacted by outages.
- Take into consideration non-climate considerations, such as population growth and social equity, when identifying and prioritizing resilience-related actions.
- Work collaboratively with local governments and communities on holistic, locationally specific solutions and incorporate actions outside of Duke Energy's regulatory scope of responsibility.

TWG meetings

ICF convened five virtual TWG meetings in addition to two presentations to Duke Energy's broader Integrated Systems and Operations Planning (ISOP) stakeholder group.

TWG meeting 1 was held on September 21, 2021, and included the following topics:

- Introduction and purpose (ICF)
- Overview of NC DEQ Climate Risk Assessment and Resilience Plan (NC Dept. of Environmental Quality)
- Stakeholder panel: Local Resilience Planning
  - City of Asheville
  - Durham County
  - New Hanover County
- Climate Vulnerability Assessment Framework for T&D (ICF)

TWG meeting 2 was held on February 17, 2022, and included the following topics:

- Welcome and feedback received to date (ICF)
- Climate data/exposure update (ICF)
- Vulnerability Assessment update (ICF)
- Adaptation Planning (Duke Energy & ICF) + Adaptation Brainstorming
- Next steps (ICF)

TWG meeting 3 was held on August 10, 2022, and included the following topics:

- Welcome and introductions (ICF)
- Vulnerability Assessment Findings and Feedback (ICF)
- Adaptation Planning Scoping (ICF)
  - Stakeholder panel on adaptation strategies recommended by the TWG
- Next steps (ICF)

TWG meeting 4 was held on February 27, 2023, and included the following topics:

- Update on process and recap of TWG contributions to date (ICF)
- Federal Infrastructure Investment and Jobs Act and Inflation Reduction Act activities (NC DEQ)
- Proposed resilience road map (ICF)
- Duke Energy's support of community resilience efforts (ICF)
- Adaptation framework and potential strategies for the T&D system (ICF)

TWG meeting 5 was held on June 8, 2023, and included the following topics:

- Overview and discussion of the draft CRRS Report (ICF)

Dedicated mailbox and bimonthly email updates

ICF maintained an email inbox for the project to provide TWG members with an outlet for questions or comments about the study. In addition, stakeholders received email updates about the project every other month to allow stakeholders to remain engaged during the interim periods between TWG meetings.

Surveys

ICF distributed a survey to stakeholders following the first TWG meeting in 2021, to seek input on ICF's proposed climate science scenarios and Vulnerability Assessment framework, and how ICF should engage stakeholders throughout the two-year study process. Survey respondents emphasized the need for transparency and meaningful, interactive engagement with the TWG early in the study process. They also recommended that the Vulnerability Assessment consider community impacts, equity and future clean energy growth.

Stakeholder Input

Table 2 below summarizes TWG feedback and how ICF incorporated stakeholder input into the study and recommendations for Duke Energy's approach.

Table 2. TWG feedback summary and actions taken or recommended by ICF.

TWG Feedback	Actions Taken/Recommendation by ICF
Goals and Scope of Vulnerability Assessment TWG members underscored the importance of the study outcomes being accessible and readily usable by communities to inform their own resilience planning. TWG members also recommended additional assets for consideration and adjustments to the study time horizon.	• Established Vulnerability Assessment goals. • Adjusted framing of asset scope and time-period focus.
Social Equity Social equity is a concern among several TWG members. The CRRS should consider how populations are differentially vulnerable to or impacted by outages.	• Incorporated the U.S. Centers for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI) into the Vulnerability Assessment based on recommendations from the TWG and its strong reputation as an accurate and geographically refined dataset. • Recommended consideration of populations differentially vulnerable to or impacted by outages in future adaptation prioritization efforts (see Section VII. D).
Engagement Process TWG members want to be engaged early and often throughout the study and want to be engaged in resilience work moving forward. The more interaction and information, the better.	• Interviewed stakeholders early in the process. • Established bimonthly email update to keep TWG informed on progress and how feedback is being incorporated. • Added TWG meeting 2 to the schedule; leveraging interactive whiteboard software. • Included the "Partnering with Local Communities" pillar in the Climate Adaptation Flexible Framework.
Exploring Climate Adaptation Solutions TWG members have recommended many approaches that Duke Energy should consider to mitigate climate risks to its T&D system (e.g., enhanced local government coordination, undergrounding, vegetation management, community microgrids, and incentives for distributed generation).	• Kicked off Adaptation Planning discussion at TWG meeting 2 (February 2022). • Used this feedback to inform the Adaptation Planning phase of the study—ideas from the meeting are woven throughout this report.

Climate Adaptation Flexible Framework Overview

Based on Duke Energy's and ICF's work over the past two years and stakeholder input, the Climate Adaptation Flexible Framework is centered around four primary pillars, as shown in Figure 7.

These pillars will help keep climate change adaptation investments focused on areas with the greatest potential risk reduction for Duke Energy's customers and will facilitate Duke Energy's ability to replicate this planning effort in the future as the needs, capabilities of, and pressures on its system change. The approach outlined for each pillar is flexible enough to incorporate additional planning considerations such as existing grid modernization plans, community-led efforts to address climate resilience and differential needs of populations (e.g., due to factors such as energy burden, environmental and climate hazards experienced, socioeconomic vulnerabilities and fossil dependence).

Within each pillar, Duke Energy will need to identify potential resilience investments to incorporate into its adaptation strategy. This report provides examples of those options. Duke Energy can evaluate these options against each other to create a set of prioritized investments that achieve the most benefits per dollar invested. It should be noted that, while resilience is the primary focus, other benefits, such as carbon reduction, or supporting populations that are particularly vulnerable to or may be differentially impacted by outages, will be considered when prioritizing solutions.

Figure 7. Four Pillars of Duke Energy's Climate Adaptation Flexible Framework.

Monitor Climate Science

Monitoring climate science is the first pillar of Duke Energy's Climate Adaptation Flexible Framework.

Climate science and policy continues to evolve. While this report is focused on strategies that Duke Energy can use to mitigate the physical impacts of climate change, the company also understands the necessity of reducing greenhouse gas emissions to reduce the magnitude of change in climate. Duke Energy was one of the first U.S. electric utilities to have a carbon reduction goal; they have published a TCFD[4]-aligned climate report since 2018 and disclosures of activities related to climate-related risks in several reports (including climate reports, CDP disclosures, and others). According to the Net Zero Tracker report (a collaboration between Oxford University, EnviroLab at the University of North Carolina-Chapel Hill, the NewClimate Institute in Germany and the UK nonprofit Energy & Climate Intelligence Unit), Duke Energy is the only electric utility that has developed a credible "detailed plan" for how to reach net zero emissions.[5] Duke Energy clearly sees emissions reduction as its first line of defense against climate change impacts.

Duke Energy also has a number of grid resilience programs that have been developed over the past several years to respond to increasing severe weather impacts. Going forward, Duke Energy is committed to using best available climate science to determine the timing and magnitude of projected

[4] Task Force on Climate-Related Financial Disclosures.

[5] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/survey-finds-just-1-us-utility-has-detailed-plan-for-reaching-net-zero-by-2050-76146165

Figure 8. The first pillar of the Climate Adaptation Flexible Framework is to monitor climate science.

climate change in the service area and help inform adaptation planning. As part of this effort, ICF assisted Duke Energy in reviewing climate science developed for the Vulnerability Assessment and selecting a climate change adaptation planning scenario, which provides standardized climate change projections to inform Duke Energy's adaptation efforts. Moving forward, Duke Energy plans to continue to monitor and update its understanding of climate risks and its climate change adaptation planning scenario as climate science and understanding of climate change improves.

Climate Change Scenarios from the Vulnerability Assessment

The vulnerability analysis focused on the range of plausible climate change futures for five climate hazard categories: (1) high temperatures and extreme heat; (2) extreme cold and ice; (3) flooding and precipitation; (4) wind; and (5) wildfire. The analytical focus was on plausible upper and lower bounds of climate projections, using the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCPs) greenhouse gas concentration trajectories and an ensemble of downscaled Global Climate Models. The lower bound used the 50th percentile projection (i.e., median) of RCP 4.5, and the upper bound used the 90th percentile projection (i.e., right-tail) of RCP 8.5. The RCP 8.5 90th percentile scenario represents a complete failure of global emissions reduction efforts and high-end climate sensitivity, thus reflecting an extremely conservative approach or a "worst-case" understanding of risks. The RCP 4.5 50th percentile projections represent a more likely scenario under current and pledged emissions policies than RCP 8.5. The study provided exposure and impact analysis for both scenarios.

Selecting a Climate Change Adaptation Planning Scenario

Climate science provides a range of plausible climate change outcomes, reflecting uncertainty in future greenhouse gas emissions, climate system sensitivity, natural climate variability, and other factors. While it is valuable to understand the full range of potential impacts, ultimately engineers require a specific scenario to build to. To narrow the range and standardize Duke Energy's adaptation efforts and planning, ICF assisted Duke Energy in selecting a

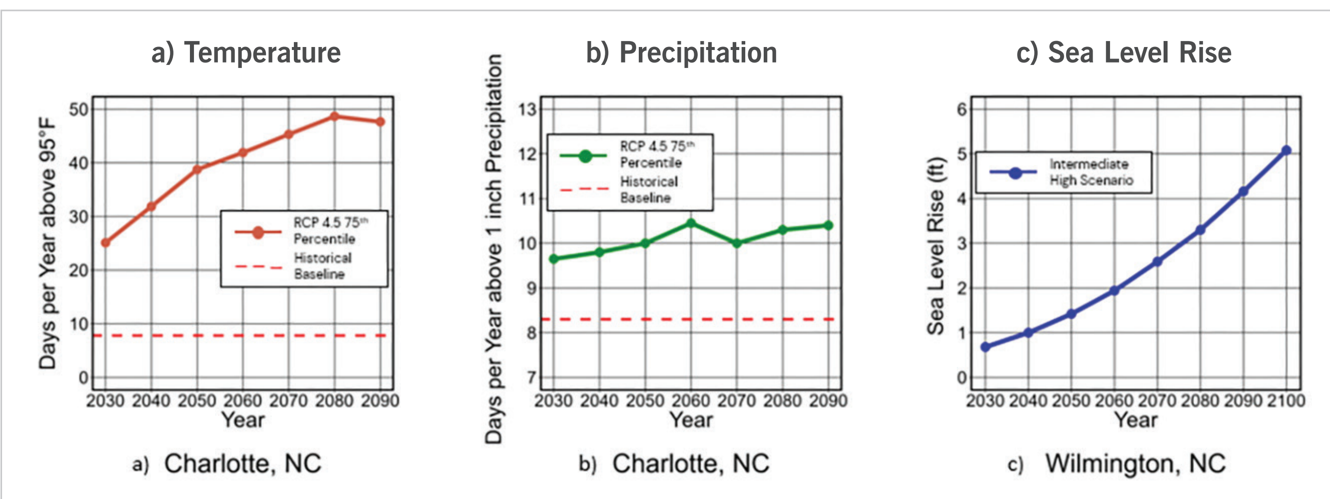


Figure 9. Example climate projections corresponding to Duke Energy's selected climate change adaptation planning scenario: (a) The projected number of days per year with daily maximum temperature above 95°F for Charlotte, North Carolina, in each decade from 2030-2090. The historical baseline from 1991-2010 is 7.8 days above 95°F; (b) The projected number of days per year with precipitation above 1 inch in Charlotte, North Carolina, in each decade from 2030-2090. The historical baseline from 1991-2010 is 8.3 days, with precipitation above 1 inch; (c) The projected intermediate-high scenario sea-level rise in feet for each decade from 2030-2100, relative to sea level in a baseline year of 2000. Data for sea-level rise was collected from the Interagency Sea Level Rise Scenario Tool: https://sealevel.nasa.gov/task-force-scenario-tool.

climate change adaptation planning scenario. The selected scenario is the 75th percentile projection of RCP 4.5.[6] The resulting climate projections provide information on a range of variables relevant to adaptation activities, including future ambient and extreme temperatures, precipitation levels (see Figure 9 for example data points, and data that Duke Energy uses to inform load forecasts.

Selection of the climate change adaptation planning scenario considered a range of criteria, including benchmarking against regional resiliency standards, risk aversion, and evaluation of the latest climate science and climate policy. Duke Energy identified RCP 4.5 as a more likely trajectory for future global greenhouse gas concentrations because it better aligns with global pledged emissions reductions and policies. In comparison, RCP 8.5 assumes largely unabated and growing global greenhouse gas emissions through end of century, which is very unlikely to occur. Duke Energy selected the 75th percentile projection to establish a higher risk aversion level because it is above the median projection (i.e., 50th percentile) and to better capture the potential for worse climate outcomes in the service area. Ultimately, the climate change adaptation planning scenario establishes levels of warming that exceed goals set by the Paris Agreement to limit global warming below 1.5 degrees Celsius compared with preindustrial levels and well aligns with warming under RCP 8.5 through midcentury.

Sea-level rise projections do not use the same scenario nomenclature. The best available science on sea-level rise projections was developed for the 2022 Federal Interagency technical report,[7] which is a key input to the Fifth National Climate Assessment. Based on this report, Duke Energy has selected the intermediate-high sea-level rise projection as its climate change adaptation planning scenario, which projects future sea-level rise commensurate with unabated greenhouse emissions. The intermediate-high projection is commonly used in support of climate adaptation activities (e.g., by the state of Virginia for infrastructure planning). This scenario projects approximately 5.0 feet of sea-level rise at Wilmington by 2100 (Figure 9c).

Moving Toward Implementation

ICF recommends that Duke Energy explore the development of a Climate Change Design Guideline to further support adaptation efforts. The guideline would serve as a key implementation document summarizing the climate change adaptation planning scenario and how corresponding climate projections and information should apply to, for example, planning, design, operations, processes, and emergency response practices across the company.

In addition to forward-looking climate projections, Duke Energy extensively uses weather data to help inform decision-making across the company. The high-quality data that Duke Energy invests in is extremely useful. Moving forward, it would be advantageous to invest in standardizing Duke Energy's data collection and internal solutions for weather and climate data. Doing so would facilitate the use of consistent and aligned data sets across the company.

