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Climate Change Vulnerability Study

Niagara Mohawk Power Corporation

d/b/a National Grid

Case 22-E-0222

CLIMATE CHANGE VULNERABILITY STUDY

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Acronyms

ANSI	American National Standards Institute
CCRP	Climate Change Resilience Report
CCRT	Climate Change Risk Tool
CCVS	Climate Change Vulnerability Study
CRWG	Climate Resilience Working Group
CMIP	Coupled Model Intercomparison Project
CAIDI	Customer Average Interruption Duration Index
DAC	Disadvantaged community
EPRI	Electric Power Research Institute
ERO	Emergency Response Organization
ERP	Emergency Response Plan
EHTM	Enhanced Hazard Tree Mitigation
FLISR	Fault, Location, Isolation and Service Restoration
FEMA	Federal Emergency Management Agency
GCM	Global Climate Model
GDD	Growing Degree Days
I&M	Inspection and Maintenance
IVM	Integrated Vegetation Management
IPCC	Intergovernmental Panel on Climate Change
ISA	International Society of Arboriculture
MIT	Massachusetts Institute of Technology
NESC	National Electrical Safety Code
NYISO	New York Independent System Operator
NYSERDA	New York State Energy and Development Authority
NMPC	Niagara Mohawk Power Corporation
PSC	Public Service Commission
RCP	Representative Concentration Pathway
SSP	Shared Socioeconomic Pathway
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
T&D	Transmission and Distribution

Executive Summary

Niagara Mohawk Power Corporation (NMPC) d/b/a National Grid (National Grid or Company) is committed to taking proactive action to address the impacts of climate change on its electric assets and operations. Climate change can no longer be considered a future threat: many of its effects, including changes in temperature and precipitation, and increases in the frequency and severity of extreme weather events, are already evident today. National Grid will continue to work to reliably meet the electricity needs of the customers and communities it serves, especially in the face of climate change.

To understand and prepare for potential climate risks, National Grid carried out this Climate Change Vulnerability Study[1] (CCVS or the Study) by assessing the vulnerability of its electric infrastructure, design specifications, and planning and operational procedures. The Study leverages the best available climate science to develop an understanding of potential impacts of climate change on National Grid's electric assets and operations, to inform plans for maintaining reliability and strengthening resilience. National Grid dedicated a team of experts with deep knowledge of the electric system to review the climate data and assess impacts on the infrastructure from projected changes in climate hazards. The Company also created a Climate Resilience Working Group (CRWG), composed of stakeholders from state agencies, municipal and community leaders, and customer and environmental advocacy groups, who provided valuable feedback and input to the Study.

National Grid reviewed a wide range of potential climate hazards for this Study, and ultimately focused on four key climate hazards: 1) high temperature (extreme heat), 2) inland flooding, 3) high winds, and 4) ice. These four hazards present the greatest climate-related risks to National Grid's assets and its ability to deliver electricity safely and reliably to its customers. The Study evaluated substation, transmission line, and distribution line[2] assets against a planning pathway, representing a level of climate change commensurate with high future greenhouse gas emission levels,[3] to understand their exposure and vulnerability to the key climate hazards.

Key Climate Hazards

High Temperature (Extreme Heat)

The capacity of electrical equipment is influenced by ambient temperatures, and finding ways to mitigate these impacts will be key to minimizing costs and other impacts to customers. Climate projections show both average and extreme temperatures increasing across the National Grid service territory throughout mid- and late-century timeframes (2050s and 2080s). For example, projections indicate that substations across National Grid's service area could experience up to 9 days per year with average daily temperatures over 32°C[4] (89.6°F) by the 2080s (Figure 1). Temperatures that exceed the 32°C (89.6°F) threshold can reduce the effective capacity of substation transformers and increase the rate of aging of internal components. Transmission and distribution lines are also projected to experience increasing extreme heat throughout the later part of the 21st century.

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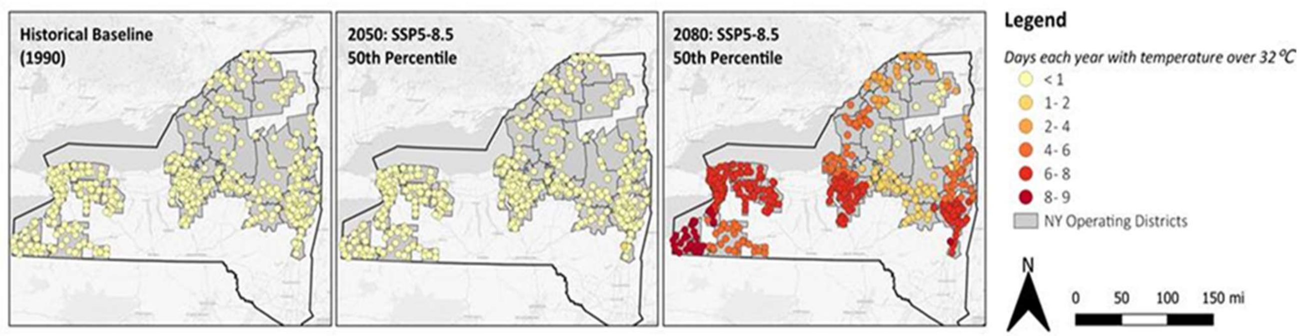
[1] The Climate Change Vulnerability Study was conducted pursuant to New York State Public Service Law §66 and New York Public Service Commission Case 22-E-0222, Proceeding on Motion of the Commission Concerning Electric Utility Climate Vulnerability Studies and Plans.
[2] Sub-transmission assets were examined as part of the distribution line asset group.
[3] National Grid selected Shared Socio-economic Pathway 5-8.5 50th percentile as the climate pathway to which to align its resilience efforts.
[4] National Grid rates its substation transformers based on a daily average ambient air temperature of 32°C (89.6°F).

Figure 1. Change in total days per year with average temperatures over 32°C (89.6°F), across baseline (1990s), 2050s, and 2080s, under the SSP5-8.5 50th percentile scenario. The dots represent substation locations.



Inland Flooding

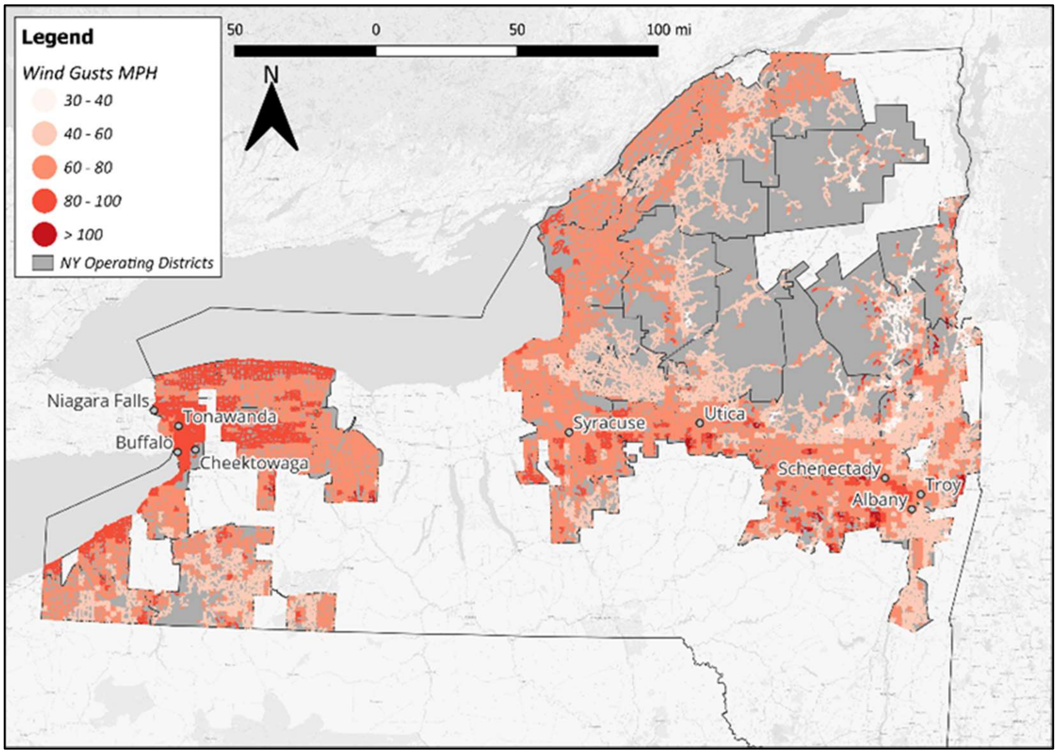
Severe damage to equipment and customer outages caused by flooding highlights the importance of understanding where flooding is most likely to occur and taking proactive measures to minimize its impacts. Climate change is projected to drive increases in inland flooding, specifically along riverbanks, as precipitation becomes more variable and high-precipitation events become more intense and frequent. The Study found that flooding may pose a significant threat to National Grid's assets, particularly for substations. Substation components are highly vulnerable to flooding due to their sensitivity to water exposure. Substations in high flood risk areas are scattered throughout the National Grid service territory, but predominantly located in the Central and Eastern divisions.

High Winds

Understanding where higher wind speeds are likely to occur and finding effective ways to better withstand those conditions will be key to minimizing associated customer outages. Climate change is projected to drive an increase in extreme weather events, which could increase wind gusts across the service territory. Near-term (2025-2041) projections show that National Grid's distribution poles and, sub-transmission and transmission structures could experience a range of extreme wind gusts. For example, distribution poles in the Great Lakes and Lower Mohawk Valley regions are projected to experience particularly high wind gusts, with 1-in-10-year[5] maximum wind gusts reaching more than 100 mph (Figure 2). High winds and wind gusts pose a threat to National Grid's electric assets and have resulted in outages in the past due to downed trees, as well as physical damage to transmission and distribution conductors and poles.

[5] Projections for wind were based on two different risk tolerances - 1-in-10-year and 1-in-100-year maximum wind gust speeds. While 1-in-10-year represents a 10% annual likelihood of occurrence, 1-in-100-year represents a 1% annual likelihood of occurrence. The 1-in-100-year values represent more of a worst-case scenario and are used for systems with lower risk tolerances, such as transmission and sub-transmission lines. This approach is consistent with National Electric Safety Code (NESC) standards traditionally used to inform line designs.

Figure 2. 1-in-10-year near century (2025-2041) maximum wind gust speeds (mph) at National Grid distribution poles across the service territory



Ice

Like wind, understanding which areas and assets are likely to experience higher impacts from icing and preparing to better withstand those conditions will help enhance resilience and reduce customer outages. Climate projections show that distribution and transmission line assets across National Grid's service territory may face increasing risk from icing. For example, in the near term (2025-2041) transmission structures in the western regions of the service territory, near Buffalo, are projected to see the highest 1-in-100-year[6] radial icing totals at more than 0.6 inches. Radial icing can have adverse effects on energy infrastructure as the added weight can cause line sag, mechanical and electrical line failure, or other consequences that result in electric infrastructure damage and outages.

Summary of Priority Vulnerabilities

The Study identified **priority vulnerabilities**, which represent the asset-hazard combinations with the highest potential for negative outcomes for National Grid customers. In other words, priority vulnerabilities characterize sensitive, critical assets that are located in areas of high exposure to a given climate hazard. Table 1 provides a summary of the asset-hazard combinations that were identified as priority vulnerabilities for National Grid. National Grid's substation assets were identified to be particularly vulnerable to extreme heat and precipitation-driven inland flooding. Transmission and distribution line assets were identified to be highly vulnerable to extreme heat, high winds, and ice.

[6] Projections for ice were based on two different risk tolerances - 1-in-10-year and 1-in-100-year maximum radial icing totals. While 1-in-10-year represents a 10% annual likelihood of occurrence, 1-in-100-year represents a 1% annual likelihood of occurrence. The 1-in-100-year values represent more of a worst-case scenario and are used for systems with lower risk tolerances, such as transmission and sub-transmission lines. This approach is consistent with National Electric Safety Code (NESC) standards traditionally used to inform line designs.

Concurrent impacts from wind and ice can also occur—particularly in the context of extreme events such as ice storms—so impacts from high winds and icing events are often considered together when addressing resilience.

Table 1. Identified priority climate vulnerabilities for National Grid assets

ASSET GROUP	High Temperature	Inland Flooding	High Winds	Ice
Transmission Line	✓		✓	✓
Distribution Line	✓		✓	✓
Substation	✓	✓		

In addition to assessing the vulnerability of physical infrastructure, the Study also reviewed potential impacts to National Grid's internal operational procedures, based on the understanding that resilience to climate change cannot be achieved through hardening of physical infrastructure alone. From this review, National Grid identified several key functional areas likely to be impacted by the changing climate, including emergency response, workforce safety, vegetation management, reliability planning, capacity planning, and load forecasting. Each of the operational areas examined showed a range of potential impacts from different climate hazards. Table 2 summarizes the results from this review, indicating climate hazards of most concern for each functional area.

Table 2. Identified climate hazards with potential impacts on Operations and Planning functions

OPERATIONS AND PLANNING FUNCTION	High Temperature	Inland Flooding	High Winds	Ice
Emergency Response	✓	✓	✓	✓
Vegetation Management		✓	✓	✓
Workforce Safety and Methods	✓	✓	✓	✓
Reliability Planning	✓	✓	✓	✓
Load Forecasting	✓			
Capacity Planning	✓			

Climate vulnerabilities identified by this Study, if unaddressed, could have potentially significant implications for National Grid's assets and its ability to provide safe and reliable delivery of electricity to customers. Projected changes in temperature, flooding risk, and extreme events with concomitant high wind speeds or icing, may increase rates of asset failure, cause more frequent and longer outages, and reduce system reliability. These impacts result from having to respond to more frequent and/or severe extreme events, such as heat waves and storms, which could result in higher repair and restoration costs. In addition, these impacts raise potential concerns related to the workforce being exposed to more extreme working conditions more frequently, as well as potential impacts from damaged or downed utility facilities on public safety.

This Study highlights priority areas where National Grid can focus its future climate resilience planning and investment decisions. National Grid has long been committed to considering climate resilience in its investments and operations. National Grid is also participating in the Electric Power Research Institute's (EPRI) Climate READi initiative, that is aimed at creating more resilient power systems through collaborative research on climate data, vulnerability assessments, and resilience planning.

The CCVS represents National Grid's first, comprehensive, service territory-wide vulnerability assessment based on the latest climate datasets. As the next step in its resilience journey, National Grid will develop a Climate Change Resilience Plan (CCRP) based on a multipronged resilience framework, encompassing a range of approaches to maintain and strengthen electric system resilience. The priority vulnerabilities identified in this Study will be the focus of resilience measures in the CCRP. The goal will be to build on the Company's robust reliability and resilience plans that are already in place and widen their focus to incorporate future climate conditions. The CRWG will continue to be engaged in the development of the CCRP.

National Grid acknowledges that while the findings from this Study are critical to resilience planning and investment decisions for the next 5-20 years, the vulnerability of its assets to different climate hazards will continue to evolve. This Study should be seen as part of an ongoing process through which National Grid will regularly evaluate and adapt its resilience planning.

