Duke Energy Climate Resilience and Adaptation Study

DUKE ENERGY

Guidehouse

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A Message from our Enterprise Strategy and Chief Risk Officer and Chief Sustainability Officer

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Our commitment to providing accessible, reliable and affordable energy to customers means our system must become more resilient in the face of the changing climate and extreme weather. This year, we experienced two historic storms — hurricanes Helene and Milton. Those impacts were felt in each of our service territories. These tragic events reaffirmed our belief that incorporating climate data into our transmission and distribution (T&D) planning processes as well as into the design standards of our generation portfolio is fundamental, not only in preparing for the future, but also to meeting the needs of our customers today.

Duke Energy has been making targeted investments to mitigate the impacts of increasingly severe weather for many years. While these investments do not make our assets impervious to extreme weather events, like we experienced with hurricanes Helene and Milton, they are critical to reducing the impact of these events and helping us restore an essential service to our communities faster when outages occur.

In 2023, we published the Carolinas Climate Resilience and Adaptation Report, where we shared our initial progress on climate resiliency. This report was the result of a robust partnership with communities and stakeholders. Together, we developed a flexible adaptation framework to guide our path toward climate resiliency for the T&D system in the Carolinas. The study identified four themes to streamline our efforts: (1) employing climate scenarios in planning and design and updating those scenarios as the science improves over time, (2) continuing to evolve transmission and distribution (T&D) planning and operational practices so that capital investments and plans are informed by a forward-looking view of climate projections and gradually replacing assets with more robust designs as needed, (3) implementing recommended T&D investments to improve resilience and (4) partnering with local communities to incorporate their priorities into resilience planning.

This study helped ensure our investments continue to effectively enhance the resiliency of the grid in alignment with evolving climate related risks, including extreme weather events. For example, our continued deployment of smart, self-healing technology on the electric grid helped avoid more than 1.5 million customer outages in 2023, saving nearly 3.5 million hours of total outage time across our six-state electric service area, half of which came during major storms. While a self-healing system can't repair the physical damage to a power line that a human crew must repair, it can reduce the number of customers affected by an outage by up to 75% and can often restore power in less than a minute.

Our work on resilience is not new as it is a critical component of our strategy to deliver accessible, affordable, reliable and increasingly clean energy to our customers. Our customers' energy needs are rapidly growing and evolving, as a result of advanced manufacturing, artificial intelligence, population and other economic growth. These new dynamics require a consistent and responsible pace of change to meet our customer's demands to power a modern economy. As a 100+ year company, we have a rich history of evolving our portfolio to meet the needs of our customers. We take this business responsibility seriously as we evaluate our aging assets

Lineworker supporting restoration in Western North Carolina (left). The roof at Tropicana Field, the home of the Tampa Bay Rays, sustained major damage because of high winds associated with Hurricane Milton — St. Petersburg, Florida (right).

including plants that have run for over 50 years. To ensure consistent reliability, we look to responsibly replace these assets with more efficient and resilient infrastructure that also allows us to reduce our carbon emissions substantially. Our energy infrastructure investments will enable us to reach our goal of achieving net-zero carbon emissions by 2050. We are trending toward a 50% reduction in CO2 emissions from electricity generation in 2030. As we grow our system to meet the needs of our customers, our progress toward net-zero emissions will be constant but not linear. We will continue to work with stakeholders as we seek necessary regulatory approvals to retire our aging coal assets by 2035 and bring new, highly efficient generation resources online — in a way that preserves customer affordability and reliability. In our natural gas business, we remain committed to achieving our goal of net-zero methane emissions by 2030. These energy infrastructure investments complement our work to continue hardening our system against increasingly severe weather and other climate-related risks.

Historic Storm Season

With the majority of our customers in the Carolinas and Florida experiencing outages during hurricanes Debby, Helene and Milton, self-healing technology played an important role in reducing the duration of outages for our customers. These investments helped avoid nearly 550,000 customer outages and saving 7 million hours of total outage time across all 3 storms. During hurricane Helene, self-healing technology helped avoid around 185,000 customer outages across the Carolinas, saving more than 1.2 million hours of total outage time.

We are taking a comprehensive approach to rebuilding in the hardest hit areas of the mountains after Hurricane Helene. At the time of publication, remaining outages are largely concentrated in Swannanoa, Bat Cave and Chimney Rock in North Carolina and where broader recovery efforts are being coordinated due to catastrophic damage to buildings and infrastructure. Affordability is central to our efforts to restore and rebuild communities. As such, we're also engaging with policymakers to enhance the availability of disaster recovery support for our customers.

System-wide Analysis

Against this backdrop, which underscores the importance of considering extreme weather in our planning, we are proud to share our Enterprise Climate Resilience and Adaptation Study. This study extends the important work we did in the Carolinas to our generation assets, our Florida and Midwest T&D systems and our Piedmont Natural Gas utility. It highlights how proactive analysis of climate-related risk is informing our investments across the company. Key takeaways include:

- Without adaptation investments, extreme heat and flooding are projected to be the greatest concern to our existing assets in 2050;

- Flooding and extreme heat can impact the operating limits of cooling water reservoirs at our generation facilities, which could, in turn, restrict the overall generation capacity of a given plant. As we design and plan for the deployment of our future fleet, we will consider implementing new infrastructure design standards to accommodate higher temperatures and to mitigate the impacts from flooding. We will also consider installing cooling towers in areas where water supply might be impacted by climate hazards;

- As we continue to plan our future T&D assets, we will continue to monitor the latest flood projections and evaluate the need to update our transmission and distribution design standards to accommodate rising temperatures. These investments will supplement our ongoing commitment to effective T&D climate resiliency solutions, including targeted undergrounding and self-healing technology;

- Leveraging learnings from this and our 2023 Carolinas study can lead to federal and state support for our proposed investments. For example, in partnership with the state of North Carolina, we were recently selected to receive a grant award from the Department of Energy for a transmission rebuild project that was identified within our Carolinas study. The project will incorporate climate-resilient designs, including advanced high-temperature, low-sag conductors; and

- Although extreme heat, flooding and extreme cold can have impacts on asset performance, climate related hazards are relatively low for gas assets.

Opportunity & Innovation

We launch this study at a time when we are also experiencing both tailwinds and headwinds that will shape our path forward. As one example, the Inflation Reduction Act's clean energy tax credits are reducing the cost to deploy clean energy technology today and stimulating innovation in advanced technologies that will be critical for our future, including advanced nuclear, long duration energy storage, carbon capture and hydrogen. Tax credits for nuclear energy and energy storage are especially important in keeping energy affordable and reliable for our customers in the near-term. We continue to advocate for the durability of these credits.

Further, the demands on our system will continue to grow. We are experiencing load growth in our service territories to power data centers, artificial intelligence (AI) and domestic manufacturing. We estimate significant load growth of 1.5–2% per year, compared to flat–0.5% per year just a few years ago.

Increasing demand represents both an opportunity and a challenge and innovation will be a key to our success. We are finding new ways to collaborate with our customers to accelerate the deployment of advanced clean energy technologies like new nuclear and long duration energy storage. One of the examples is the executed Memorandum of Understanding (MoU) between Duke Energy, Amazon, Google, Microsoft, and Nucor for renewable energy development in North and South Carolina. The signed MoU is for new rate structures that are intended to lower the long-term cost of investing in clean energy technologies.

A New Era of Resiliency

As we continue to work with our valued stakeholders on a clean energy future, we will provide updates along the way. Trust starts with transparency, and we aim to provide our stakeholders with insight into our practices so that they continue charting our progress and help hold us accountable. Our next Climate Report, which we anticipate releasing in 2025, will provide a more detailed look at how we are navigating these and other emerging market, technology and policy dynamics on the way to net zero carbon emissions by 2050. At Duke Energy, we aim to mitigate our emissions while meeting our customers' demands for reliability and affordable energy. We do this all while continuing our work to ensure system resiliency against severe weather. In the pages that follow, we share more about how we are investing in climate-resilient infrastructure today to provide our customers with reliable, affordable and increasingly clean energy into the future.

Climate Resilience and Adaptation Study

Prepared for:

DUKE ENERGY®

December 2024

guidehouse.com

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Executive Summary

In the face of the changing climate and extreme weather, 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. While this type of work is not new to the company, Duke Energy continues to review the long-term exposure, risk, and vulnerability to physical impacts of climate change to their assets.

To that end, Duke Energy initiated a Climate Resilience and Adaptation Study of its transmission and distribution (T&D) system, as well as its generation system to 1) assess the vulnerability of its assets and operations to current and projected physical impacts of climate change and 2) to develop a flexible framework to improve resilience across all six of its regulated electric utilities, including Duke Energy Carolinas (DEC), Duke Energy Progress (DEP), Duke Energy Florida (DEF), Duke Energy Indiana (DEI), Duke Energy Ohio (DEO) and Duke Energy Kentucky (DEK), as well as the Piedmont Natural Gas utility. For the purposes of this study the climate analysis conducted for Duke Energy Kentucky and Ohio were grouped together, and therefore they will be referred to as DEOK. The DEOK gas utilities were not included in the study as they had negligible impacts from climate. Guidehouse 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.

The study reviewed exposure, risk and vulnerability to physical impacts of climate change at the individual asset level, focusing on the 2050 time frame, and provided data to support Duke Energy's assessment of adaptation options that would improve the system's resilience amid future potential risks. The study's findings are organized by asset group (e.g., transmission, substations, distribution, generation) and by planning and operations process areas (e.g., asset management, workforce safety). The vulnerability ratings are summarized throughout as low, medium or high, with supporting documentation and additional details located in the appendix. Importantly, these ratings reflect incremental risk associated with plausible climate change effects, for the 2050 time frame, and are not intended to indicate current or cumulative risk levels. To provide a robust and comprehensive understanding of the potential vulnerabilities, this assessment was conducted assuming that the projected risks are not mitigated. The exclusion of adaptation measures allows for a baseline of hazard risk to be determined without factoring in the mitigation efforts Duke Energy is undertaking and will undertake in the future.

Included alongside the vulnerability findings are current and potential future adaptation strategies and measures that Duke Energy can deploy to mitigate risk from these climate hazards. For instance, among the efforts that are currently in flight is the North Carolina Innovative Transmission Rebuild project, an endeavor that resulted from Duke Energy's 2023 Climate Resilience and Adaptation Report, which focused on the company's Carolina's T&D system. This project, for which Duke Energy was awarded $57 million from the U.S. Department of Energy, involves rebuilding a 40-mile transmission line with climate change-resilient designs to harden the system against heat exposure and to enable the integration of more renewable resources.

Beyond the adaptation measures to mitigate physical risk, Duke Energy is driving toward a clean energy future in a responsible pace of change for customers while balancing affordability and reliability. While transitioning to clean energy, Duke Energy must also respond to unprecedented load growth and economic development. Duke Energy operates in some of the most attractive jurisdictions and is projecting 1.5%–2% annual average load growth through 2028. While residential customer load growth remains robust across the jurisdictions, Duke Energy is also serving hyperscale customers through data centers and advanced manufacturing. Acknowledging that load growth, among other topics, is creating some pressure, Duke Energy continues to trend towards the stated goal of at least a 50% carbon reduction from electricity generation by 2030 (from 2005 levels) and net zero by 2050. Progress to net zero will not be linear and will continue to fluctuate as coal plants are retired and new generation resources continue to come online.

To reach this goal at an enterprise-wide level, Duke Energy has adopted a set of innovative emission mitigation strategies currently being developed and pursued across all jurisdictions. These efforts include, among many others, retiring coal units, installing new renewables, deploying advanced grid monitoring and control technologies that enable grid operators to shift and shape demand, developing a green hydrogen facility, conducting a carbon capture and storage Front-End Engineering Design study, and pursuing advanced nuclear technologies. Details of these efforts are outlined in Section 5 of this study.

Historic Hurricane Season

The 2024 Atlantic hurricane season produced above-average hurricane activity due to near-record warm temperatures in the Atlantic Ocean and the Gulf of Mexico, development of La Nina conditions in the Pacific, and an increase in climate change conditions that favor tropical storm formation.[1] As of season end, there were 18 named storms, 11 hurricanes, 5 of which were major (category 3 or above) and two in particular, Helene and Milton, that have brought catastrophic damage across Duke Energy's service territories. This section will discuss the impacts of the two hurricanes, the science behind their record impacts, and Duke Energy's efforts to restore power and rebuild communities in affected areas.

Hurricane Helene made landfall in Florida as a Category 4 storm. Due to the high winds and extreme rainfall, the hurricane brought storm surges to areas from Tampa Bay to the Florida panhandle. Helene continued to grow more powerful as it moved through Atlanta and the Appalachian region in Western North Carolina eventually impacting every Duke Energy service territory from Florida to Indiana. Unlike previous storms in recent years, Hurricane Helene's impact once it made landfall was unprecedented. This was due to a storm system forming along a stalled cold front that drew in tropical moisture from Helene's outer edges.[2] The system fueled large amounts of precipitation and flooding, lending to all conditions being present for Helene to be potentially considered a Gray Swan Event. A Gray Swan Event is similar to a Black Swan Event in that both have significant impacts and are considered unlikely. However, a Black Swan Event is unpredictable while in a Gray Swan event, there is a level of predictability. Helene happened during a predicted hurricane season, but the strength, amount of precipitation, and the regions impacted that were considered immune and highly unlikely to be at risk lends to this being a catastrophic Gray Swan Event. As much as 30 inches of rain fell in certain areas in the Carolinas causing extreme flash flooding as Helene became one of the largest storms of the last decade. Weather forecasters called the deadly rainfall and flooding a "once in 1,000 years event." Hurricane Helene also carried maximum sustained winds over 70 mph. These impacts jeopardized the safety of customers, employees and crew members and placed assets in danger. See Figure 1 on the next page for a visual of the accumulated precipitation from September 25th through 27th over Helene's path (represented by the series of red points). Due to the mountainous terrain in these areas, the rainwater channeled into rivers and creeks, causing flash flooding as high as rooftop levels.

A recent scientific report produced by the World Weather Attribution organization found that the impact of Hurricane Helene and unprecedented rainfall was intensified due to climate change and climate driven warming, causing an increase in sea surface temperature.

As the ocean absorbs more heat, sea surface temperature increases, altering the circulating patterns that move warm and cold water around the world. Sea surface temperatures interact with the atmosphere, and an increase in temperature can lead to an increase in the amount of atmospheric water vapor over oceans, causing heavy precipitation.[3] Analysis in the report and findings from the Climate Central's Climate Shift Index: Ocean (Ocean CSI) tool[4] concluded that temperatures along Helene's track were 1.26°C (2.3°F) warmer than historic ranges due to climate change. Helene's path also coincided with the Loop Current, an area of warm water that travels up from the Caribbean into the Gulf Stream

1 NOAA predicts above-normal 2024 Atlantic hurricane season | National Oceanic and Atmospheric Administration
2 Scientific report — Hurricane Helene.pdf
3 https://doi.org/10.1017/9781009157896
4 Climate Shift Index: Ocean for sea surface temperatures | October 22, 2024

and maintains record sea surface temperatures with ocean heat in the upper 80-degree range. The water current prevented cooling from the storm and allowed for rapid intensification. Once the storm arrived, the severity of downed trees and powerlines from widespread wind damage, and historical flooding in the North Carolina mountains resulted in one of the most devastating weather events to ever hit the state.[5]

Hurricane Helene caused catastrophic damage across Duke Energy's service territories. The company's storm preparations began days before Helene made landfall. More than 20,000 workers answered the call to restore power to Duke Energy's customers and communities in particular across Western North Carolina, Upstate South Carolina, and the communities along Florida's west coast, the most heavily impacted areas. Crews utilized helicopters to move power poles into the hardest-hit areas that needed equipment in place to restore power as soon as it was safe to do so. Duke Energy also utilized drones to assess and disperse intel on system damage to crews to better inform their restoration efforts. Drones were able to identify survey areas that were unsafe for human crews and identify additional hazards, including spotting downed trees and washed-out equipment. In areas with significant damage, like Western North Carolina, certain portions of the electrical system required complete rebuilds due to high winds and flooding. Duke Energy immediately began undertaking efforts to install new transformers, poles and main power lines. Since Helene hit, the company has replaced more than 16,000 poles and over 10 million feet of wire.