Signposts for Updates

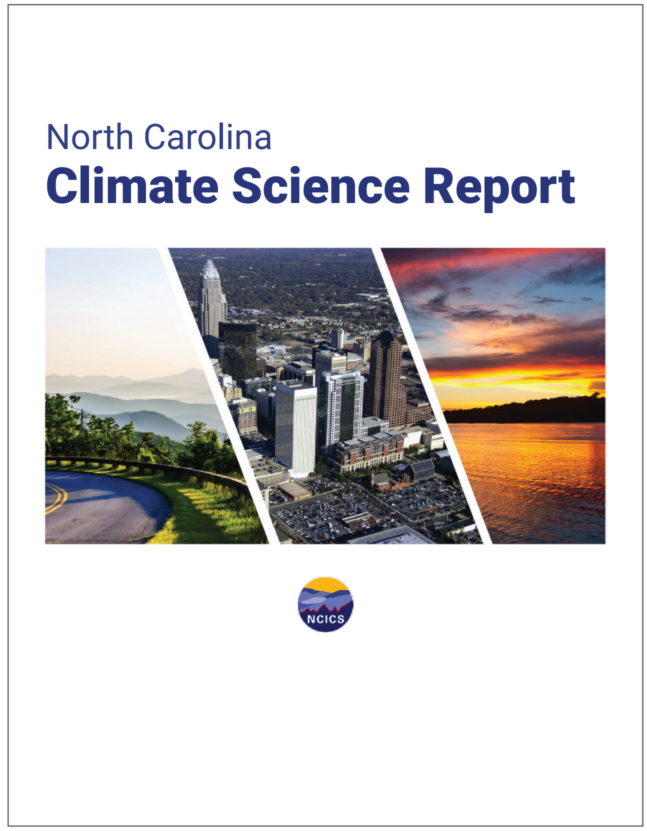
Duke Energy's climate change adaptation planning scenario is preliminary and should be updated and refined over time to reflect changes in scientific understanding, state policy or other factors. These changes may also motivate updates to the vulnerability study and broader adaptation efforts across the company. The study team identified several signposts to monitor and help determine the timing of updates, including:

- Major climate science advances, such as the completion of new Coupled Model Intercomparison Project (CMIP) projections.

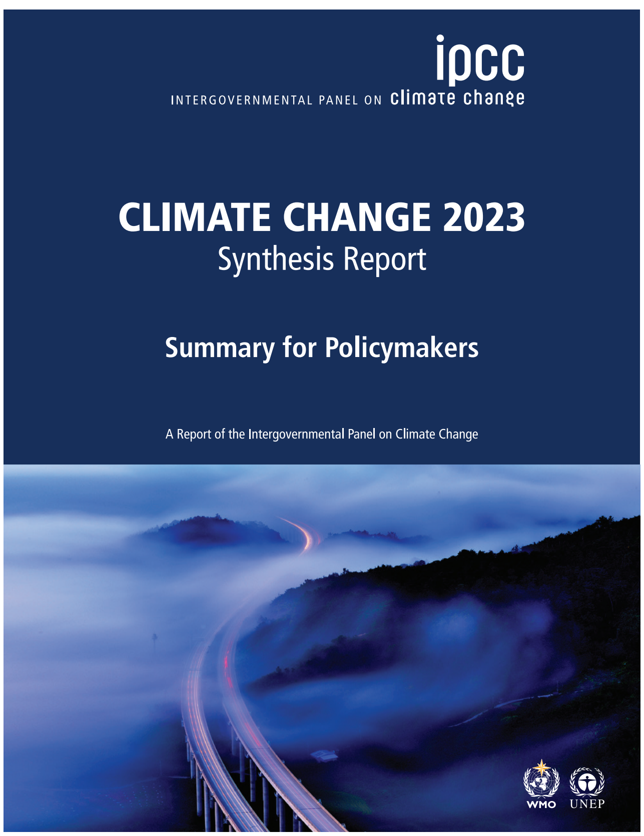
[6] This scenario selection does not reflect Duke Energy's climate change mitigation ambitions or preferences on greenhouse gas emission policies.

[7] NASA. 2022. Global and Regional Sea Level Rise Scenarios for the United States. https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report-sections.html

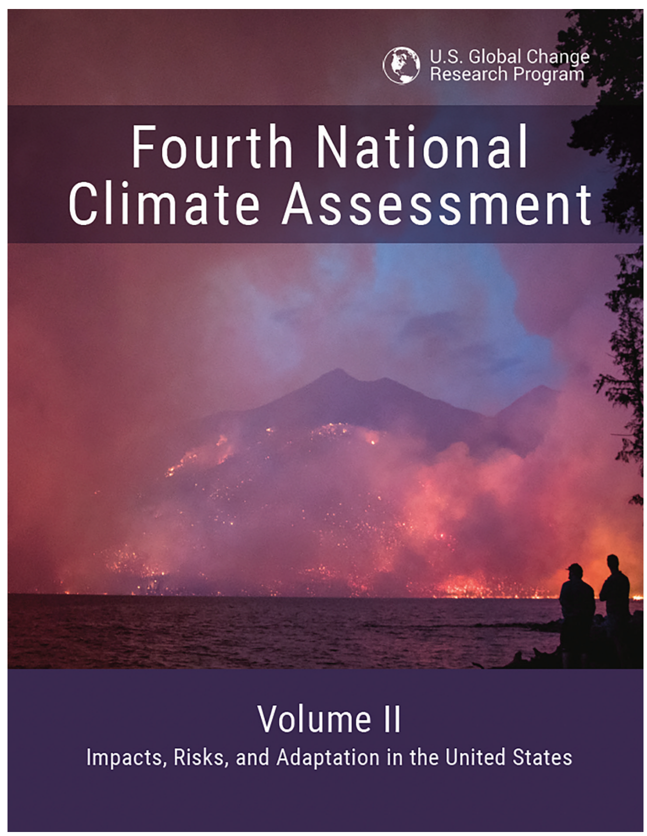
- The inclusion of new climate science in landmark and authoritative reports, such as Intergovernmental Panel on Climate Change Assessment Reports, the National Climate Assessment and state-level reports, which help establish the state of the science.
- Monitoring of climate change within the service area, including observations of long-term trends in temperature, precipitation, and other variables at weather stations and the frequency and intensity of extreme weather events.
- Climate change adaptation planning scenario updates could also result from signposts related to the selection of more or less risk averse climate projections such as:
    - Global emissions trends or policies
    - Changes in external standards established by city, state or regional stakeholders
    - Industry shifts in risk aversion and resilience activities



https://ncics.org/wp-content/uploads/2020/10/NC_Climate_Science_Report_FullReport_Final_revised_September2020.pdf



https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf



https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf

Maintain Readiness

Maintaining readiness is the second pillar in Duke Energy's Climate Adaptation Flexible Framework, and arguably may be the most impactful and cost-effective way to increase climate resilience. Continuing to evolve Duke Energy's planning and operations capabilities to account for climate change sets the stage for continued long-term, incremental increases in resilience. Making these incremental updates ensures that capital investments and plans are informed by a forward-looking view of climate and allows assets to be gradually replaced with more robust designs (if needed) over time. For the majority of Duke Energy's T&D system, these incremental updates will be sufficient for keeping pace with the projected changes in climate given the gradual nature of the changes.

Findings from the Vulnerability Assessment

As part of the Vulnerability Assessment, the study team reviewed the potential risks to Duke Energy's planning and operations practices. This section summarizes ICF's recommended enhancements to planning and operating functions to continue to adapt to climate change and maintain readiness for what may come.

To understand the risks, the study team relied on ICF's professional knowledge as well as in-depth conversations with Duke Energy SMEs. The overall risk of the planning and operation areas were determined based on the number of process components that were identified as potentially being at risk if they were not modified to account

Figure 10. The second pillar in Duke Energy's Climate Adaptation Flexible Framework is to maintain readiness.

for climate change (see Table 3). A score of "low" corresponded to no process vulnerabilities being identified, a score of "medium" corresponded to one or two process vulnerabilities being identified and a score of "high" corresponded to more than two process vulnerabilities being identified.

Table 3. 2050 projected vulnerability priority ratings for asset and operations planning groups.

Process Area	Risk Score
Asset Management	High
Load Forecasting	Medium
Capacity Planning	Medium
Reliability Planning	Medium
Emergency Response	Low
Workforce Safety	Low
Vegetation Management	Low

Recommendations for asset management, load forecasting, capacity planning and reliability planning are provided below.

While **emergency response**, **workforce safety** and **vegetation management** will all be impacted by climate change, their existing processes were found to be flexible and robust enough to address future changes in climate through 2050. Thus, no recommendations are provided for those areas at this time. However, Duke Energy will continue to monitor these areas to ensure their continued effectiveness. In addition, while Duke Energy may not need to significantly change their existing practices, they may need to increase the budget for these areas. For example, current emergency response procedures may be robust enough to respond to future storms, but climate change may increase the frequency of storm events, which would require higher budget levels to address. Likewise, workforce safety may need to account for more frequent high heat breaks or wind interruptions, and vegetation management may need to increase the frequency of trimming, but current monitoring programs that help determine when to trim will make this an automatic process.

Recommendations for Updating Planning and Operations Processes to Maintain Readiness

This section outlines the recommendations for addressing climate-related risks in Duke Energy's planning and operations process to maintain readiness. Some of these adaptation options may ultimately result in the need to invest in T&D infrastructure. For example, incorporating climate change into the load forecasting and capacity planning processes will result in forecasted higher peak demand and corresponding lower equipment ratings that will require investments in system capacity and/or deployment of energy efficiency and demand response measures.

Asset management

Asset management, or Duke Energy's processes to specify, source, commission, monitor, repair, replace, and augment equipment and systems, is the only process area that received a **high** priority vulnerability rating. Risks to Duke Energy's asset management processes include:

- Accelerated equipment aging due to higher ambient temperatures;
- The potential need to adjust asset specifications and design criteria to address the risk of changing precipitation, flooding and heat patterns;
- Limited insight into failure data and impact of climate on failure rates; and
- An incomplete understanding of the condition and thus weather readiness of non-Duke Energy-owned poles on which Duke Energy-owned assets are installed.

Without adaptation, these risks could result in reduced service reliability for customers and higher capital costs. To address these risks, ICF, informed by TWG input, recommends four key actions.

Proactively revise specifications to address increasing climate risks. For several years, Duke Energy has been identifying and revising design and operations specifications to address emerging extreme weather risks. Examples of prior updates include:

- Building new substations to updated standards that consider flood risk. They are designed to a design flood elevation (DFE) standard that requires equipment elevations at or above the 100-year storm level plus 2 feet, the 500-year flood level plus 1 foot, or local ordinances, whichever is higher.
- Installing permanent flood protection at selected substations and planning newly sited substations (such as the one near Whiteville 230) on high ground to protect against flooding.
- Increasing overhead distribution conductor ambient temperature assumptions to 104°F across DEP, DEC and other Duke Energy operating areas to harmonize specifications across the Duke Energy system.

Moving forward, Duke Energy could accelerate this process by proactively revising specifications to incorporate the climate change adaptation planning scenarios. Duke Energy is currently moving in that direction by conducting a review of specifications to identify candidates for update. More specifically, they are identifying specifications in which:

- Climate hazards are explicitly included, such as a purchase specification with ambient temperatures for equipment.
- Climate hazards are implicitly included through industry standards, such as ice and wind loading, as specified by the National Electrical Safety Code (NESC).
- Assets in particular geographic locations that may be threatened by flooding.

Quantify the impact of climate change on asset failure and replacement rates. The Duke Energy asset management group uses the Health Risk Management (HRM) system, which houses condition data on major assets such as transformers and circuit breakers. Duke Energy is evaluating the addition of other assets to HRM including batteries, underground cables, and so on. Duke Energy also uses the Copperleaf asset management software application, which is a financial tool for planning and prioritizing investments. The Copperleaf application includes aging models that support developing projections of future asset health based on input data about the asset. These model outputs support financial planning over a five- to 10-year period. Duke Energy should explore the potential to use the Copperleaf application, equipment condition data, and climate exposure data to quantify the future impact of climate change on asset replacement rates and adjust the asset management process to reflect their findings. Such adjustments could include accelerating proactive replacement, changing the frequency of inspections or identifying technologies or processes that could improve condition assessment of assets.

Improve data related to joint-use poles. Duke Energy should explore options to collect and analyze data on the condition of its joint-use pole fleet. This includes compiling available inspection data from the entities that own and maintain the poles as well as deploying targeted inspection teams to develop a condition baseline of the fleet. With this improved data, Duke Energy would be able to advance the resilience of its system by flagging areas of concern for the pole owners and potentially replacing poles that do not meet the design criteria.

Improve integration between data management systems. Duke Energy is a data-rich company, which allows it to make informed decisions about how best to manage its system. Like many others, as Duke Energy continues to increase the number of sensors and data management systems, it is an appropriate time to revisit data management processes and re-map how best to coordinate across these systems. Investing in integrated data management systems would help ensure that all departments are able to easily access relevant and comprehensive information when needed.

Load forecasting

Load forecasting is the process of forecasting the peak demand and energy consumption at future dates to support investment projects that align demand with system capacity. The load forecasting process received a **medium** vulnerability rating. The risks to Duke Energy's load forecasting process include:

- The forecasting process does not incorporate projected trends in ambient temperatures.
- Extremes in temperature are not considered consistently between the "top-down" and circuit-level forecasting processes.

Duke Energy is already taking action to address these risks, but without additional modification, these risks could result in Duke Energy under-forecasting its 10-year load projections, resulting in higher costs to reactively increase capacity compared to gradually increasing it over time using forecasts that consider climate projections. To address these risks, ICF, after consultation with the TWG, recommends the following actions:

- **Continue the efforts to incorporate climate projections into the load forecasting process**. Duke Energy has completed some initial work to explore incorporating climate projections into its top-down or jurisdictional load forecasting process, including completing the development of a forecast based on the RCP 4.5 scenario. As a next step, Duke Energy should consider how to gain regulatory and stakeholder support to use the outputs of this analysis in its planning processes. The climate-adjusted forecast could be used as a sensitivity test in the planning process, or it could be adopted as the official planning forecast. Regarding the circuit-level forecast (also termed "Morecast"), discussions with Duke Energy SMEs indicate that because the circuit-level forecasting process considers a 10-year time frame and gives more weight to recent higher temperatures, incorporating climate projections are less likely to result in forecast revisions. However, since the Morecast process is flexible enough to incorporate climate projections, Duke Energy should continue to explore the merits of incorporating climate projections into this process.
- **Explore options to reflect weather extremes in the top-down forecasting process**. Duke Energy's circuit-level forecast considers weather extremes, but the top-down forecast used in transmission planning does not. Duke Energy should explore options to incorporate weather extremes into the top-down forecast in a way that would be consistent with the circuit-level forecast's consideration of extremes. The insights provided by this change will be valuable as climate change increases the frequency and intensity of extreme heat.