1. Introduction

1.1 Overview

According to the latest report by the Intergovernmental Panel on Climate Change (IPCC),[7] changes in temperature, precipitation, and patterns of extreme weather events such as heatwaves, floods, and storms are having adverse impacts on ecosystems and communities across many regions of the globe. Some of these impacts have already been observed in the northeastern United States,[8] including New York State.[9]

National Grid is committed to actions that address impacts of climate change on its electric assets and operations. The impacts of climate change are no longer a potential future threat: they are happening now, as demonstrated by the increasing frequency and severity of extreme weather events witnessed today. For example, in 2022, historic Winter Storm Elliott in Buffalo brought multi-day blizzard conditions and caused outages that impacted thousands of customers and key facilities in New York.[10] More recently, torrential rains brought severe flash flooding to the Hudson River Valley, closing roads, causing mudslides, and interrupting power to thousands of customers.[11] These impacts often disproportionately affect certain communities, either due to their location in vulnerable areas, such as flood zones, or from a lack of resources and services that can help them prepare for or adapt to the impacts of climate change.[12]

To respond to projected climate risks and support resilience planning, New York State in February 2022 enacted a law requiring electric corporations in the state to conduct climate change vulnerability studies to better understand the electric system's vulnerability to climate change.[13]

National Grid carried out this Climate Change Vulnerability Study (CCVS or the Study) to help prepare for climate risks by evaluating the vulnerability of its electric infrastructure, design specifications, and planning and operating procedures. National Grid, which owns and operates electric transmission and distribution facilities and networks across the northeastern United States, serves approximately 1.7 million electric customers throughout New York State (Figure 3). National Grid is committed to continue

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[7] IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34.

[8] L.A., E.L. Mecray, M.D. Lemcke-Stampone, G.A. Hodgkins, E.E. Lentz, K.E. Mills, E.D. Lane, R. Miller, D.Y. Hollinger, W.D. Solecki, G.A. Wellenius, P.E. Sheffield, A.B. MacDonald, and C. Caldwell, 2018: Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742.

[9] Rosenzweig, C., W. Solecki, A. DeGaetano, M. O'Grady, S. Hassol, P. Grabhorn (Eds.). 2011. Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation. Technical Report. New York State Energy Research and Development Authority (NYSERDA), Albany, New York.

[10] Wagner, 2023. Lessons learned from the Buffalo Blizzard - Recommendations for Strengthening Preparedness and Recovery Efforts. New York University.

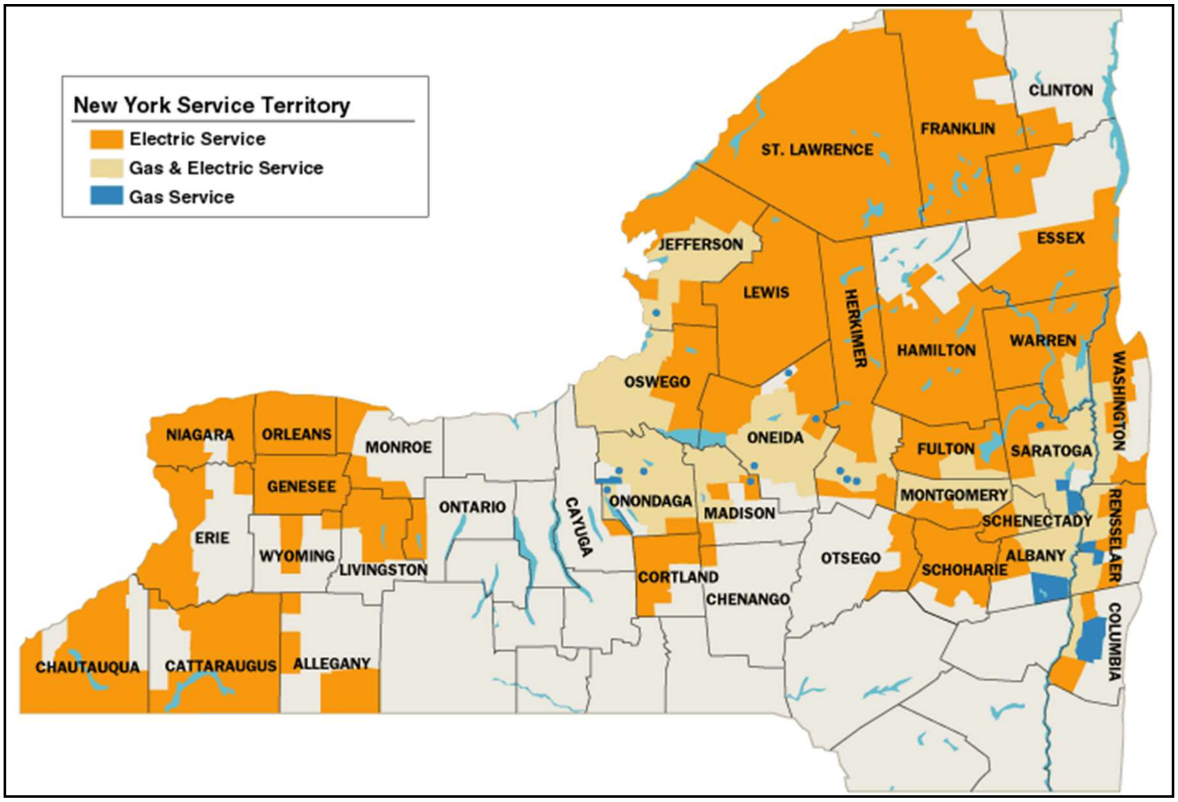
[11] New York State (2023) Governor Hochul Declares State of Emergency in Orange County as Excessive Rains Cause Flash Flooding and Other Life-Threatening Impacts Across Mid-Hudson Region. Available at:governor.ny.gov/news/governor-hochul-declares-state-emergency-orange-county-excessive-rains-cause-flash-flooding.

[12] EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003. Available at:epa.gov/cira/social-vulnerability-report.

[13] New York State in February 2022 enacted a law requiring electric corporations in the State to conduct climate change vulnerability studies. To oversee implementation of the new law, the Public Service Commission commenced Case 22-E-0222. New York Public Service Commission. 2022. "PSC Directs Utilities to Conduct Climate Vulnerability Studies" 22057 / 22-E-0222. Available at:dps.ny.gov/system/files/documents/2022/10/psc-directs-utilities-to-conduct-climate-vulnerability-studies.pdf.

to reliably meet the energy needs of the customers and communities it serves, especially in the face of climate change.

Figure 3. National Grid New York service territory[14]



The CCVS leverages the best available climate science to develop a clear understanding of potential impacts of climate change on National Grid's physical assets and operations to improve resilience to these impacts. National Grid dedicated a team of experts with deep knowledge of the electric system to review the climate data and assess impacts on its infrastructure from projected changes in climate hazards. The findings from the CCVS will feed into the development of the CCRP, which will identify and prioritize resilience measures to address the vulnerabilities identified by this Study.

This CCVS Report describes the datasets, methods, and approach used for the vulnerability assessment and presents the assessment's findings.

- The remainder of **Section 1** provides an overview of the approach, including underlying assumptions, primary climate hazards considered, and significance of equity considerations in the development of the Resilience Plan.
- **Section 2** describes historical climate data and future climate projections. It also presents a detailed discussion on the methods and results of the exposure assessment.
- **Section 3** describes the approach and results of the vulnerability assessment, covering both the vulnerability of assets as well as the impact on planning and operational functions.

[14] A map showing National Grid's Operating Regions in New York is provided in Appendix A. References to National Grid operating regions have been used in the CCVS Report.

- **Section 4** presents a preliminary list of potential resilience measures that will be further evaluated and prioritized as part of the CCRP.
- **Section 5** discusses conclusions and next steps.

Assessing vulnerability of energy infrastructure to climate-driven risks is becoming increasingly significant to ensure reliable and safe delivery of electricity to customers. In addition to New York, several other states have developed regulatory requirements for utilities to identify climate vulnerabilities in their service territories.[15,16]

EXPERT ENGAGEMENT IN THE CLIMATE CHANGE VULNERABILITY STUDY

Subject matter experts (SMEs) from across National Grid formed deep-dive groups and worked together to analyze climate data and identify vulnerabilities for various assets and operational dimensions. These deep-dive groups included SMEs from distribution line, transmission line, and substation planning, standards, design, and operations, as well as experts from the forecasting, reliability planning, and emergency planning teams. These groups worked closely with National Grid's internal data science group, which assisted in analyzing climate projections and developing visuals that combined climate and asset data. Results produced by the data science team were used by the deep-dive groups to feed into the exposure and vulnerability assessment and identify priority vulnerabilities that are presented in this CCVS Report.

1.2 Climate Change Vulnerability Assessment Approach

Vulnerability represents the potential for National Grid's assets and operations to be adversely impacted by projected climate hazards, and the significance of potential outcomes for National Grid's systems, services, and customers. Figure 4 graphically summarizes the approach used for assessing the vulnerability of National Grid's electric assets. High temperature (extreme heat), inland flooding, high winds, and ice were identified as key climate hazards based on projections of climate data and inputs from subject matter experts who prioritized climate variables likely to have high impacts on National Grid.

The first step in the vulnerability assessment process was to evaluate exposure. **Exposure** represents the degree to which assets could experience changes in climate hazards, based on their physical locations and the magnitude of projected future changes in climate hazards. Exposure information was derived by combining climate hazard and asset data. Findings from the exposure analysis are discussed in detail in Section 2.6.

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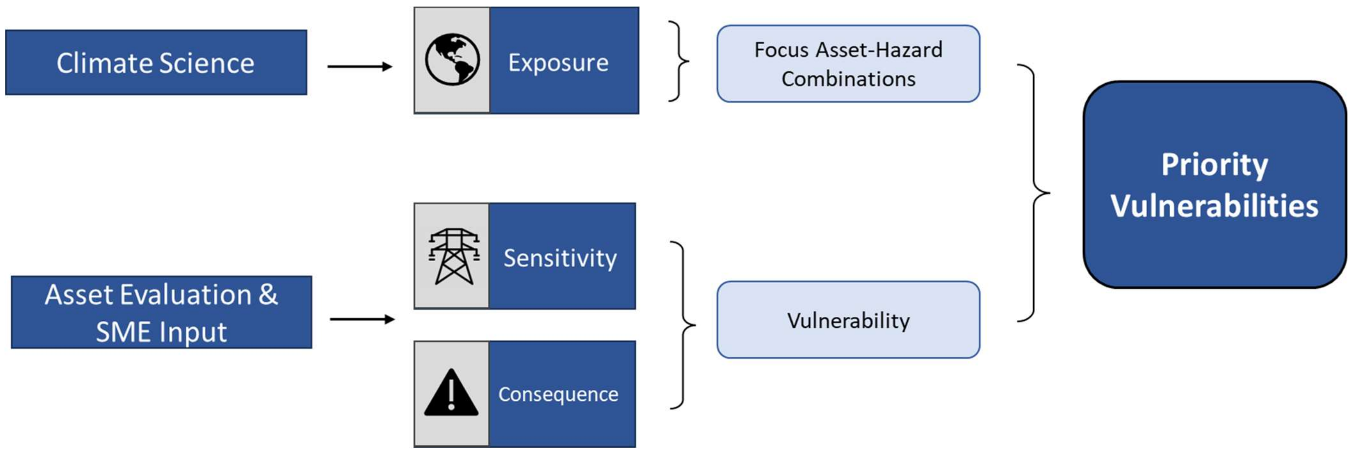
15 For example, in 2022, the California Public Utilities Commission issued decision D.20-08-046 that requires investor-owned utilities to submit a Vulnerability Assessment, Community Engagement Plan, and a Disadvantaged Vulnerable Communities Survey Report. Available at:docs.cpuc.ca.gov/PublishedDocs/Published/G000/M346/K285/346285534.PDF.

16 In 2022, Maine also enacted legislation LD 1959, that requires transmission and distribution utilities to submit every two years to the Maine Public Utilities Commission a 10-year plan for protecting utility assets and operations from the expected impacts of climate change. Available at:maine.gov/governor/mills/news/governor-mills-unveils-legislation-improve-maines-electric-utilities-enhance-accountability#:~:text=The%20legislation%20requires%20transmission%20and,this%20manner%20would%20be%20required.

Figure 4. Vulnerability assessment approach for National Grid assets



Asset-hazard combinations were subsequently evaluated for sensitivity and consequence ratings. **Sensitivity** represents the degree to which National Grid's assets could be negatively affected by exposure to a climate hazard, and **consequence** represents the magnitude (or criticality) of negative outcomes for National Grid's systems and customers in the event of asset failure or damage. For the CCVS, National Grid assets were grouped into three asset groups: substation, transmission line, and distribution line. Sub-transmission assets were included as part of the distribution line asset group.

Electrical substations are facilities where one or more generation, transmission, or distribution systems interconnect to distribute electricity to other parts of the grid. Substations often include complex pieces of interconnected electrical equipment, such as transformers and circuit breakers, that are crucial to the functioning of the grid. Transmission assets transport energy over long distances at high voltage from where it is produced, and onward to supply the distribution system. Transmission line structures, conductors, and other current-carrying components were included in the transmission line asset group. The sub-transmission system operates at voltages lower than the transmission system and serves as an intermediary between the transmission system and the distribution networks in more remote areas such as the Adirondack Park or legacy systems closer to urban areas, where it supplies larger industrial customers and distribution stations. Distribution networks deliver electricity at lower voltages to homes and businesses. Sub-transmission and distribution conductors, structures, transformers, regulators, capacitors, and other current-carrying components were included in the distribution line asset group.

Evaluations of sensitivity and consequence ratings were based on extensive consultation with subject matter experts at National Grid. These ratings were then combined to derive asset vulnerability ratings. Vulnerability ratings are a valuable indicator that communicates whether an asset might be impacted by a given climate hazard and the criticality of the outcome to National Grid's systems and customers if it is impacted. Vulnerabilities that were identified as a priority were considered for further evaluation and will be the focus of the resilience recommendations included in the CCRP.

Resilience to climate change cannot be achieved through hardening of physical infrastructure alone; utilities must also be operationally prepared to adapt to changing climate and weather conditions. Therefore, in addition to assessing the vulnerability of physical infrastructure, National Grid also assessed the vulnerability of internal operations and processes to potential climate risks, based on extensive review of operating procedures and consultations with subject matter experts. Emergency response, workforce safety, vegetation management, reliability planning, capacity planning, and load forecasting were the key functional areas included in the CCVS. Findings from the vulnerability analysis, for assets and operations, are discussed in detail in Section 3.3.

1.3 Baseline Assumptions

Although National Grid has leveraged the best available science to understand and assess exposure and vulnerability to climate hazards, the use of climate data and the methods for vulnerability assessments involve a number of assumptions. It is vital that all findings from the Study are considered in light of these assumptions.

1.3.1 Climate Data

- Climate projections are inherently uncertain and are not meant to be construed as predictions of future climate. These uncertainties can be attributed to an incomplete understanding of Earth's systems and their interactions, natural climate variability, limitations of climate models, errors in observational data, and other factors. It is important to recognize and account for these uncertainties, but they should not be used as justification to postpone actions that can mitigate or help adapt to potential impacts of climate change. The Study used a large ensemble of climate models and 30-year time horizons to help account for some of these uncertainties.
- For exposure analysis using the Columbia/New York State Energy and Development Authority (NYSERDA) data,[17] the Study used a weather station-based, nearest-neighbor approach, which operates under the assumption that climate patterns are more similar in closer proximities. However, this approach may homogenize intra-regional differences by not accounting for more localized conditions driven by topography, vegetation, or other factors. This approach is discussed in more detail in Section 2.2.
- National Grid selected Shared Socioeconomic Pathway[18] (SSP) 5-8.5 50th percentile as the climate pathway to align resilience efforts. Climate change projections provide a range of plausible climate futures reflecting uncertainty associated with both future greenhouse gas emissions trajectories and the sensitivity of Earth's climate to changes in greenhouse gas concentrations. A climate pathway narrows this range and provides standardized climate change projections to guide a utility's resilience planning. SSP5-8.5 represents a planning pathway that encompasses a level of climate change commensurate with high future emissions levels. The 50th percentile represents the median of models from the ensemble of 16 provided by Columbia and NYSERDA. National Grid's decision to select this pathway is informed by available climate science, appropriate risk levels established by Company policies, and peer benchmarking. All vulnerabilities identified in the CCVS and resilience recommendations that will be included in the Resilience Plan will be developed around future conditions representative of this climate pathway. The selection of the climate change pathway is discussed in more detail in Section 2.4.