Shortly following Helene, Hurricane Milton tore through Florida, impacting significant portions of Duke Energy's service territory in the state. As hurricane Milton neared landfall close to Siesta Key, Florida, it interacted with the jet stream over the southeastern part of the United States, causing

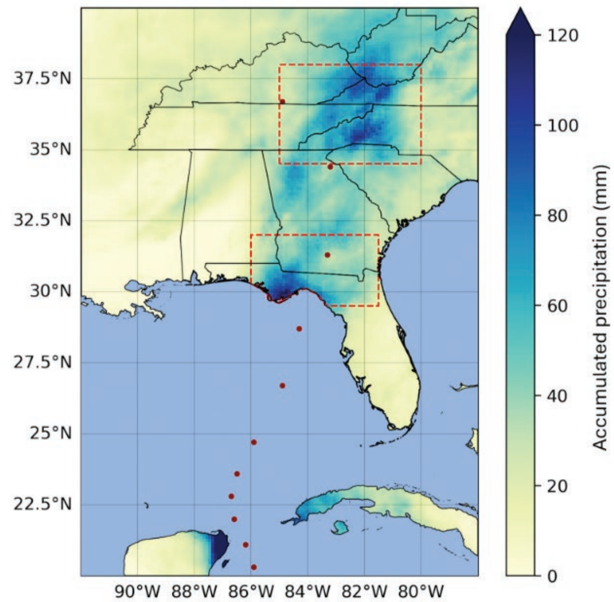


Figure 1. Accumulated Precipitation over the Southeastern US from Hurricane Helene

unusually strong winds. Milton moved across the Florida peninsula and out over the Atlantic Ocean as a Category 3 hurricane. Crew members worked tirelessly to restore power to the over 1 million customers that lost power.

Upon landfall Milton brought storm surges, high winds, and extreme flooding to the coast of Florida, leading to widespread damage and severe risks to local communities. Additionally, the wind field grew abnormally far from the storm's center as it approached the peninsula and the extreme wind speeds brought on by the hurricane fueled an outbreak of 46 tornadoes across the state. Milton set a state record for the most tornadoes brought on by a single event in 70 years, and it was the first tropical storm since 1972 to spawn a F/EF3 tornado in Florida.[6] While it is not rare for tornadoes to come from tropical systems, this year there have been damaging tornadoes spawned in Duke

5 PSHGSP_2024AL09_Helene_Data.xlsx
6 Hurricane Milton's Record Florida Tornado Tally | Weather.com

Energy's territory by three hurricanes: Debby, Helene and Milton. Although climate modeling can provide a certain level of forecasting, impacts from extreme storms, tornadoes and their potential impact remain difficult to predict, model and design. According to the Center for Climate and Energy Solutions (C2ES), limited data collection methods, high year-to-year variability, and modeling physical elements necessary for the formation of tornadoes lend them to being one of the most difficult hazards to predict with a given level of certainty.

Duke Energy continues to provide support to customers and employees located in areas that were hardest hit by hurricanes Helene and Milton. In Duke Energy Florida, customer care units were mobilized into the community to answer questions and provide account assistance for customers. In North Carolina, 1,360 food supply kits were brought to the Western part of the state through aircraft to help employees and their families in need.

The Duke Energy Foundation has also committed more than $2 million in the wake of hurricanes Helene and Milton. More than 2,000 employees have made donations or volunteered their time on community relief efforts including blood drives, feeding events and donation packing. The Foundation double matched employee donations to the American Red Cross, and its Relief4Employees program is actively granting dollars to employees personally impacted by these natural disasters. These regions are continuing to recover from the devastating effects of Hurricanes Helene and Milton. As customers begin to repair and rebuild their homes and businesses, the company will be ready to respond and reconnect power where necessary.

The impacts stemming from Hurricanes Helene and Milton underscores the importance of conducting climate risk analysis and incorporating resiliency findings into regional planning processes. The findings in this study were focused on modeled climate hazards to 2050 and available data at the time of the report, with data from Helene and Milton incorporated into subsequent iterations. While Duke Energy has incorporated Black Swan events into their regional planning and workshops, there is a level of uncertainty in scenario modeling and the impacts of these events cannot be predicted for every possible outcome. However, as the technology to predict these events advances, Duke Energy's response and action will follow suit, as they continue to invest in climate resilient infrastructure and adaptive measures.

1. Introduction

1.1 Goals and Objectives

Through the Climate Resilience and Adaptation Study, Duke Energy aims to develop an improved understanding of the physical vulnerabilities and risks that climate change could pose to its T&D, generation and Piedmont Natural Gas assets and operations. The analysis is comprised of two assessments. The first, released in 2022 and 2023, is a two-part assessment of climate risks and a potential adaptation framework for the T&D system in the company's Carolinas jurisdictions.[7] The second, summarized in this report, includes a comprehensive assessment of climate risks and potential adaptation options for the entire Duke Energy T&D, generation and Piedmont Natural Gas systems.

The goals of these assessments are to:

- Develop a clear and detailed understanding of potential climate change vulnerabilities to Duke Energy's T&D and generation assets and operations across a range of climate change scenarios.

7 carolinasresiliencetransmissiondistributionstudy.pdf (duke-energy.com) (2022) and carolinsresiliencetransdiststudyfinal.pdf (duke-energy.com) (2023)

- Identify Duke Energy's projected highest priority climate vulnerabilities, based on reasonably bounding potential exposures and system-level impacts.
- Explore Duke Energy's adaptation planning process and identify future projects and investments to mitigate risk and enhance reliability and resiliency.
- Affirm Duke Energy's commitment to providing reliable and resilient energy in the face of changing weather and climate conditions. This work is complementary to Duke Energy's existing efforts to enhance the present-day resiliency of its T&D system.

The objectives of these assessments are to:

- Consolidate the knowledge base describing relevant sensitivities and potential system consequences by asset type.
- Provide a robust collection of tailored climate change insights to support Duke Energy's ongoing climate change analysis and adaptation planning.
- Support transparent public report findings that can comprehensively inform community resilience planning.

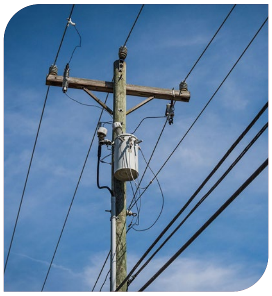
As part of the study, Duke Energy captured adaptive measures that are currently underway and potential actions to further improve resilience from the hazards studied. In many cases, the adaptive actions have multiple benefits in addition to enhancing resilience. For example, using vegetation and nature-based solutions to mitigate the impacts of flooding can also help protect soil from further erosion in coastal and inland regions.

To supplement existing adaptive measures and in-flight projects, Duke Energy is investing in a variety of innovative technologies and renewable energy resources to meet growing customer needs. These advanced grid solutions will increase grid capacity while improving resilience across all jurisdictions.

1.2 Electricity Assets 101

This report analyzes the projected impacts and vulnerabilities of climate change-related hazards on transmission, distribution, substation, generation and natural gas assets. Please see below for an overview of the different types of electricity grid structures. For an in-depth look at the sub-categories of assets covered in this report please refer to Appendix B.

Transmission structures are typically made of wood, concrete or steel and stand at least 60 feet tall. They can be in the form of a single pole (round or square), H-Frame (a two-pole structure connected by cross-arms), or metal lattice tower. These structures carry the high voltage lines that can be followed across the entire grid from one electric substation to another, in rights-of-way made up of easements and/or land owned by Duke Energy. They are responsible for transporting large amounts of high-voltage currents over long distances.

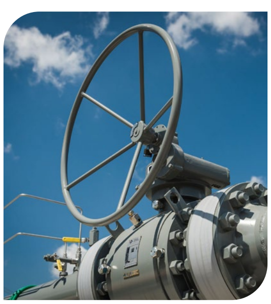


Distribution structures are also generally made of wood and are 30 to 40 feet tall. In contrast to transmission structures, they are used to carry power over shorter distances using lower voltage electricity. Distribution poles are commonly the smaller poles seen along roads or property lines through subdivisions and connect directly to homes or businesses.[8] Distribution infrastructure carries the energy that powers lights and the appliances we use every day. A typical household runs on 120 volts.[9]

8 Transmission vs. Distribution Structures (duke-energy.com)
9 PJM Learning Center - Transmission & Distribution

Substations are assets used within the T&D and generation system that help manage the grid and include transformers that convert electricity between high and low voltages. Substations are composed of metal structures and are commonly referred to as the 'junction point' or 'control house' for managing the grid. Substation assets often include equipment for electricity flow, as well as tools for automation, protection, and communication. Primary substation equipment deals directly with electricity flow, and secondary equipment is responsible for substation automation.[10]

Electricity is generated from a wide variety of sources. Duke Energy owns and operates a diverse mix of regulated power plants — including hydro, coal, nuclear, natural gas, solar and battery storage. Solar, nuclear, and natural gas were the primary focus of the vulnerability analysis and adaptive actions identified in this report.[11] As global climate-related risks increase, maintaining a diverse generation profile, which includes adding renewable sources and energy storage in long-term planning, provides important resilience to facilitate a more reliable grid.



Many natural gas assets, including pipelines, are located underground, near public streets and highways, or on property owned by others for which Duke Energy and Piedmont Natural Gas have obtained necessary legal rights to place and operate facilities on such property. For the vulnerability analysis and adaptive actions identified in this report, above ground assets were the primary focus.

1.3 Introduction to Duke Energy's Service Territories

Duke Energy is one of America's largest energy holding companies. The company's electric utilities serve 8.4 million customers in North Carolina, South Carolina, Florida, Indiana, Ohio and Kentucky and collectively own approximately 54,800 megawatts of energy capacity. Duke Energy also operates one of the nation's largest electric grids, which encompasses over 31,000 miles of transmission power lines and over 280,000 miles of distribution power lines.

Duke Energy's electric utility service area spans 90,000 square miles. These utilities include Duke Energy Carolinas (DEC), Duke Energy Progress (DEP), Duke Energy Florida (DEF), Duke Energy Indiana (DEI), Duke Energy Ohio (DEO) and Duke Energy Kentucky (DEK). This study focuses on the assets and operations across all six of Duke Energy's regulated electric utilities, as well as Piedmont Natural Gas, a natural gas distribution subsidiary. Piedmont Natural Gas distributes gas to over 1.2 million customers in North Carolina, South Carolina and Tennessee. Duke Energy's service area in North Carolina and South Carolina is comprised of DEC and DEP, and for the analysis included in this study the two regulated utilities have been combined and are referred to as the Carolinas. Due to their geographical proximity, Duke Energy Kentucky and Ohio were grouped together, and therefore will be referred to in the study as DEOK. The DEOK gas utilities were not included in the study as they had negligible impacts from climate.

10 Substation Equipment - an overview | ScienceDirect Topics

11 Due to the targeted scope of 2050 climate impacts coal is not listed as a primary focus of this report as Duke Energy plans to phase out coal and retire plants in compliance with Section 111 of the Clean Air Act.

2. Methodology

The methodological framework for the vulnerability assessment was built to improve the development and understanding of the nature, extent, and priority of the vulnerabilities that Duke Energy may face as a result of climate change. At the most basic level, vulnerability is defined as the potential for assets or operations (and, by extension, customers) to be affected by climate change, and the significance of the potential consequences. This incorporates the degree to which assets may be exposed to climate hazards and the potential impacts of those exposures, which are assessed on the infrastructure's sensitivity to the hazard and the consequence of impacts.

For each major asset group (i.e., transmission, distribution, generation and natural gas assets) and climate hazard (i.e., extreme heat, wind, flooding, precipitation, and extreme cold and ice) combination, the vulnerability rating is summarized as **low, medium, or high.** These ratings reflect the overall priority level of potential vulnerabilities under reasonably bounding future climate change conditions. Importantly, the rating reflects incremental risk associated with plausible climate change effects, focusing on the 2050-timeframe, and are not intended to indicate current or cumulative risk levels.

Climate risk is generally distinguished between acute and chronic risks. Acute risks are severe and short-term while chronic risks are present over a longer period. Acute physical risks refer to those that are event-driven, including increased severity of extreme weather events, such as hurricanes, wildfires, or floods. Chronic physical risks refer to longer-term shifts in climate patterns, such as sustained higher temperatures and sea level rise.

Climate forecasts in this study are based on global climate models that are "downscaled" to identify potential local vulnerabilities. For this study, Duke Energy subject matter experts (SMEs), in collaboration with industry experts, considered the vulnerabilities along with design and failure thresholds and asset criticality to assess the significance of potential vulnerabilities and associated risks. The scoring criteria in the study do not reflect existing mitigation and/or adaptation strategies planned by