Capacity planning

Capacity planning is a process that identifies portions of the grid where demand growth could exceed asset ratings and identifies and executes the necessary investments to align system capacity with expected customer demand. The capacity planning process received a **medium** vulnerability rating. The risks to Duke Energy's capacity planning process include:

- Ambient temperature assumptions do not reflect potential local variations in temperature;
- Incomplete real-time visibility into substation transformer temperatures; and
- Projected trends in ambient temperatures are not incorporated.

Without adaptation, Duke Energy risks an increasing potential for mismatch between planned and actual energy delivery capacity. This could create the potential for accelerated equipment aging, along with a marginally higher risk of equipment failure and potential impact to customers. To address these risks, ICF recommends the following actions:

- **Consider incorporating more granular temperature assumptions when developing equipment ratings**. ICF's analysis showed significant regional temperature variation in Duke Energy's Southern and Central regions. To better match actual conditions with planning assumptions, Duke Energy should explore ways to compile and use more granular ambient temperature data to inform equipment ratings.
    - The recent FERC order 881, requiring transmission operators to develop ambient adjusted ratings for transmission lines, will help to better align the rating assumptions for Duke Energy's transmission system to actual ambient temperatures. However, this improved alignment may result in higher flows on transmission lines and correspondingly lower levels of margin under some conditions.
- **Increase the level of SCADA temperature monitoring to improve visibility**. Duke Energy has supervisory control and data acquisition (SCADA) temperature monitoring for 90% of DEP substations, but only about 50% of DEC substations. Duke Energy should develop a project to expand SCADA monitoring to all substations. This monitoring will be of more immediate use in real-time operations, but a historic look back at the SCADA monitoring data could be of use to capacity planning.
- **Investigate use of climate change projections in the capacity planning process**. Historically, only 3% of overhead transmission conductors and 1% of overhead distribution conductors have experienced ambient temperatures exceeding planning assumptions. However, by 2050, up to 80% of overhead transmission conductors and up to 75% of distribution conductor could experience ambient temperatures exceeding planning assumptions at least once every 10 years. To address this, Duke Energy should investigate use of a selected climate change adaptation planning scenario to incorporate appropriate climate projections into the process of developing load forecasts, asset ratings, and potential capacity reductions due to increasing ambient temperatures into the appropriate processes.

Distributed Energy Resources

Distributed energy resources used in Duke Energy or third-party-owned projects can lower the demands on current distribution equipment. This may help mitigate increasing demand and reductions in equipment capacity due to increasing temperatures.

Reliability planning

Reliability planning processes include setting reliability performance targets, understanding the factors that influence reliability, and identifying investments and operating process improvements to achieve target reliability. The reliability planning process received a **medium** vulnerability rating. The risks to Duke Energy's reliability planning process include:

- Transmission planning criteria may not reflect the potential risks posed by climate change despite complying with North American Electric Reliability Corporation (NERC) requirements; and
- Distribution reliability planning processes are not structured to incorporate climate change projections.

Given the potential for climate change to impact the magnitude and types of events that will stress Duke Energy's systems, not considering these changes in risk may result in sub-optimal performance and declining reliability and resilience of Duke Energy's system over time. To address these risks, ICF recommends the following actions:

- **Consider revising the transmission planning criteria to reflect the potential for increasing severity of extreme events**. Although Duke Energy's transmission planning process meets NERC TPL-001 Transmission System Planning Performance Requirements, Duke Energy should consider using more conservative transmission-planning criteria than the NERC TPL-001 assumptions due to the potential for climate change to increase the frequency and severity of extreme events, along with the experience of past storms. In addition, Duke Energy might explore the potential for other high-impact, low-probability events, such as landslides, to impact reliability. Duke Energy should engage its neighboring transmission operators through the Planning Collaborative in a discussion about how climate change may impact the criteria used for transmission planning and encourage consistent planning.

- **Explore reliability analysis tools that can incorporate climate projections as well as the impact of new technologies.** Duke Energy's reliability analysis for distribution is performed via an in-house, data-driven tool that considers historical reliability performance but does not have the capability to incorporate the impact of projected changes in climate on reliability. ICF conducted an initial analysis to explore the sensitivity of the Charlotte distribution system to extreme heat. Duke Energy should explore the merits of such analysis for other areas of its system for heat and other hazards of concern, such as increases in storm frequency.

Duke Energy's investment plans include investments in a smart-thinking and self-healing grid that is projected to improve reliability by increasing the visibility into the state of the system, automating some operational decisions and reducing the impact of outages, both in the number of customers affected and the duration of the interruption. Duke Energy should work to incorporate the potential benefits of these investments into its reliability modeling tools as they consider the potential impacts of climate change.

Incorporate New Factors in T&D Investments

Incorporating new factors in T&D investments is the third pillar in Duke Energy's Climate Adaptation Flexible Framework.

Climate change is increasing the severity and frequency of some climate hazards across Duke Energy's territory, which may create the need for additional T&D system investments to maintain consistent, affordable and reliable service. As shown in the Vulnerability Assessment, hazards such as flooding, extreme heat, high winds, and wildfire can pose risks to the T&D system (particularly to substations), potentially resulting in power outages, grid damage, operational disruptions and higher costs.

Duke Energy works to strengthen and build infrastructure that will deliver reliable and affordable energy. The company uses historic customer experience and historic system data in its "monitor, assess and prioritize" approach. Duke Energy is already rapidly upgrading and strengthening its electric grid through initiatives to "harden" the grid against extreme weather, such as hurricanes, by elevating substations in flood-prone areas, replacing and strengthening utility poles and burying vulnerable overhead power lines underground. As Duke Energy considers potential projects, it evaluates the site, the technology, and the design to maximize benefits, including economic advantages, to communities while reducing environmental impacts. Duke Energy's project development process incorporates a thorough risk evaluation that includes potential environmental and stakeholder impacts.

Continued proactive investment to address future changes in climate hazards requires an informed investment prioritization framework that outlines how

Figure 11. The third pillar of Duke Energy's Climate Adaptation Flexible Framework is to incorporate new factors in T&D investments.

adaptation solutions should be selected, as well as where and when solutions should be implemented. Figure 12 summarizes the key “what, where, when” considerations for T&D system investment prioritization. These prioritization considerations should be married with Duke Energy’s broader project prioritization process moving forward, which may result in the acceleration or delay of certain investments. As a reminder, this framework is meant to be flexible and to evolve over time as Duke Energy works toward implementation.

The following subsections provide more detail on how Duke Energy could prioritize adaptation solutions. Specifically, these sections summarize the Vulnerability Assessment results, describe Duke Energy’s current and planned investments for improving system resilience, and explore potential system adaptation options. A discussion of the criteria for prioritizing adaptation locations, the specific timing of investments, as well as potential methods for assessing effectiveness, costs and benefits of future adaptation solutions follows.

Findings from the Vulnerability Assessment

The Vulnerability Assessment found that some elements of Duke Energy’s T&D system are at risk to changes in climate between now and 2050. Table 4 provides a summary of 2050 vulnerability ratings for all hazard and asset group combinations under RCP 4.5 50th percentile and RCP 8.5 90th percentile scenarios. Without adaptation investments, under both scenarios, substations are projected to be at the highest potential risk, with extreme heat and flooding likely being the greatest concerns for existing assets. The transmission and distribution systems face medium- or low-scoring risks for most climate hazards (depending on scenario, with lower risks under RCP 4.5). For more information on how these scores were developed and the explanations behind them, please see the Interim Report.

Investment Prioritization Framework

What

- Additional T&D resilience investments could include traditional and non-traditional solutions
- Solution prioritization could include decision-support tools that consider a range of possible cost effectiveness approaches

Where

- Prioritized locations for adaptation solutions can be based primarily on the vulnerability of assets, drawing from the Vulnerability Assessment results
- Siting considerations may include how vulnerable the local community is to outage events; this is already used in some program criteria

When

- Risks to consider when determining adaptation solution timing
  - ✓ Climate adaptation planning scenario
  - ✓ Acceptable level of risk
  - ✓ Life span of assets
  - ✓ Asset-specific capital investment plans
  - ✓ Regulatory filings
  - ✓ Other entities’ investment plans

Figure 12.. Duke Energy investment prioritization framework considerations

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Sep 05 2023

Table 4. Summary of vulnerability ratings for all hazards and asset groups (transmission, substations, distribution) under RCP 4.5 50th percentile and RCP 8.5 90th percentile under the 2050 time frame.

Climate Hazard	RCP	Trans.	Subs.	Dist.	2050 Projected Change and Impact
High Temperature and Extreme Heat	8.5	Med.	High	Med.	Temperatures and extreme heat are projected to increase across North Carolina and South Carolina over the coming decades. For example, 1-in-10-year daily maximum temperatures (temperatures with a 10% annual probability of occurrence) are projected to increase approximately 4-9°F (from a baseline of 91-106°F). Such an increase would feature widespread exceedances of 110°F, the hottest temperature ever recorded at any location in North Carolina and 109°F, the hottest temperature ever recorded in Duke Energy's territory in South Carolina. Heat-related impacts to substation equipment (accelerated aging, need for additional capacity during extreme heat, or, in the worst case, load shedding) represent the greatest potential risk for Duke Energy, with capacity and degradation impacts to transmission and distribution equipment also possible.
	4.5	Low	Med.	Low	Under RCP 4.5, very few assets are projected to be exposed to 1-in-10-maximum temperatures of 110°F or higher. While 1-in-10-maximum temperatures of over 104°F are projected in this scenario, a typical year could see few to no days above this threshold, depending on location. This means that the capacity of the system would be reduced on the hottest days of the year, but it is unlikely that temperatures will result in exceptional levels of accelerated aging or require load shedding.
Extreme Cold and Ice	8.5	Low	Low	Low	Projections show that climate change will drive overall warmer temperatures in the Carolinas, although cold snaps and winter storms are still expected to occur. A warmer climate does not preclude severe winter weather or extreme cold temperatures (i.e., polar vortex events). Future winters in North Carolina and South Carolina will likely see less total snowfall and fewer heavy snowstorms and icing events. Based on low certainty of any detrimental effects as well as Duke Energy's existing standards, these changes present relatively low incremental vulnerability across asset types.
	4.5	Low	Low	Low	Under RCP 4.5, winters are anticipated to warm, though not as much as under RCP 8.5. As under RCP 8.5, severe winter weather and cold temperatures are projected to still occasionally occur. Overall, the incremental risk of extreme cold and ice is projected to decrease over time.
Coastal Flooding	8.5	Med.	Med.	Low	Rising sea levels and projected increases in hurricane intensity may result in increased flood risk for coastal infrastructure on a permanent basis and/or an increase in the degree and duration of storm surge events. Impacts to transmission assets are more likely to be chronic, while impacts to substations, which are highly sensitive to flooding, may be more likely at a limited number of locations, where storm surge coupled with rising sea levels could exceed flooding thresholds, resulting in severe impacts. Substation flooding analysis may be updated as modeling improvements are made.
	4.5	Med.	Med.	Low	Under both RCP 8.5 and 4.5, hurricane intensity is anticipated to increase over time. Since increasing intensity of hurricanes is a major driver of the coastal flooding vulnerability scores, the ratings remain the same under both future scenarios.
Precipitation and Inland Flooding	8.5	Med.	High	Low	Over the coming decades, higher atmospheric moisture content and other factors may increase the amount of rainfall during periodic heavy downpours, increasing the potential for flash flooding and resulting in destructive landslides and debris flows. These changes could affect many of the 124 (5% of Duke Energy's total) substations located in existing FEMA 500-year flood plains (which can be considered a proxy for future 100-year flood plains), as well as the 38% of total substations and 21% of total transmission structures that are located in regions of high landslide incidence or susceptibility. Note that these ratings may be considered conservative, given that the territorywide analysis does not identify severity of potential flood exposure, and that subsequent site-specific analysis may narrow the list of at-risk sites.
	4.5	Low	Med.	Low	Under RCP 4.5, projected increases in the average annual maximum five-day precipitation ranges from approximately 5% to 20% across the service area. While certainly an increase, it is much less than the up to 35% increase under RCP 8.5. Substations within existing flood plains are projected to be at elevated risk of flooding compared to today, but overall there is a lower likelihood of significant, repeated flooding when compared to RCP 8.5, especially given changes in Duke Energy's design standards and recent investments in substation flood protection.
Wind	8.5	Med.	Low	Med.	Projections show small changes in average windspeeds across North Carolina and South Carolina through 2050. However, extreme windspeeds from hurricanes and storms may increase over the coming decades with increasing storm intensity. While Duke Energy's assets are generally built to be resilient to high wind conditions, extreme winds – as well as the indirect effects of wind-driven vegetation and debris impacts – may result in damage to or collapse of T&D overhead structures, resulting in a medium rating for transmission and distribution.
	4.5	Med.	Low	Med.	Under both RCP 8.5 and 4.5, hurricane and storm intensity is anticipated to increase over time. Since increasing intensity of hurricanes and other storms is a major driver of the wind vulnerability scores, the ratings are the same under both future scenarios.
Wildfire	8.5	Med.	Med.	Med.	Projections indicate a moderate increase in the frequency of conditions conducive to wildfires within North Carolina and South Carolina (e.g., dryness, temperature, wind, lightning, forest density).
	4.5	Low	Low	Low	Projections under RCP 4.5 demonstrate a more moderate increase in wildfire risk than under RCP 8.5. In addition, projections of wildfire are subject to uncertainty, and some evidence suggests mitigating development trends and improved wildfire control measures may reduce the degree to which climate change increases this risk.

Duke Energy's Current T&D System Resilience Investments

As mentioned above, Duke Energy has been investing in T&D system climate resilience for almost a decade. For example, Duke Energy is installing smart, self-healing technology that can automatically detect power outages, isolate the problem, and then quickly reroute service to other available lines to restore power faster. When layered with improved system control technologies, this helps Duke Energy increase the resiliency of the power supply, as well as be alerted to and mitigate cyber risks. In 2022, smart, self-healing technology helped avoid more than 1.4 million customer outages and saved around 7.2 million hours of total outage time across Duke Energy's footprint. In addition, a growing number of Duke Energy's existing substations are protected from flooding through a combination of permanent flood walls and temporary modular flood walls that can be deployed prior to an adverse weather event. Existing substations that have experienced past flooding have been retrofitted with permanent flood walls, and new substations are currently designed to a design flood elevation (DFE) standard above the 100- or 500-year flood level.