[17] NYSERDA partnered with Columbia University to develop new climate projection datasets that have been used by the Joint Utilities of New York, which includes National Grid, for the CCVS and CCRP.

[18] SSPs represent plausible major global developments that together would lead to different future challenges for mitigation and adaptation to climate change. Population growth, economic growth, urbanization, trade, and energy use are some of the socioeconomic and technological factors included in the development of the SSP narratives.

1.3.2 Asset Data

- The Study assumes the data on physical assets and information on system-wide operations used in this assessment represent the current state of National Grid's system at the time the data and information were collected. Also, only National Grid electric assets and operations in New York State were included in the scope of this Study.
- The vulnerability assessment does not account for the impact of risk mitigation measures that may be implemented in the future and thereby affect the vulnerability and resilience of National Grid's electric assets and operations. The Study focuses on existing levels of vulnerability, which would include benefits derived from existing risk mitigation measures in place. Risk mitigation benefits of future resilience recommendations will be captured as part of the upcoming CCRP.
- Information and evaluations provided by National Grid's subject matter experts are based on their professional experience and understanding of the technical specifications of electric assets and operational procedures.

1.4 Summary of Priority Climate Hazards

Climate change is projected to exacerbate a range of climate hazards in the National Grid service territory, such as increasing the frequency and intensity of extreme temperatures, causing more frequent and widespread flood events, and driving changes in wind speeds and ice events with increasingly severe storms.

National Grid leveraged best available climate data to assess future changes in climate hazards across its service territory and inform the selection of four key climate hazards for inclusion in the CCVS: 1) **high temperature (extreme heat), 2) inland flooding, 3) high winds,** and **4) ice**. To select these climate hazards, National Grid carried out a preliminary vulnerability assessment, where a wide range of climate hazards were considered, including low temperatures, drought, sea level rise, cyclones, etc. Based on extensive consultations with internal SMEs, four key climate hazards were selected for in-depth assessment in the CCVS. For each of these hazards, the Study analyzed variables tailored to the sensitivities of National Grid's assets. For example, exposure analysis for temperature, among other variables, looked at days with average ambient temperatures above 32°C (89.6° F), which represents a temperature threshold relevant to substation transformer ratings.

WILDFIRE RISK

Due to the generally low probability of wildfires in New York State today, the CCVS did not evaluate the potential vulnerability of National Grid assets to wildfire. Given the possibility for wildfire to have catastrophic consequences, as seen in wildfire events in other parts of the country, National Grid will assess emerging risks, including those from wildfire, in future iterations of the Study and actively monitor new information related to wildfire risk as it becomes available.

1.4.1 High Temperature (Extreme Heat)

Historically, the National Grid's service territory has experienced significant seasonal temperature variations. Both average and extreme temperatures are projected to increase across the National Grid service territory throughout the mid- (2050s) and late-century (2080s) timeframes considered in the analysis of temperature. National Grid leveraged the Columbia/NYSERDA weather station data to generate a suite of temperature variables, which were used to understand the potential exposure of various assets to increasing heat. Both acute and chronic heat pose challenges to National Grid's capacity for safe and reliable delivery of energy, due to the high heat sensitivity of critical substation, transmission line, and distribution line assets.

1.4.2 Inland Flooding

Inland floods in the service territory have historically resulted from extreme tropical cyclones and extratropical cyclones, with high winds and heavy precipitation from these events driving both pluvial and riverine flooding. Climate change is projected to drive increases in inland flooding, as precipitation becomes more variable and high-precipitation events become more intense and frequent. Flooding poses a significant threat to National Grid's assets, especially those located in substations. National Grid evaluated future flood exposure by leveraging National Grid's in-house Climate Change Risk Tool (CCRT), which provides future flood risk ratings based on precipitation projections and complemented this information with present-day Federal Emergency Management Agency (FEMA) flood risk designations to identify future "at-risk" areas where substations are located across the service territory.

1.4.3 High Winds

Historically, extreme wind gusts in New York State have been driven by tropical cyclones and extratropical cyclones, which, while rare, can cause significant impacts to National Grid assets, systems, and operations. For example, during Hurricane Ida in 2021, wind gusts exceeded 78 mph and were coupled with extreme pluvial and riverine flooding in many locations which impacted areas just south of the Company's service territory. Climate change is projected to drive increasingly extreme weather events, which could increase wind gusts across the service territory. High winds and wind gusts pose a threat to National Grid's electric assets and have resulted in outages in the past due to downed trees as well as physical damage to transmission and distribution conductors and poles. National Grid evaluated the exposure of transmission and sub-transmission structures, as well as distribution poles, to extreme wind gusts using dynamically downscaled projections of wind speeds for the near future (2025-2041) developed by the Massachusetts Institute of Technology (MIT).[19]

1.4.4 Ice

Severe historical storms on record have driven ice accumulations that resulted in widespread damage to energy infrastructure in New York State. Radial icing can have adverse effects on transmission and distribution structures, as the added weight can cause line sag, line failure, or other consequences that could result in asset failure and outages. Projections show that assets across the service territory may face significant radial icing events in the future. National Grid evaluated the exposure of transmission and sub-transmission structures, as well as distribution poles to radial icing using dynamically downscaled projections for radial ice accumulation totals for the near future (2025-2041) that were developed by MIT.

1.5 Equity Considerations in Resilience Planning

National Grid strives to obtain an equitable outcome for all its customers by incorporating equity considerations into all processes. The Company recognizes that some communities may be disproportionately impacted by climate change, and distributional and procedural inequities are often associated with differential vulnerability of communities to climate change. Extreme climate events can further exacerbate existing inequities. National Grid is committed to ensuring that affected communities realize the benefit of Company projects, including health, safety, reliability, equity, and economic benefits.

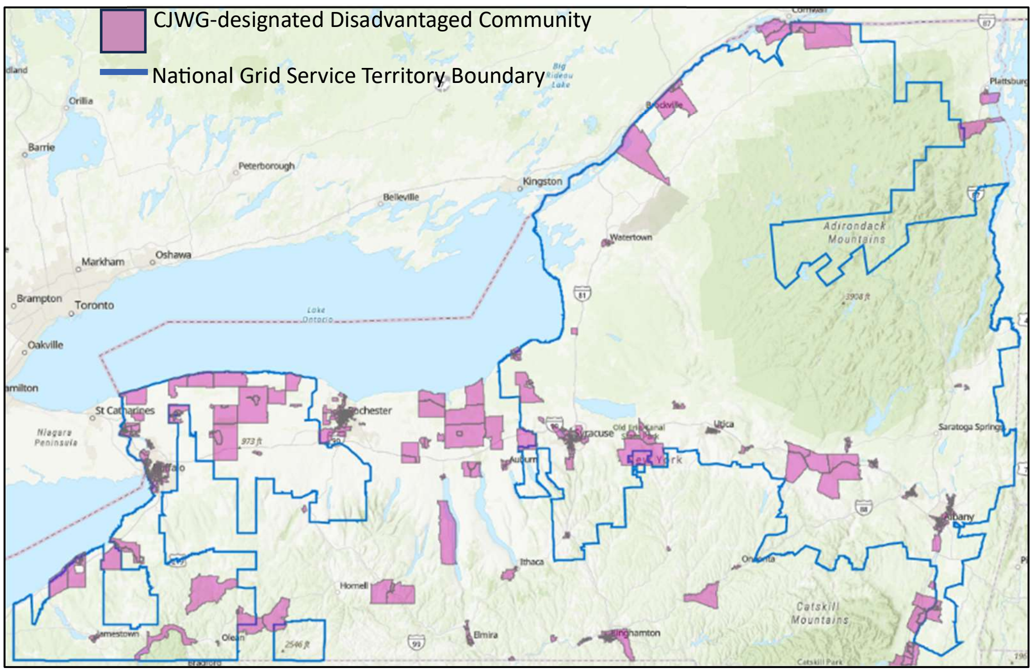
In July 2019, New York State enacted the Climate Leadership and Community Protection Act (CLCPA or Climate Act),[20] one of the most ambitious climate laws in the United States. The Climate Act charged the Climate Justice Working Group (CJWG)[21] with the development of criteria[22] to identify disadvantaged communities (DACs),[23] to ensure that frontline and otherwise underserved communities benefit from the clean energy transition, reduced air pollution, and overall benefits from investments that the state

[19] Komurcu, M. and S. Paltsev (2021): Toward resilient energy infrastructure: Understanding the effects of changes in the climate mean and extreme events in the Northeastern United States. Joint Program Report Series Report 352, June, 16 p. Available at:globalchange.mit.edu/publication/17608.
[20] New York State, 2023. Climate Act, Available at:climate.ny.gov/.
[21] New York State, 2023. Climate Act. Available at:climate.ny.gov/resources/climate-justice-working-group/.
[22] New York State, 2023. Climate Act. Available at:climate.ny.gov/Resources/Disadvantaged-Communities-Criteria.
[23] Under the Climate Act, disadvantaged communities (DACs) are defined as "communities that bear burdens of negative public health effects, environmental pollution, impacts of climate change, and possess certain socioeconomic criteria, or comprise high-concentrations of low- and, moderate- income households" ECL § 75-0101(5).

makes toward climate action. The Climate Act mandates that DACs receive no less than 35% (with a goal of 40%) of the overall benefits of spending on clean energy and energy efficiency programs, projects, and investments to achieve the goals of the CLCPA. The CJWG has developed and adopted a list of criteria based on indicators of environmental burdens, climate change risks, population characteristics, and health vulnerabilities to designate DACs. The CJWG also produced an interactive mapping tool that identifies census tracts designated as DACs. The DAC criteria identifies 1,736 census tracts across New York State, representing 35% of all census tracts in the State.

As part of developing the CCRP, National Grid will leverage the findings of the CJWG on DACs to integrate inclusion and equity considerations into resilience planning. The Commission's directive, requiring this CCVS, also calls for equity considerations to be included in the Resilience Plan.[24] Figure 5 shows a map of the CJWG-designated DACs overlaid on National Grid service territory.

Figure 5. Map of CJWG-designated Disadvantaged Communities in the National Grid service territory



National Grid's intent is to make equity an integral part of project planning to suitably prioritize the interests of disadvantaged communities and avoid undue burdening any affected community. National Grid is exploring equity approaches to account for and track equity considerations in asset and project planning, by focusing on both:

- ***Procedural Equity:*** To ensure that stakeholders and communities impacted by resilience projects and programs are provided the necessary information and opportunities to participate in and inform project development and implementation.
- ***Distributional Equity:*** To ensure our resilience planning is implemented in a way that drives equitable outcomes including the equitable realization of the benefits and burdens.

[24] Case 22-E-0222, press release, PSC Directs Utilities to Conduct Climate Vulnerability Studies, 22057 / 22-E-0222. Available at:dps.ny.gov/system/files/documents/2022/10/psc-directs-utilities-to-conduct-climate-vulnerability-studies.pdf.

As a leader in the energy transition, National Grid works with a diverse range of environmental justice communities to ensure provision of clean, affordable energy to all communities and support climate change and environmental justice initiatives throughout New York while also working with consumer advocacy groups to balance affordability and the needs of its customers. The development of the CCRP offers an additional opportunity for National Grid to continue supporting its climate justice goals.

1.5.1 Climate Resilience Working Group

Stakeholder Engagement

National Grid created a comprehensive *stakeholder engagement roadmap* to enlist input into the development of the CCVS and the CCRP, ensuring that the Plan is responsive to customer and community priorities while continuing to meet its obligation to provide safe and reliable service and fulfil compliance requirements of the legislation.

Stakeholder Engagement Requirements

The New York State legislation and accompanying Public Service Commission (PSC) order outlining the requirements for the CCVS and CCRP, calls for stakeholder engagement in the development and implementation of the CCRP. Notably, utilities must:

- Identify opportunities for coordination with municipalities, customer advocate groups, the New York Independent System Operator (NYISO), NYSERDA and other utilities, including telecommunications.
- Serve climate resilience plan on the parties from its prior rate case.
- Establish a utility Climate Resilience Working Group (CRWG) no later than one year after the effective date of the legislation (March 2023) to advise and make recommendations to the utility and PSC on the development and implementation of the CCRP. The CRWG should include representatives from municipalities, customer advocacy groups, energy and environmental advocacy organizations and meet twice annually.
- Provide the county executive or chief elected official for each county within its service territory with an approved copy of its CCRP.

Stakeholder Engagement Roadmap

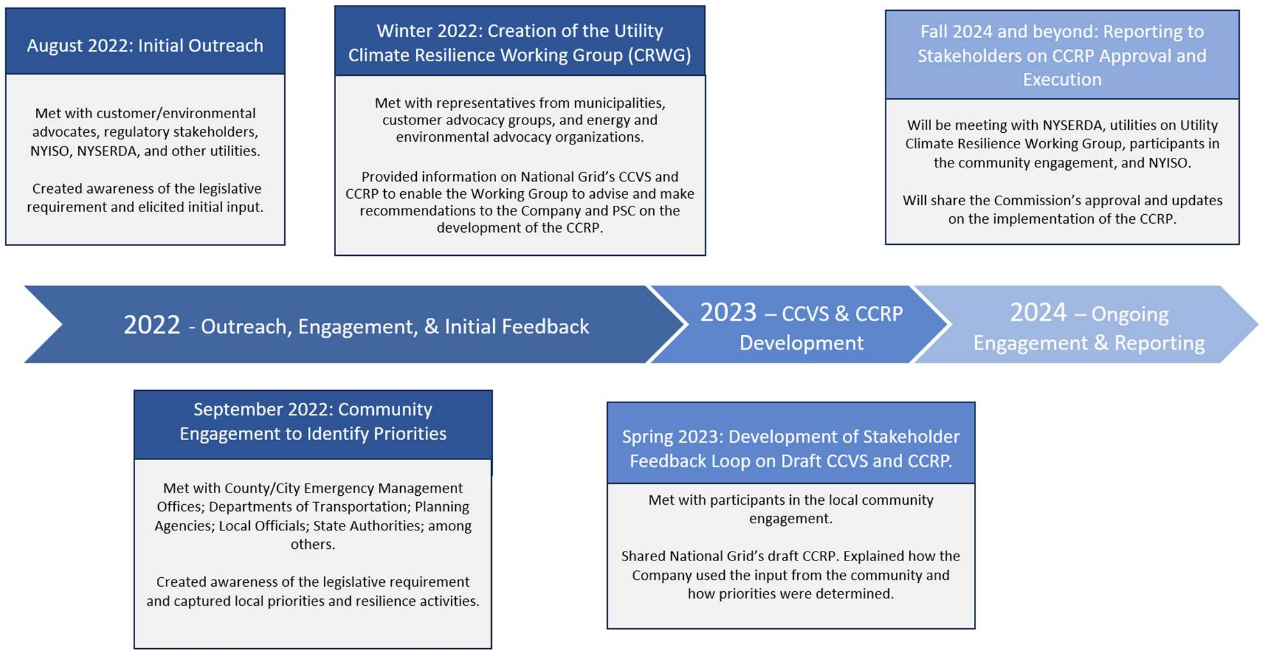
National Grid's Stakeholder Roadmap (Figure 6) involves several phases in conjunction with the deliverable timelines and compliance obligations, beginning with initial localized outreach at the community level and then expanding our efforts to include regulatory intervenors, state agency representatives, customers, policy makers, and environmental and customer advocates.