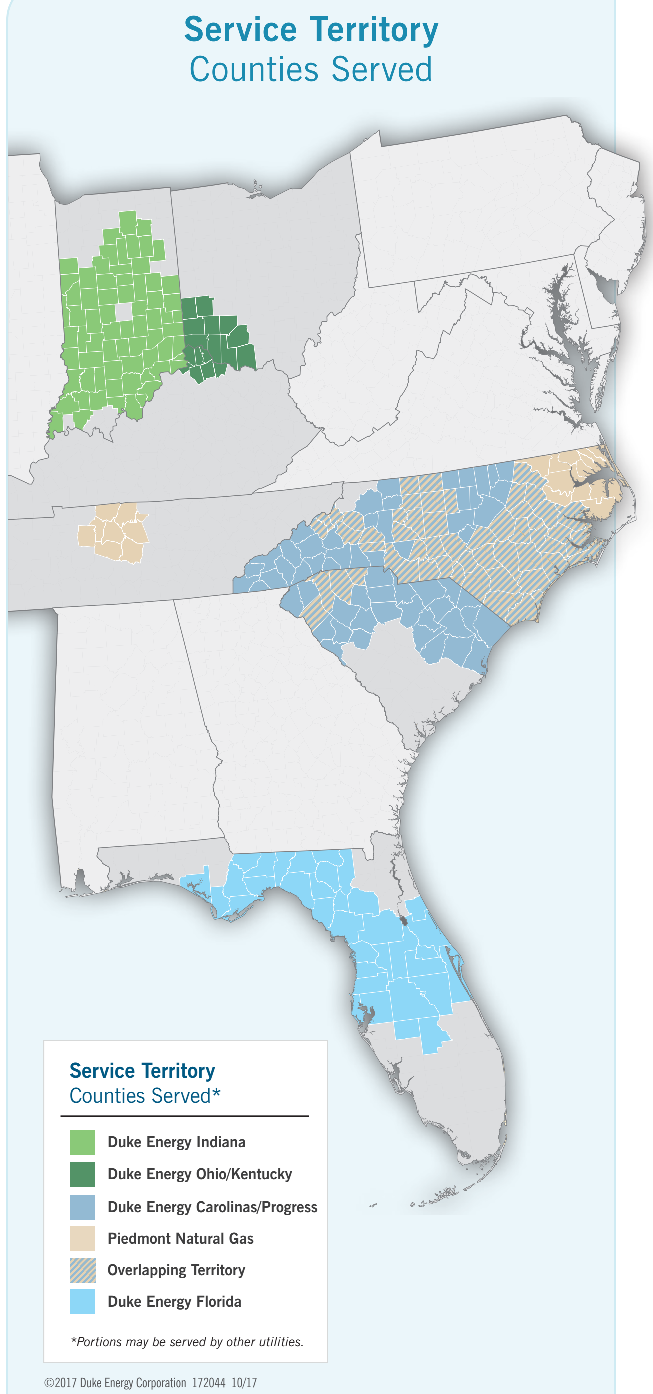


Figure 2. Duke Energy and Piedmont Natural Gas Service Territory

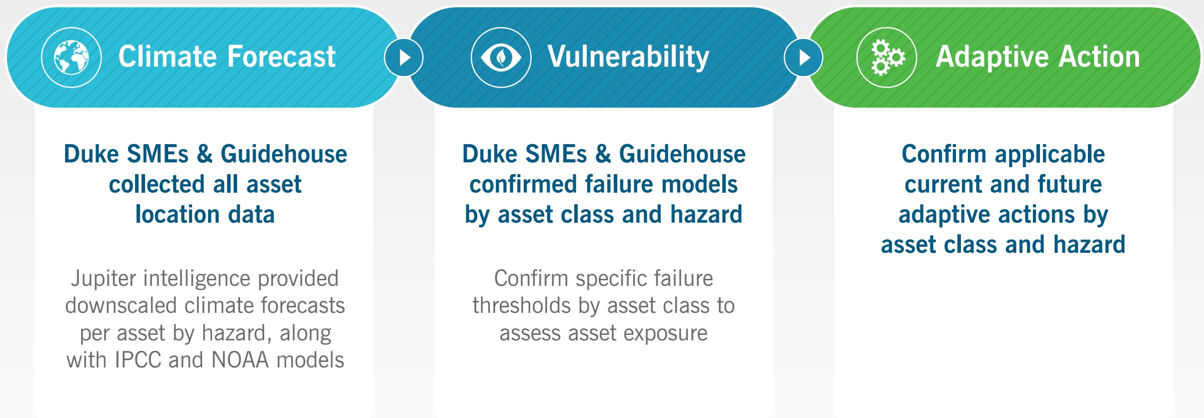


Figure 3: Scope of Work for the Climate Assessment

Duke Energy, with the intent to provide a clearer picture of the potential risks associated with a changing climate.

The outputs of the vulnerability assessment in each jurisdiction inform the development of adaptive strategies that Duke Energy can take to mitigate climate risks and avoid asset failures. When implementing adaptive actions, consideration is given to specific characteristics of the geography, regional impacts, and economic feasibility to ensure measures with the greatest positive impact are prioritized. These actions can be referenced in greater detail in Section 4.

2.1 Climate Change Projections

This study focuses on the range of projected plausible climate change futures for five climate hazard categories in 2050:[12]

1. High temperatures and extreme heat;
2. Extreme cold and ice;
3. Flooding;
4. Precipitation; and
5. High wind events such as hurricanes and storms.

The analytical focus is on plausible upper and lower bounds of climate scenario projections, using the Coupled Model Intercomparison (CMIP6) Representative Concentration Pathway (RCP)/Shared Socioeconomic Pathway (SSP) scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). The four RCPs used for climate modeling in the IPCC Fifth Assessment Report (AR5) describe different concentrations of GHG and other radiative forcings that may occur in the future. These pathways do not include socioeconomic variables, and as such, in the IPCC Sixth Assessment Report (AR6), new modeling using SSPs was introduced to account for how socioeconomic factors may change over the next century. AR6 was released in 2023 and AR7 in anticipated in 2029. It is recommended to update the analysis as more detailed scientific information becomes available and Duke Energy's resiliency work advances.

While there are complementary attributes between RCPs and SSPs, the RCPs are focused on the level of potential warming by 2100 whereas the SSPs define the different baselines for narratives of what reductions in emissions may or may not be achieved

12 This study is focused on 2050 time horizon to align with the IPCC Sixth Assessment Report climate projections. Duke Energy will implement the adaptive actions identified from this analysis in the near term to mitigate the risks from climate hazards presented in 2050 projections.

based upon factors such as population, economic growth, climate policy, and technological advancements. SSPs and RCPs correspond to each other; for example, SSP2 (Middle of the road) corresponds to RCP 4.5. When analyzed together, one can see the broader narrative of where we are heading as well as why, and what the path is to get there.[13] In the CMIP6 scenarios, the SSPs are paired with their matching RCP scenario.

The prior (2022 and 2023) report across Duke Energy's Carolinas T&D regions of operations have focused on the IPCC RCP scenarios, including RCP 2.6, RCP 4.5 (50th percentile), and RCP 8.5 (90th percentile). However, in light of the recent CMIP6 transition to SSPs, this report studies the range between SSP1-2.6, SSP2-4.5, and SSP5-8.5 scenarios, representing uncertainty in global emissions, scientific modeling and understanding of Earth systems.

SSP1-2.6 represents a state of "Sustainable development", where the world is gradually moving towards a more renewable and stable future with an increasing commitment to achieving sustainable developmental goals. This is a very optimistic scenario and is included for academic reasons as a scenario where the world is collectively able to limit global warming during the 21st century to 1.5°C above pre-industrial levels.

SSP2-4.5 is referred to as "Middle of the road", a route with persistent challenges to mitigation and adaptation but with some countries making strong progress towards sustainable development goals. This is a scenario with projections that are better aligned with current and pledged governmental emissions policies.

SSP5-8.5, represents "Fossil fueled development", a global society where markets are increasingly integrated, and humans rely on innovation and development of human capital as the path to sustainable development. This scenario represents a complete lack of global emissions reduction efforts, thus reflecting a conservative approach or a "worst-case" understanding of climate-related risks.[14]

Table 1 provides a summary of projected changes in 2050 for each climate hazard and vulnerability ratings for all hazard and asset group combinations under SSP1-2.6, SSP2-4.5, and SSP5-8.5. Accompanying Table 1, Figure 4 shows the emissions trends and the projected global surface temperature change increases through 2100.

IPCC CMIP6 Scenario	2100 Temperature Rise (°C)	Emissions Trend	Description
SSP1-2.6 (RCP 2.6)	1.8	Strong Decline	Sustainable Development
SSP2-4.5 (RCP 4.5)	2.7	Slow Decline	Middle of the Road
SSP5-8.5 (RCP 8.5)	4.4	Rising	Fossil Fueled Development

Table 1. Description of the Three IPCC CMIP6 Scenarios Used in Duke Energy's analysis

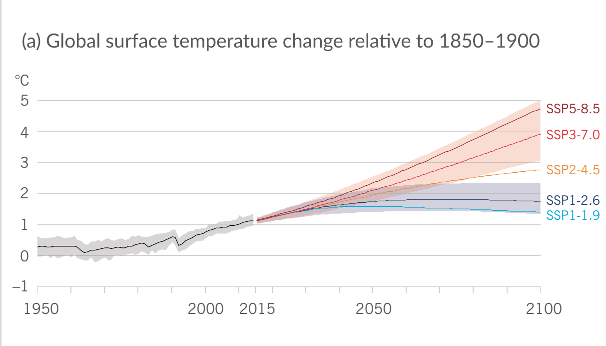


Figure 4. Global Surface Temperature Change Increase Source: Sixth Assessment Report of the IPCC

13 What are climate model phases and scenarios? | USDA Climate Hubs
14 Climate Model — Surface Temperature Change: SSP1 (Sustainability) - 2015 - 2100 - Science On a Sphere (noaa.gov)

Spotlight — Black Swan Workshops

In addition to the vulnerability assessment, Duke Energy Florida and Duke Energy Ohio and Kentucky conducted Black Swan workshops centered on the case studies of Hurricane Ida and Winter Storm Uri. A black swan scenario can be defined as an unpredicted event beyond a normally expected situation. In these workshops, Duke Energy's subject matter experts engaged in simulated events to analyze the long-term effects of climate catastrophes and reflected on how to be best prepared for success moving forward. The simulated events were developed using worst-case scenarios of multiple hazards convening simultaneously, where the impact of one event amplifies the impacts of another. For example, Duke Energy Ohio and Kentucky simulated the combined effects of a Midwest flood and tornadoes.

The Hurricane Ida simulation looked at four stages of action — preparation, landfall, restoration, and recovery — to determine the impact, mitigation actions, and key dependencies that need to be accounted for to succeed. In the Ohio and Kentucky workshop, a similar approach was taken but with the inclusion of additional simulated events aside from winter storm Uri, such as midwestern floods and tornadoes.

The impact of these workshops was far-reaching, and the effects can be seen in Duke Energy's efficient response and storm recovery efforts.

The technological progress and downscaling of climate models have enabled Duke Energy to develop region-specific vulnerability analyses for select climate hazards. These regions of Ohio, Kentucky, Indiana, the Carolinas, Tennessee and Florida, represent the vast geographical diversity of Duke Energy's service territories.

As illustrated by the IPCC's sixth assessment and in the acknowledgement of the importance of integrating vulnerability to communities into scenario modeling, Duke Energy considers the social aspects and vulnerabilities important within their climate planning, and as such, this is a focus area within the adaptive actions recommended in this report and within many in-flight projects across each of Duke Energy's electric utility and Piedmont Natural Gas jurisdictions.

2.2 Potential Climate Change Implications for Planning & Operations

In addition to assessing the climate change vulnerabilities of Duke Energy's T&D infrastructure and generation assets across its service territory, the study team reviewed potential risks to Duke Energy's planning processes and operations. Planning processes and operations that exhibit relatively high vulnerability to climate change are fuel supply and storage, reliability planning, capacity and integrated resource planning, and grid operations. This is in part due to the number of different climate hazards that could impact these activities (both acute and chronic), and in part due to the intensity of the vulnerability. While showing lower vulnerabilities than the activities listed above, load forecasting, capacity planning, engineering and standards, and workforce safety also show vulnerabilities to climate hazards.

Asset management, or Duke Energy's processes to monitor, repair, replace, and augment equipment and systems, exhibits medium vulnerability to climate change. Risks to Duke Energy's asset management include accelerated equipment aging; a potential need to adjust design criteria to address the risk of changing precipitation, flooding, and heat patterns; an incomplete understanding of the T&D poles weather readiness; and limited insight into failure data and impact of climate on failure rates. Without adaptation, these risks could result in higher capital costs and reduced service reliability for customers.

Rising temperature and extreme heat, cold, flooding and wind are the climate hazards that are expected to create the greatest vulnerabilities for planning and operations. Cold weather, particularly when coupled with high winds can have broad impacts on multiple functions including load forecasting, resource planning, and fuel supply planning. By comparison, hail and drought have more limited impacts to Duke Energy's planning and operational functions. The severity of acute impacts, such as flood and wind, tend to skew toward operating capabilities while chronic, longer-term hazards, such as extreme heat and cold, skew toward planning functions.

Across operations, Duke Energy is already taking action to improve the resilience of its capabilities from climate-related impacts. Duke Energy is adjusting design standards and operating procedures in some areas to account for an expected increase in extreme events, including asset design standards and asset locations for new facilities such as substations. Duke Energy has evaluated climate-related impacts on its multi-year load forecasts and reserve margins. Across these process areas, Duke Energy may consider incorporating local variations in temperature and projected future changes in temperature and extreme weather events, which may enhance Duke Energy's system reliability, avoid accelerated equipment aging or equipment failure, and ensure that Duke Energy continues to avoid the need for implementing load shedding.

Table 2 below shows the results of the operations performance assessment, illustrated by a heat map of the severity scores assigned to each operations capability area for Duke Energy's electric business. The results are based on a qualitative analysis of their climate hazard impacts. The scoring criteria ranges from high, medium, and low. Capabilities scoring high for severity may see massive disruption to current business operations/processes, and/or major changes required to accommodate impacts from climate change by 2050. Those scoring medium will see moderate disruptions, and those scoring low will see minor disruptions and changes required to accommodate.

	Climate Hazards						
	Flood	Wind	Heat	Cold	Drought	Convective Storms	Precipitation
Asset Management	Low	Med	Med	Med		Med	
Capacity Planning	Low		Med	Med			
Emergency Response	Med	Med	Low	Med	Low	Med	Low
Engineering and Standards	Low	Low	Med	Low		Med	
Fuel Supply and Storage	High	Low		Med		Low	Med
Grid Operations	Med	High	Med	Med	Low	Med	Low
Integrated Resource Planning	Low	Low	High	High	Med	Low	Med
Load Forecast	Low		Med	Med			
Reliability Management	High	Med	Med	Med		Low	
Vegetation Management	Med	Med	Low		Low	Med	
Workforce Safety	Low	Low	Low	Low	Low	Low	Low

Table 2. Heat Map of Severity of Climate Hazards Impacts by Capability Area by 2050.

3. Vulnerability Assessment & Future Climate Projections

The assessment determined that climate change will likely increase the frequency and intensity of extreme events across Duke Energy's service territories. While the impact of climate change will vary based on geography, trends such as an overall increase in temperature and extreme precipitation will be consistent across regions. Please see Appendix A for the details on the full vulnerability assessment, inclusive of the analysis on the asset hazard pairings for each region.

Flooding (Fluvial and Coastal) and Precipitation
Climate change is projected to drive heavier precipitation across all service areas. In addition, warmer sea surface temperatures can increase the intensity of coastal storms, including hurricanes, and increase the amount of precipitation that they produce.

For example, all of Duke Energy's Ohio and Kentucky assets are exposed to at least five inches of rain in a 100-year precipitation event. In 2020, 6% of assets were exposed to greater than 6 inches of rain, and that is forecasted to increase to 100% of assets by 2050. Similarly, if looking into events in other Duke Energy regions, such as Duke Energy Indiana, a 100-year precipitation event would expose the company's assets to at least five inches of rain, growing to nearly seven inches by 2100 (SSP5-8.5).

For the Carolinas, projections show potentially significant increases in average annual maximum five-day precipitation. Increases are projected to exceed 30% in some western mountainous areas under SSP5-8.5 90th percentile. Increases commensurate with this level could significantly increase the potential for riverine and pluvial flooding, as well as precipitation-driven landslides and debris flows. The impact of flooding in the Carolinas from tropical storms and the recent Hurricane Helene are discussed in the Historic Hurricane Season section.

In addition to the projected heavier rainfall, projections show that sea level rise will continue along the coast of the Carolinas and Florida through the 21st century. Projected sea level rise will also exacerbate coastal storm surge in the future, leading to flooding.

Chronic & Acute Heat
Both chronic (rising mean temperature) and acute heat (extreme heat days) are expected to increase across all of Duke Energy's territory with varying impacts for the different regions.

Historically, the warmest parts of the Duke Energy Carolinas service territory are within the coastal plain and southern Piedmont region, with temperatures generally decreasing toward the west and mountainous areas. In the Carolinas, in 2030, average July temperatures are projected to increase between approximately 1.9°F and 3.4°F across the territory under SSP2-4.5 50th and SSP5-8.5 90th percentiles, respectively. Overall, rising mean temperatures and extreme heat are both projected to increase over the coming decades.