Duke Energy is already planning to increase investments in resiliency to address the evolving climate risks. The North Carolina multiyear rate plans for DEC and DEP propose significant investments in the coming years to increase the resilience of its assets and services. In South Carolina, Duke Energy plans to continue the execution of the grid improvement plan, a program built upon strategic, data-driven investments to, among other things, improve reliability and resiliency of the system and implement innovative technologies across a two-way, smart-thinking grid. Table 5 lists examples of proposed programs that incorporate resilience to a variety of climate hazards, including extreme precipitation, flooding, storms/hurricanes and extreme wind. Future multiyear rate plans and grid improvement plans appropriately should draw from the findings in this study to recommend continued investment in resilience to stay ahead of potential risks.

Table 5. Resilience improvement programs from Duke Energy in the Carolinas.

Program	Overview
Capacity	• Capacity upgrades and improvements, including both retail substation upgrades and distribution system capacity upgrades. • Higher capacity lines improve voltage quality and make it easier to troubleshoot outages and restore service. Additional capacity and connectivity can also support self-healing networks to lessen the duration and scope of outages on the system during extreme weather events.
Self-Optimizing Grid (SOG)	• The SOG program will redesign key portions of the distribution system and transform it into a dynamic self-healing network. • SOG creates a network of interconnected circuits that are split into smaller automatically switchable segments that can isolate faults and reconfigure, thus greatly reducing the number of customers affected by sustained outages, including those caused by extreme weather events. • The program also reduces the number of outages and decreases the duration of those outages, if they do occur.
Distribution Hardening & Resiliency: Laterals	• This program will proactively replace and upgrade damaged, deteriorated, or at-risk lateral distribution lines that can lead to unplanned outages. • More robust design and construction standards can help to avoid outages, but also help crews restore power faster, after extreme events. Upgrades that help shorten outages can also free up line and tree crews sooner to help with outage restoration in other areas.
Distribution Hardening & Resiliency: Storm	• This program includes distribution improvements to strengthen the grid in areas vulnerable to severe weather, and in other high-impact areas. • Assets will be engineered to better withstand high winds and impacts from snow and ice to help reduce outages and restoration time in areas prone to physical damage during severe storms. Strengthening the grid in these areas can also help free up resources faster to assist with outage restoration in other areas.
Long- Duration Interruption	• This program will reroute segments of main overhead feeder lines in hard-to-access areas to improve accessibility for utility trucks. This program will target areas that experience consistently higher-than-average outage durations, which are particularly impactful to customers during extreme events. • During extreme weather events, vegetation, erosion, and flooding can create challenges and potentially unsafe conditions for restoration crews trying to restore power, resulting in longer outage times. Relocating the feeder segment to a more accessible and maintainable right of way will reduce outages and promote faster responses when outages do occur.

Table 5 – continued on next page

Program	Overview
Hazard Tree Removal	• This program will identify and remove dead, structurally unsound, dying, diseased, leaning, or otherwise defective trees from outside the maintained right-of-way that could strike electrical lines or equipment. • Managing trees and other vegetation will make the grid more resistant to outages from extreme wind events.
Substation Hardening & Resiliency	• This program involves substation rebuilding and flood mitigation, including replacing degraded structures and installing flood-proofing measures. • This program will create a stronger and more resilient transmission grid capable of withstanding or quickly recovering from extreme weather events.
Transmission System Intelligence	• This program includes (1) the replacement of electromechanical relays with remotely operated digital relays, (2) the implementation of intelligence and monitoring technology capable of providing asset health data and driving predictive maintenance programs and (3) the deployment of remote monitoring and control functionality for substation and line devices enabling rapid service restoration. • Investing in system intelligence programs with modern technology provides additional capabilities to create a more reliable and sustainable grid, and that improves the restoration response following a fault.

While these investments would meaningfully improve the resilience of the T&D system, it is important to acknowledge that a comprehensive resilience strategy would require additional measures over time. The following subsections outline how to consider additional investment needs.

Potential T&D System Adaptation Options

Over time and as needed, Duke Energy will develop a more robust resilience strategy that directly addresses the identified T&D system vulnerabilities. There are multiple approaches to adaptation for each climate hazard and asset combination. Approaches include:

- **Withstanding** climate change and extreme weather events (e.g., strengthening assets or upgrading capacity);
- **Absorbing** the impact of those events with limited impacts to the operation of the system as a whole (e.g., changing grid topology); and
- **Recovering rapidly** to minimize disruptions and customer impacts (e.g., facilitating de-centralized solutions).

Non-Traditional Solutions

Duke Energy is not only considering typical hardening options for building resilience. Non-traditional solutions (NTS), sometimes called non-wires alternatives, is a term for projects that allow Duke Energy to delay or avoid conventional T&D investments. Duke Energy considers these projects to be an important tool for reliability and resilience, but also to handle increased loading in areas with changing usage patterns. Duke Energy's current approach to reliability-driven NTS is to deploy battery-powered microgrids to communities that, because of geography or service territory boundaries, are served by a single, potentially vulnerable feeder line.

Figure 13. Duke Energy's community microgrid in Hot Springs, North Carolina.

Duke Energy's Hot Springs microgrid is its first NTS project focused on improving community resilience.[8] When the feeder serving that community fails, the microgrid isolates the community's electrical distribution system from the larger grid and serves that load until the utility can repair the line or whatever other problem caused the outage.

Duke Energy currently has several more battery NTS projects being considered. Duke Energy will continue to evaluate effective siting of these projects by identifying long-distribution feeders with load pockets and sizing a battery to meet reliability challenges. From there, Duke Energy will compare the net cost of a battery system (taking into account other services that battery can provide to the grid, like capacity, energy arbitrage or ancillary services) to more traditional solutions. If an energy storage system is the most cost-effective, feasible approach, Duke Energy will then pursue further development of the project. The development cycle for these efforts is typically on the order of seven years.

[8] Duke Energy, "Duke Energy Places Advanced Microgrid into Service in Hot Springs, North Carolina," Duke Energy | News Center, 2023, https://news.duke-energy.com/releases/duke-energy-places-advanced-microgrid-into-service-in-hot-springs-nc.

Table 6 outlines some representative approaches for asset adaptation for a range of climate hazards (more options can be found in Appendix A). The identified adaptation strategies and solutions outlined here are a good starting point but do not represent an exhaustive list of options.

The following sections outline a process for Duke Energy to use when determining when, where, and what strategies are the most appropriate for a given location.

Prioritizing Adaptation Locations

Across DEC and DEP, Duke Energy operates an extensive system with tens of thousands of miles of transmission and distribution lines across a service area of some 56,000 square miles. Effectively executing plans for climate adaptation requires that the company have a process to prioritize the locations where adaptations will be implemented. This process should be harmonized with Duke Energy's existing robust and multifactor decision-making processes for evaluating and prioritizing T&D projects.

Table 6. Potential approaches for T&D Asset Adaptation.

Hazard	Asset	Approach	Example Adaptation
Flooding	Substation (at large)	Perimeter protection	Temporary or permanent flood walls, nature-based solutions
	Substation (all sub-assets)	Defense in depth	Elevation or flood protection of selected equipment within station
	Transmission structures	Strengthen assets	Increase robustness of foundations
Heat	Transmission conductors	Reduce loading	Energy efficiency, demand response, non-wires alternatives
		Upgrade capacity of asset	Reconductor transmission line, dynamic line rating
		Shift load to new assets	New transmission line
	Substation transformers	Reduce loading	Energy efficiency, demand response, non-wires alternatives
		Upgrade capacity of asset	Replace transformer with higher capacity unit, increase capacity of cooling system
		Shift load to new assets	Install additional transformer in station, new substation
Wind	Transmission structures	Strengthen assets	Reinforce or replace poles
		Change grid topology	Install sectionalizing devices
		Retreat from threat	Underground infrastructure
		Reduce threat	More robust vegetation management
		Alternative sources of supply	Microgrids, resilience hubs
Wildfire	T&D structures	Strengthen assets	Fire-resistant coatings on poles
		Reduce threat	More robust vegetation management, wider rights of way
		Retreat from threat	Undergrounding
	Substations	Reduce threat	More robust vegetation management around station
Various	Distribution system	Improve grid intelligence	Smart-thinking grid technologies including sensors and decision intelligence
Various	Distribution system	Incorporate self-healing	Self-healing grid technologies including reclosers and other sectionalizing devices
Various	Distribution system	Facilitate de-centralized solutions	Voltage-optimization technologies that help integrate distributed resources

Prioritization Based on Asset Vulnerability

The main consideration for selecting adaptation locations is the **vulnerability of the assets**. As covered in Section II.C Overview of the Vulnerability Assessment Methodology, vulnerability is assessed based on three primary factors:

- **Exposure:** The exposure measure conveys the severity and frequency with which assets may face climate hazards based on their physical locations and climate projections. For example, inland transmission lines may be exposed to lower wind speeds than transmission lines near the coast.
- **Sensitivity:** The sensitivity measure accounts for the degree to which assets could be affected by exposure. For instance, an ambient temperature above that assumed when rating a transformer might result in higher--than-expected internal temperatures.
- **Consequence:** The consequence measure accounts for potential negative outcomes should the asset not perform as designed. For example, unavailability of a transmission line would have a higher consequence than unavailability of a pole top distribution transformer.

Table 7 shows a simplified version of asset vulnerability ratings (see Table 1 or the Interim Report for a more detailed summary of the findings). Note that within each overall score, there may be subgroups of system elements with higher vulnerability levels (e.g., a small number of distribution poles facing permanent inundation). As can be seen, substations rank high with respect to both extreme heat and flooding. The following discussion will outline the process of prioritizing individual substations for adaptation to these climate hazards.

Table 7. Summary of Asset Vulnerability Ratings under RCP 8.5 (worst-case scenario).

Process Area	Transmission	Substations	Distribution
Extreme Heat	Medium	High	Medium
Coastal Flooding	Medium	Medium	Low
Precipitation & Inland Flooding	Medium	High	Low
Cold and Ice	Low	Low	Low
Wind	Medium	Low	Medium
Wildfire	Medium	Medium	Medium

Further Prioritizing Among Vulnerable Assets

Given the high vulnerability score of substations to extreme heat and flooding under RCP 8.5, we will use it as an example of how Duke Energy could identify factors to prioritize individual locations for adaptation. The severity of exposure of individual substations provides one dimension for prioritization, and the consequence of exposure provides a second dimension for prioritization.

For **exposure**, Figure 14 shows substations within the 100-year or 500-year flood plains, and labels them based on the amount of risk at that location.

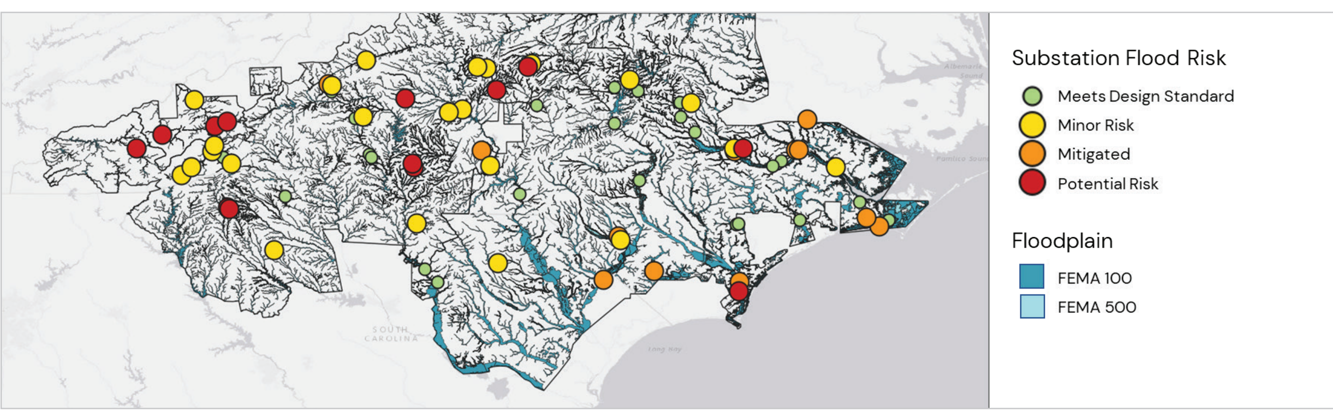

Figure 14. Substations within the current-day FEMA-designated 100-year and 500-year flood plains.

This information provides three levels of exposure prioritization, as shown in Table 8.

Table 8. Substation Vulnerability Prioritization.

Location	Substation Exposure Score
Potential Risk	3 (High Priority)
Minor Risk	2 (Moderate Priority)
Mitigated Risk/Meets Design Standard	1 (Low Priority)

However, locations with the same exposure score can have significantly different risk profiles due to local conditions such as the elevation of substation site and equipment. Accordingly, the framework should also evaluate the **sensitivity** of individual assets to the exposed hazards, including local mitigating factors.

Where assets have similar exposure and sensitivity, further prioritization to inform the phasing of adaptation investments may be required. The substations could be further prioritized based on the potential **consequence** to Duke Energy's customers.

Duke Energy's existing resilience prioritization process focuses on maintaining reliability, and when necessary, restoring power in a sequence that enables power restoration to community lifelines (such as highways and transit) and public health and safety facilities (such as hospitals and first responders) and to the greatest number of customers as safely and quickly as possible. These are important indicators of consequence and should continue to be used. Based on feedback from the TWG, it is recommended that Duke Energy explore tools to better understand how different populations may be impacted by energy supply interruptions to inform adaptation prioritization. Certain characteristics may mean that some populations experience higher consequences from extended energy outages. For example:

- Low wealth may result in additional strain on those impacted by losses in an outage.
- Underlying health issues, or limited physical mobility, may affect needs (e.g., refrigeration for medicine) or impacts from an extended outage.
- Compared to the average age of adults, populations over 64 may be at greater risk of heat-related illnesses and other health impacts due to an outage.
- Community members with transportation barriers may be less able to leave an outage area and its resulting impacts.

Nature-Based Solutions

USS Battleship, NC

There are opportunities for Duke Energy to collaborate beyond its own system to achieve resilience. One such approach is partnering with local communities to implement nature-based solutions to mitigate climate impacts. These solutions mimic natural conditions (e.g., beaches and dunes, vegetated environments, oyster reefs) to create an integrated natural and structural risk management strategy that combines protection with ecosystem benefits. An example of such a project is the "Living With Water" project at the site of the USS North Carolina, which converted two acres of impervious surface to tidal wetland and installed a living shoreline along the Battleship's berth. This effort helps mitigate flooding, protecting local infrastructure.[9]

While nature-based solutions, on their own, often cannot address the full spectrum of climate threats to critical utility systems, they provide many benefits and Duke Energy should evaluate opportunities to partner with communities interested in implementing nature-based solutions.