Stakeholder Engagement Activities

In August 2022, National Grid carried out initial outreach to create awareness about the CCVS and CCRP and seek preliminary input from stakeholders. At the first meeting with municipal and community leaders, National Grid informed stakeholders about plans to develop the CCVS and CCRP, solicited their inputs via a survey to identify areas of concern, and encouraged participation in the CRWG. A second meeting was held in December 2022 to update and inform this group on the results of the survey and reemphasize the role and significance of the CRWG in the development of the CCVS and the CCRP. A third meeting was held in August 2023 to provide an update to community and municipal leaders on progress to date and next steps.

An informational meeting was also held with environmental and consumer advocates, and other interested parties, in January 2023, where the Company stressed the twin goals of sharing ideas and seeking feedback to ensure that both the CCVS and the CCRP are aligned with stakeholder concerns.

Figure 6. National Grid Climate Change Vulnerability Study & Resilience Plan - Stakeholder Engagement Roadmap



In early 2023, National Grid established the CRWG, composed of members from state agencies, community, and municipal leaders, as well as customer and environmental advocacy groups and state agencies. The Company recognizes that meaningful collaboration with this diverse group of stakeholders is critical to understanding and incorporating their concerns and priorities, including equity concerns, into the Resilience Plan.

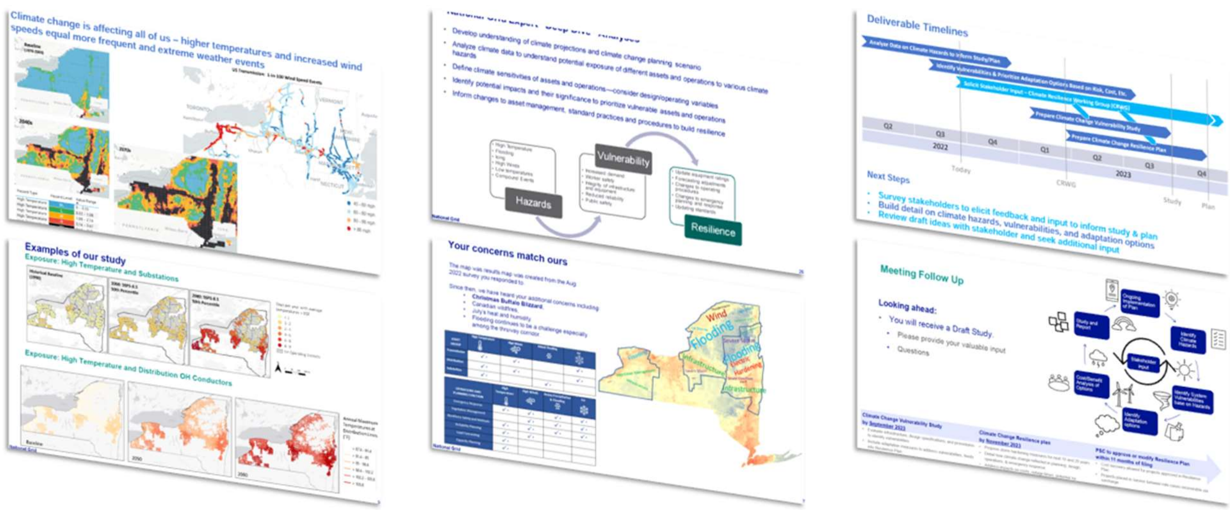
Two CRWG meetings[25] were held during the CCVS development process, in which vulnerability assessment methods and preliminary findings were presented to the CRWG members, and their inputs sought for incorporation into the CCVS. The first CRWG meeting was held in February 2023, to orient participants to the overall objectives of the Study and the Plan and seek their feedback to ensure that both efforts are proceeding in the right direction. The second CRWG meeting was held in June 2023, to present the approach and preliminary findings from the vulnerability analysis and seek participant feedback prior to the drafting of the CCVS Report. A third meeting is planned for October 2023 which will be used to highlight resilience proposals for inclusion in the CCRP and solicit stakeholder input as National Grid works toward finalizing the Resilience Plan.

National Grid has created a dedicated webpage (nationalgridus.com/Our-Company/New-York-Climate-Resiliency-Plan) as a source of information and an email address (box.NYClimateresiliency@nationalgrid.com) which stakeholders can use to ask questions or provide

[25] See Appendix B for Meeting Summaries from CRWG Meeting 1 and CRWG Meeting 2. The appendix also provides a list of CRWG member organizations as well as a list of community and municipal organizations included in stakeholder engagement activities.

feedback. National Grid has also created various informational materials for outreach and stakeholder engagement (Figure 7).

Figure 7. Examples of informational materials created by National Grid for outreach and stakeholder engagement



Incorporation of Stakeholder Feedback

National Grid is committed to not only soliciting input from stakeholders and customers but using that information to inform Company policies and projects, by bringing customers, communities and advocates at the front end of decision making. The Company values flexibility to adapt processes as new information and feedback becomes available. It is critical that all stakeholders understand this process, have avenues to make their opinions known, and most importantly, see their input realized in National Grid's policies and projects. National Grid will continue to work with stakeholders during the development of the CCRP and beyond, to gauge the impact of resilience measures on communities.

2. Historical Climate and Future Climate Projections

2.1 Overview

Projections show climate change could drive changes in temperature and precipitation patterns and exacerbate a range of extreme weather events such as heat waves, flooding, and storms resulting in high wind gusts and icing.

This section discusses the climate datasets used in the CCVS, explores trends in current and future climate in the service territory, and introduces the climate pathway selected by National Grid to standardize climate information and guide resilience planning. It also presents a detailed discussion of the exposure assessment[26] conducted to understand the potential exposure of National Grid's electric infrastructure to projected climate hazards.

2.2 Climate Datasets

Climate is the prevailing long-term average of weather and ocean conditions. Climate change refers to a long-term shift in the state of the climate and occurs due to both natural and human-caused forcings. Climate change drives changes in chronic, average conditions, such as warmer average temperatures, as well as acute, extreme events, such as hurricanes and droughts.

Global Climate Models (GCMs) simulate future climate based on hypothetical scenarios of future greenhouse gas emissions. These emissions scenarios reflect potential changes in future global socioeconomic conditions as represented in Shared Socioeconomic Pathways (SSPs)[27] developed in preparation for IPCC's Sixth Assessment Report. For this Study, National Grid selected SSP5-8.5, which represents largely unabated greenhouse gas emissions through end of century; the rationale for this choice is discussed in Section 2.4**.**

Climate projections from GCMs provide a mechanism for quantifying future changes in climate and are useful tools for analyzing potential impacts of climate change across a range of geographic scales. Importantly, climate projections best resolve longer-term climate trends, rather than day-to-day weather. Climate projections constrain future hazard levels, that, in turn, can support resilience planning in the National Grid service territory.

The Study leveraged climate projection datasets to evaluate future changes in climate hazards across the service territory and, in turn, exposure of National Grid's assets to those hazards. This effort primarily used new downscaled climate projections developed for the State of New York by NYSERDA, in partnership with Columbia University. These projections are complemented by wind and ice datasets developed by MIT and using National Grid's CCRT. The following subsections describe each of these datasets and discuss their function in the CCVS.

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[26] Besides the maps and charts provided in this Section, detailed results from exposure analysis for National Grid assets is provided for reference in Appendix C – Detailed Results of Exposure Assessment for National Grid Assets

[27] SSPs represent plausible major global developments that together would lead to different future challenges for mitigation and adaptation to climate change. Population growth, economic growth, urbanization, trade, and energy use are some of the socioeconomic and technological factors included in the development of the SSP narratives.

2.2.1 Columbia/NYSERDA Downscaled Climate Projections

NYSERDA partnered with Columbia University to develop climate projection datasets for the State of New York, which were also adopted by the Joint Utilities of New York for the CCVS and CCRP. These datasets use the new Coupled Model Intercomparison Project (CMIP) 6 Global Models downscaled at a set of weather stations across New York State and provide daily and, in some cases, hourly time series projections. These projections reflect updated climate science relative to older CMIP5 projections, and now comprise the climate projections of record for New York State. These projections use an ensemble of 16 GCMs and both SSP2-4.5 and SSP5-8.5, representing strongly mitigated and largely unabated future greenhouse gas emissions, respectively.

The Study leveraged these daily climate projection datasets to derive tailored calculations corresponding to asset sensitivities. For example, the Study identified key temperature thresholds for asset ratings and calculated the number of days exceeding those thresholds in the future.

Projections were calculated at decadal time horizons from 2030s through 2080s. To account for interannual and interdecadal variability in the daily temperature datasets, the Study calculated variables as 30-year averages surrounding each time horizon of interest. For example, projections for the 2050s represent averages of daily data from 2041 to 2070. Projections are relative to a baseline, or base period, which comprises the dataset of historical observations from 1981 to 2010[28] at each weather station.

2.2.1.1 Variables and Methods

The Study used the datasets developed by NYSERDA and Columbia University to develop projections for the following temperature variables tailored to the sensitivities of assets, which were in turn used to understand their exposures to increasing temperatures and extreme heat:

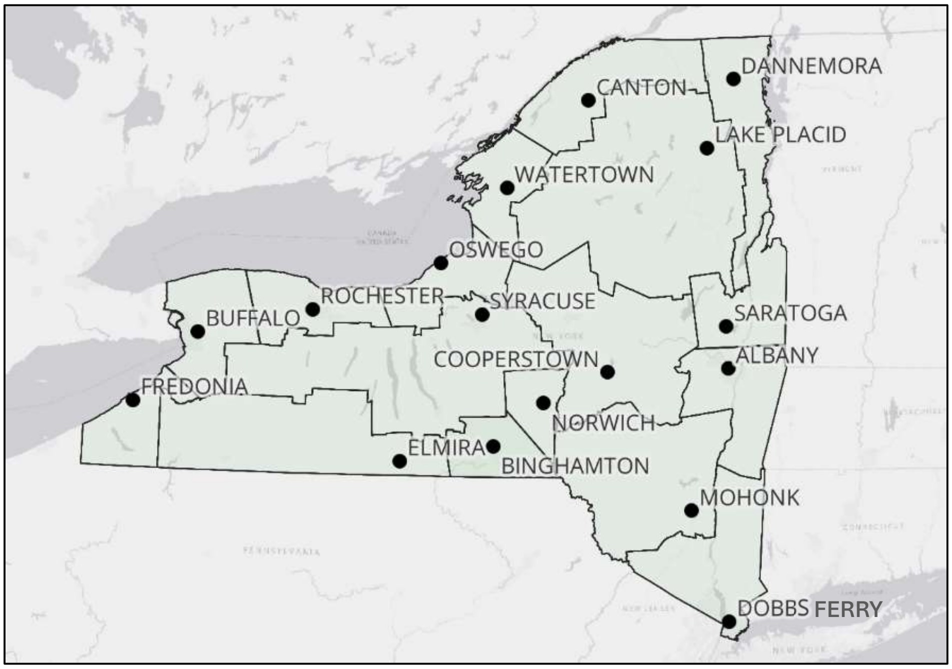
- Annual maximum daily temperatures
- Number of days per year with average ambient temperatures over 32°C (89.6°F)[29]
- Number of days per year with maximum ambient temperatures over 40°C (104°F)[30]

The Study generated a set of regions reflecting the nearest neighbor to stations within the NYSERDA climate domains, meaning assets were assigned to data from the closest weather stations while following climate region outlines, which were designed to capture regional gradients in temperature, precipitation, and other climatological factors (Figure 8). This approach operates under the assumption that climate patterns are more similar in closer proximity.

Climate hazard spatial data were then overlaid with National Grid's assets to map exposure within the regions described in the paragraph above. In other words, all assets within a region received the projection values for the station in that region.

[28] These years represent the baseline time period that was selected and used by Columbia/NYSERDA for the New York State climate projections.
[29] The CCVS analyzed daily average temperatures relative to a threshold of 32°C (89.6°F) due to its significance in National Grid substation transformer ratings.
[30] The CCVS analyzed daily maximum temperature relative to a threshold of 40°C (104°F) due to its significance in National Grid distribution line ratings.

Figure 8. Nearest neighbor within NYSERDA climate regions for weather stations across New York State



2.2.2 Climate Projections from MIT

The MIT Joint Program on the Science and Policy of Global Change developed projections for average and extreme temperatures, wind speed, and radial ice accumulation in the near future (2025-2041).[31] To accomplish this, MIT dynamically downscaled a GCM simulation using the Weather Research Forecasting Model to a 3km horizontal grid spacing and hourly time resolution. The analysis used Representative Concentration Pathway (RCP) 8.5, which represents largely unabated greenhouse gas emissions and closely aligns with SSP5-8.5 used elsewhere in the Study.

The CCVS used these MIT-generated wind speed and ice projections to understand the exposure of National Grid's transmission and sub-transmission structures, as well as distribution poles to extreme wind gusts[32] and radial icing. These projections were based on two different risk tolerances - 1-in-10-year and 1-in-100-year maximum wind gusts and radial icing totals. While 1-in-10-year represents a 10% annual likelihood of occurrence, 1-in-100-year represents a 1% annual likelihood of occurrence. The 1-in-100-year values represent more of a worst-case scenario and are used for systems with lower risk tolerances, such as transmission and sub-transmission lines. For distribution poles, higher frequency, lower impact, 1-in-10-year events were considered in the analysis. This approach is consistent with National Electric Safety Code (NESC) standards traditionally used to inform line designs.

2.2.3 National Grid's Climate Change Risk Tool

National Grid previously developed an in-house Climate Change Risk Tool (CCRT) to support strategic efforts through a high-level assessment of climate and asset data. The CCRT offers both a spatial and dashboard-type display, and provides information on hazard, exposure, and risk levels for National Grid

[31] Komurcu, M. and S. Paltsev (2021) Toward resilient energy infrastructure: Understanding the effects of changes in the climate mean and extreme events in the Northeastern United States. Joint Program Report Series Report 352, June, 16 p. Available at: globalchange.mit.edu/publication/17608.

[32] MIT generated sustained wind speed projections at 150 feet were converted by National Grid to NESC equivalent of 3s wind gust at 33 feet.

assets. The CCRT analyzes nine climate hazards: high temperatures, low temperatures, freeze-thaw cycles, heatwaves, high winds, coastal flooding, river flooding, compound events, and lightning. Most hazards consider projections across a model ensemble for both RCP 4.5 and RCP 8.5 and consider multiple future time horizons, including the 2030s, 2040s, 2050s, and 2070s.