In Ohio and Kentucky under SSP2-4.5, assets are set to experience a median value of over 15 days of extreme heat (over 95°F) in 2050, climbing to over 20 days by 2075. Currently, these regions experience only a couple days of extreme heat on average per year. Extreme heat does not present an acute risk of equipment failure for transmission and distribution assets, and analysis has found that the impact on equipment life was insignificant because of the low degradation rate of transmission and distribution equipment. However, the study found that higher temperatures cause a moderate but well understood reduction in the output from generating assets, most notably for combined cycle and combustion turbine plants. Indiana is expected to experience a similar trend, and assets are expected to experience just over 17 days exceeding 100°F in 2050, increasing to 19.3 days in 2075 under SSP2-4.5.

Extreme heat stress, defined as the number of days exceeding 100°F, only shows significant changes after

2050 in Florida, though the relative increase in heat is uniform across asset classes. By 2050 in a SSP5-8.5 scenario, Florida assets are set to experience a median value of 1.2 days exceeding 100°F (compared to ~0.3 days in SSP1-2.6). The increase in extreme heat days is significant beyond 2050 and reaches over 19.1 days by 2100 in an SSP5-8.5 scenario.

Wind

Exposure to wind from hurricanes is expected to increase between 2020 and 2050 throughout all territories. Assets in Florida which were historically at risk of facing Category 3 wind speeds will become increasingly subject to Category 4 and 5 hurricane force winds. Stronger or more frequent thunderstorms could also have implications for tornadoes in the service area. Hurricane Milton resulted in several tornadoes to the Duke Energy Florida territory, the impacts of which are examined in the Historic Hurricane Season section.

Extreme Cold

While climate models show the average winter temperature increasing over time, climate change dynamics related to winter extreme events are difficult to model and are not reflected in the currently available climate datasets. Annual temperatures in general are difficult to predict because they are driven by smaller scale forcings rather than decadal temperature averages (climate forcings such as El Niño/La Niña and other lesser understood phenomena). Climate change does not preclude potential for cold snaps, and events such as polar vortex may even increase in likelihood due to weakening of the polar jet stream.[15]

There is evidence that annual variability has increased along with the increase in long-term temperatures, and this will likely continue. When comparing the vulnerability of this hazard against others, it can be weighed lower with these additional nuances in mind.

Wildfire

Wildfire risks in the Duke Energy Carolinas service territory was analyzed as part of Duke Energy's 2022 Climate Risk and Resiliency Study. Climate projections show low risk in a SSP2-4.5 scenario, with a more moderate increase in the frequency of conditions conducive to wildfires under SSP5-8.5 (e.g., dryness, temperature, wind, lightning, forest density). More information can be found in the full report.[16]

15 Understanding the Arctic polar vortex | NOAA Climate.gov

16 carolinasresiliencetransmissiondistributionstudy.pdf (duke-energy.com) (2022) and carolinsresiliencetransdiststudy final.pdf (duke-energy.com) (2023)

4. Adaptive Actions Assessment

Duke Energy has implemented adaptive measures across each of its service territories to mitigate some of the anticipated adverse consequences and impacts from increasingly severe weather and climate hazards. Current and future adaptive actions are designed and deployed based on industry best practices, new and emerging innovations, economic feasibility and a focus on implementing standards with the greatest positive impact to operations, service, and the community. Duke Energy is actively investing in the resiliency of its system to address climate hazards that have the most significant impact to each of its unique territories. Examples of these investments are in Appendix C, with highlighted projects below.

4.1 The Carolinas

Due to microclimate variations and weather patterns throughout Duke Energy's service territory across the Carolinas and a broad footprint of assets, no single hazard poses the greatest overall risk. In general, precipitation and flooding pose the most significant physical risk for substations and generation assets. Solar sites are more vulnerable to extreme wind, while nuclear and natural gas facilities experience a moderate decrease in generation output when temperatures rise. Typically, extreme wind is defined as gusts greater than 58 mph.

Spotlight — North Carolina Innovative Transmission Rebuild

Duke Energy's initial Climate Resilience and Adaptation Report, published in 2023, addressed climate risks and resilience for North Carolina and South Carolina transmission and distribution (T&D) systems. Leaning into the findings of this study, the North Carolina Department of Environmental Quality (NCDEQ), State Energy Office (SEO), and Duke Energy proposed to proactively implement the adaptation framework by rebuilding a key Eastern NC 230 kV transmission line on the existing right of way (ROW). This project, the North Carolina Innovative Transmission rebuild, was recently awarded $57 million from the U.S. Department of Energy.

This project incorporates climate-resilient designs that are needed for adaptation of infrastructure such as advanced high-temperature, low-sag conductors. It also enables the interconnection of new clean energy generation needed to meet the carbon reduction goals required by North Carolina's House Bill 951. The right of way optimization will reduce the impact of greenfield transmission lines on communities and increase transmission system capacity for integrating more renewable resources.

The climate-resilient design will replace aging assets such as wooden poles and temperature-susceptible traditional aluminum conductor streel reinforced (ACSR) wire. The benefits of this line will be a reduction of customer interruptions to over 11,000 retail customers and 3,000 wholesale customers.

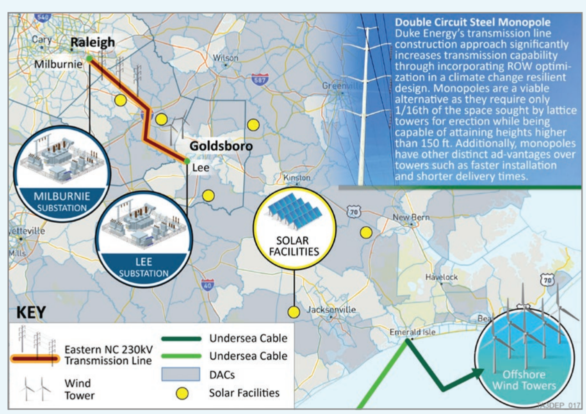


Figure 5. Location of the Innovative North Carolina Transmission rebuild

Permanent flood barriers at Duke Energy's Nichols 115-KV substation in South Carolina

A growing number of Duke Energy's existing substations are protected by a combination of permanent flood walls and temporary modular flood walls that can be deployed prior to an adverse weather event. Permanent flood walls have been built at locations that experienced past flooding, while temporary flood walls (e.g., "Tiger Dams") can be deployed at facilities that are in flood zones, but which have not experienced past flooding. Given the increase in the percent of assets that will experience repair- or replacement-level flooding, this adaptation strategy remains an important option. Duke Energy continues to evaluate the performance of implemented measures for future improvements as the frequency and intensity of storms is likely to increase from climate change. Duke Energy personnel monitor weather forecasts and river tide gages to monitor flooding conditions and identify where temporary flood protections may be needed.

In recent years, new substations are currently designed to a Design Flood Elevation (DFE) standard that requires equipment elevations at or above the 100-year storm level plus two feet, the 500-year flood level plus one foot, or local ordinances, whichever is higher. However, due to the age difference of these assets, not all existing substations are built to Duke Energy's current flood resilience standard, as some were constructed before the standard was put in place.

4.2 Ohio / Kentucky

In the Duke Energy Ohio and Kentucky service territories, extreme heat, wind, and flood risk are the key hazards to assets. Extreme heat is the primary driver of risk for generation assets while wind and flooding present the greatest risk to T&D assets. Extreme heat can reduce asset performance, reducing useful life and driving earlier replacement. High winds can result in structure failure and faults of T&D assets, while flooding poses the most significant impacts to substations. Flooding can lead to asset failure, corrosion, loss of power, and limited access to devices which may prolong outages.

Across the Midwest service territory, Duke Energy is investing in targeted undergrounding to mitigate risks from wind, vegetation, and other weather-related outages. Targeted undergrounding improves storm response and reliability by using smart data to strategically identify the most outage-prone power lines and move those lines underground. This not only reduces power outages and service interruptions, but also ensures a quicker restoration time following a major event.[17]

When it comes to generation, Duke Energy is working on innovative approaches to deploy new utility-scale rooftop solar. For example, customers in Northern Kentucky are benefiting from a new utility-scale rooftop solar project now generating power for area homes and businesses. Kentucky's largest rooftop solar array operates over 5,600 photovoltaic panels on the 800,000-square-foot

Rooftop Solar Arrays in Northern Kentucky

17 Targeted Underground - Duke Energy (duke-energy.com)

Spotlight — Duke Energy's West End Substation and the Brent Spence Bridge Corridor

The Brent Spence Bridge Corridor Project will transform an eight-mile portion of the I-71/75 interstate corridor between Kentucky and Ohio. This $3.6 billion project includes significant improvements to the existing Brent Spence Bridge as well as the construction of a new companion bridge to help support travelers across one of the nation's most important corridors for commerce and freight. Duke Energy will support the Brent Spence Bridge Corridor project by relocating existing gas and electric infrastructure. Additionally, Duke Energy Ohio's investments in its nearby West End Substation will support grid resiliency and reliability.

The Brent Spence Bridge Connecting Ohio and Kentucky

Duke Energy Ohio will make investment in its West End Substation by modernizing and relocating distribution and transmission power lines, deploying advanced technologies such as self-optimizing grid systems and automation, and making significant investments in additional substation hardening and coordination for distributed energy resource integration. Duke Energy's efforts throughout the course of these projects will benefit the community and mitigate the impacts of extreme weather events on the system.

Amazon Air Hub rooftop adjacent to the Cincinnati/Northern Kentucky International Airport. This Duke Energy facility will feed up to two megawatts of solar power directly onto the electric distribution grid, energizing approximately 400 homes and businesses in the area.

Duke Energy is also investing in enhancing and further deploying a Self-Optimizing Grid (SOG), also known as Distribution Automation, with a focus on bolstering reliability and facilitating two-way power flows crucial for the expansion of renewables and distributed technologies. To date, this work has delivered significant resiliency benefits, allowing Ohio and Kentucky customers to avoid over 2 million interruptions and save over 320 million customer minutes interrupted (CMI).

Among many benefits, SOG and rooftop solar align with Duke Energy's goal to provide a cleaner and smarter energy future for customers and communities.

4.3 Indiana

The hazards posing the most significant impacts by 2050 in the Indiana service territory are extreme heat, flooding, and wind, with the relative increase in heat uniform across all asset classes. Overall, the increase in heat and extreme temperatures will have the greatest impact on generation assets' efficiency and performance. Transmission substation assets (i.e., regulators, relays, breakers, and transformers) are most at risk to flooding, while T&D assets, such as overhead poles and transformers, are exposed to high winds.

In 2017, DEI stepped up investment in modernizing and making its grid more resilient with its Transmission, Distribution and Storage System Improvement Charge (TDSIC) plans. TDSIC projects include replacing and upgrading overhead electric lines and underground lines nearing the end of their service life with the latest equipment and adding new ener-

Spotlight — Innovative Technology to Support Transmission Vegetation Management

To combat T&D failures from wind and flooding, Duke Energy has developed an industry-leading Transmission Vegetation Management (TVM) system, driven by innovative technologies and a data-focused operational strategy. The TVM program includes an enterprise-wide remote-sensing program (RSP) and a Work Planning, Analysis and Scheduling System (WorkPASS).

The RSP program utilizes light detection and ranging technology (LiDAR) to gather data and identify potential threats to tree-canopy polygons and tree-canopy tops for field work planning. The WorkPASS work management system allows Duke Energy to map out the various areas in precise measures. For example, it promotes ecosystem preservation, such as being able to identify bald eagle's nests and tag appropriate conservation zones. Together these programs allow the TVM team to create optimized annual work plans, predict vegetation threats over a six-year to eight-year period, and manage reliability over a multiyear horizon. Duke Energy's TVM program has streamlined efforts and led to increased resiliency in T&D assets in the Midwest service territory.

Work Unit	Code
Danger tree removal - no cleanup (Capital)	DTC
Danger tree removal - cleanup (Capital)	DTM
Tree removal - cleanup (O&M)	CRB
Tree removal - no cleanup (O&M)	CTB
Manual subsequent removals (Capital)	MAR
Mechanical subsequent removals (Capital)	MSR
Manual side trim (O&M)	MTR
Mechanical side trim (O&M)	MST

Work Unit	Code
Bucket Work - Tree Pruning (O&M)	BTR
Heavy Mowing (O&M)	HMW
Light Mowing (O&M)	LMW
Handcut - chip (O&M)	HCC
Handcut - no chip (O&M)	HCT
Herbicide (O&M)	HRB
No work required (O&M)	NWR

Figure 6. Example of Duke Energy's WorkPASS tool for transmission vegetation management (Kentucky)

gy pathways and expanding capabilities of lines that support self-healing and grid efficiency improvements. So far in 2024, smart, self-healing technology has helped to avoid more than 23,000 customer outages, saving around 130,000 hours (7.9 million minutes) of total outage time for customers in Duke Energy Indiana. Around 80% of those savings occurred during major storms. To combat failures from wind and flooding, TDSIC projects focus on making distribution and transmission pathways more resilient through targeted undergrounding of distribution lines in outage prone areas to help reduce outages and improve reliability, and strategically upgrading the strength of utility poles in vulnerable areas to better withstand high winds from severe storms. Projects include converting high-voltage line sections in vulnerable and hard-to-reach areas from wooden poles to steel poles and stepping up pole inspections to proactively identify the need for replacements. These investments are paying dividends; when DEI's service territory was hit with a series of tornados in the spring of 2023, steel transmission poles located in the path of the storms were undamaged, reducing the impact of the storms on customers.

Spotlight — Edison Electric Institute Emergency Response Award

In June of this year, Duke Energy was awarded the Edison Electric Institute (EEI) Emergency Response Award. Chosen by a panel of judges following an international nomination process, this award recognizes recovery and assistance efforts of electric companies following service disruptions caused by extreme weather or other natural events. Duke Energy was selected for this award due to its investments to mitigate risk and commitment to hold a proactive role in storm recovery response efforts. Hurricane Idalia, a devastating Category 3 storm that made landfall in Florida in August of 2023, was one of the most damaging storms to hit the Big Bend. Advanced forecasting, damage modeling, and lessons learned from previous storms and scenario-based workshops helped Duke Energy strategically place more than 4,000 line workers, tree professionals, and damage assessors ahead of the storm to respond as quickly as possible. These actions led to restored power for over 90% of impacted customers within 24 hours of the storm exiting the company's service territory. The insights gained from Duke Energy's experiences in Florida led to the advancement of innovative solutions that can be found in the subsequent section.

Crews respond to storm damage in Crystal River, Florida

4.4 Florida

In Florida, coastal and inland flooding, as well as wind, pose the greatest threat to distribution assets and substations, especially in the higher emission scenarios (SSP5-8.5). For transmission assets, wind as well as high temperature and extreme heat will cause the most impact. Generation assets will be most impacted by higher temperatures and extreme heat, as heat can reduce asset performance, reduce useful life, and drive earlier replacement. With regards to lightning risks to assets, understanding of cloud electrification processes is still incomplete. Due to this it is impossible to forecast individual strikes because lightning is so widespread, frequent, and random.[18]

When Hurricane Debby made landfall in Florida in August 2024, Duke Energy was prepared with over 10,000 line and tree workers. Prior investment in grid strengthening measures and advanced technologies helped field workers restore power to 93% of customers within 24 hours of Debby's arrival. Storm hardening at substations, including raising equipment off the

18 https://www.nssl.noaa.gov/education/svrwx101/lightning/forecasting/

Floating Solar Facility at Hines Energy Complex in Florida

ground, as well as upgraded poles and wires that better withstand severe weather impacts proved successful in enhancing the overall resiliency of the electric grid.