9 https://www.atlanticfishhabitat.org/project/living-with-water-uss-battleship-nc-habitat-restoration-cape-fear-river/

Duke Energy recognizes that characteristics such as age, income and wealth, health, physical mobility and transportation barriers may affect those who face high risks from energy outages. Given these considerations and data availability, it is recommended that Duke Energy leverage publicly available tools that help identify populations with characteristics that could be predictive of increased consequences due to outages. Tools such as the CDC Social Vulnerability Index (SVI)[10] and the Climate and Economic Justice Screening Tool (CEJST)[11] are widely regarded metrics that identify census tracts with high social vulnerability and are considered to be disadvantaged, respectively. To determine how this data might inform the prioritization of climate adaptation investments, ICF recommends that Duke Energy consider – based on the unique characteristics of each state – deploying tools such as these in a pilot study. If these types of tools identify areas of need for additional resilience beyond what is planned in each state, Duke Energy should consider discussing those results with regulators. These discussions should focus not just on the needs identified but whether tools like these should become a more formal independent variable in resilience planning.

The vulnerability study in the Interim Report included an analysis of Duke Energy assets both exposed to climate-related hazards and located in census tracts with high CDC SVI scores. For that analysis, high and extremely high SVI tracts were defined as follows:

- Census tracts with scores in the 75th to 90th percentile nationwide – considered highly vulnerable (482 in Duke Energy service territory, or 18% of tracts in the service area).
- Census tracts with scores less than the 90th percentile nationwide – considered extremely vulnerable (312 in Duke Energy service territory, or 12% of tracts in the service area).

Figure 15 illustrates an example of how high or extremely high SVI census tracts (summarized at the county level) could be overlayed with climate hazard data for substations in the FEMA 100-year and 500-year flood plains. While this does not indicate specific risk, the graphic below is representative of how the SVI tool can be leveraged as an additional factor in planning for future resilience efforts.

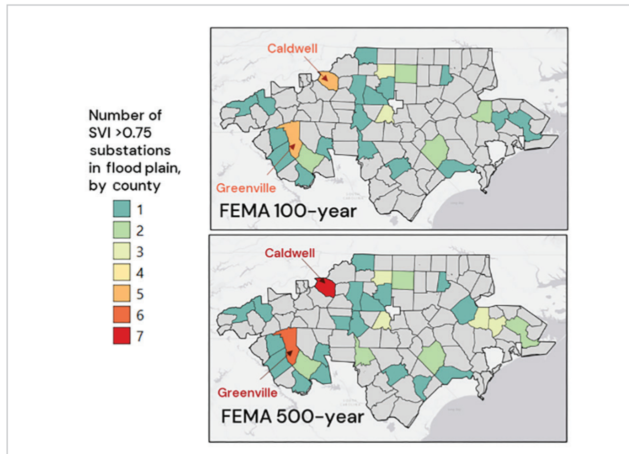

Figure 15. Representative example of an overlay of FEMA flood plains and high or extremely high SVI counties. Further analysis would be required to understand how best to leverage the SVI as an additional factor in the larger prioritization of resilience efforts.

Timing Adaptation Investments

Even if a location is flagged as a priority for adaptation, that may not mean that immediate action is required. Adaptation planning must consider the timing of proposed actions; since future climate change is uncertain, acting too soon can risk committing to inappropriate outcomes, but acting too late can risk sustaining unacceptable impacts from climate change.

This section outlines the key factors that are most meaningful in determining when to invest in adaptation, provides a case example showing how adaptation timing may look in practice, and discusses some potential next steps for Duke Energy concerning timing adaptation investments.

[10] The SVI tool characteristics include socioeconomic status (such as income and education), household characteristics (such as age, disabilities, and English proficiency), racial and ethnic minority status, and housing type and transportation access.

[11] The CEJST characteristics include exposure to climate change risks, energy costs as a percentage of income, physical health, access to affordable housing, pollution, transportation barriers and impacts, education, and access to employment.

Adaptation timing must be considered in the context of a particular asset and relative to a specific climate hazard. This section uses transmission conductors' vulnerability to extreme heat as a case example.

Key Considerations in Determining When to Adapt

The key factors that are most meaningful in determining when to invest in T&D system adaptations include:

- The selected climate adaptation planning scenario
- The acceptable level of risk
- The projected life span of the asset(s)
- The capital investment plans for the asset(s) in question
- Investment plans of other infrastructure providers, municipalities, etc.
- The timing of regulatory filings

Each of these bullets are covered in more detail below.

Selected climate adaptation planning scenario. The selected climate adaptation planning scenario discussed earlier defines the degree of exposure for the relevant climate hazard and asset or process and how quickly that exposure may change. Investments should be made prior to when the climate adaptation planning scenario indicates that the risk to the infrastructure may be realized. For changes in climate that are not linked to the adaptation planning scenarios (i.e., inland flooding, wildfire, wind), Duke Energy should monitor the actual trends in these climate hazards against an objective criteria or signpost to gauge when to adapt.

Acceptable level of risk. Energy systems are planned and operated with an implied acceptable level of risk. Despite the fact that engineering and planning specifications most often outline deterministic criteria, such as a specific ambient temperature to be assumed when rating a transmission line, in practice, ambient temperatures can occasionally exceed those assumed in planning. For example, Duke Energy's planning standard assumes an ambient temperature of 104°F for rating much of its transmission system. However, a temperature of 110°F was recorded in Fayetteville, North Carolina, on August 21, 1983. Historically, 517 miles or about 3% of Duke Energy's transmission system has had a 10% annual probability of exposure to ambient temperatures exceeding 104°F. This historical 3% risk can be thought of as an implied "acceptable" level of risk since the system has been operating within this level of risk. It should be noted, however, that there may be a "tolerable" level of risk that may be higher than the historical level at which the system has been operating. In planning the timing of adaptations, Duke Energy might conclude that having 7% of transmission miles with a 10% annual risk of exceeding planning assumptions is an acceptable level of risk. Accordingly, Duke Energy should identify an acceptable level of risk, project when that acceptable level will be reached based on the selected planning scenario, and monitor developments over time.

Projected life span of assets. The projected life span of assets, relative to the projected time at which the acceptable risk threshold will be exceeded, is another consideration for timing adaptation investments. For existing assets, planners may choose to upgrade them or plan for their early replacement, depending on whether the acceptable risk threshold is projected to be reached before or after the end of the expected useful life. For new assets, planners may incorporate more robust design standards when those assets are installed, or they may plan for upgrades at a future time.

Capital investment plans. Capital investment plans for utility assets, as well as the capital plans for other infrastructure providers and municipalities, are another important consideration for adaptation timing. It may make sense to invest in adaptation for an asset if that adaptation can be incorporated into an existing planned capital program. For example, for a planned transmission line upgrade, choosing a slightly larger conductor size or technology that provides a higher rating may provide advance adaptation for the line against projected increases in ambient temperature and avoid the need to de-rate the line during its useful life due to increasing temperatures. Utilities routinely coordinate their capital plans with those of other infrastructure providers and municipalities. Such coordination may present opportunities to incorporate adaptations while executing infrastructure upgrades that either synergize with or accommodate projects being done by others.

Timing of regulatory filings. Regulatory filings also present occasions to evaluate climate vulnerability and consider opportunities to adapt. Since climate projections indicate that the most significant changes will occur at midcentury or later, capital projects that are funded under current or near-term rate cases are opportunities to implement adaptation in the near-term for assets that will be long-lived.

Let's look at how the climate adaptation planning scenario, acceptable level of risk, and projected asset life span are used together to help inform the timing of additional T&D system investments. Figure 16 shows a graphical timeline for adaptation, while Table 9 outlines the considerations and planning options for adaptation timing.

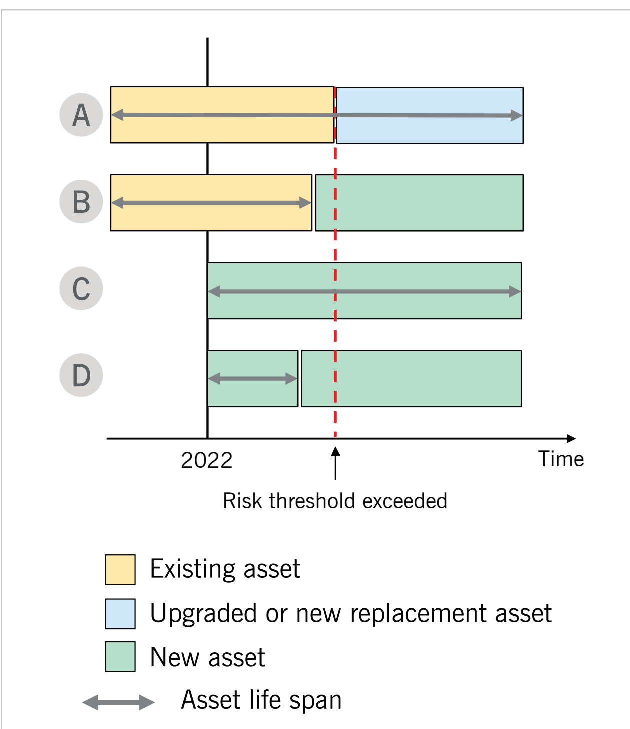

Figure 16. Timeline for Adaptation Timing.

Table 9. Considerations for Adaptation Timing.

		Asset life span vs. time to reach risk threshold	Planning Options
Existing Assets	A	Risk threshold will be reached before end of useful life	• Early replacement with asset designed or rated for appropriate exposure risk level during its lifetime • Revise or upgrade existing asset to new exposure risk level
	B	Risk threshold will be reached after expected end useful life	• Plan for replacement at end of useful life with asset designed or rated for appropriate exposure risk level during its lifetime
New Assets	C	Risk threshold will be reached before expected end of useful life	• Incorporate expected future exposure risk level in initial design • Plan for upgrade of asset for new exposure risk level during its lifetime
	D	Risk threshold will be reached after expected end of useful life	• Plan for replacement at end of life with asset designed or rated for appropriate exposure risk level during its lifetime

Take the example of applying this adaptation timing framework to a set of transmission lines that Duke Energy has selected for adaptation based on its exposure to extreme heat, as well as considerations of the customers that it supplies. For relatively new transmission lines within this group, the target risk threshold[12] will likely be exceeded before the end of life, and Duke Energy might expect to de-rate or de-load these lines at some future time. Older transmission lines within this group may "age out" before the target risk threshold is reached, and it may make sense to significantly upgrade or completely replace such lines. If load growth or reliability needs among these target communities warrant new transmission lines, it could make sense to either incorporate the full expected future capacity needs into the initial line design or the ability to efficiently upgrade the line capacity when the risk threshold is reached.

[12] Say, for example, a greater than 10% likelihood of being exposed to ambient temperatures exceeding design assumptions.

Case Study Example of Transmission Line Ratings and Heat

This section provides an example of using an adaptation planning scenario to inform the adaptation of transmission system ratings to rising ambient temperatures. As discussed earlier, historically, approximately 517 miles of Duke Energy's transmission system had a 10% annual probability of exceeding the planning standard of an ambient temperature of 104°F. Under RCP 4.5, 50th percentile, that number grows by over 30 times by 2050 to 15,511 miles. As the ambient temperature increases, Duke Energy can adapt its transmission system by revising transmission line ratings by adopting a higher assumed ambient temperature. Figure 17 shows a representative illustration of the process and timeline.

As time passes, more and more transmission line miles will experience a risk of ambient temperature exceeding planning assumptions. Duke Energy could plan, at some future climate adaptation decision point when the level of risk exceeds an acceptable level, to reset its planning assumptions by adopting a higher assumed ambient temperature for relevant portions of its transmission system (left-most blue downward arrow in Figure 17). Making this planning change would reduce the number of line miles with

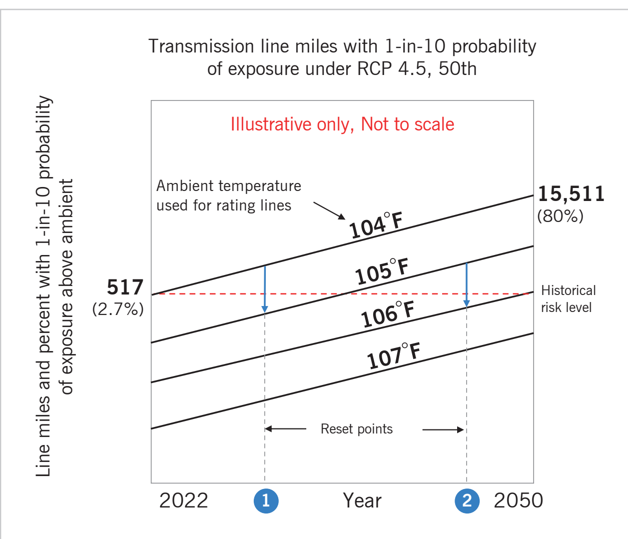

Figure 17. Adapting transmission line ratings to Increasing Ambient Temperature.

a probability of exposure exceeding the planning standard to within the acceptable risk level. Making such a change would reduce the ratings of transmission lines and would therefore require other adaptations to either reduce demand such as demand response or to increase capacity such as reconductoring existing lines or installing new transmission lines.

T&D Considerations for Selecting Adaptation Solutions

As outlined in Section VII.C Potential T&D System Adaptation Options, there are many potential strategies for adapting the T&D system to be resilient to climate change risks. Once it's determined when and where to adapt the system, Duke Energy will have to determine how best to address the identified vulnerabilities, while also aligning with other priorities and system changes.

This section provides an example of an approach for selecting adaptation solutions and outlines cost and benefit considerations.

Case Study Example of Adapting a Transmission Line to Increasing Temperatures

There are many potential ways of combining the timing of adaptation solutions and other considerations to select a preferred solution. This section provides an example of how Duke Energy could build out simple decision support tools that include answering a set of critical questions about the asset and other capital programs to help with adaptation option selection. The case study example focuses on a transmission line that is facing rising ambient temperatures. In the case study, the transmission line to be adapted would have been selected via the previously discussed process of prioritizing adaptation assets and locations. If this framework proves useful, Duke Energy could consider building out this type of approach for other asset types.