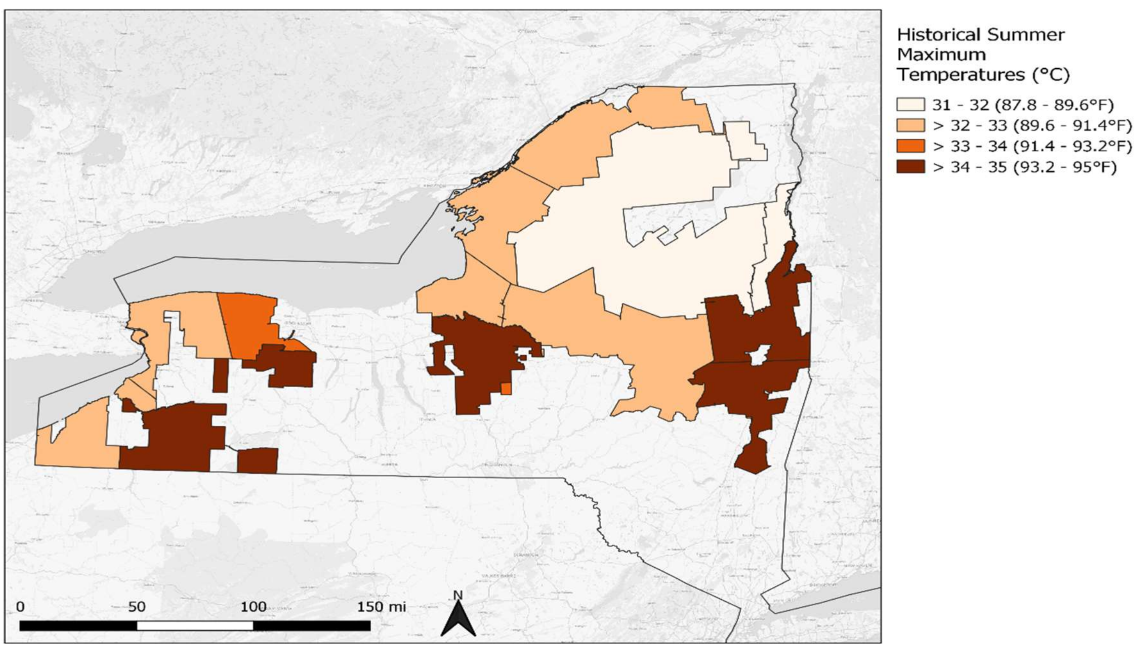
The Study leveraged future flood risk information from the CCRT, which uses precipitation projections from CMIP5 GCMs as a proxy for changes in future inland floodplains. This future flood risk information was used to complement FEMA flood risk designations to understand present-day and future flood risk levels and identify substations located in potentially high flood risk areas across the service territory.

2.3 Historical Climate

2.3.1 Temperature

Historically, National Grid's service territory has experienced significant seasonal temperature variations. The area sees warm summer temperatures, particularly along the Hudson River Valley, and cool winters, particularly in the northern regions of the state around the Adirondacks and Champlain Valley. Summer mean maximum daily temperatures[33] throughout the National Grid service territory have ranged from 23.3°C (74°F) to 27.2°C (81°F), with a territory-wide average of 25°C (77°F) and temperatures for the hottest day of the summer ranging from 31.7°C (89°F) to 36.1°C (97°F) across cooler and warmer regions of the service territory, respectively (Figure 9).

Figure 9. Historical mean maximum summer temperatures across the National Grid service territory



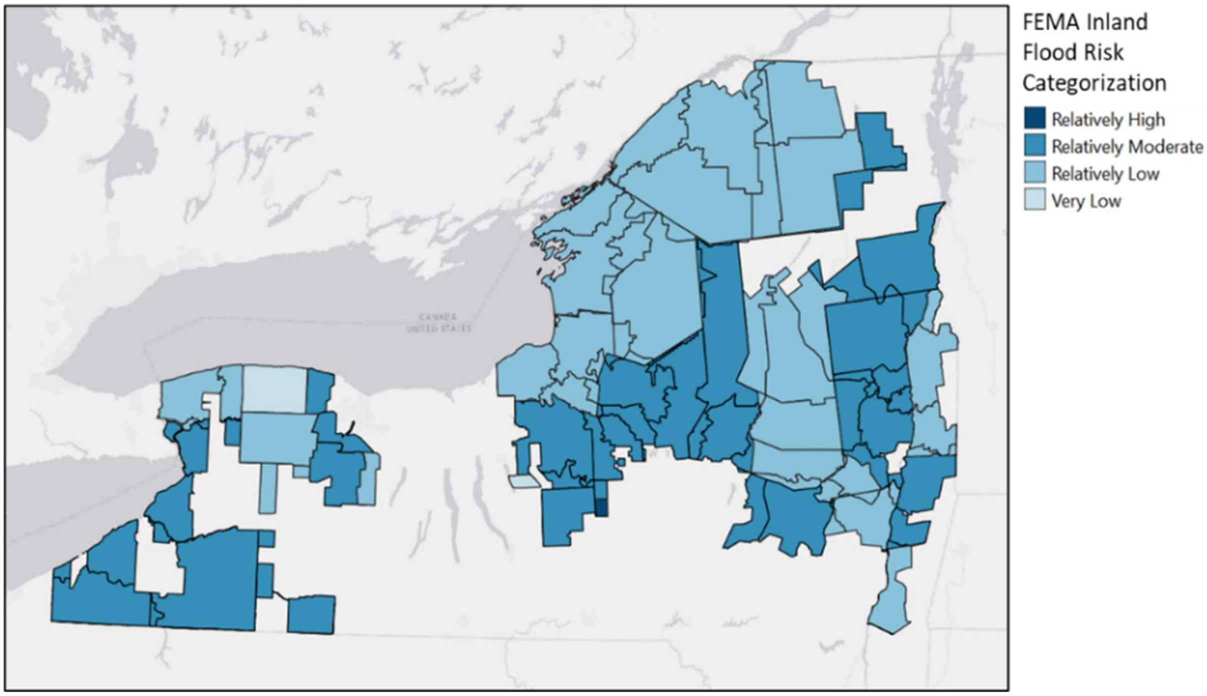
In the past, the warmer regions of the service territory have experienced extreme heat; daily average temperatures have rarely exceeded 32°C (89.6°F), but parts of the Hudson River Valley have seen this occur approximately once in every 10 years. Additionally, daily maximum temperatures have not historically exceeded 40°C (104°F) in any location across the National Grid service territory.

[33] Mean summer maximum daily temperatures are calculated by taking the average of all daily maximum temperatures across June, July, and August.

2.3.2 Inland Flooding

Historically, southwestern and eastern parts of the service territory, including the eastern portion of the Central Division (the Mohawk Valley) have experienced the highest inland flood risk. According to the FEMA riverine risk index, these regions still experience only *relatively moderate* exposure, and the majority of the rest of the service territory sees *relatively low* exposure (Figure 10). Inland flooding may be pluvial (precipitation-driven) or riverine (river overflowing), or a combination of both. High winds and heavy precipitation from tropical and extratropical cyclones drive both pluvial and riverine flooding.

Figure 10. FEMA-designated inland riverine flood risk levels across the National Grid service territory



2.3.3 Wind

Historically, extreme wind gusts in New York State have been driven generally by tropical cyclones and extratropical cyclones, which, while rare, can cause significant impacts to National Grid assets and operations. Land-falling tropical cyclones, for example, have occurred infrequently, as westerly winds divert hurricane tracks away from the coast in storms approaching the northeastern United States. Nevertheless, these storms can drive significant impacts when they move inland, such as high winds and flooding that extend beyond the coastal regions of the state. During Hurricane Ida in 2021, for example, high gusts exceeded 78 mph and were combined with extreme precipitation-driven and riverine flooding in many locations.

2.3.4 Ice

In the past, New York State recorded an average of 3-7 days per year with freezing rain, with northern regions experiencing slightly more days and southern regions experiencing slightly fewer. More extreme ice storms, however, which drive intense and prolonged impacts, are rarer. Severe historical storms on record have driven ice accumulations of 2-5 inches, which can persist for upwards of five days, especially when followed by a cold snap. In January 1998, for example, an ice storm over northern New York State caused more than 4 inches of radial icing, which lasted over 4 days in some colder areas. The storm was declared to be one of the worst ice storms on record in New York and drove widespread power outages across many of the northern portions of the state.

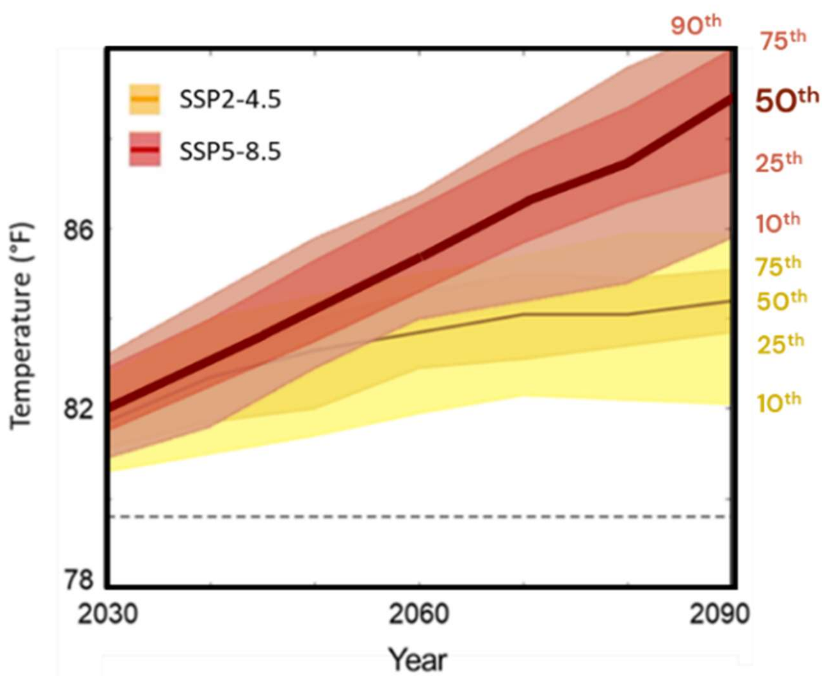
2.4 Climate Change Pathway Selection

Climate change projections provide a range of plausible climate futures reflecting uncertainty associated with both future greenhouse gas emissions trajectories and the sensitivity of Earth's climate to greenhouse gas emissions. Climate pathways narrow this range and provide standardized climate change projections to guide resilience efforts at National Grid. Ultimately, climate pathways represent the level of climate change the Company will incorporate into its planning to enhance existing resilience considering risks posed by future climate events.

National Grid adopted an approach to limit risk in climate planning by using SSP5-8.5, which represents a level of climate change commensurate with high future emissions levels, and the 50th percentile, or median of models, from the ensemble of 16 models provided by Columbia and NYSERDA. The selection of the SSP5-8.5 pathway at the 50th percentile reflects a range of considerations and criteria, including benchmarking against other utilities, analyzing the most up-to-date climate science, assessing current climate policies, and consideration of risk aversion levels to plan for and adapt to climate change while also providing co-benefits, including blue-sky functionality and resilient service to customers.

Figure 11 shows an example of the range of model projections across both SSP2-4.5 (yellow) and SSP5-8.5 (red). The bold dark red line signifies the pathway selected by National Grid. The figure illustrates the relative nature of this selection with the pathway falling at the higher range of model projections.

Figure 11. Example temperature projections through late century, showing two SSPs and full model ranges, with the selected pathway (SSP5-8.5) in bold dark red.



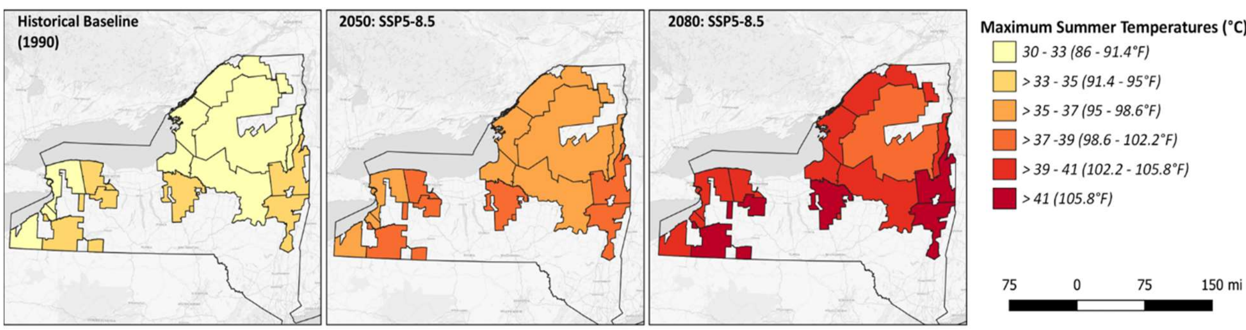
2.5 Future Climate Projections

2.5.1 Temperature

Average and extreme temperatures are projected to increase across the National Grid service territory, with the warmest temperatures projected to occur in the southwest, the southern Genesee, and the southern portion of the Central and Eastern region.

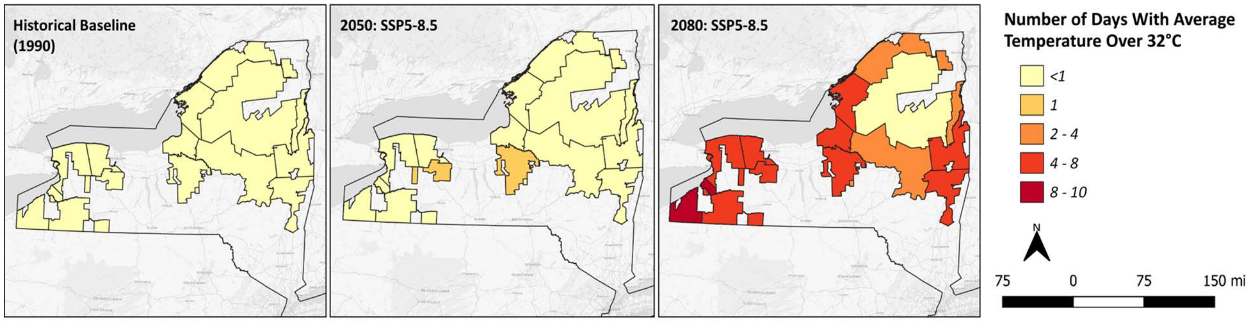
Historically, summer maximum temperatures have ranged geographically from 31.7°C (89°F) to 36.1°C (97°F), with cooler regions along the western shores of Lakes Erie and Ontario, and warmer regions in the interior. In the 2050s, summer maximum temperatures are projected to increase and range from 35°C (95°F) to 38.9°C (102°F), with Central, Northeast, and Capital regions projected to remain relatively warmer. By the late century (2080s), geographic trends of a cooler north and warmer south are projected to persist, and summer maximum temperatures are projected to see a larger increase ranging from 38.3°C (101°F) to 42.2°C (108°F). Figure 12 shows these increases across the service territory, with the leftmost panel showing the historical baseline, the middle panel showing projections for 2050s, and the rightmost panel showing projections for 2080s under the SSP5-8.5 50th percentile scenario.

Figure 12. Summer maximum temperatures in the National Grid service territory, across Baseline, 2050s, and 2080s



In addition to increasing summer maximum temperatures, projections reveal that the National Grid service territory may experience more days per year with average daily temperatures above 32°C (89.6°F) throughout the later part of the 21st century (2080s). Historically, daily average temperatures have infrequently exceeded this threshold in warmer parts of the service territory. Throughout the later part of the 21st century (2080s), the frequency of days with average temperatures exceeding 32°C (89.6°F) is projected to increase, with southern regions of the service area seeing largest increases. Fredonia, for example, is projected to see more than 8 days each year with average temperatures over 32°C (89.6°F) by 2080s, closely followed by Syracuse and Albany, which are projected to see more than 7 and 6 days, respectively (Figure 13).