During Hurricane Debby, the company's self-healing technology saved more than 12.5 million minutes of customer total outage time and automatically restored more than 62,000 customer outages. While a self-healing system can't repair the physical damage to the power line that a human crew must repair, it automatically detects power outages and quickly reroutes power, which can reduce the number of customers affected by a power outage by up to 75% and can often restore power in less than a minute.

Duke Energy Florida is also investing in innovative approaches to deploy new clean energy generation. In 2023, the company completed construction on the first floating solar array pilot at its Hines Energy Complex in Polk County, Florida. The 1,872 solar panels float on a 1,200-acre pond, creating clean power while providing the added benefit of limiting algae growth. The floating solar panels reduce sunlight penetration into the pond, which can help prevent harmful algal blooms and in turn, improve aquatic life and reduce the need for chemical treatments. These unique bifacial solar panels absorb light from both sides and can produce 10% to 20% more power than their single-sided counterpart. Floating on water also allows the panels to cool faster, making them up to 15% more efficient. The pilot is part of Duke Energy's Vision Florida program, which is designed to test innovative projects such as micro-grids, hydrogen and battery energy storage, to prepare the electric grid for smarter cleaner generation sources.

4.5 Piedmont Natural Gas

The Piedmont Natural Gas Business Unit distributes natural gas to customers in North Carolina, South Carolina, and Tennessee. Most pipeline assets are underground and not exposed to temperature fluctuations, wind impacts, or storms. Assets that are above ground, such as Regulator Stations, Energy Reliability Centers, and Liquified Natural Gas (LNG) facilities, have exposure to extreme and rising mean temperatures. Flooding, extreme storms, and extreme heat remain a potential risk to above ground assets in future scenarios. These risks are being addressed through adopting and implementing design standards and parameters that allow systems to withstand severe impacts from greater intensity and frequency of extreme events going forward. For example, to reduce the negative impacts of extreme temperatures, Duke has incorporated design parameters in self-protected Energy Reliability Centers

that withstand high heat temperatures and shut down if thresholds are breached. To reduce impacts of flooding, new above ground assets are not installed in floodplains. To mitigate the impacts of extreme heat, Energy Reliability Centers are protected by enclosures.

4.6 Generation

Scenario analysis of nuclear and fossil fuel generation plants indicates future risk will increase from heat, flood, and wind. Increasing temperatures pose a growing risk to the operating limits for cooling water reservoirs used by nuclear and thermal generation at natural gas plants, which could result in a forced derate or plant shutdown. In addition to the impact on cooling water for thermal generation, rising temperatures will also have a negative impact on the operating capacity of transformers at generating stations due to how transformer insulation functions at high temperatures.

Current measures to mitigate risks from extreme heat include: condition monitoring and local cooling to ensure equipment is operated within its qualified range; identifying thermal limiting processes and evaluating new equipment to improve thermal efficiency; evaluating operating procedures to prevent the failure of critical electrical components during periods of high heat; and ensuring plant design conditions reflect temperature increase predicted from climate forecasting models over useful life of the asset.

Future opportunities include modifying the station equipment design to accommodate higher ultimate heat sink temperature and installing cooling towers in areas projected to have inadequate water supplies under climate-related scenarios. Additionally, opportunities to mitigate flood risk for natural gas plants include conducting in-depth flood analyses that incorporate local flood defenses, including sustainable infrastructure measures.

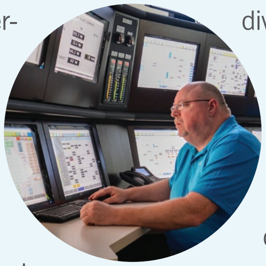
High winds pose the highest risk to solar generation assets. Out of the solar generation assets included in the analyses, over 30% were found to have exposure above the wind failure threshold. Adaptive measures to reduce wind damage include ensuring plant designs accommodate the predicted extreme wind speed and that design is not solely based on historic weather trends. Future measures may include installing additional support bracing and windbreaks to increase the design failure wind speed, including evaluating options for designing wind breaks using nature-based solutions. In addition to wind risk, both inland and storm surge flooding present threats to solar assets. Adaptive measures for flood prone areas include raising more sensitive equipment above published flood elevations and ensuring that equipment which is installed below such levels is fully rated for occasional submergence without failure.

Spotlight — Carolinas Adaptive Actions:

In response to the increasingly severe weather that continues to impact the Carolinas, Duke Energy has invested in several weather-related improvements at its generation facilities to mitigate the impacts from extreme cold, rising temperatures, flooding and wildfires. These new improvements and procedures bolster the resiliency of Duke Energy's generation infrastructure and make them safer to operate and maintain.

Extreme Cold:

In response to Winter Storm Elliott in December 2022, which brought extreme temperature drops and high winds to the Carolinas, Duke Energy made several cold weather improvements to make its generation infrastructure more resilient to cold weather. These improvements include investments to mitigate the occurrence of frozen instrumentation, monitor the temperature of key equipment, and conduct planned maintenance at generation sites to help maximize the available capacity that is available during the cold weather season.



Extreme Heat:

As mentioned earlier in this report, rising temperatures are anticipated to impact the Carolinas over the coming decades. Duke Energy is taking proactive action to ensure its generating facilities are more resilient to high temperatures and its workforce is equipped with the tools they need to operate and maintain them safely. In 2023, Duke Energy revamped the seasonal readiness procedures for each of its generating facilities across the Carolinas. These updated procedures reflect current and anticipated weather conditions and include measures to ensure personnel safety, equipment protection and system reliability.

Flooding:

In 2018, Hurricane Michael caused significant flooding at Duke Energy's Sutton Combined Cycle plant in Wilmington, NC, taking the plant offline for six weeks. Over the past several years, Duke Energy has made significant improvements at Sutton Energy Complex to mitigate flood risk, including:

1. Improvements to the Sutton Lake dam to ensure river levels are properly controlled;
2. Regrading and enlargement of several storm water retention ponds throughout the property to contain any localized flooding concerns;
3. Enhancements to the Sutton Energy Complex's Emergency Response Plan (ERP) for natural disasters to account for actions the station can take to prepare for flooding.
4. Introduction of protocols for monitoring river levels and adjusting (lowering) the Lake Sutton water level to preemptively reduce flooding potential; and Improvements to secure the flood control berm in the event of a flood warning to divert local flood waters from entering the station's powerblock.

These improvements have greatly increased the reliability of Sutton Energy Complex, specifically in the face of increasingly severe impacts from flooding.

Wildfires:

As the frequency and intensity of wildfires continues to increase across the country, Duke Energy is enhancing its ability to monitor, assess and mitigate the wildfire risk that exists across its service territories. The Company is instituting robust risk assessment processes as well as new procedures to respond to high-risk scenarios and events when they occur. Duke Energy is deploying a wildfire status alert system to help align transmission, distribution and generation functions around wildfire risk potential. On the generation side, this includes introducing new safety improvements to ensure work conducted during high wildfire potential periods is completed with a high-risk work plan, which are designed to mitigate further risk to the company's workforce or assets.

5. Next Steps: Innovations & Future Mitigation Strategies

While the vulnerability assessment focuses on physical risk and the adaptation strategies to mitigate climate-related risk, Duke Energy is also focused on the energy transition to a low-carbon future economy through innovative greenhouse gas mitigation strategies.[19] This includes transitioning to and integrating new technologies and decarbonization pathways, as highlighted by the following innovations and future mitigation strategies:

DeBary Hydrogen (Duke Energy Florida): Duke Energy has developed and is implementing a plan to add a green hydrogen production/storage facility at the existing DeBary Solar Power Plant to help enhance system reliability for customers and deliver on the company's commitment to increasingly clean energy. As the 74.5 MW DeBary Solar Power Plant captures energy from the sun, clean energy makes its way onto the grid. A portion of this energy will power two 1 MW hydrogen electrolyzer units, which effectively split water molecules into hydrogen and oxygen. Oxygen is then released into the atmosphere and the hydrogen is safely stored in reinforced containers. The hydrogen will then be used as an alternative fuel to support grid balancing during peak hours at the existing combustion turbine at DeBary Power Plant. This innovative project represents one of the first solar-tied facilities to produce and store green hydrogen for power generation in the nation and will benefit the community by enhancing system reliability.

Grid Hosting Capacity Maps (Duke Energy Carolinas and Duke Energy Progress): Duke Energy's Grid Hosting Capacity Maps provide geographical visualization of the distribution system to inform the siting of distributed generation (DG) sites greater than 20 kilowatts (kW). These public maps enable customers to more economically deploy distributed energy resources by displaying capacity-favorable locations on Duke Energy's distribution system in 80-acre increments. While innovative tools like the Grid Hosting Capacity Maps are not intended to be a substitute for existing interconnection processes (i.e., the generator interconnection process), they could help accelerate the deployment of new, clean energy resources.

The Grid Edge Evolution and Energy Orchestration (Duke Energy Carolinas): As part of the energy transition, a growing portfolio of capacity resources reside at customer premises at the edge of the grid. As technology continues to evolve, leveraging technologies such as smart thermostats, water heaters, pool pumps, residential energy storage and electric vehicles can provide additional capacity at the edge of the grid, enabling the company to shape and shift customer load. Duke Energy calls efforts to prepare for this opportunity the Grid Edge Evolution, and the control of these technologies Energy Orchestration. As a first step in deploying the Grid Edge Evolution strategy, Duke Energy will be piloting its Energy Orchestration capabilities in 2024. The insights derived from these pilots will greatly impact the company's ability to scale these new tools across its jurisdictions. Duke Energy believes the Grid Edge Evolution and Energy Orchestration present its grid operators with opportunities to better control the

19 In addition to the strategies covered in this section to transition to a low carbon economy, Duke Energy is retiring coal plants and investing in renewables, the details of which can be found in the latest Duke Energy Impact Report.

grid and, in some scenarios, will allow it to avoid activating reserve generation to meet excess load.

Carbon Capture Demonstration Projects Program Front-End Engineering Design (FEED) Studies (Duke Energy Indiana): The Carbon Capture Demonstration Projects Program, managed by the U.S. Department of Energy's Office (DOE) of Clean Energy Demonstrations (OCED), aims to de-risk integrated carbon capture and storage (CCS) demonstrations and catalyze significant follow up on investments from the private sector for commercial-scale, integrated CCS demonstrations on carbon emissions sources across industries in the United States. To advance CCS demonstrations, OCED sought applications to execute and complete front-end engineering design (FEED) studies for prospective integrated carbon capture, transport (if required) and storage systems projects. OCED awarded this FEED study to Duke Energy Indiana in September 2023.

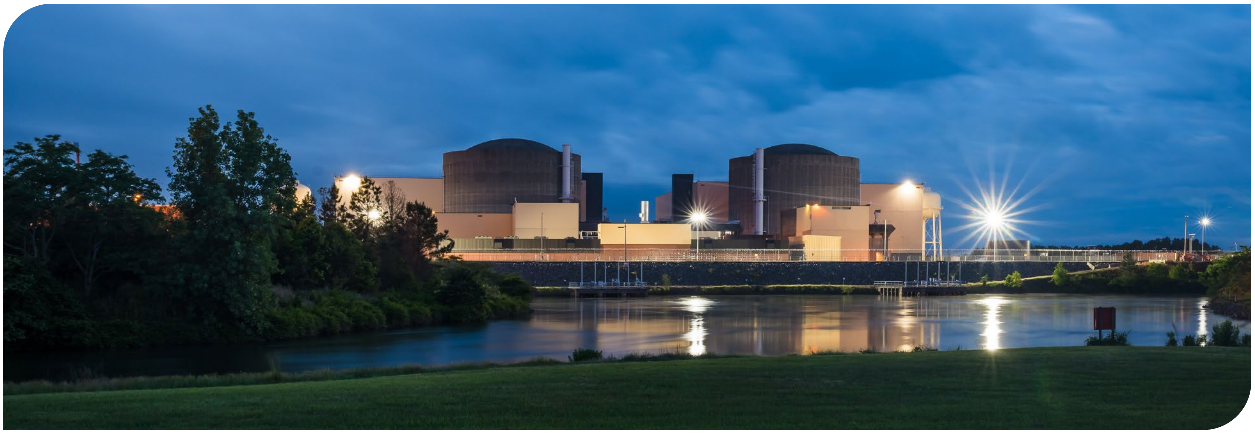
OCED is working with Duke Energy to evaluate CCS technology. The study will evaluate the feasibility of capturing and storing carbon dioxide from the flue gases of the two heat recovery steam generators at the Edwardsport Integrated Gasification Combined Cycle (IGCC) power generation plant in Knox County, Indiana. The study will target the capture, compression, and local storage of 3.6 million tons of carbon dioxide per year, achieving a carbon capture efficiency of more than 95%.

A key advantage of the Edwardsport IGCC plant site is the availability of ample pore space underground for storage of carbon dioxide. The host site has an estimated 400 million metric tons of pore space. An initial nine-month validation period will be conducted first, and then the FEED study will be delivered in the next 24 months. The project will also include the development of a robust Community Benefits Plan along with both preliminary and final design engineering packages, cost estimates, an Environmental Health & Safety Assessment Report, and a final FEED report, which will be completed in 2026.

Edwardsport, Indiana site of the Carbon Capture FEED Study

Methane Reduction Program: Duke Energy is executing an ambitious clean energy transition, keeping reliability, affordability, and accessibility at the forefront as the company works toward net-zero methane emissions from its natural gas business by 2030. In 2023, work continued on Duke Energy's Integrated Methane Monitoring Platform Extension project, which was selected by the DOE's Office of Fossil Energy and Carbon Management to receive nearly $1 million of funding to expand the project for applicability to upstream assets using more technologies. The company's current industry-leading methane-monitoring platform, which has reduced recordable leaks by more than 85% since the beginning of 2022, uses satellites, sensors, and other cutting-edge technologies to detect leaks and measure real-time methane emissions on natural gas distribution systems. The Integrated Methane Monitoring Platform Extension will expand this work to upstream interstate and downstream customer natural gas assets.

The Natural Gas Business Unit is also continuing to work on minimizing upstream emissions related to gas purchased for customers and the downstream carbon dioxide emissions related to customers' consumption of the natural gas sold. Key efforts include 1) surveying upstream suppliers to understand each of the emissions and activities to reduce emissions 2) conducting ongoing conversations with upstream suppliers on emission reduction efforts and outcomes and 3) actively participating in ONE Future, a group of more than 50 natural gas companies working



Advanced Nuclear technologies as well as our existing nuclear fleet like McGuire Nuclear station are critical to achieving the clean energy transition

together to voluntarily reduce methane emissions across the natural gas supply chain to 1% methane intensity or less by 2025. Duke Energy is also making investments in and exploring the use of Renewable Natural Gas (RNG). RNG is considered carbon-neutral because it displaces geological gas, and reduces the methane released into the atmosphere.

Advanced Nuclear Technologies (Enterprise wide): Utilizing Duke Energy's existing nuclear fleet is critical to achieving the company's net-zero goals, as is investing in advanced nuclear technologies. Advanced nuclear describes the next generation of reactors. Small modular reactors (SMRs) are cooled by water, liquid metal, molten salt or gas. Like traditional nuclear plants, SMRs have a proven safety record and history of operational excellence, as the U.S. Navy has been using SMRs for propulsion for 75 years. SMRs are currently one of the most promising emerging nuclear technologies and can produce up to 350 MW of carbon-free energy while also offering many safety, environmental and economic benefits.