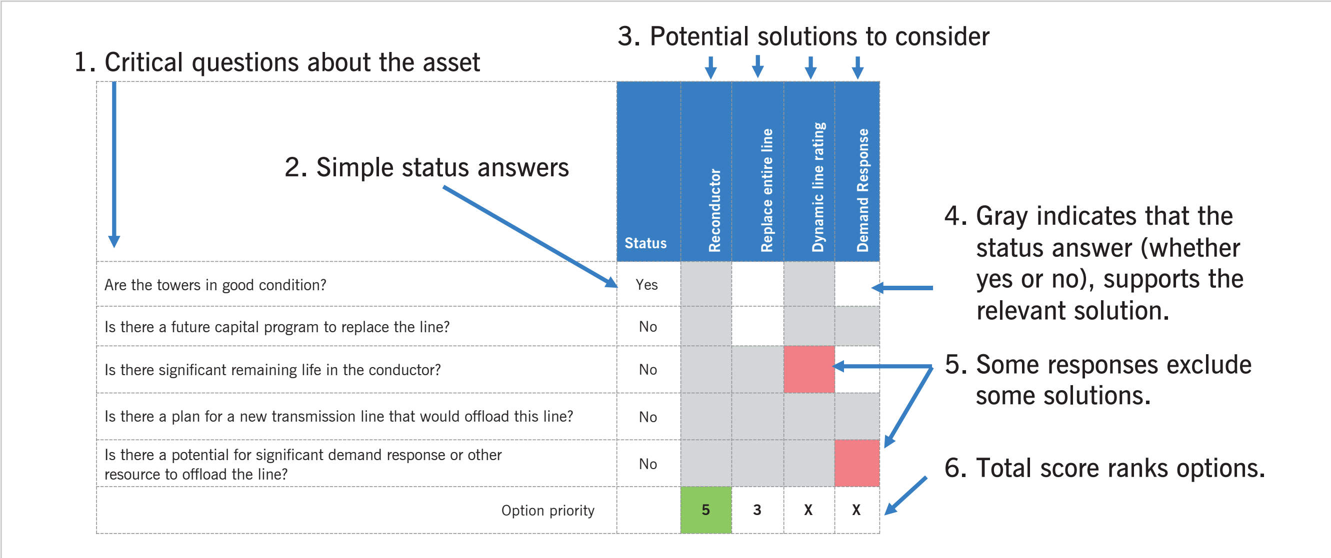

Figure 18. Scoring matrix for selecting a Transmission Line Adaptation.

Figure 18 provides a graphic of a scoring matrix that could be used to rank adaptation options. The critical questions are listed in the rows of the matrix, and the adaptation options are placed in the matrix columns. Answers to the questions are shown in the status column. The gray cells indicate that the status answer, whether yes or no, supports the relevant solution. Some responses exclude some solutions, such as the case where a transmission conductor in poor condition would preclude installing dynamic line rating technology. The responses are then aggregated and scored to develop a priority of solutions.

In this example, some questions about the transmission line might include:

- Are the towers in relatively good condition?
    - Since the towers are in relatively good condition, or can be repaired at reasonable cost, reconductoring and dynamic line rating may be options. Replacing the entire line (towers and all) would not make sense since the towers are in good condition or are salvageable.
- Is there a future capital program to replace the line?
    - Since there is no future capital program to replace the line, the line replacement solution is not an option, but other options remain viable for this row.
- Is there significant remaining life in the conductor?
    - Since the conductor is beyond its useful life, solutions like reconductoring and replacing the entire line are viable options for this row.
    - Dynamic line rating is off the table as a solution since it would not make sense to instrument a line where the conductor has little remaining life.
- Is there a plan for a new transmission line that would offload this line?
    - Since no other transmission line that would offload this line is planned, all other solutions are viable options for this row.
- Is there a potential for significant demand response or other resource to offload the line?
    - Since sufficient demand response to offload the line is not available, demand response is eliminated as an option, but other options remain viable for this row.

The total scores are computed by vertically summing the number of gray boxes in the matrix. In this example, reconductoring receives the highest score (5) followed by replacing the entire line (3). As discussed above, the options for dynamic line rating and demand response are eliminated.

The benefit of developing these sort of simple scoring templates is that they could help Duke Energy engineers easily and quickly think through the set of potential adaptation solutions to determine the one or two that may be most appropriate. Moving forward, Duke Energy could further build out this approach for more asset types and incorporating more considerations. Then, the approach could be used to develop a prioritized list of investments to be considered in the next multiyear rate plan.

Cost and Benefit Considerations

Using the framework above, there may be more than one promising strategy that emerges. In that case, Duke Energy should evaluate the rate impacts and cost-effectiveness of the various solutions, pursuing the solutions that will provide the greatest resilience improvements with the lowest impact on customers. Most of the climate adaptations available to Duke Energy use currently available technologies, and so adaptation costs can generally be estimated reasonably accurately. Adaptation benefits are more challenging to estimate, and there are several efforts across the energy industry to quantify adaptation benefits. Three potential approaches for understanding costs and benefits (i.e., Interruption Cost Estimate Calculator, Risk Spend Efficiency, Multi-Criteria Assessment) are described below.[13]

One tool is the **Interruption Cost Estimate (ICE)** Calculator,[14] which helps utilities estimate the benefits of building resilience by computing the avoided costs of interruptions to customers. The ICE Calculator was developed through a collaboration between the Department of Energy's Office of Delivery and Energy Reliability and the Lawrence Berkeley National Laboratory (LBNL). The "costs of interruption" refers to the economic impacts or losses that customers experience due to power outages. The calculator includes several components of cost:

- Lost productivity for commercial and industrial customers, estimated based on factors such as the size and type of business.
- Spoilage of goods such as food and medicine, estimated based on the type and quantity of goods.
- Inconvenience for residential customers, such as loss of heating or air conditioning, and difficulty in performing household tasks based on the type and number of appliances affected.
- Health and safety risks based on factors such as the number and severity of health impacts, the duration of the outage, and the availability of backup power sources.
- Economic impact to businesses, based on factors such as the type and size of business, the duration of the outage, and the availability of backup power sources.

Duke Energy currently uses data from the online ICE Calculator to value customer reliability benefits (outage savings to customers) in cost-benefit analysis processes in DEC and DEP. These customer benefit values are a key component in the evaluation of reliability and resiliency projects. Duke Energy is also participating in the LBNL initiative to update ICE data for its service territory, which will be released in 2024.

Although the ICE Calculator can be a useful tool for estimating the costs of power outages, there are some disadvantages, including:

- Dependence on data quality: The accuracy of ICE Calculator estimates is a function of the quality and availability of data on power outages and their economic impacts.
    - ICE Calculator cost estimates are built from survey data that is dated (some surveys are more than 25 years old) and not statistically representative for all regions of the U.S.

[13] This is not a comprehensive set of approaches for evaluating costs and benefits. Other examples include a break-even point analysis (as explored by HECO), a priority criteria and restoration cost analysis (FPL) using FEMA's methodologies and the Power Outage Economics Tool (POET) under development by Lawrence Berkeley National Lab and ComEd.

[14] "ICE Calculator," https://icecalculator.com/home.

- Simplifying assumptions: The ICE Calculator makes several simplifying assumptions about the costs of interruption that may not reflect actual costs, such as assuming that all customers within a given class experience the same level of impact from electric interruptions.
- Narrow scope: While the ICE Calculator includes economic impacts of power outages, it does not effectively capture factors such as environmental impacts or social costs. It also is not designed for use of widespread, long-duration (more than 24-hour) outages.

The interruption costs computed by the ICE Calculator are then compared, typically as net preset values, against the costs for various investments to build resilience to allow selection of the preferred option.

The **Risk Spend Efficiency (RSE)** approach is another method being used by utilities to prioritize resilience investments. RSE is a prioritization approach that provides an estimate of the cost-effectiveness of initiatives based on the risk reduction benefits and costs of a specific solution. In its simplest form, it is calculated by dividing the risk reduction benefit by the cost estimate, displayed by the following formula:

$$RSE = \frac{\textit{Quantified risk reduction}}{\textit{Cost}}$$

One of the benefits of this approach is that not all benefits have to be converted into dollar values, which allows utilities to capture a broader set of benefits (e.g., environment, equity, social vulnerability). The method ultimately provides a quantified risk reduction value via an RSE score, rather than a dollar-based ratio provided by a cost benefit analysis approach. The RSE framework is included as part the California Public Utilities Commission's wildfire mitigation plan guidelines.[15] Several California utilities including PG&E, SDGE, SoCalGas, and SCE[16] have applied the RSE framework as part of their wildfire planning processes.

To understand and quantify the inputs and outputs needed to support RSE computations, the energy industry is increasingly employing a "bow-tie method." This method (pictured on the next page) allows the user to graphically represent the drivers and consequences of a particular outage event, along with identified solutions that prevent failures, and identify solutions that mitigate the impact of potential failures, thereby reducing risk to customers. This RSE and bow-tie methodology was used by Southern California Edison in their 2022 Risk Assessment Mitigation Phase[17] filing to the California Public Utilities Commission.

Figure 19 shows the bow-tie method for an extreme wind event causing outages to overhead distribution. The left side of the bow tie captures threats such as vegetation falling on overhead lines, downed poles that were in poor condition or any other way in which extreme winds could lead to overhead distribution outrages. The preventive barriers are actions that modulate the likelihood of the event occurring, such as pole reinforcement, tree trimming and enhanced design standards. The mitigative barriers are actions that reduce the impact after the event has occurred, such as sectionalized distribution grid via switches, backup generation and efficient response processes. Finally, the consequences capture the outcomes, such as the number and types of customers interrupted as well as the duration of those interruptions. The metrics used to evaluate consequences may vary, depending on the desired level of analysis and stakeholders involved.

It should be noted that implementing an RSE and bow-tie approach requires time and resource

[15] California Public Utilities Commission, "2021 Wildfire Mitigation Plan (WMP) Guidelines Template," November 2020, https://energysafety.ca.gov/wp-content/uploads/docs/wmp-2021/attachment-2.2-to-wsd-011-2021-wmp-guidelines-template.pdf.

[16] Southern California Edison, "SCE Risk Spend Efficiency Workshop Presentation," December 2021, https://efiling.energysafety.ca.gov/eFiling/Getfile.aspx?fileid=51907&shareable=true.

[17] SCE, "SCE 2022 RAMP: 2022 SCE Risk Assessment Mitigation Phase (RAMP) Proceeding," 2022, https://www.cpuc.ca.gov/about-cpuc/divisions/safety-policy-division/risk-assessment-and-safety-analytics/risk-assessment-mitigation-phase/sce-ramp/sce-2022-ramp#:~:text=2022%20SCE%20Risk%20Assessment%20Mitigation%20Phase%20(RAMP)%20Proceeding&text=It%20is%20expected%20to%20address,and%20maintenance%20of%20its%20assets.

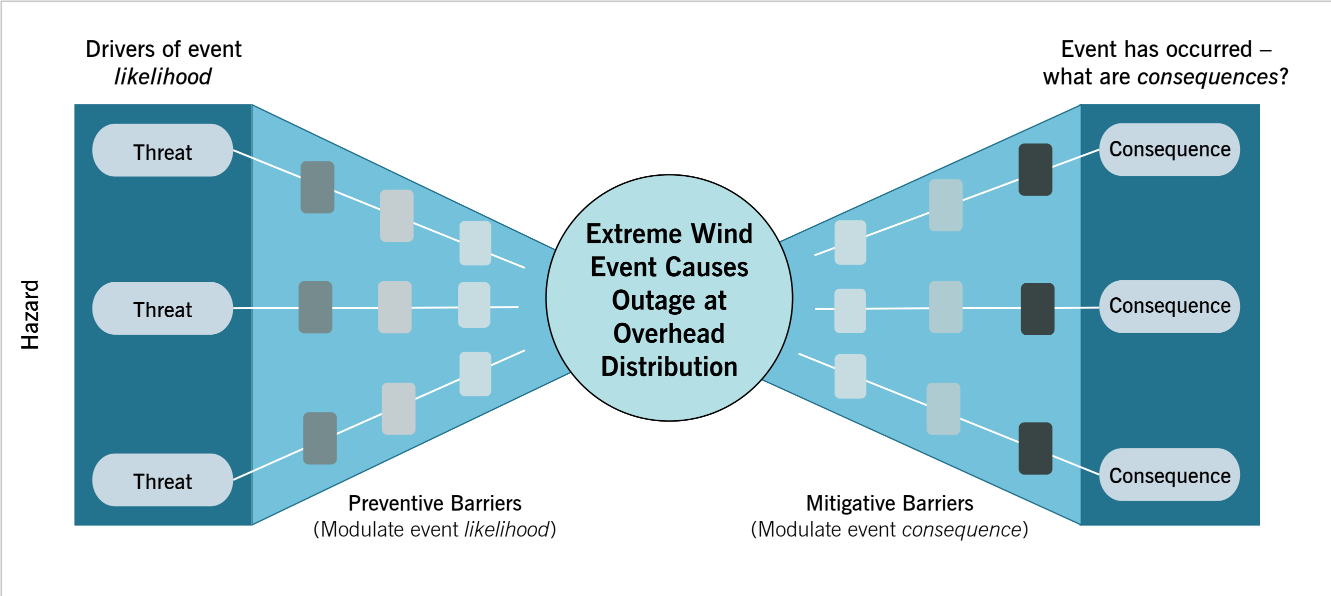

Figure 19. Bow-tie diagram for extreme wind event.

investment to quantify the necessary elements, build models and conduct analysis. Such investments could support a robust process that provides transparency into how Duke Energy is making resilience investment decisions.

One additional example of evaluating the costs and benefits of resilience investments is a **Multi-Criteria Assessment (MCA)**. For example, the 2019 Con Edison Climate Change Vulnerability Study[18] used an MCA to compare benefits that may be difficult to quantify or monetize, or that may not be effectively highlighted in financial analysis (see Table 10).

A resilience MCA can use metrics that fall into two categories: co-benefits and adaptation benefits. Co-benefits such as environmental, reputational, safety, and customer financial benefits encompass the additional challenges that climate change can pose on energy delivery systems. Adaptation benefits such as flexibility, reversibility, robustness, proven technology, and customers' resilience help to support long-term planning under climate uncertainty. At the time of the vulnerability study, Con Edison's processes included some of the metrics identified in the MCA (environmental and safety) but not others (customer's resilience and reversibility). A recommendation of the study was for Con Edison to work to incorporate a wider set of metrics as it incorporates resiliency planning into its broader capital budgeting process.

[18] Con Edison, "Climate Change Vulnerability Study," December 2019, https://www.coned.com/-/media/files/ConEd/documents/our-energy-future/our-energy-projects/climate-change-resiliency-plan/climate-change-vulnerability-study.pdf?la=en.

Table 10. MCA example. Source: Table 7 of Con Edison's Climate Change Vulnerability Study.