Figure 13. Number of days with average temperatures over 32°C (89.6°F) in the National Grid service territory, across Baseline, 2050s, and 2080s



2.5.2 Inland Flooding

Climate change is projected to drive increases in inland flooding as precipitation becomes more variable and high-precipitation events become more intense. Within the National Grid service territory, the Syracuse, Troy, and Buffalo areas are projected to see the highest increases in rainfall through mid-century. These locations are thus likely to see heightened inland flood risk, with increased flood depth and more extensive floodplains due to increasingly extreme precipitation.

2.5.3 Wind

Climate change is projected to drive an increase in extreme weather events, which could increase wind gusts across the service territory. Near-term (2025-2041) projections based on MIT data show varied extreme wind gust speeds across the state, with regions around Lake Erie generally exhibiting the highest gusts. These areas are projected to experience 1-in-100-year wind gusts ranging from 100 to 120 mph, with the Buffalo region showing the highest potential wind gusts. Wind gusts in the northern and eastern regions of the service territory are projected to be relatively lower, with 1-in-100-year wind gusts generally ranging from 50 to 80 mph.

2.5.4 Ice

Warming temperatures do not preclude the potential for future icing events, and projections based on the MIT data indicate that near-future (2025-2041) ice storms could lead to a range of icing totals across the National Grid service territory. Icing totals are projected to be highest around Buffalo and the coastal regions of Lake Ontario, as well as along the St. Lawrence River, in the northwestern region of the service territory. Projections show that radial icing totals during the 1-in-100-year ice event in these locations could range from 0.5 to 0.9 inches. Southern and Central regions of the service territory are projected to see relatively lower icing totals.

2.6 Exposure Assessment

This section evaluates exposure of National Grid assets to four key climate hazards—high temperature (extreme heat), inland flooding, high winds, and ice—and identifies locations at which electric assets are likely to experience potential impacts. The exposure analysis focuses on three key asset groups: substations, transmission line, and distribution line. Sub-transmission line assets were examined as part of the distribution asset group. Findings for these generalized asset groups are assumed to represent exposure to specific equipment across the service territory. The exposure assessment provides raw exposure information based on combining climate hazard data and National Grid asset data. Specifically, the CCVS assessed the asset-hazard combinations shown in Table 3.

Table 3. Asset-hazard combinations analyzed in the exposure assessment

CLIMATE HAZARDS	Assets
High Temperature	Substations
	Distribution Overhead Conductors
	Transmission Overhead Conductors
Inland Flooding	Substations
High Winds	Distribution Poles and Sub-transmission Structures
	Transmission Structures
Ice	Distribution Poles and Sub-transmission Structures
	Transmission Structures

Datasets and methods used to calculate exposure differ across hazards. An overview of datasets and methods for each hazard is provided below, and findings from the assessment are provided in the subsequent subsections:

- **High Temperature (Extreme Heat)**: The Study used temperature projections developed by NYSERDA and Columbia University. Since these projections are not gridded and only developed for a set of weather stations across the service territory, assets were assigned to weather station projections using a nearest neighbor approach within each NYSERDA climate region. This approach allowed assets to be assigned to the closest weather stations while adhering to climate region outlines, which were designed to capture regional gradients in temperature, precipitation, and other climatological factors. The approach operates under the assumption that climate patterns are more similar in closer proximity.
- **Inland Flooding:** FEMA flood information was overlaid with substation data to determine inundation risk at substations as a result of a 100-year flood event. Additionally, to understand future flood risk, the Study used information from National Grid's in-house CCRT, which uses CMIP5 precipitation projections as a proxy for understanding changes in future inland floodplains. This forward-looking information was combined with FEMA flood designations to identify substations located in potential high flood risk areas in the future.
- **High Wind:** The CCVS overlaid high spatial resolution, gridded, dynamically downscaled wind speed projections developed by MIT onto National Grid's transmission, sub-transmission, and distribution line assets to evaluate segment-specific exposure.
- **Ice:** The CCVS overlaid high spatial resolution, gridded, dynamically downscaled radial icing projections developed by MIT onto National Grid's transmission, sub-transmission, and distribution line assets to evaluate segment-specific exposure.

2.6.1 High Temperature (Extreme Heat)

Both average and extreme temperatures are projected to increase across the National Grid service area throughout the later part of the 21st century (2080s), posing potential risks to electric assets. To understand present day and future exposure to temperatures, the Study analyzed the following variables:

- **Average summer daily maximum temperature –** average of all daily maximum temperatures in June, July, and August
- **Maximum summer daily maximum temperature –** maximum of all daily maximum temperatures in June, July, and August
- **Days with average temperature over 32°C (89.6°F) –** days per year with average temperatures exceeding 32°C (89.6°F)
- **Days with maximum temperature over 40°C (104°F) –** days per year with maximum temperatures exceeding 40°C (104°F)
- **Future Equivalent Temperatures to Present Day 35°C (95°F) –** temperatures representing the same annual probability of exceedance as historical 35°C (95°F) (i.e., temperatures with the same number of days per year showing exceedance as 35°C (95°F) has had in the past)

TEMPERATURE VIARIABLE SELECTION

The Study team developed projections for temperature variables tailored to the sensitivities of National Grid's system. For example, days with temperatures above 32°C (89.6°F) are relevant to transformer ratings, and maximum summer temperatures and days with temperatures over 40°C (104°F) are relevant to distribution line ratings.

The Study calculated asset-specific exposures for all substations, and distribution, sub-transmission, and transmission lines in the National Grid service territory by overlaying climate projections with asset locations. As described in earlier sections, the Study used a nearest neighbor approach within NYSERDA climate regions to assign assets to future climate projection data.

2.6.1.1 Substations

Substations across the National Grid service territory are exposed to increasingly extreme heat in the coming decades, with the largest average temperature increases occurring in the southern regions.

Frequency of Days with Average Temperatures over 32°C (89.6°F)

Across almost all regions of the service territory, daily average ambient temperatures at substations have not historically exceeded 32°C (89.6°F). Substations in the northern and southern regions of the Hudson River Valley are an exception, experiencing average ambient temperatures over 32°C (89.6°F) less than once per year. Projections show that instances of extreme heat could increase throughout the later part of the 21st century (2080s), with the highest increases occurring in the Western and Capital regions. Specifically, these projections indicate that substations across the service territory could experience up to 1 day more per year with average temperatures over 32°C (89.6°F) in 2050s, under the SSP5-8.5 50th percentile scenario, with a territory-wide average of < 1 days per year. Additionally, projections show that substations could experience up to 9 days per year with average daily temperatures over 32°C (89.6°F) by 2080s, with a territory-wide average of approximately 6 days per year.

Substations in the southern regions of the service territory are projected to see the most frequent extreme-heat days, while substations in the Northern and Northeast regions are projected to remain cooler and experience fewer days annually with average temperatures over 32°C (89.6°F) (Figure 14).

Figure 14. Change in total days per year with average ambient temperatures over 32°C (89.6°F) at substations, at Baseline, 2050s, and 2080s, under the SSP5-8.5 50th percentile scenario

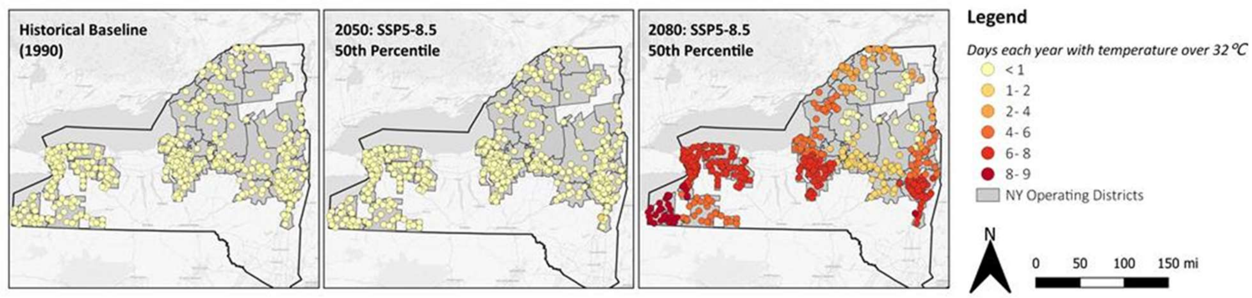
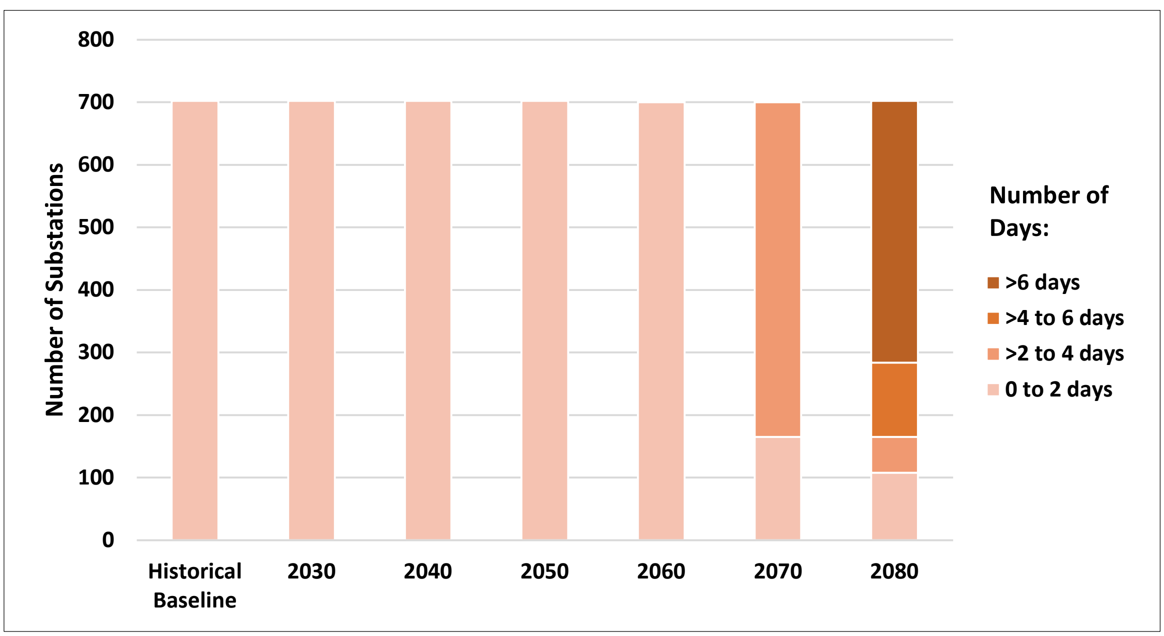


Figure 15 provides counts of substations falling within ranges of days with average daily temperatures exceeding 32°C (89.6°F). The figure illustrates an increase in days of threshold exceedance into the future. Prior to 2060S, *all* substations are projected to experience fewer than 2 days per year with average ambient temperatures over 32°C (89.6°F). However, more than half of substations are projected to experience more than 6 days per year over this threshold by 2080s, with substations in the southern parts of the service territory projected to see the highest totals at more than 8 days per year.

Figure 15. Number of substations experiencing total days per year with average ambient temperatures over 32°C (89.6°F)



2.6.1.2 Distribution Overhead Conductors

Projections show exacerbated and prolonged extreme heat at distribution overhead conductors, with largest maximum temperature increases occurring in the Eastern, Central, and Western regions of the service territory.

Intensity of Maximum Summer Temperatures

Historically, summer maximum ambient temperatures have ranged from 31.4°C (88.6°F) to 35.9°C (96.6°F) at distribution overhead conductors, and projections show that these temperatures could increase steadily throughout the latter part of the century. Specifically, projections indicate that summer maximum ambient temperatures at distribution conductors could range from 35.2°C (95.3°F) to 39.6°C (103.2°F) by 2050s under the SSP5-8.5 50th percentile scenario (Figure 16). By 2080s, distribution conductors in even the coolest regions of the service territory could experience summer maximum ambient temperatures reaching 38.4°C (101.1°F), which is 3.6°C (6.4°F) higher than those in the historically *hottest* regions have experienced in the past. Similarly, projections show that summer maximum ambient temperatures at distribution conductors in the hottest regions could reach 42.6°C (108.7°F) by 2080s, representing a 7.1°C (12.8°F) increase from the historical baseline. Distribution conductors in the Capital, Central, and Western regions of the service territory show the highest exposure to hotter summer maximum temperature.

Figure 16. Change in summer maximum ambient temperature at distribution overhead conductors at Baseline, 2050s, and 2080s under SSP5-8.5 50th percentile scenario

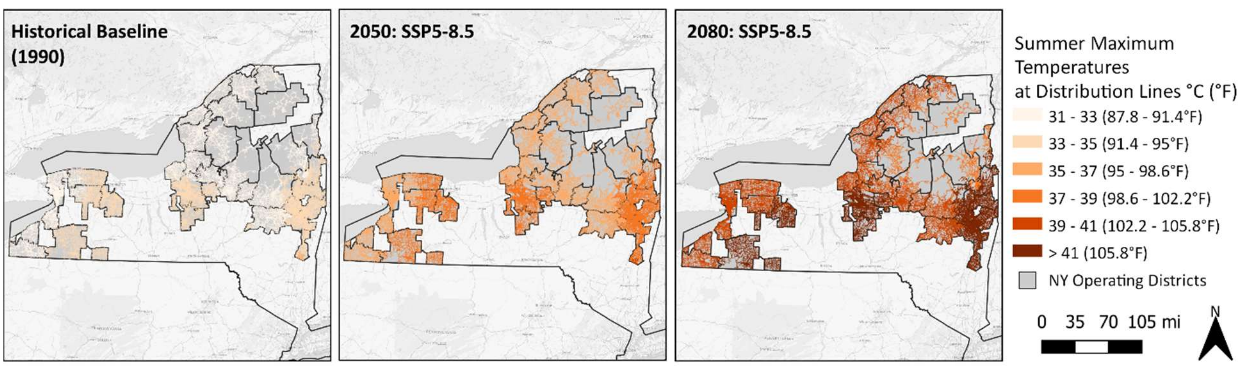
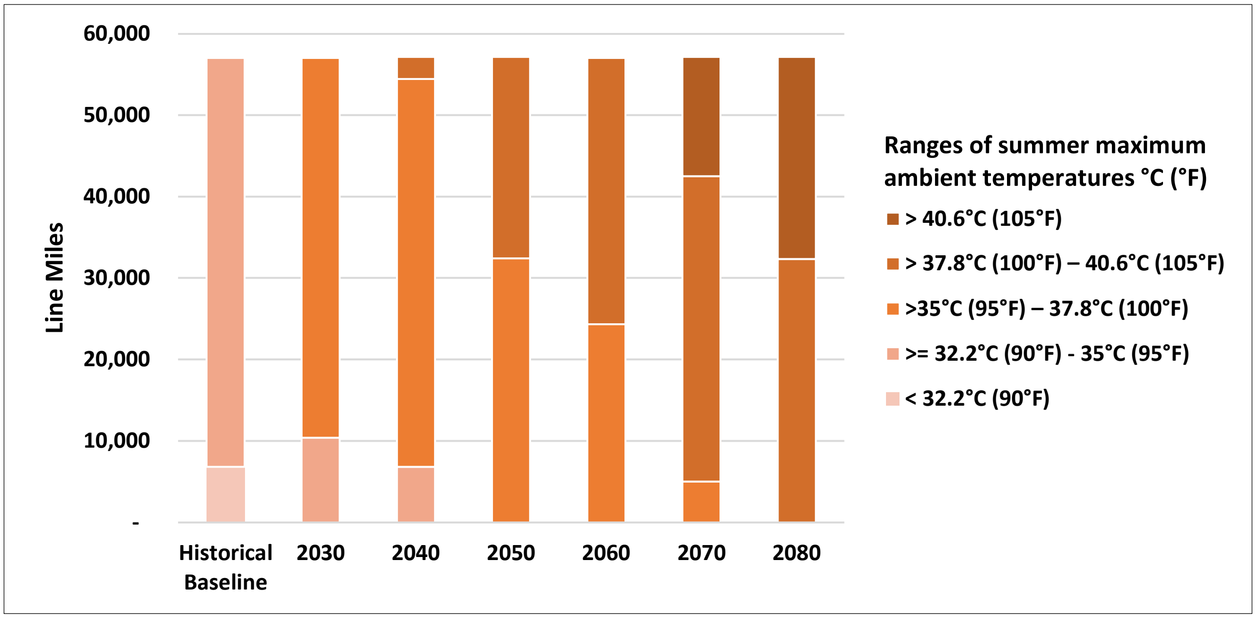


Figure 17 provides the total line mileage for distribution overhead conductors falling within different ranges of summer maximum ambient temperatures. While summer maximum temperatures have been below 37.8°C (100°F) across all distribution conductors in the past, 100% of conductors are projected to experience temperatures *exceeding* 37.8°C (100°F), and of that 43% of conductors, or 24,809 line miles, are projected to experience summer maximum temperatures exceeding 40.6°C (105°F) by 2080s.