In 2023, Duke Energy selected the Belews Creek site in Stokes County, North Carolina, for potential development of SMRs, with the first unit coming online in 2034, subject to regulatory approvals. Belews Creek is an existing coal and natural gas facility that will transition to accommodate advanced nuclear technologies. The site is ideal for SMRs because of its access to water, transmission infrastructure and a skilled workforce. Through 2025, Duke Energy is focused on developing and submitting an early site permit application to the U.S. Nuclear Regulatory Commission and selecting a reactor technology based on rigorous evaluations.

For existing nuclear plants, the work in this adaptation report is being used to support the Institute of Nuclear Power Operations (INPO) climate analysis for nuclear plants.

Conclusion

This Climate Resilience and Adaptation Study of Duke Energy's T&D and generation systems assessed the vulnerabilities of assets and operations from the physical impacts of climate change. Alongside this effort, the study evaluated the current and potential adaptive actions that Duke Energy can deploy to mitigate risk from climate hazards. The innovative future mitigation strategies covered in this section integrate both data driven new technologies and decarbonization pathways that will aid in the grid transition to become more resilient against extreme weather events impacting Duke Energy's service territories such as with Hurricanes Helene and Milton. This report serves as an initial step for adaptation planning across all jurisdictions and will require long-term undertaking and investments over the following years to ensure alignment with Duke Energy's strategy and enterprise-wide priorities.

Appendix A. Vulnerability Assessment

The methodology for the climate vulnerability ratings (low, medium, and high) are assigned based on the average exposure and vulnerability of a particular asset class (e.g. substations) to a particular climate hazard (e.g. extreme heat) within the service territories. 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. The ratings assume an "as is" grid infrastructure, meaning that no adaptation measures were deployed beyond what exists today and accounting for regular operations and maintenance on the existing assets. Additionally, within a territory, there are microclimate variations due to topographical features that create distinct areas where exposure may be greater or less than in other areas of the same territory. For example, within North Carolina, rising temperature may be projected for inland regions while coastal areas have a much less pronounced increase in temperature for the same time frame and scenario.

A.1 Carolinas[20]

Climate Hazard	RCP	SSP	Trans.	Dist.	Subs.	Gen.	2050 Projected Change and Impact
High Temperature and Extreme Heat.	8.5	5	Med.	Med.	High	High	Temperatures and extreme heat are projected to increase across the Carolinas over the coming decades. Extreme heat stress, defined as the number of days exceeding 95°F, has a strong climate signal across Duke Energy's portfolio in the Carolinas. Heat-related impacts to substation equipment (accelerated aging, need for additional capacity during heat waves, or, in the worst case, load shedding) represent the greatest potential climate related risks for Duke Energy, with capacity and degradation impacts to transmission and distribution equipment also possible.
	4.5	2	Low	Low	Med.	High	Extreme heat exposure is largely a coastal-inland dependence, with inland assets experiencing higher extreme heat exposure than coastal and assets located in the western portion of the states. The number of assets exposed to extreme heat for more than 5 days annually increases slightly from 94 assets (89%) in 2020 to 97 assets (92%) by 2050 across all generation asset classes.
	2.6	1	Low	Low	Low	Low	
Coastal Flooding	8.5	5	Med.	Low	Med.	Med.	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	2	Med.	Low	Med.	Med.	Under both SSP5-8.5 and SSP2-4.5 hurricane intensity is anticipated to increase over time. Since hurricane intensity is a major driver of the coastal flooding vulnerability scores, ratings remain the same under both scenarios. Additionally, under SSP2-4.5 the number of assets exposed to flood depths greater than 4 ft in the 100-year flood increased from 8 (4.3%) in 2020 to 10 (5.4%) in 2050. The same dynamic is clear in the 200- and 500- year return period.
	2.6	1	Low	Low	Low	Low	

20 The analysis on projected impacts to T&D assets for the Carolinas is from Duke Energy's Carolinas Climate Risk & Resilience Study. SSP1-2.6 was not part of the original analysis in the Carolinas.

Climate Hazard	RCP	SSP	Trans.	Dist.	Subs.	Gen.	2050 Projected Change and Impact
Precipitation and Inland Flooding	8.5	5	Med.	Low	High	Med.	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 the territory wide 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	2	Low	Low	Med.	Med.	Under SSP2-4.5 acute precipitation exposure increases by at least 3% from 2020-2050 regardless of asset class. Fossil assets experience the most severe precipitation exposure and the most significant change over time, reaching 13.8 inches by 2050 (9% increase from 2020). Nuclear plants see the second most significant change over time, growing from 10.7 inches/day in 2020 to 11.6 inches in 2050, an 8% increase. Hydro assets see a reduction in precipitation exposure from 11.4 inches/day in 2020 to 11.0 inches/day in 2050. Substations within existing flood plains will be at elevated risk of flooding compared to today, but overall, there is a lower likelihood of significant, repeated flooding when compared to SSP5-8.5, especially given changes in Duke Energy's design standards and recent investments in substation flood protection.
	2.6	1	Low	Low	Low	Low	
Wind	8.5	5	Med.	Med.	Low	Med.	Hurricane intensity is projected to increase, producing extreme wind speeds across all scenarios. 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	2	Med.	Med.	Low	Med.	Under both SSP5-8.5 and SSP2-4.5 hurricane and storm intensity are anticipated to increase over time, and therefore the ratings are the same under both scenarios. By 2050 in a 500-year wind event, 24 (21%) assets will be exposed to Category 4 intensity winds or higher compared to 21% in 2020. The most exposed assets are solar and fossil plants. 43% of fossil plants (6 assets) are exposed to Category 4 wind speeds, and 15 solar sites (36% of DEC/DEP solar) are exposed, the highest number for any asset class. Exposed assets are located both on the coast and inland, though they do not extend far into the western parts of the states.
	2.6	1	Low	Low	Low	Low	
Extreme Cold and Ice	8.5	5	Low	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 the Carolinas 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	2	Low	Low	Low	Low	Under SSP2- 4.5, winters are anticipated to warm, though not as much as under SSP5-8.5. As under SSP5-8.5, severe winter weather and cold temperatures will still occasionally occur. Overall, the incremental risk of extreme cold and ice will decrease over time.
	2.6	1	Low	Low	Low	Low	

A.2 Ohio & Kentucky

Climate Hazard	RCP	SSP	Trans.	Dist.	Subs.	Gen.	2050 Projected Change and Impact
High Temperature and Extreme Heat	8.5	5	Med.	Med.	High	High	Extreme heat stress, defined as the number of days exceeding 100°F, sees high exposure in Ohio and Kentucky assets. A systematic increase in heat stress exposure occurs ranging from 1% to +13% from 2020-2050 depending on the future climate scenario. Under SSP5-8.5, this number increases to 21.9 days. The relative increase in heat is uniform across all asset classes. In 2020 none of the Ohio and Kentucky assets are exposed to more than 20 days of extreme heat in a year. However, that number increases to about 90% of assets in 2050.
	4.5	2	Low	Low	Med.	High	In the SSP2-4.5 scenario, assets are set to experience a median value of over 15 days of extreme heat in 2050, climbing to over 20 days by 2075. Extreme heat does not present an acute risk of equipment failure for transmission and distribution assets, and analysis has found that the impact on equipment life was insignificant because of the low degradation rate of transmission and distribution equipment (e.g., 0.059 years of lost life per day above 100°F for distribution regulators). However, the lifetime risk for generation assets is entirely attributable to heat from one fossil plant and accounts for 98% of all DEO/DEK risk.
	2.6	1	Low	Low	Low	Med.	In 2050 assets under this scenario are predicted to experience a median value of 18.1 days exceeding 100°F. By 2100 this number steadily decreases to 17.7, representing stable exposure.
Flooding	8.5	5	Med.	High	High	Med.	Due to increased intensity in the hydrologic cycle, flood-related runoff and stream heights are expected to rise, and there is a change in expected depths and inundation areas for all return periods. Flood risk remains relatively constant to 2050 and in the back half of the century with baseline resilience risk driven largely by substations.
	4.5	2	Low	Med.	Med.	Med.	In the SSP2-4.5 scenario, the number of assets exposed to flood depths greater than 4 ft in the 100-year flood has a minor increase from 2020 to 2050. Substations, which includes substation transformers, regulators, breakers, and relays show the largest risk from flooding across all asset classes by 2050.
	2.6	1	Low	Low	Low	Low	
Precipitation	8.5	5	Low	Low	Med.	Med.	Extreme precipitation events in Ohio and Kentucky are likely to increase in severity due to increasing air temperatures that increase water vapor in the atmosphere. However, acute precipitation exposure increases by ~0-5% from 2020-2050 regardless of scenario, and the rise is uniform across asset classes, making its exposure relatively minor. Beyond 2050, outcomes diverge significantly. An SSP5-8.5 scenario yields very significant growth by the end of the century. In reviewing exposure to 100-year precipitation events across asset classes, 100% of assets are exposed to greater than 6 inches of rain by 2050. The western portion of the state could be prone to extreme precipitation events across the region. 2050 is likely to see heavier precipitation due to overall warming trends in the coming decades for this scenario.
	4.5	2	Low	Low	Med.	Med.	Under SSP2-4.5, precipitation growth is mostly linear. By 2050 the 100-year maximum daily total water equivalent across asset classes is estimated to be a median value of 6.3 inches, and by 2075 steadily increases to 6.5.
	2.6	1	Low	Low	Low	Low	By 2050 the 100-year maximum daily total water equivalent across asset classes is estimated to be a median value of 6.1 inches. Overall precipitation exposure starts to decrease by 2075 in this scenario.

Climate Hazard	RCP	SSP	Trans.	Dist.	Subs.	Gen.	2050 Projected Change and Impact
Wind	8.5	5	Med.	Med.	Med.	Low	Extreme wind events in Ohio and Kentucky are associated with events such as derechos and tornadoes. However, the winds associated with them are not yet well defined and able to be properly captured in a climate model. Under SSP5-8.5 wind speeds will reach ~70 mph by 2050, and the count of assets above the 60-mph failure threshold in 2050 is 8.2%. The most exposed asset classes include mostly overhead assets including distribution and transmission poles, distribution pads, distribution conductors, and distribution transformers.
	4.5	2	Low	Low	Low	Low	Setting aside tornados and derechos, wind exposure is negligible across Duke's Ohio and Kentucky operations with wind speeds topping out at ~65 mph in 2050 under this scenario. Furthermore, 1.4% assets are exposed to over 60-mph wind speeds in a 500-year event, and they are all located in the western part of Ohio. Fall in risk from vegetation, particularly trees outside of the right of way, could still cause issues at these wind speeds even if trim specifications are followed as prescribed.
	2.6	1	Low	Low	Low	Low	Wind risk doesn't range much between SSP2-4.5 and SSP1-2.6
Cold	8.5	5	Low	Low	Low	Low	Extreme cold, defined as the number of days below 14°F, is predicted to decrease uniformly among asset classes across Duke Energy's portfolio in Ohio and Kentucky. Under SSP5-8.5, the number of days of extreme cold decreased from 11 days in 2020 to 6.6 days in 2050. Additionally, the number of assets exposed to extreme cold for more than 15 days annually is predicted to decrease from 9 in 2020 to 0 in 2050.
	4.5	2	Low	Low	Low	Low	By 2050 under an SSP2-4.5 scenario, Ohio and Kentucky assets are set to experience a median value of less than 8.1 days below 14°F. The decrease in extreme cold days is significant beyond 2050 and reaches less than 4.7 days by 2100 (SSP2-4.5).
	2.6	1	Low	Low	Low	Low	Under SSP1-2.6, the decrease in the number of days of extreme cold is less drastic, ranging from 10.6 days in 2020 to 8.2 days in 2050.

A.3 Indiana

Climate Hazard	RCP	SSP	Trans.	Dist.	Subs.	Gen.	2050 Projected Change and Impact
High Temperature and Extreme Heat	8.5	5	High	Med	High	High	Extreme heat stress, defined as the number of days exceeding 100°F, has a strong climate signal across Duke Energy's portfolio in Indiana. Similar to Ohio and Kentucky, a systematic increase in heat stress exposure occurs ranging from 4% to +13% from 2020-2050 depending on the scenario. Under SSP5-8.5, there 68% of assets are exposed to > 20 days of extreme heat in 2050. This trajectory diverges after 2050 where the median number of days with extreme heat stress increases to 41.3 days by 2100. Extreme heat exposure largely has a north-south dependence with southern locations in the state having more extreme heat days on average. This is largely due to the northern portion of the state being influenced by polar air masses from the North and the southern part being influenced by warm, moist Gulf of Mexico air masses. The northern portions of the state can also be influenced by the cooling effect of Lake Michigan.
	4.5	2	Med.	Low	Med.	High	Under SSP2-4.5 assets are expected to experience just over 17 days exceeding 100°F in 2050, with that number slightly increasing to 19.3 in 2075 but then steadily decreasing to stay below 20 days. The relative increase in heat is fairly uniform across all asset classes.
	2.6	1	Med.	Low	Med.	Med.	Under SSP1-2.6 the highest count of extreme heat days Indiana assets are expected to experience is in 2050 at 17.4 days. That number decreases into 2075 and 2100.
Flooding	8.5	5	Med.	Med	High	Med.	Flood risk in the Midwest is predominantly driven by flash floods from excessive rainfall. A warmer atmosphere can hold more water and therefore flash flood frequency is expected to decline while severity is expected to grow. The decline in frequency outpaces the increase in severity and the net effect is a lower probability of failure for assets. For Indiana, the change in flood risk is negligible. Under SSP5-8.5, the number of assets exposed increases 23% from 2020 to 2100.
	4.5	2	Low	Med.	High	Med.	Under SSP2-4.5, the number of assets exposed to flood depths greater than 4 ft in the 100-year flood has a minor decrease of less than 0.5% from 2020 to 2050. Transmission substation assets such as regulators, relay, breakers, and pad mount transformers, carry the most significant climate hazard risk from flooding.
	2.6	1	Low	Low	Low	Low	

Climate Hazard	RCP	SSP	Trans.	Dist.	Subs.	Gen.	2050 Projected Change and Impact
Precipitation	8.5	5	Low	Low	Med.	Med.	Similar to Ohio and Kentucky, extreme precipitation events Indiana are likely to increase in severity are likely to increase in severity primarily due to a warming atmosphere being able to hold more water. However, acute precipitation exposure increases by ~2 to 5% from 2020-2050 regardless of scenario, and assets in the southern part of the state face the highest levels of extreme precipitation exposure both today and in the future. Under SPP 5-8.5, all of Duke's Indiana assets are exposed to at least 5 in of rain in the 100-year Maximum Daily Total Water Equivalent (inches) event. In 2020, 32% of assets were exposed to greater than 6 inches of rain, and that increases to 63% of assets by 2050.
	4.5	2	Low	Low	Med.	Med.	Under SSP2-4.5, precipitation growth is mostly linear. By 2050 the 100-year maximum daily total water equivalent across asset classes is estimated to be a median value of 6.2 inches, and by 2075 steadily increases to 6.4.
	2.6	1	Low	Low	Low	Low	Under SSP1-2.6, the 100-year maximum daily total water equivalent across asset classes is estimated to be a median value of 6.1 by 2050, but steadily decreases following the end of the century.
Wind	8.5	5	Med	Med	Med	Med	Extreme wind events in Indiana are associated with events such as derechos and tornadoes. However, those events and the extreme winds associated with them are not yet well defined in a climate model. Setting aside tornadoes and derechos, wind exposure is negligible across Duke's Indiana operations with wind speeds topping out at ~70mph under SSP5-8.5. The majority of the assets with exposure to >65 mph wind speeds are in the northern part of the state. The most exposed asset classes include mostly overhead assets including distribution and transmission poles, distribution conductors, and distribution transformers.
	4.5	2	Low	Low	Low	Low	Here, 0.9% of the total assets are exposed to over 65 mph wind speeds in a 500-year event.
	2.6	1	Low	Low	Low	Low	
Cold	8.5	5	Low	Low	Low	Low	Under SSP5-8.5, the number of assets exposed to extreme cold for more than 15 days annually decreases from about 52% in 2020 to 0% assets in 2050 across all asset classes.
	4.5	2	Low	Low	Low	Low	Under SSP2-4.5, Indiana assets are set to experiences a median value of 11.4 days of extreme cold in 2025, this number decreases to almost half the amount, at 6.6 days in 2100. Extreme cold in Indiana is primarily driven by intrusions of Arctic air masses from the north. The likelihood of these intrusions drops off the further south in the state you go, making extreme cold more prevalent in the northern portions of the state.
	2.6	1	Low	Low	Low	Low	Under SSP1-2.6 Indiana assets are expected to experience a median value of 11.5 days of extreme cold in 2050. That number decreases into 2075 by a day and then returns to 11.5 by 2100.