		Co-Benefits			Adaptation Benefits				
Load Relief Measure	**Adaptation Resilience Score**	**Reputational**	**Safety**	**Customer Financial Benefits**	**Flexibility**	**Reversibility**	**Robustness**	**Proven Technology**	**Customer's Resilience**
Utility distributed generation	8	*High* (Investing in distributed generation may be popular with customers)	*Negligible* (No significant benefits)	*High* (May decrease customer costs)	*High* (Con Edison could enter into contracts for additional distributed generation)	*Moderate* (Cost-prohibitive to remove generation sources due to contract obligations)	*Moderate* (Can be scaled to provide benefits under most climate scenarios)	*High* (Known to provide needed benefit)	*High* (Provides benefit if equipment allows for islanding)
Storage (e.g., batteries)	7	*High* (Customers are in favor of non-wires solutions)	*Negligible* (No significant benefits)	*High* (Rate structures may provide incentives)	*High* (It is possible to increase programs as needed)	*Moderate* (The system can be turned off or retired in place)	*Moderate* (Can be scaled to provide benefits under most scenarios)	*Moderate* (Technology not as well established as others)	*High* (Provides benefit if equipment allows for islanding)
Implement additional or expanded energy efficiency, demand response, or other demand-side management	6	*High* (Customers are in favor of non-wires solutions)	*Negligible* (No significant benefits)	*High* (Customers get rebates and lower bills)	*High* (It is possible to increase programs as needed)	*Moderate* (It is possible to end programs as needed)	*Moderate* (Can be scaled to provide benefits under most scenarios)	*Moderate* (Technology not as well established as others)	*Moderate* (Allows for longer duration sheltering in place during extreme heat events)
Add capacitor banks	5	*Negligible* (The customer is not aware this change)	*Moderate* (Installation may pose risk)	*Negligible* (No significant benefits)	*Moderate* (More capacitor banks could be added as needed, but may be space-constrained)	*Moderate* (Assets can be removed from the rate base)	*Moderate* (Only provides benefits under some climate scenarios)	*High* (Known to provide needed benefits)	*Negligible* (No significant benefits)

Partner with Local Communities

Partnering with local communities is the fourth pillar in Duke Energy's Climate Adaptation Flexible Framework.

Resilience is not one activity. It is a range of activities to meet a range of needs. While this plan has discussed options for Duke Energy to continue to prepare its grid assets to handle a changing climate and extreme events, there may be more that can be accomplished in partnership with the communities and customers that Duke Energy works with. These long-standing partnerships are particularly critical when extreme events cause extended power outages. Duke Energy's current T&D system is both robust and resilient. However, not all risks can be designed out of the system; addressing every potential risk would be impossible. On occasion, extreme events may lead to extended power outages, but it is Duke Energy's intention to mitigate these to the best extent possible and put measures in place to protect communities when they happen. In addition, Duke Energy seeks to support and collaborate with communities to enhance their resilience to climate-related events.

Duke Energy already has very robust partnerships with local communities around extreme event resilience. Almost all of the recommendations in this section are for incremental enhancements or additional areas of focus within existing practices and programs.

For the purposes of this document, a "**community**" is a geographic area with a discrete government such as a town, county, or city.

Figure 20. The fourth pillar in Duke Energy's Climate Adaptation Flexible Framework is partner with local communities.

Duke Energy's three-pronged approach to community support (pictured to the right in Figure 21) includes:

Proactive planning and coordination – Collaboration throughout the year to ensure that Duke Energy and its community partners are prepared for major events.

Real-time coordination during emergencies – Duke Energy partners with communities to respond to major outages, to safeguard community residents, and accelerate system restoration.

Funding and grant support – Duke Energy's efforts to support the research and programs that support community resilience.

For each of these areas, this report presents current Duke Energy activities and proposed areas for potential expansion of these efforts.

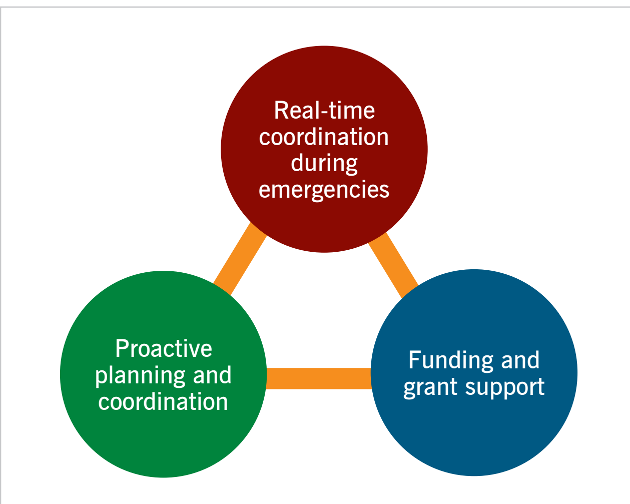

Figure 21. Three elements of Duke Energy community resilience support.

Proactive Planning and Coordination

Duke Energy's Government Community Representatives (GCR) team work with county emergency managers in every government in their service territory to prepare ahead of time for major events. Duke Energy hosts "Storm Schools" each year where local government representatives, first responders, and policymakers are invited to learn about responding to major events and coordinating with Duke Energy on resilience preparedness.

Community needs gathered by the GCR team are provided to Duke Energy's Product Development team, which specializes in helping Duke Energy's customers solve problems. This team works closely with Duke Energy customers on resilience efforts including disaster planning, grant application, and deploying new technologies like microgrids or electric vehicle charging stations. Most of this work is provided by Duke Energy at its own expense. Through this team's work, Duke Energy has developed a variety of resources for its customers around energy resilience planning, including an energy emergency preparedness checklist and an Energy Resiliency Spectrum eBook. The eBook provides a range of energy resiliency solutions, from generator and battery backup to full microgrids. Duke Energy also makes proactive investments in resilience through clean energy microgrids, commercial backup generators, and uninterruptible power supply, which are all designed to withstand unplanned outages due to extreme weather events.

Duke Energy supports local energy resilience efforts, such as the Planning an Affordable, Resilient, and Sustainable Grid project in North Carolina. This $300,000 project aims to examine storm-related impacts and the costs and benefits of investments in grid resiliency. Duke Energy supported this project by providing historical outage data following major weather-related disasters in North Carolina, and subsequently proposing various grid-hardening measures, such as distribution automation and undergrounding power lines.

Duke Energy is actively supporting the understanding of and proactive engagement around resilience planning. It is sharing its climate research with communities through the Duke Energy Climate Resiliency WayPoint page (see Figure 22), which includes projections through 2080 on temperature, precipitation, sea-level rise and social vulnerability.[19]

[19] Duke Energy, "Duke Energy Climate Resiliency WayPoint," https://ecosystems.azurewebsites.net/dukeclimate/.

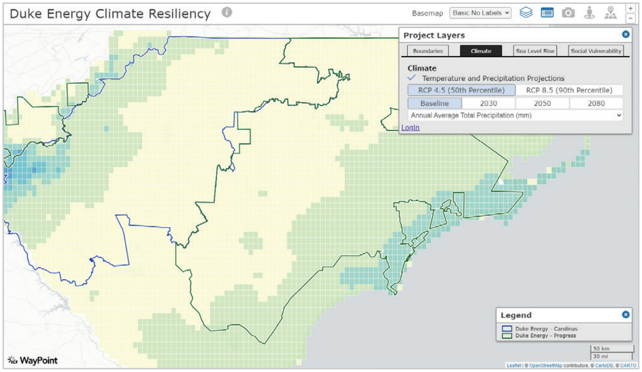

Figure 22. The Duke Energy Climate Resiliency Online Tool.

It is also working to educate communities about opportunities for federal infrastructure funding opportunities and how they can partner with Duke Energy to pursue these grants.[20]

As Duke Energy continues to strengthen its energy resilience planning support for communities, it should continue working to match its support to the needs and capabilities of the communities it serves. The TWG identified a few areas of increased collaboration, including:

- Expanding the detail included in scenario-based tools to help communities identify planning priorities for different types of major events. While these scenarios are discussed at Duke Energy storm schools, providing additional details for communities about how a given extreme event is likely to impact the grid will support local planning efforts. Include feedback to communities on how the grid improvement planning efforts have addressed energy resilience.
- Incorporating a metric and measure to gauge community involvement and satisfaction with resilience efforts into existing customer satisfaction processes. Duke Energy's current Net Promoter Scores capture customer satisfaction, but some additional detail on how Duke Energy is supporting resilience needs could help identify if more effort is necessary. This could include an additional question on the Net Promoter Score survey or a separate inquiry with community partners.
- Expanding the development of maps of the ancillary benefits and potential conflicts that

[20] Duke Energy, "Infrastructure Investment and Jobs Act," https://www.duke-energy.com/partner-with-us/infrastructure-investment-jobs-act.

PRE-EVENT – mass and direct-to-customer communications on what to expect and how to prepare

- News Release
- Social Media
- Customer Email
- Outbound Call Script
- Web Banner

DURING EVENT – communications acknowledge event and continue to define what's happening and what to expect

- Outage Map
- Proactive Text Messages
- News Release
- Social Media
- Customer Email

POST-EVENT – mass, direct, and local communications for restoration updates and visuals showing restoration progress

- Localized Outreach
- Proactive Text Messages
- News Release
- Social Media Customer Email

RECOVERY – thank-you ads, success messages

- News Release
- Web Banner
- Social Media
- Customer Email
- Advertising

Figure 23. Duke Energy's major event coordination with communities.

could arise from various community resilience solutions (e.g., microgrids and other NTS). This information would allow communities to better understand how their efforts might bolster or undermine other projects.

- Showing that community engagement goes two ways so that Duke Energy's customers not only have an opportunity to provide input, but hear from Duke Energy about how that input has been incorporated into the planning process.
- Further engaging with local planning departments (through sharing data and participating in the planning process) in community efforts to explore larger, more holistic solutions to shared risks, such as nature-based solutions projects to help address flood risks.

Additionally, ICF proposes that Duke Energy evaluates the following community resilience planning opportunities:

- Curate resilience modules and materials that local communities can draw upon and customize for their needs. This could include community-focused energy outage planning modules or local resilience best practices identified as part of Duke Energy's community engagement. At least some of these resources should be targeted at marginalized or historically underserved communities. Many of these resources already exist in the marketplace, and Duke Energy could play a role in curating and coordinating these resources for communities.
- Continue to evaluate microgrids where they are most critically needed. This could include working with the distribution planning team to evaluate specific feeders that would benefit from a distribution-level grid (as Duke Energy has done in Hot Springs, North Carolina, and is currently proposing elsewhere).[21] This could also include working with communities or businesses that desire to develop their own microgrids and minimizing barriers to those projects.
- Expand efforts to identify local infrastructure decisions that may affect grid equipment. For example, this could include zoning regulations or nature-based solutions that might increase or decrease stress on grid assets. When making these kinds of decisions, Duke Energy can provide input on how they will impact the grid. Duke Energy is having these conversations now, but they could be expanded with a specific focus on resilience impacts.

As Duke Energy develops new resources, the TWG requested the consideration of a range of approaches to serve communities with limited resources (e.g., staff) as well as those interested in deploying a more comprehensive approach.

[21] Duke Energy, "Duke Energy Places Advanced Microgrid into Service in Hot Springs, North Carolina," Duke Energy | News Center, 2023, https://news.duke-energy.com/releases/duke-energy-places-advanced-microgrid-into-service-in-hot-springs-nc.

Real-Time Coordination During Emergencies

The GCR team coordinates with communities in real time when there are outage events and when there are anticipated significant outage events due to severe weather. This includes understanding critical facilities that Duke Energy should prioritize for reconnection – a list that could differ based on the kind of threat or the situation on the ground. The GCR team also partners with communities to evaluate performance in past outage events and understand how Duke Energy can serve that community better.

Duke Energy currently has robust community and customer outreach plans in place in case of major events. Beyond direct communication with community leaders, Duke Energy communicates with the community at large during each stage of a potential major outage event, as shown in Figure 23.

Continuing this theme of two-way partnership, Duke Energy should consider further exploring opportunities for collaboration with communities in major event responses. ICF, using input from the TWG, has identified areas where Duke Energy might request additional assistance from community partners to facilitate its preparation and response to major events:

- Expand communications procedures to reach every part of the community. Duke Energy is speaking to every community in its service territory via coordination with the local government during extreme weather events. In between events, Duke Energy might engage in additional community conversations (e.g., webinars, town hall meetings) to more broadly discuss climate resilience planning.
- Enhance the relationships between Duke Energy operations and other services that may be impacted by a major event (e.g., passable roads, water access, telecommunications). When these communications have happened in the past, the results have saved Duke Energy time and money while improving safety. This should continue to be an area of focus.

Funding, Grants and Innovation

The final piece of the puzzle is funding innovative projects. Duke Energy helps communities here in two primary ways. The first is by partnering with communities as they seek state and federal grants for resilience projects. Duke Energy has a website (Figure 24) dedicated to connecting communities with grant opportunities from the Infrastructure Investment and Jobs Act.[22]

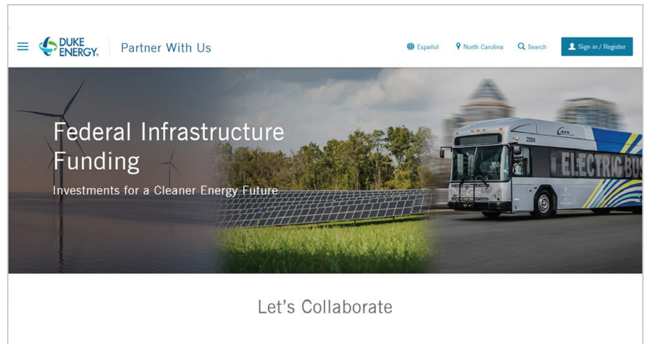

Figure 24. Duke Energy's web page for federal grant collaboration.

The second avenue of support is the Duke Energy Foundation and its grant programs to support community resilience efforts – largely informed by community needs identified by the GCR team. The Duke Energy Foundation has programs in both North Carolina and South Carolina that target three pillars for charitable giving: (1) climate resilience; (2) vibrant economies and (3) justice, equity and inclusion.[23] The foundation describes its climate resilience work as supporting three areas:

1. Environmental projects supporting land conservation, clean water, and biodiversity of plant and animal species;
2. Environmental resiliency projects that prepare communities for and mitigate against the effects of climate change; and
3. Natural disaster preparedness and response.

[22] Duke Energy, "Infrastructure Investment and Jobs Act," https://www.duke-energy.com/partner-with-us/infrastructure-investment-jobs-act.

[23] For more information on how to apply for Duke Energy Foundation grants, visit Applying for Grants - Funding Guidelines - Duke Energy.