Figure 17. Line mileage of distribution overhead conductors falling within ranges of summer maximum ambient temperatures

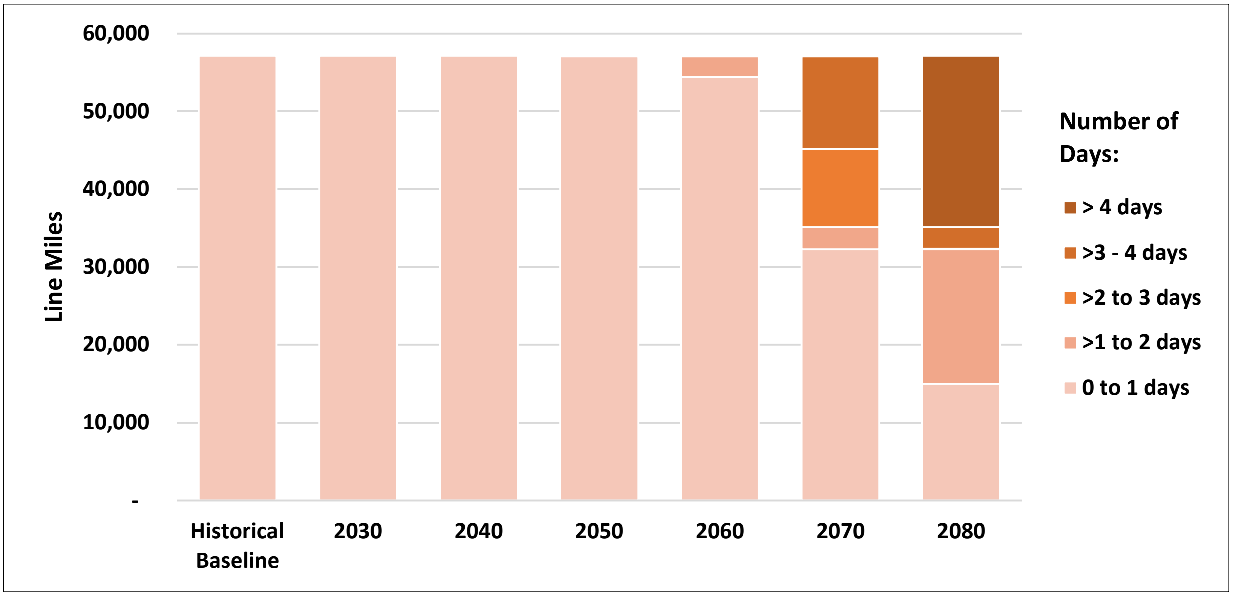


Frequency of Days with Daily Maximum Temperatures over 40°C

Historically, distribution overhead conductors across the National Grid service territory have not experienced daily maximum ambient temperatures over 40°C (104°F). Projections show small increases in days over 40°C (104°F) in warmer regions of the state by the 2050s, although distribution conductors in these regions are still projected to experience these hotter days less than once per year on average. Larger increases could occur through the later part of the 21st century (2080s); specifically, the Mohawk Valley and Capital regions of the service territory are projected to experience almost 9 days per year with maximum ambient temperatures over 40°C (104°F) by 2080s. In contrast, distribution conductors in cooler regions, or the Northern and Northeastern regions of the service territory, are projected to experience temperatures exceeding 40°C (104°F) less than once per year by 2080.

Figure 18 shows line mileage of distribution overhead conductors experiencing different ranges of days with daily maximum ambient temperatures exceeding 40°C (104°F). Notably, at baseline, 100% of line miles experienced less than one day per year with maximum temperatures over 40°C (104°F). By 2080s, however, 39% of line miles, or 22,060 miles, are projected to see more than 4 days per year above this threshold.

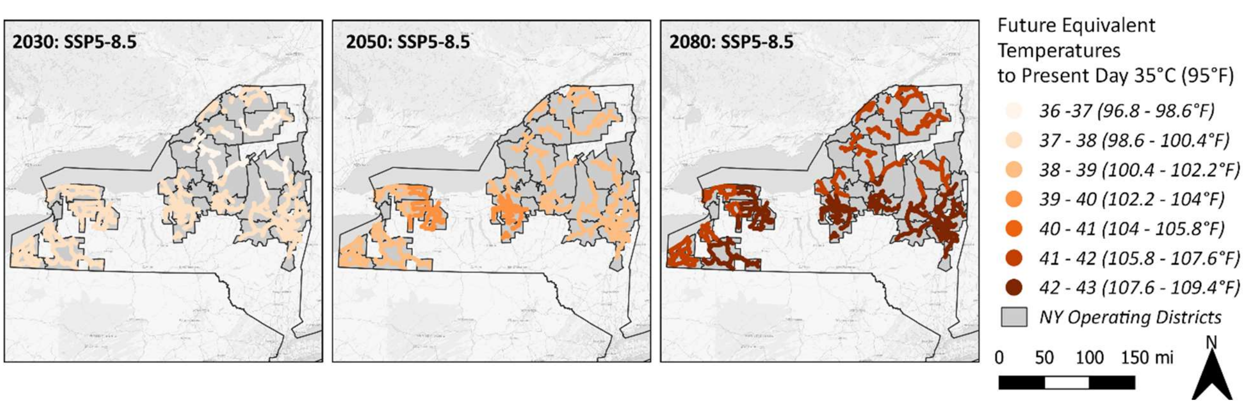
Figure 18. Line mileage of distribution overhead conductors experiencing ranges of days with daily maximum ambient temperatures over 40°C (104°F)



Future Equivalent Temperatures to Present Day 35°C (95°F)

Across the National Grid system, 35°C (95°F) represents an important threshold for sub-transmission lines. [34] This threshold has been exceeded at a range of rates, with warmer regions historically seeing higher rates of exceedance and cooler regions seeing lower rates. To understand how these might change in the future, the Study calculated the number of times per year 35°C (95°F) has historically been exceeded at each weather station and projected the future equivalent temperatures to 35°C (95°F), or the temperatures that have the same annual probability of exceedance in the future. Projections reveal that equivalent temperatures to the historical 35°C (95°F) threshold could range from approximately 38°C (100.4°F) to 40°C (104°F) in 2050, and from approximately 41°C (105.8°F) to 43°C (109.4°F) in 2080s, depending on location in the service territory (Figure 19).

Figure 19. Future equivalent temperatures to the historical 35°C (95°F) at sub-transmission lines in 2030s, 2050s, and 2080s, under the SSP5-8.5 50th percentile scenario



[34] The CCVS analyzed maximum ambient temperature relative to a threshold of 35°C due to its significance in National Grid sub-transmission line ratings.

2.6.1.3 Transmission Overhead Conductors

Transmission lines are also projected to experience increases in the intensity and frequency of extreme heat throughout the later part of the 21st century (2080s), with the largest increases occurring in the more southern regions of the state.

Future Equivalent Temperatures to Present Day 35°C (95°F)

Across the National Grid system, 35°C (95°F) represents an important threshold for National Grid's transmission overhead conductors.[35] This threshold has historically been exceeded at different annual frequencies across the service territory, with warmer regions historically seeing higher annual rates of exceedance and cooler regions seeing lower rates.

Projections reveal that equivalent temperatures with the same annual probability of exceedance to the historical 35°C (95°F) threshold could range from approximately 38°C (100.4°F) to 40°C (104°F) in 2050, and from approximately 41°C (105.8°F) to 43°C (109.4°F) in 2080, depending on location in the service territory (Figure 20). In warmer southern regions, where 35°C (95°F) has historically been exceeded on a relatively more frequent basis, these equivalent temperatures will similarly see higher levels of exceedance. Conversely, in northern cooler regions, where 35°C (95°F) was exceeded on a less frequent basis historically, future equivalent temperatures will also see lower rates of exceedance. Projections show the Capital, Central, Mohawk Valley, and parts of the Western regions exhibiting slightly higher future equivalent temperatures, when compared to the Northern and Northeastern regions (Figure 20).

Figure 20. Future equivalent temperatures to the historical 35°C (95°F) in 2030s, 2050s, and 2080s, at transmission lines, under the SSP5-8.5 50th percentile scenario.

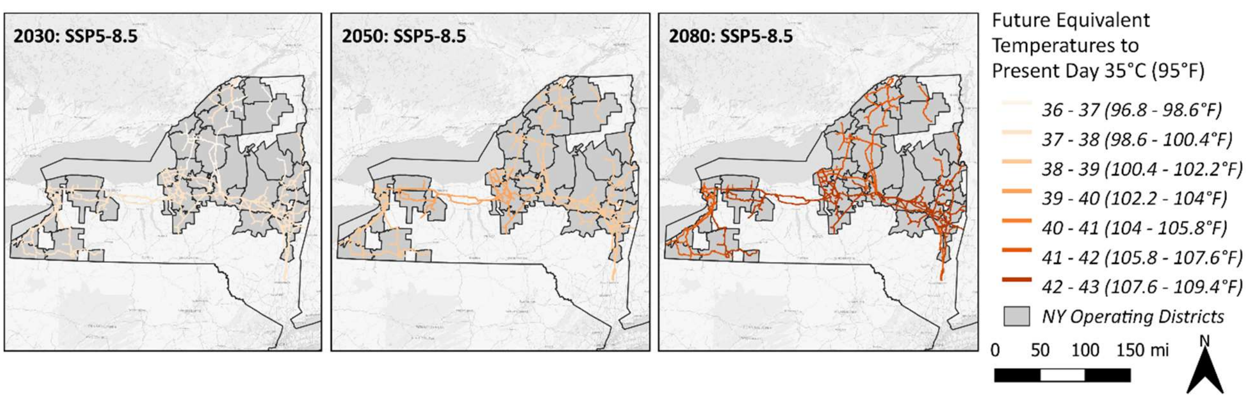


Figure 21 shows line mileage of transmission overhead conductors experiencing ranges of temperatures with the same annual probability of exceedance as the historical 35°C (95°F). Results reflect a notable shift toward warmer equivalent temperatures. By 2080s, 57% of line miles are projected to see equivalent temperatures between 42°C (107.6°F) and 43°C (109.4°C). Projections indicate that the remaining 43% could see equivalent temperatures between 41°C (105.8°F) and 42°C (107.6°F). While this manifests in different day exceedance totals in different locations, the figure illustrates that warming relative to historical temperatures is increasing across all locations in the service territory.

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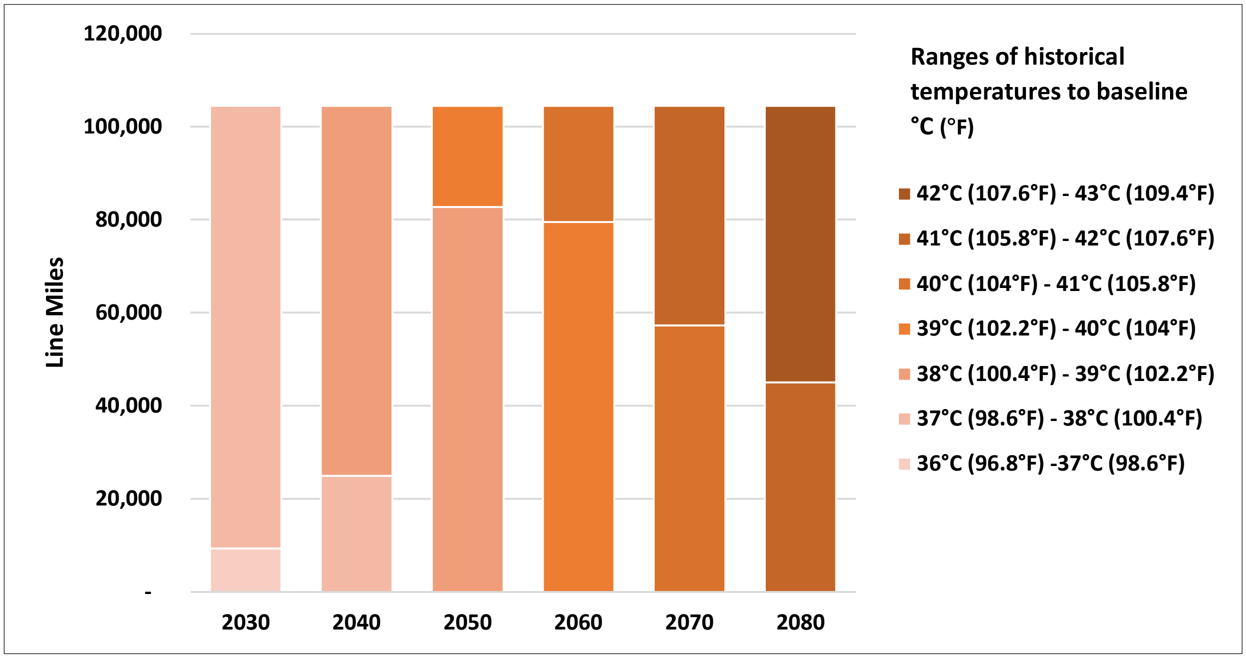
[35] The Study analyzed maximum ambient temperature relative to a threshold of 35°C (95°F) due to its significance in National Grid transmission line ratings.

Figure 21. Line mileage of transmission overhead conductors experiencing ranges of days with equivalent temperatures to baseline 35°C (95°F)



2.6.2 Inland Flooding

The Study evaluated inland flooding exposure using complementary datasets based on information on present-day FEMA floodplains and forward-looking projections of heavy precipitation from National Grid's CCRT.

2.6.2.1 Substations

The Study used FEMA-defined flood risk scores to evaluate present-day flooding exposure at substations throughout the service territory. Specifically, it screened for substation locations that correspond to the following flood risk categories:

- **High Risk:** 100-year flood zone
- **Moderate Risk:** 500-year floodplain
- **Low Risk:** areas of minimal flood hazard

Substations located in high flood risk areas are most frequently located near river systems throughout the service territory (Figure 22). Present-day FEMA risk scores show that approximately one tenth of substations, or 60 substations, are located in *high* flood risk regions. These high-risk areas include 34 distribution substations and 26 transmission substations, all of which are located in areas projected to experience inundation under the 100-year flood event. These substations are predominantly located in the Central and Eastern regions of the service territory.