A.4 Florida

Climate Hazard	RCP	SSP	Trans.	Dist.	Subs.	Gen.	2050 Projected Change and Impact
High Temperature and Extreme Heat	8.5	5	High	Med.	Med.	High	Extreme heat stress, defined as the number of days exceeding 95° F, is expected to increase due to global warming across emission scenarios. By 2050, Florida assets are set to experience a median value of 1.2 days exceeding 100° F. The increase in extreme heat days is significant beyond 2050 and reaches over 19.1 days by 2100.
	4.5	2	Med.	Med.	Med.	Med.	Inland regions tend to experience higher exposure over time as compared to coastal assets. Temperature increases in coastal areas are moderated by the higher heat capacity of the ocean as compared to soil and rock. There are 4.7% of assets exposed to more than five days of extreme heat in 2020. That number increases to about 4.9% of assets in 2050. While this number does not change substantially by 2050, extreme heat exposure increases significantly past 2050 through the end of the century. For example, 66% of assets are exposed to more than five days of extreme heat by 2075.
	2.6	1	Low	Low	Low	Low	Florida assets see a small rise (median value of 0.3 day) in days exceeding 100° F between 2020 and 2050. However, chronic heat degradation is a meaningful risk across scenarios for generation assets due to derating.
Coastal Flooding	8.5	5	Low	High	High	Med.	The number of assets facing more than 4 feet of flooding increases from 6.7% in 2020 to 8.7% in 2050 for a 100-year flood event. Surface mounted equipment is the asset class most impacted by flooding.
	4.5	2	Low	Med.	High	Med.	The number of assets facing more than 4 feet of flooding increases from 6.7% in 2020 to 8.7% in 2050 for a 100-year flood event. Surface mounted equipment is the asset class most impacted by flooding.
	2.6	1	Low	Low	Low	Med.	Coastal flooding presents a small but meaningful risk to solar and battery assets in coastal regions such as Cape San Blas.
Precipitation and Inland Flooding	8.5	5	Low	Med.	High	Med.	All of Duke Energy's Florida assets are expected to see median rainfall of over 12 inches in the 500-year maximum daily total water equivalent event, growing to near 13 inches by the end of the century. Acute precipitation exposure increases by ~7-8% from 2020 to 2050 regardless of scenario, reaching a maximum of 12.8 inches/day in SSP5-8.5 scenario.
	4.5	2	Low	Med.	High	Med.	Assets closest to Florida's coasts have the greatest exposure to extreme rain events. In 2020, 15% of Duke Energy's assets are exposed to 10 inches or less in a 100-year precipitation event, and that number decreases to 8% by 2050. Assets located in the St. Petersburg, Clearwater and Apalachicola service areas face the highest levels of extreme precipitation exposure both today and in the future.
	2.6	1	Low	Low	Low	Med.	Maximum daily total water equivalent for a 100-year event increases slightly from 11.6 inches/day in 2020 to 12.4 inches/day in 2050 and thereafter decreasing to 12.1 inches/day by 2100.

Climate Hazard	RCP	SSP	Trans.	Dist.	Subs.	Gen.	2050 Projected Change and Impact
Wind	8.5	5	High	High	Low	Med.	With nearly 1 million poles, distribution poles show the largest risk from wind failures at over 2.5x the next highest asset class-hazard pair. SSP5-8.5 represents the highest wind risk driven by increases in the coastal areas.
	4.5	2	Med.	Med.	Low	Med.	Ten percent of assets are exposed to over 157 mph wind speeds in a 500-year event. The impact on asset classes varies, with percent above the wind threshold ranging from 0%-44%. Distribution poles and transmission structures are some of the most impacted asset classes from wind speeds. Between 2020 and 2050, 11.6% of assets transition from facing Cat-3 wind speeds to Cat-4 wind speeds. 3.6% of assets transition from facing Cat-4 wind speeds to Cat-5. Exposed assets are aggregated around the Gulf coast in northern and central Florida.
	2.6	1	Low	Low	Low	Low	

A.5 Natural Gas[21]

Climate Hazard	RCP	SSP	Service Lines	T&D Pipelines	Metering & Regulating Stations	Energy Reliability Centers	LNG	2050 Projected Change and Impact
High Temperature and Extreme Heat	4.5	2	Low	Low	Med.	High	High	Extreme heat can reduce asset performance, reduce useful life of ancillary components, and drive earlier replacement for Energy Reliability Center units, LNG facilities, and other above ground monitoring equipment. Temperatures - both average and maximums rise throughout Piedmont Natural Gas territory, e.g. days above 95°F rise from about 8 in 2020 to 40 by 2050 under SSP5-8.5 for coastal North Carolina; annual max temperatures rise by 2.5 deg F for Greenville, SC by 2050 under SSP2-4.5; annual maximums rise by 2.5 deg F for Nashville, TN by 2050 under SSP2-4.5.
Flooding	4.5	2	Low	Low	Med.	Med.	Med.	Energy Reliability Center units, LNG facilities, and other above ground monitoring equipment will trip if electrical control equipment is immersed causing station outage and/or equipment replacement. In North Carolina, municipalities like Plymouth, Ogden, and Emerald Isle have 30% to 50% of the areas at risk of a major flood under SSP2-4.5 by mid-century. In South Carolina, Greenville County has more than 20% of properties at the risk of major flood under SSP2-4.5.
Precipitation	4.5	2	Low	Low	Low	Low	Low	This increase will not have a significant impact on natural gas assets. Annual precipitation will rise across Piedmont Natural Gas service territory, e.g. by 3 inches between 2020 and 2050 under SSP2-4.5 and 6 inches under SSP5-8.5 for coastal North Carolina; and by 0.5 inches by 2050 under SSP2-4.5 and SSP5-5.8 inches under SSP5-8.5 for Greenville, SC.
Extreme Cold	4.5	2	Low	Low	Low	Med	Med	Sustained extreme cold may have upstream supply impacts due to well freeze-off, causing Energy Reliability Centers to derate. These cold events could also exceed storage capabilities of LNG facilities and increase refill times. Extreme cold risks will get lower for SSP2-4.5 and further for SSP5-8.5. For example, minimum average temperatures will increase by 2.5 deg F for Nashville and 2.3 deg F for Greenville between 2020 and 2050 under SSP5-8.5.
Wind	4.5	2	Low	Low	Low	Low	Low	No impact.
Storms	4.5	2	Low	Low	Med.	Med.	Med.	Hail and lightning could damage gas coolers and Energy Reliability Center cooler fan blades reducing station performance, possible station shutdown, and equipment replacement. Within Piedmont Natural Gas territory, the probability of category 1 hurricanes is the highest in coastal North Carolina increasing to ~4% by 2050 for cities such as Chowan, and Edenton.

21 The SSP2-4.5 scenario was applied across each hazard for all Piedmont Natural Gas assets due to the intrinsically lower risk of these challenges to Piedmont Natural Gas compared to other facilities.

Appendix B. Types of Assets & Definitions

Transmission Assets

Line Structures (poles/towers)	Transmission-scale poles and towers, which may be steel lattice, concrete, or wood.
Conductors	Transmission-voltage overhead and underground wire.
Open-Air Current Carrying Components	Non-conductor current-carrying components that are exposed to the air outside the substation physical plant. (e.g. switches, jumpers)

Substation Assets

Substation Transformers / Regulators	Large power transformers and regulators within substations.
Circuit Breakers	Substation circuit breakers designed to interrupt short circuits or overloads
Open-Air Carrying Components	Non-conductor current-carrying components that are exposed to the air outside the substation physical plant.
Protection & Control Devices	Equipment such as protective relays and control systems that manage substation operation.
Instrument Transformers	Transformers that reduce current from high voltage for the purposes of measurement and control

Distribution Assets

Structures	**Overhead**: Distribution-scale utility poles, typically wood. Also includes crossarms and overhead support structures. **Underground**: Vaults and underground infrastructure to support electric distribution equipment
Conductors	Overhead and buried (underground) distribution wire
Transformers	Overhead distribution transformers. Padmount: Enclosed ground-level distribution transformers mounted on concrete or fiberglass pads.
Regulators (pole mounted)	Distribution-scale voltage regulators mounted on poles throughout the system.
Reclosers	Automatic electric switch designed to detect and interrupt faults.
Capacitors	Devices to adjust distribution power factor, located overhead
Open-Air Current Carrying Components	Non-conductor current-carrying components that are exposed to the air outside the substation physical plant, located overhead.
Batteries	Rechargeable batteries that are integrated into distribution equipment such as overhead reclosers.

Generation Assets

Solar Power	Solar technologies convert sunlight into electrical energy through photovoltaic panels
Nuclear Plants	Nuclear reactors are the core technology that control nuclear chain reactions that produce heat through a physical process called fission.
Hydropower	Energy prouced through dams and altering the flow of streams to direct water towards turbine blades, spinning a generator to produce electricity.
Fossil Fuel Plants	Power station that burns a fuels such as coal, oil, natural gas, or hydrogen.

Natural Gas Assets

Natural Gas Service Lines	The underground pipe which carries natural gas from the mains to the customer's meter.
Natural Gas Distribution and Transmission Pipelines	Mains are generally underground, located near public streets and highways, or on property owned by others for which the Natural Gas Business Unit have obtained the necessary legal rights to place and operate facilities on such property.
Metering and Regulator Stations	Piping and related equipment whereby natural gas moves, and pressure is reduced to prescribed limits or can be used to control pressure as needed.
Energy Reliability Centers	Energy Reliability Centers are natural gas or electric powered compression facilities which supply the energy to move gas in transmission or distribution lines by increasing the pressure.
Liquefied Natural Gas Facilities	Natural gas liquefaction assets cool natural gas to a liquid state for storage purposes. From the liquid state, regasification assets return the natural gas into the pipelines when needed.
Gas Compression	Machinery that compresses natural gas by increasing the pressure and decreasing volume so it can be used for power

Appendix C. Adaptive Actions

The sections below list all the current and future potential adaptive actions identified by Guidehouse and Duke Energy SMEs, separated by asset category (e.g., generation, transmission, distribution, natural gas). To note, many adaptive actions Duke Energy currently invests in are not targeted to specific hazards but are implemented as overarching resilience strategies. This may include adaptive measures such as selective undergrounding and vegetation management practices which mitigate the impacts of flooding, extreme precipitation, and storms. Where 'no action' has been noted in the Appendix below, it should be inferred that measures from an overall resilience perspective are in place and no additional, hazard-specific strategy has been identified.

C.1 Transmission

Adaptive Actions for Transmission Structures

	Structures	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Structures built above current flood plain levels & with Corrosion Protection in high-risk areas	Evaluate moving existing line structures from areas expecting increased levels of flooding.
Precipitation	No action	Relocate structures and avoid installing new structures in areas prone to wash-out during periods of heavy rainfall.
Wind	Leverage the predictive risk analytics data (from 'Predictor' App) to evaluate elevated tree canopy fall-in risk for potential removal beyond existing targeted buffer	Evaluate undergrounding critical equipment. Modify design standards to meet or exceed new wind speed expectations.
Heat	No action	N/A
Cold	No action	N/A
Storms	Shielding, grounding, grounding maintenance.	Review vegetation management practice to reduce trees blowing or falling into overhead lines. Review lightning protection standards to provide improved lightning protection. Review line inspection and repair practices to ensure lightning arrestors are functioning for maximum protection.

Adaptive Actions for Transmission Conductors

	Conductors	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action	Avoid building Line Structures in updated flood zones - especially those that will have fast moving water. Evaluate moving existing line structures from areas expecting increased levels of flooding.
Precipitation	No action	N/A
Wind	Leverage the predictive risk analytics data (from 'Predictor' App) to evaluate elevated tree canopy fall-in risk for potential removal beyond the existing targeted buffer	Evaluate vegetation management specs to reduce trees from blowing into overhead lines. Evaluate undergrounding critical lines.
Heat	No action	Modify conductor loading design specifications to mitigate the impact of increased heat.
Cold	No action	N/A
Storms	No action	Evaluate undergrounding critical lines. Review vegetation management practice to reduce trees blowing or falling into overhead lines. Review lightning protection standards to provide improved lightning protection. Review line inspection and repair practices to ensure arrestors are functioning for maximum protection.

Adaptive Actions for Transmission Circuit Breakers and Circuit Switchers

	Circuit Breakers and Circuit Switchers	
Climate Hazard	**Strategies in Place**	**Potential Future Adaptive Actions**
Flood	Meets current design standards	Install breakers on raised foundation. Raise height for box containing controls. Install substation flood protection
Precipitation	Meets current design standards	N/A
Wind	Circuit Switchers designed to handle 130mph wind speeds being installed in FL	Ensure circuit switchers are designed to withstand increased wind speeds.
Heat	No action	N/A
Cold	No action	N/A
Storms	Lightning Arrestors installed to meet current standards.	Ensure lightning protective design is adequate to protect equipment. Ensure existing lightning protection equipment is operating as designed and repaired in a timely manner.

Adaptive Actions for Transmission Substation Transformers

	Substation Transformers	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Install substation flood protection, e.g., wall around the transformer.	Build Transformer on higher foundation. Install substation flood protection in areas where flood plains change
Precipitation	No action	Build larger oil containment system in areas with high precipitation risk.
Wind	No action	N/A
Heat	Cooling systems and fans are installed to counteract overheating.	Develop new operating guidelines to ensure devices operate properly at higher temperatures.
Cold	LTC equipment heated in areas susceptible to cold LTC equipment shut off in extreme cold	Continue current adaptive actions
Storms	Ensure lightning protective design is adequate to protect equipment.	Ensure existing lightning protection equipment is operating as designed and repaired in a timely manner.

Adaptive Actions for Transmission Protection and Control Equipment

	Protection and Control Equipment	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Flood Barriers are implemented in high-risk substations ahead of forecasted storms.	Build raised control houses in high-risk flood areas. Height can vary based on risk and flood height.
Precipitation	No action	N/A
Wind	No action	N/A
Heat	Control Houses are designed with climate control	Ensure enclosed control houses are adequately cooled. Evaluate relocating any outdoor protection & control devices that are susceptible to heat to air-conditioned enclosures.
Cold	Control Houses are designed with climate control	Outdoor batteries are the most susceptible asset - ensure they are heated. Move outdoor batteries inside where possible and economical.
Storms	Lightning Arrestors installed within substations to protect relaying equipment	Ensure existing lightning protection equipment is operating as designed and repaired in a timely manner. Ensure lightning protective design is adequate to protect equipment.