The foundation provides over $30 million in grants each year to local governments and nonprofit organizations. Some examples of recent resilience work include:

- During the past two years, $1 million has been dedicated to a microgrant program to help South Carolina communities weather future storms by investing in things like first responder training, communications tools, rescue equipment and planning efforts.
- $750,000 in grants to North Carolina communities to reinforce their ability to help residents prepare for and recover from severe weather events.
- A $100,000 donation to the PowerPlantSC program, which helped communities plant 20,000 native tree species in flood-prone areas to create greater climate resilience.
- $250K in grants to organizations supporting resilience in North Carolina like the Nature Conservancy, NC Voluntary Organizations Active in Disaster, Ducks Unlimited, and UNC's Institute for the Environment.

In summer 2023, the Duke Energy Foundation will award $650,000 in accelerator grants in North Carolina to support resilient communities. The grants will be made in partnership with local stakeholders from the Regions Innovating for Strong Economies and Environment (RISE) program and the North Carolina Office of Resiliency and Recovery. The Duke Energy Foundation accelerator grants will help identify resiliency-based projects and the funding required for implementation. The U.S. Economic Development Association will work to connect these projects to a diverse array of federal, state and local organizations for completion.

In addition to continuing efforts like sharing climate data, providing information about grant opportunities, and conducting joint resilience training efforts, Duke Energy should take proactive steps to identify opportunities for innovation with partners. These could be local governments, other customers, universities, and nonprofit organizations. TWG participants and ICF resilience SMEs have identified a series of ways Duke Energy can better leverage these partnerships. Some of these concepts have already been identified in North Carolina's Climate Risk Assessment and Resilience Plan.[24]

- Partner with communities on projects where joint-adaptation actions may be cost efficient. For example, if a flood barrier is needed to protect a substation but extending that barrier could also protect vital community assets, Duke Energy and the community could join forces to jointly pursue the project.
- Continue to support academic research that will contribute to community resilience. Where possible, Duke Energy could provide access to data and expertise to university researchers pursuing this topic, as it has in the past.
- Continue to support the development of other businesses that contribute to resilience. For example: The Joules Accelerator was founded in 2013 with an initial grant from Duke Energy as a nonprofit to support emerging clean energy startups that drive innovation in a range of energy sectors. Through 2022, Joules startups have raised over $750 million and employed more than 2,100 people.

Two-way communication and engagement are important for Duke Energy to share these opportunities and discuss the needs of specific communities. The Duke Energy GCR team is present in the communities they serve and work to build and maintain relationships with diverse local stakeholders. Prioritization will be important to manage expectations and capacity for community members and Duke Energy personnel.

[24] "North Carolina Risk Assessment and Resilience Plan," June 2020, https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf.

Evaluating Opportunities to Support Community Energy Resilience in Response to Climate Threats

Duke Energy will continue its productive engagement with communities through the GCR teams, product development team, and Duke Energy Foundation support. Based on TWG input and industry best practices, ICF recommends that Duke Energy consider a subset of the following lenses to evaluate potential community resilience efforts.

- Which efforts reasonably fall within Duke Energy's role as a utility?
- What would the cost be to implement this, and how would that impact customers?
- Does the effort provide co-benefits like supporting the economy and/or public health?
- Which opportunities improve resilience but also target other joint objectives like grid reliability, customer satisfaction and carbon reduction?
- Where are there local government partners ready to lead the local portion of any given resilience effort, with Duke Energy supporting from the grid side?
- Where are there opportunities for flexible, replicable approaches that would establish a particular solution for adoption more broadly or create resources that could be used by other communities in Duke Energy's territory?
- Where are there opportunities to deploy resilience solutions that target populations at greater risk from extended outages within communities that Duke Energy is partnering with?

Addressing the final bullet about populations at greater risk, ICF recommends that Duke Energy leverage an existing tool that identifies census tracts with high social vulnerability (e.g., the CDC/ATSDR Social Vulnerability Index)[25] or that are considered to be disadvantaged (e.g., the Climate and Economic Justice Screening Tool).[26] To assess social vulnerability, these tools use population characteristics likely to be major drivers of a population's sensitivity to extended energy outages – things like socioeconomic status, age and physical health. When customizing its plans to take this kind of vulnerability into account, ICF proposes that Duke Energy consider these core principles:

- Use established methods to identify communities that are socially vulnerable or disadvantaged (which likely correlates with increased vulnerability to electricity outage impacts) – to then prioritize resilience options.
- Increase meaningful engagement with communities to identify needs and resilience measures; be open to input and come prepared with context for effective conversation.
- Establish a more formal process for how community input will be factored into decisions; ensure transparency of process and results.

Meaningfully engaging populations with transparency will help ensure that Duke Energy's resilience efforts for populations at greater risk from energy outages will be productive and well targeted.

[25] "CDC/ATSDR Social Vulnerability Index (SVI)," November 16, 2022, https://www.atsdr.cdc.gov/placeandhealth/svi/index.html.

[26] Council on Environmental Quality, "Climate & Economic Justice Screening Tool," https://screeningtool.geoplatform.gov/en/#3/33.47/-97.5.

Next Steps

While the four pillars of the Climate Adaptation Flexible Framework outlined in this report sets the groundwork for future climate resilience efforts at Duke Energy, it does not dictate a specific set of investments, nor does it specify how all of this work will happen. It is another step on a path toward climate resilience – one that will require continued development, refinement and collaboration. This section outlines some of the next steps that Duke Energy may undertake to help advance the recommendations included in this report from a framework to practice.

Set expectations and assign responsibility

Any new investments in climate resilience programs are going to require effort on the part of Duke Energy's team. ICF's experience with industry peers that are directly addressing climate resilience includes dedicated staff members and budgets to design, implement and track programs. Duke Energy will require funding, staff resources and support from their regulators to ensure the success of this effort.

Recommendations for a successful climate resilience planning and execution include, but are not limited to:

1. Estimating a level of effort for plan development, implementation and evaluation;
2. Ensuring that there are people (Duke Energy staff or a combination of Duke Energy staff with consulting support) with the bandwidth and focus to implement that level of effort; and
3. Ensuring that the project has executive support and at least one senior-level Duke Energy executive has its success as part of their annual performance metrics so that there is accountability in climate resilience performance improvement.

Continue implementation of process changes to maintain readiness

Duke Energy has already begun several of the recommended actions to maintain readiness, such as changing design standards to account for climate change and updating its load forecasting process to account for future changes in temperature. These types of process changes are some of the most meaningful actions that Duke Energy can take to enhance systemwide resilience to climate change. Continuing this process and executing on the "maintain readiness" recommendations is the ideal place to focus near-term efforts.

Incorporate potential impacts of climate change into ongoing resilience planning efforts

Duke Energy's ongoing resilience planning efforts should be informed by thinking about each of the four pillars presented in this report:

1. Monitor climate science
2. Maintain readiness
3. Incorporate new factors in T&D investments
4. Partner with local communities

For each of these pillars, Duke Energy should determine if and how it will continue its current efforts and which of the recommendations included in this report it would like to pursue. These efforts should then be included in an operational resilience plan. Duke Energy should address how it plans to undertake new efforts, how it will evaluate additional efforts, how these efforts will be staffed and which of the performance metrics will be used to track success. These plans should also be closely coordinated with other grid investment plans to avoid overlap and to take advantage of every opportunity for synergy.

Approach the suite of resilience options holistically

There is a high level of interactivity between many of the resilience solutions recommended in this report. That interactivity extends beyond work done by Duke Energy on its own infrastructure to work being done by other utilities (like gas and water) and local communities in their own infrastructure and community resilience efforts. Sharing information on Duke Energy's resilience plans (both near and long-term) with these partners will help them identify how their own plans might interact with Duke Energy's plans. This will be important for identifying synergies, avoiding conflicts, and generally making the most out of resilience investments. If synergies or conflicts are identified, Duke Energy should participate in the planning process, share data, and adjust their plans accordingly (e.g., if a broader community initiative will negate the need for an independent resilience investment or if Duke Energy's project can tie into a broader resilience initiative).

Determine funding approach

Once Duke Energy scopes out a suite of new climate resilience efforts it intends to implement, it will need to determine which of those things can be done as part of Duke Energy's current activities, which will require new operational funding, and which will require investments to be included in rate plans or special docket filings. At least one stakeholder in the TWG stated that a case-by-case analysis may be necessary to determine whether there currently exists statutory authority to fund certain climate resilience programs through base rates and/or any alternative ratepayer-funded cost recovery mechanisms.

Conduct regular engagement with stakeholders

Duke Energy's external stakeholders have been a vital source of information and feedback on this effort. The team making updates to Duke Energy's resilience planning should directly coordinate with the Duke Energy teams interfacing with large commercial and industrial accounts as well as the Government Community Relations team. These teams have the best information on what Duke Energy's customers need and want when it comes to increased climate resilience and potential ancillary benefits. Additionally, the TWG convened to inform this report provided insightful comments. Duke Energy should also ensure that needs around system resilience are addressed at stakeholder engagement meetings for its integrated resource plan, integrated systems operation plan, grid improvement plan, and/or rate plan technical conference briefings. If Duke Energy decides that those are not the right venues to discuss resilience planning, it should consider scheduling additional technical working group meetings with the participants that informed this report.

Establish climate resilience performance metrics

Duke Energy needs measuring sticks by which to understand how its efforts are impacting climate resilience outcomes for the system at large and for certain groups of customers. When addressing grid reliability, there are accepted, industrywide metrics like SAIDI and SAIFI. Climate resilience is much less simple as there are a variety of threats that come in different forms and magnitudes. There are also a variety of solutions that can yield different positive outcomes. Climate resilience performance measures is an ongoing area of research, and there is no current best practice in the field. Duke Energy should continue to participate in the national conversation with other utilities on what data points best capture energy resilience performance. Once Duke Energy adopts a metric (or, more likely, a suite of metrics), those can be utilized in monitoring, evaluation and reporting.

Implement, monitor, revise

Duke Energy should build into its climate resilience plan a regular review and revision schedule to evaluate changes in climate change science and to evaluate how its efforts are impacting the customer experience and where their efforts might be expanded or refocused. By leveraging its performance metrics, stakeholder engagement, and staff experience, Duke Energy can keep its climate resilience program developing in real time to meet changing climate threats and the needs of every community it serves.

Appendix: List of Adaptation Options

This appendix provides a longer set of potential adaptation solutions for Duke Energy's consideration.

System	Asset	Hazard	Adaptation
Transmission	Structures (poles/towers)	Flooding	Increase robustness of foundations
Substation	Substation Transformers/Regulators	Flooding	Perimeter protection (temporary barrier or permanent flood wall)
Substation	Substation Transformers/Regulators	Flooding	Protect specific transformers/regulators via flood enclosures
Substation	Circuit Breakers	Flooding	Perimeter protection (temporary barrier or permanent flood wall)
Substation	Circuit Breakers	Flooding	Elevate circuit breaker
Substation	Protection & Control Devices	Flooding	Perimeter protection (temporary barrier or permanent flood wall)
Substation	Protection & Control Devices	Flooding	Elevate protection and control cabinet
Substation	Substation Transformers/Regulators	Flooding	Flood pumps
Substation	Protection & Control Devices	Flooding	Flood pumps
Substation	Circuit Breakers	Flooding	Flood pumps
Transmission	Conductors (overhead)	Heat	Energy efficiency/demand response
Transmission	Conductors (overhead)	Heat	Reconductor to increase capacity
Transmission	Conductors (overhead)	Heat	Voltage upgrade to increase capacity
Transmission	Conductors (overhead)	Heat	Install additional feeder(s) to reduce loading
Transmission	Conductors (overhead)	Heat	Non-wires solutions to reduce loading
Transmission	Conductors (overhead)	Heat	Dynamic line rating to unlock capacity
Substation	Substation Transformers/Regulators	Heat	Energy efficiency/demand response
Substation	Substation Transformers/Regulators	Heat	Replace transformer/regulator with higher rated unit
Substation	Substation Transformers/Regulators	Heat	Install additional transformers or substations to reduce loading
Substation	Substation Transformers/Regulators	Heat	Non-wires solutions to reduce demand
Substation	Substation Transformers/Regulators	Heat	Additional cooling
Transmission	Structures (poles/towers)	Ice	Replace tower with stronger tower
Transmission	Structures (poles/towers)	Ice	Reinforce towers
Transmission	Conductors (overhead)	Ice	Ice shedding technology
Transmission	Conductors (overhead)	Ice	Undergrounding
Transmission	Structures (poles/towers)	Ice	More robust vegetation management
Substation	Substation Transformers/Regulators	Ice	Install ice resistant bushings

System	Asset	Hazard	Adaptation
Distribution	Structures (poles)	Ice	Reinforce pole
Distribution	Structures (poles)	Ice	Replace pole with stronger pole
Distribution	Conductors (overhead)	Ice	Install sectionalizing devices to minimize scope of outages
Distribution	Conductors (overhead)	Ice	Undergrounding
Distribution	Conductors (overhead)	Ice	More robust vegetation management
Transmission	Structures (poles/towers)	Wildfire	Widen rights of way
Transmission	Structures (poles/towers)	Wildfire	More robust vegetation management
Transmission	Structures (poles/towers)	Wildfire	Fire retardant coatings on wooden transmission structures
Transmission	Structures (poles/towers)	Wildfire	Hardening to reduce risk of asset failure causing wildfire
Transmission	Conductors (overhead)	Wildfire	Widen rights of way
Transmission	Conductors (overhead)	Wildfire	More robust vegetation management
Transmission	Conductors (overhead)	Wildfire	Rebuild towers to increase line elevation
Transmission	Conductors (overhead)	Wildfire	Hardening to reduce risk of asset failure causing wildfire
Transmission	Conductors (overhead)	Wildfire	Undergrounding
Substation	Substation Transformers/Regulators	Wildfire	Increase cutback around substation
Substation	Substation Transformers/Regulators	Wildfire	Replace oil circuit breakers
Substation	Protection & Control Devices	Wildfire	Increase cutback around substation
Distribution	Structures (poles)	Wildfire	Fire retardant coatings on poles
Distribution	Conductors (overhead)	Wildfire	Bare conductor replacement
Distribution	Conductors (overhead)	Wildfire	More robust vegetation management
Distribution	Conductors (overhead)	Wildfire	Undergrounding
Distribution	Conductors (overhead)	Wildfire	Distribution ”hardening”
Transmission	Structures (poles/towers)	Wind	Replace towers
Transmission	Structures (poles/towers)	Wind	Reinforce towers
Transmission	Conductors (overhead)	Wind	Undergrounding
Distribution	Overall System	Various	Self-healing technologies
Distribution	Overall System	Various	Advanced voltage optimization
Distribution	Overall System	Various	Intelligent grid technologies

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