Adaptive Actions for Transmission Open Air Current-Carrying Component

	Open Air Current-Carrying Components	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action	N/A
Precipitation	No action	N/A
Wind	No action	Modify standards to meet high wind speeds
Heat	No action	N/A
Cold	No action	N/A
Storms	No action	Ensure existing lightning protection equipment is operating as designed and repaired in a timely manner.

C.2 Distribution

Adaptive Actions for Distribution Poles

	Poles	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action	N/A
Precipitation	No action	N/A
Wind	Design standards in place to meet minimum NESC climate extremes.	Modify design standards to meet or exceed new wind speed expectations. Evaluate vegetation management specs to reduce trees from blowing into lines. Evaluate undergrounding feeder lines.
Heat	No action	N/A
Cold	No action	N/A
Storms	Arrestors and grounding systems in place to current standards	Continue current adaptive actions

Adaptive Actions for Distribution Padmounted Equipment (Non-Transformers)

	Padmounted Equipment (Non-Transformers)	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Submersible switchgear is used in flood prone areas.	Current design standards were developed to maintain functionality in flood events
Precipitation	No action	N/A
Wind	No action	N/A
Heat	No action	N/A
Cold	No action	N/A
Storms	No action	N/A
Wildfire	No action	Vegetation management around padmounted equipment

Adaptive Actions for Distribution Padmounted Equipment (Transformers)

	Padmounted Equipment (Transformers)	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Design guidelines include: • Thicker and heavier transformer pads less likely to be dislodged by storm surge or flood waters. • Stainless steel transformers and switchgear. • Submersible secondary connectors within transformers and above grade pedestals. • 'Jacket seal' elbows that waterproof the connection with the elbow and transformer/switchgear bushings.	Evaluate the need for future improvements to design standard and industry standard specifications.
Precipitation	No action	N/A
Wind	No action	N/A
Heat	Modify switch loading design specifications and operating procedures to mitigate the impact of increased heat.	Modify transformer loading design specification to accommodate for increased heat impacts. Implement transformer load management program to proactively address potential transformer outages due to increased heat
Cold	No action	N/A
Storms	Lighting Arrestors installed to protect equipment.	Review lightning protection standards to provide improved lightning protection. Review line inspection and repair practices to ensure lightning arrestors are functioning as intended for maximum protection.

Adaptive Actions for Distribution Underground Conductors

	Underground Conductors	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	All medium voltage cable designed to prevent water intrusion cables are a sealed longitudinally corrugated (LC) shield in many of the cables that adds another layer of moisture protection and a strand fill material in all stranded cables that prevents the migration of water longitudinally throughout the cable.	Evaluate the need for future improvements to design standard and industry standard specifications.
Precipitation	No action	N/A
Wind	No action	N/A
Heat	No action	N/A
Cold	No action	N/A
Storms	Lighting arrestors installed to protect equipment.	Review lightning protection standards to provide improved lightning protection. Review line inspection and repair practices to ensure lightning arrestors are functioning as intended for maximum protection.

Adaptive Actions for Distribution Overhead Conductors

	Overhead Conductors	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action	N/A
Precipitation	No action	N/A
Wind	Design standards in place to meet minimum NESC climate extremes.	Evaluate vegetation management specs to reduce trees from blowing into overhead lines. Evaluate undergrounding feeder lines.
Heat	No action	Modify conductor loading design specifications to mitigate the impact of increased heat.
Cold	No action	N/A
Storms	No action	Continue current adaptive actions.

Adaptive Actions for Distribution Overhead Transformers

	Overhead Transformers	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action	N/A
Precipitation	No action	N/A
Wind	Design standards in place to meet minimum NESC climate extremes.	N/A
Heat	No action	Modify transformer loading design specifications to mitigate the impact of increased heat. Implement transformer load management program to proactively address potential transformer outages due to increased heat.
Cold	No action	N/A
Storms	Lighting arrestors installed to protect equipment	Review lightning protection standards to provide improved lightning protection. Review line inspection and repair practices to ensure lightning arrestors are functioning for maximum protection. Vegetation management to reduce trees falling on overhead conductors. Perform selective undergrounding.

Adaptive Actions for Distribution Regulators

	Regulators	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action	N/A
Precipitation	No action	N/A
Wind	Design standards in place to meet minimum NESC climate extremes.	Continue current adaptive actions
Heat	No action	N/A
Cold	No action	N/A
Storms	Lighting arrestors installed to protect equipment	Review lightning protection standards to provide improved lightning protection. Review line inspection and repair practices to ensure lightning arrestors are functioning Vegetation management to reduce trees falling on overhead conductors.

Adaptive Actions for Distribution Reclosers

	Reclosers	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action	Mount controllers to be above flood levels and/or require them to be submersible. Evaluate relocating existing structures out of potential flood areas; avoid installing new lines, especially feeder, in flood zones.
Precipitation	No action	N/A
Wind	Design standards in place to meet minimum National Electrical Safety Code (NESC) climate extremes.	N/A
Heat	No action	N/A
Cold	No action	N/A
Storms	Lighting arrestors installed to protect equipment	Review lightning protection standards to provide improved lightning protection. Review line inspection and repair practices to ensure lightning arrestors are functioning Vegetation management to reduce trees falling on overhead conductors. Perform selective undergrounding.

Adaptive Actions for Distribution Capacitors

	Capacitors	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action	N/A
Precipitation	No action	N/A
Wind	Design standards in place to meet minimum NESC climate extremes.	N/A
Heat	No action	Modify circuit loadings to reduce operating temperature of capacitor. Work with manufacturers to redesign capacitors ability to operate at higher ambient temperatures.
Cold	No action	N/A
Storms	Lighting arrestors installed to protect equipment	Continue current adaptive actions

C.3 Generation

Adaptive Actions for Solar Generation Assets

	Solar	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Raised critical equipment off the ground (not always to mitigate flood risk) Ensure flood design standards accommodates predicted flood levels. Site specific hydrology studies are conducted using NOAA 24-hour precipitation at 100 year return period.	Raise critical equipment further off the ground. Construct a flood wall around critical equipment (which is more susceptible to flood) . Ensure equipment is rated for temporary submergence.
Precipitation	Selecting and designing appropriate sites with minimal risk of erosion and vegetation management	Continue same as current actions
Wind	Ensure plant design for wind speeds accommodates the predicted wind speed at extreme return periods.	Install additional support bracing, windbreaks, etc. to increase the design failure wind speed.
Heat	Increased vegetation management to mitigate fire risk. Determine unit design temperature limits and communicate to system operators during extreme heat events. Florida sites are designed to provide max output at 104F. Carolinas and Midwest at 95F. Ensure plant design standards accommodate higher temperatures.	Continue same as current actions Consider increasing design standard for inverters to minimize potential for derates due to heat.
Cold	No action required	Continue same as current actions
Storms	Ensure current plant design meets the most current standards for lightning protection. Ensure plant design includes the most state-of-the-art protection against lightning damage	Continue same as current actions

Adaptive Actions for Wind Generation Assets

	Wind	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	No action required	N/A
Precipitation	Special coating of the leading edge of the blades to mitigate effects of excessive rain	Continue same as current actions
Wind	Ensure plant design for wind speeds accommodates the predicted wind speed at extreme return periods (designed for Category 2 hurricanes; up to 56 mph normal operation, turned off above 62 mph) and self-sustaining turbine battery packs ensure control system power even when disconnected from the grid. E.g., this includes turning the turbine away from high wind speeds.	Continue same as current actions
Heat	HTRT (high temperature ride through) allows curtailment of operations in high heat conditions	Continue same as current actions
Cold	Ensure plant design standards (e.g., equipment) accommodate lower temperatures Determine unit design temperature limits and communicate to system operators during extreme cold events.	Continue same as current actions
Storms	Ensure current plant design meets the most current standards for lightning protection.	Continue same as current actions

Adaptive Actions for Hydro Generation Assets

	Hydro	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Increase flexibility of water flow management. Ensure plant flood design standards accommodate predicted flood levels for the expected duration of plant life. (Both of the above are typically managed through permits)	Continue same as current actions — actions are tied to whether permits can be acquired
Precipitation	Increase frequency of trash rack cleaning. Increase capacity of trash racks to accommodate higher levels of debris accumulation.	Continue same as current actions — keep intakes clean
Wind	Identify structures most vulnerable to wind and install additional support bracing / wind breaks to increase design threshold. Ensure plant design for wind speed accommodates the predicted wind speed. Manage loose debris to avoid damage components Evaluate impact of wind causing damage/failure of components	Continue same as current actions
Heat	Increase flexibility of water flow management (would require permits) Ensure plant design conditions reflect higher ambient air temperatures predicted over the useful life of the asset. An example would be reviewing the design operating temperatures of heat exchangers in hydro facilities. Going beyond the operating temperature can cause rapid oxidation.	Add air conditioning to impacted sites. Add cooling mechanism for process cooling water
Cold	Identify critical equipment most vulnerable to cold temperatures and take measures to improve cold weather resilience. Ensure plant design conditions reflect lower ambient air temperatures predicted over the useful life of the asset. (May lead to icing which can limit water flow / damage components)	Continue same as current actions
Storms	Ensure plant design meets the most current standards for lightning protection. Ensure plant design includes the most state-of-the-art protection against lightening damage. Lightning arrestors and solid grounding grid are components included	Continue same as current actions

Adaptive Actions for Battery Storage Assets Assets

	Batteries	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Elevate equipment and construct a flood wall around critical equipment (which is more susceptible to flood).	Ensure flood design standards accommodates predicted flood levels. Consider using >100 year return periods for site-specific hydrology studies. Use climate projections for flooding to inform site selection
Precipitation	Ensure proper outdoor rated equipment	Future sites to include equipment rated for extreme precipitation events, e.g. horizontal water ingress.
Wind	Implement site specific wind rating based on historical zones.	Ensure plant design for wind speeds accommodates the predicted wind speed at extreme return periods. If batteries become part of black start units, could begin to fully charge batteries in preparation for storm.
Heat	Determine unit design temperature limits and communicate to system operators during extreme heat events.	Ensure plant design standards (e.g., equipment) accommodate higher temperatures and consider adding additional safety margins in new plant design.
Cold	Determine unit design temperature limits and communicate to system operators during extreme cold events.	Ensure plant design standards (e.g., equipment) accommodate lower temperatures. Ensure site and/or equipment specific operational procedures and planning are in place for extreme cold temperature.
Storms	Ensure current plant meets the most current standards for lightning protection.	Continue same as current actions

Adaptive Actions for Nuclear Generation Assets

	Nuclear	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Maintain designed condition of stormwater diversion capability. Ensure plant flood mitigation (stormwater diversion) and other design features (intrusion barriers) accommodate predicted flood levels for duration of expected plant life plus a margin. Monitoring of external hazards against design conditions. (i.e., EPRI post-Fukushima-monitoring of hazards)	Increase the capacity of plant stormwater system. Increase height of flood protection around perimeter of plant.
Precipitation	Ensure critical equipment which is exposed to rain is maintained properly so design waterproofing capability is not compromised (e.g., drainage, gaskets, enclosures, seals, etc.).	Modify equipment designs as necessary to augment waterproofing for critical equipment where practical.
Wind	Ensure plant design for wind speed accommodates the predicted wind speed at extreme return periods. Identify the equipment/structures most vulnerable to failure from wind and debris and install additional support, bracing, windbreaks, etc. to increase the design failure wind speed to withstand the predicted wind speed at extreme return periods.	Increase design margins through design modifications. Increase debris resistance for high wind events
Heat	Condition monitoring and local cooling to ensure equipment is operated within its qualified range. Identify thermal limiting processes and evaluate new equipment to improve thermal efficiency. Evaluate operating procedures to prevent the failure of critical electrical components during periods of high heat. Ensure plant design conditions reflect temperature increase predicted from climate forecasting models over useful life of the asset.	Modify station equipment design to accommodate higher ultimate heat sink temperature. Install cooling towers in areas with inadequate water supply.
Cold	Ensure plant's minimum operating temperature design is adequate to accommodate the predicted values from climate models. Identify vulnerable equipment and take measures to improve cold weather resiliency. Comparing conditions to minimum design operating temperature and communicating to the system operator for use in supply planning during extreme cold. Use heat tracing to protect sensitive equipment that is exposed to the elements.	Continue same as current actions
Storms	Ensure current plant design meets the most current standards for lightning protection. Take protective action in accordance with safety procedures.	Continue same as current actions

Adaptive Actions for Thermal Generation Assets

	Thermal	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Increase capacity of stormwater system. Ensure plant flood design standard accommodates predicted flood levels for duration of expected plant life plus some margin (e.g., redirecting water) Construct a flood wall around perimeter of plant for assets in flood-prone areas. Raise equipment above floodplain where possible, especially on betterment projects.	Increase the capacity of plant stormwater system. Increase height of flood protection around perimeter of plant. Increase the capacity of plant stormwater system.
Precipitation	Ensure critical equipment which is exposed to rain is maintained properly so design waterproofing capability is not compromised (e.g., drainage, gaskets, enclosures, seals, etc.). Provide housing or covering for critical equipment where practical.	Modify equipment designs as necessary to augment waterproofing for critical equipment where practical.
Wind	Identify equipment most vulnerable to failure from wind and install additional support, bracing, windbreaks, etc. to increase the design failure wind speed to withstand the predicted wind speed at extreme return periods.	Increase design margins through design modifications. Increase debris resistance for high wind events
Heat	Condition monitoring and local cooling to ensure equipment is operated within its qualified range. Identify thermal limiting processes and evaluate new equipment to improve thermal efficiency. Evaluate operating procedures to prevent the failure of critical electrical components during periods of high heat. Ensure plant design conditions reflect temperature increase predicted from climate forecasting models over useful life of the asset.	Modify station equipment design to accommodate higher ultimate heat sink temperature. Install cooling towers in areas with inadequate water supply. Ensure plant design conditions reflect temperature increase predicted from climate models over useful life of the asset.
Cold	Identify vulnerable equipment and take measures to improve the cold weather resiliency. Determine min. operating temp. for use in supply planning during extreme cold. Ensure plant's minimum operating temperature design is adequate to accommodate the predicted values from climate models. Use the NERC Reliability Guideline "Generating Unit Winter Weather Readiness", as well as other guidelines and required standards.	Implement periodic evaluations and action plan requirements as new lower temperatures are experienced.
Storms	Ensure current plant design meets the most current standards for lightning protection. Lightning arrestors and solid grounding grid are components included.	Continue same as current actions

C.4 Natural Gas

Adaptive Actions for Natural Gas Compressor Stations

	Compressor Stations	
Climate Hazard	**Adaptive Actions in Place**	**Potential Future Adaptive Actions**
Flood	Avoid placing above ground assets in flood plains	Continue to avoid placement of above ground assets in flood plains; Evaluate options such as enclosing above ground assets
Precipitation	No action	N/A
Wind	No action	N/A
Heat	Design parameters can withstand heat temperatures. All Energy Reliability Center is self-protected — sustained heat will be protected against as it will shut down when exposed	Evaluate options such as enclosing above ground assets.
Cold	Facilities susceptible to cold temperatures are housed in buildings	Continue designing to mitigate cold
Storms	Lighting arrestors installed to protect equipment	Continue current adaptive actions

Source: Duke Energy, Guidehouse