Figure 22. Substations located in areas with different FEMA-designated flood risk levels; substations circled in orange represent substations with 'Very High' future flood risk as identified by National Grid's CCRT based on precipitation projections.

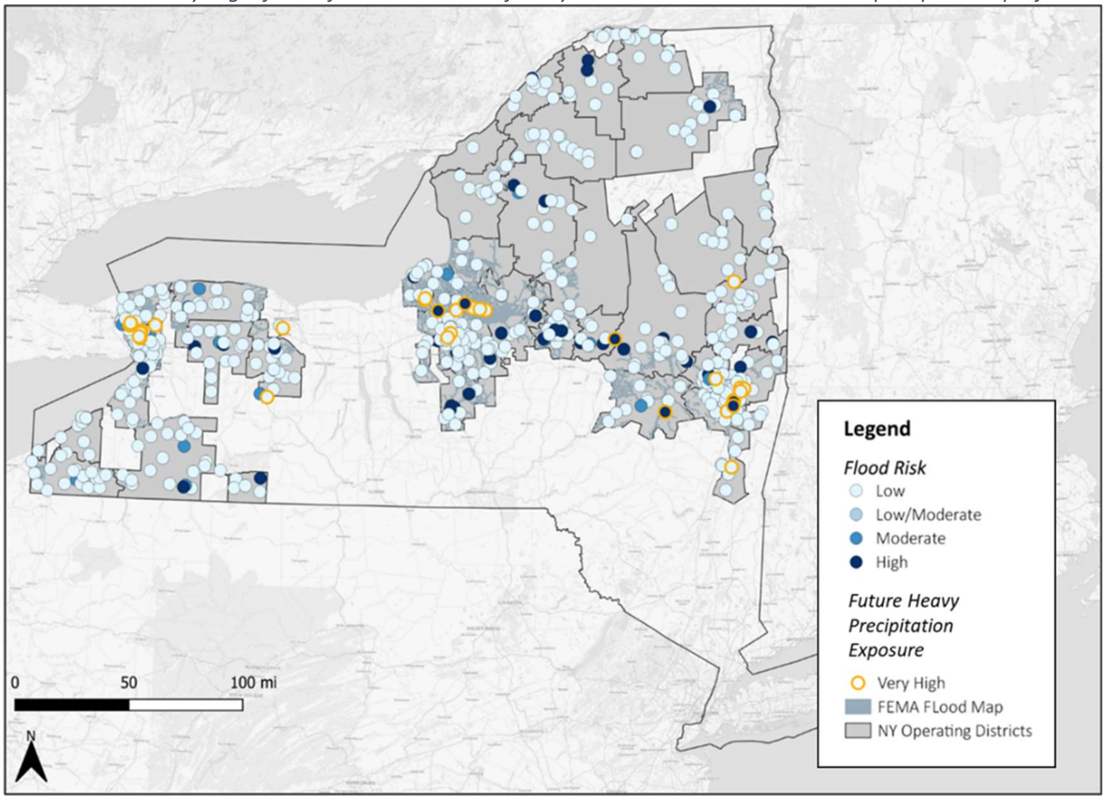


Table 4 shows the breakdown of substations presently in regions designated by FEMA as having high flood risk by substations type and service territory region. In addition, 22 substations are currently located in regions identified as *moderate* flood risk, and 630 are in areas designated by FEMA as *low* flood risk.

Table 4. Counts of National Grid substations located in FEMA-designated high flood risk areas by service territory region and substation type

REGION	Substation Type	Total Substations
Central	Distribution line	19
	Transmission line	13
East	Distribution line	12
	Transmission line	6
West	Distribution line	3
	Transmission line	7

To better understand future inland flood exposure, the Study supplemented FEMA flood risk ratings with information from National Grid's CCRT, which uses CMIP5 precipitation projections as a proxy for identifying substation locations that may face a greater likelihood of flooding in the future. These potentially high future precipitation areas are predominantly located around Syracuse, Troy, and Buffalo, but are scattered throughout the corridor from Buffalo to Albany (Figure 22).

2.6.3 High Winds

Climate change is projected to drive increasingly extreme weather events, which could increase wind gusts across the service territory. To evaluate exposure of distribution poles, and transmission and sub-transmission structures to extreme winds, the Study used wind speed projections developed by MIT for the near future (2025-2041), to derive projections of 1-in-10-year and 1-in-100-year maximum daily wind gusts, respectively. While 1-in-10-year represents a 10% annual likelihood of occurrence, 1-in-100-year represents a 1% annual likelihood of occurrence. The 1-in-100-year values represent more of a worst-case scenario and are used for systems with lower risk tolerances, such as transmission and sub-transmission lines. For distribution poles, higher frequency, lower impact, 1-in-10-year events were considered in the analysis. This approach is consistent with NESC standards traditionally used to inform line designs.

2.6.3.1 Distribution Poles and Sub-Transmission Structures

1-in-10-Year Wind Gusts

National Grid's distribution poles are projected to experience extreme wind gusts[36] as much as 100mph or greater, depending on location in the service territory. Distribution poles in the Great Lakes as well as a band extending from the Northwest portion of the Central region to the southern portion of the Capital region are projected to be subject to particularly high wind gusts, with 1-in-10-year wind gusts reaching approximately 120-130 mph (Figure 23).

Figure 23. 1-in-10-year near century (2025-2041) maximum wind gust speeds (mph) at National Grid distribution poles across the service territory

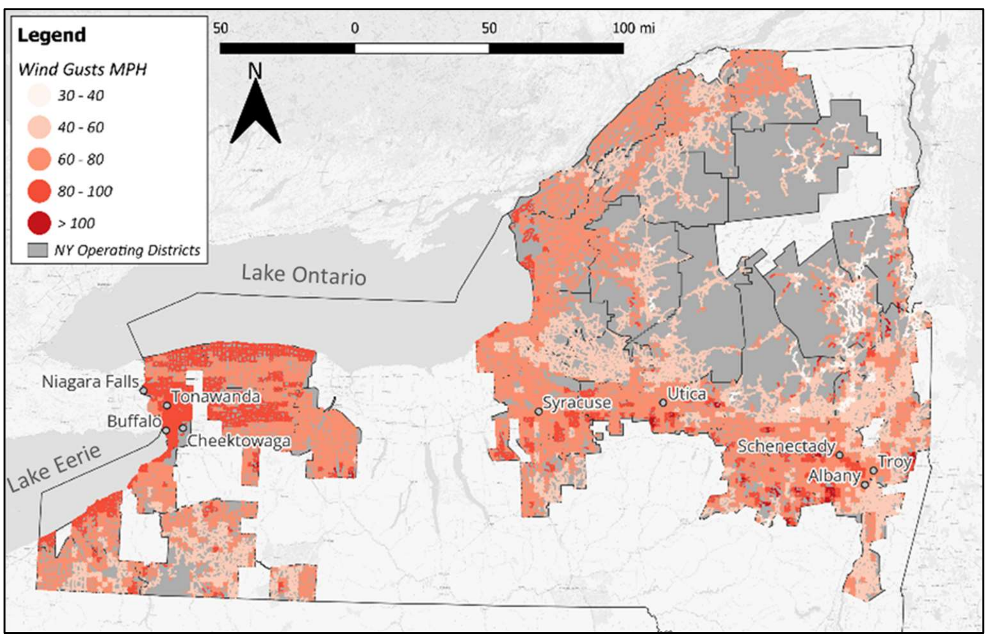
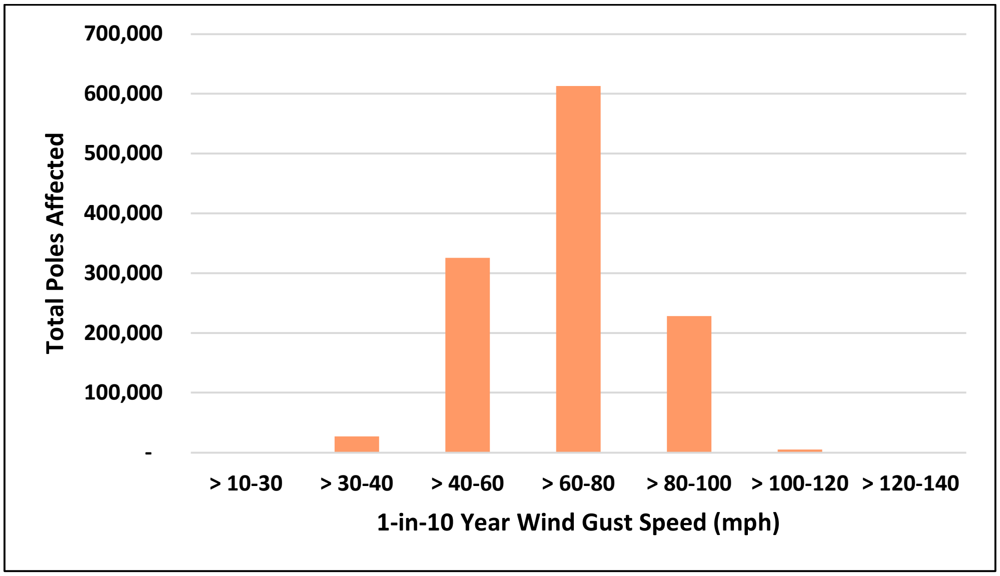


Figure 24 shows the number of distribution poles falling within ranges of projected 1-in-10-year maximum near-century (2025-2041) wind gusts. It shows that most distribution poles, or approximately 78% of poles, are projected to experience 1-in-10-year wind gusts between 40 and 80 mph. A smaller

[36] The National Weather Service defines a wind gust as a sudden, brief increase in speed of the wind. According to U.S. weather observing practice, gusts are reported when the peak wind speed reaches at least 16 knots and the variation in wind speed between the peaks and lulls is at least 9 knots. The duration of a gust is usually less than 20 seconds.

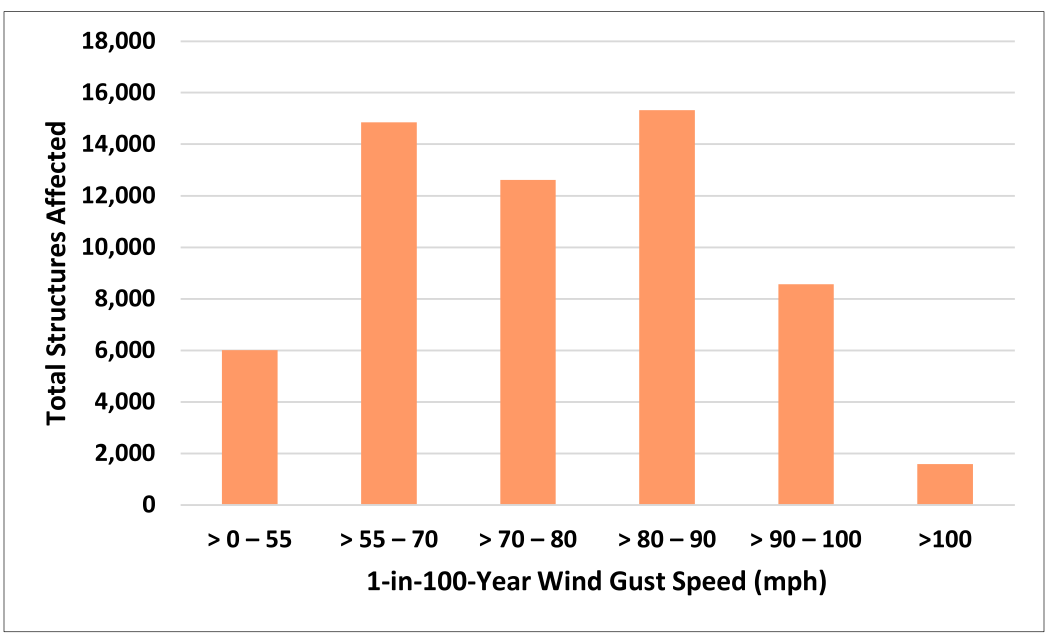
portion, or 19% of distribution poles, may experience 1-in-10-year gust speeds between 80 and 100 mph, while an even smaller portion, or less than 1%, are projected to experience higher intensity wind gusts (>100mph).

Figure 24. Number of distribution poles falling within ranges of projected near century (2025-2041), 1-in-10-year maximum wind gusts



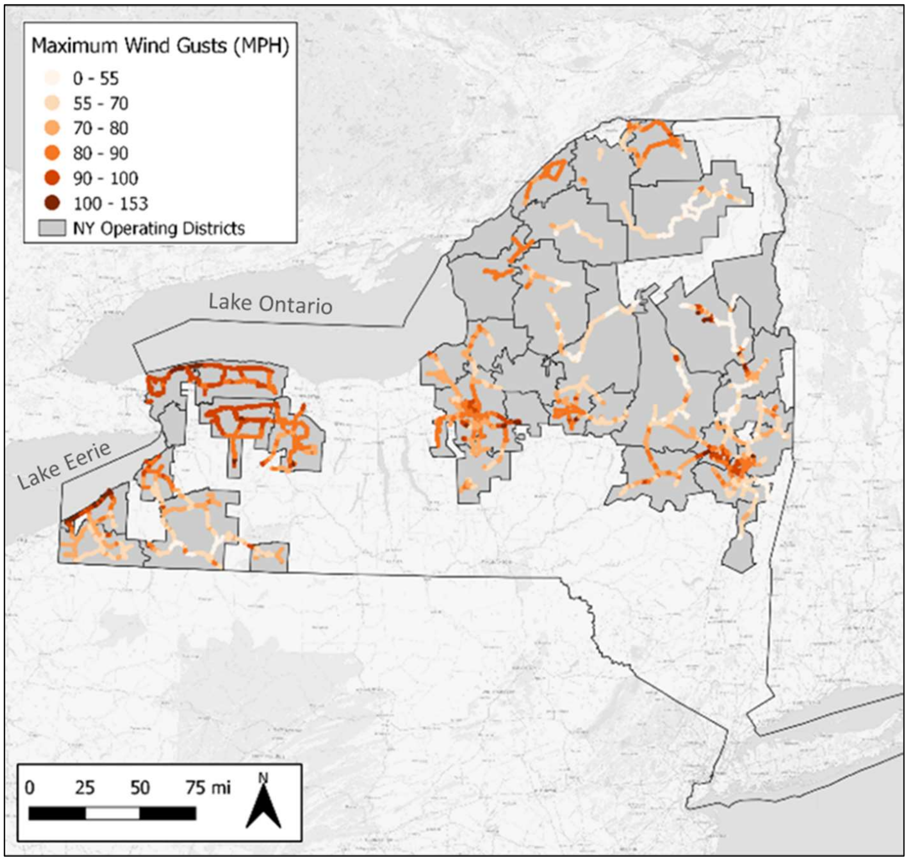
Additionally, projections show that almost 40% of sub-transmission structures could see 1-in-100-year wind gusts above 80 mph. Of this subset, 1,585 structures, or 2% of all sub-transmission structures, could see 1-in-100-year wind gusts reaching over 100 mph (Figure 25).

Figure 25. Number of sub-transmission structures falling within ranges of projected near century (2025-2041), 1-in-100-year maximum wind gusts



Projections for sub-transmission structures show similar geospatial trends to those exhibited by distribution poles, with relatively higher wind gusts occurring at sub-transmission structures in the Great Lakes and Lower Mohawk Valley regions (Figure 26). Meanwhile, sub-transmission structures in the Adirondacks region are projected to see relatively lower wind gust speeds, ranging from approximately 55 to 70 mph.

Figure 26. 1-in-100-year near century (2025-2041) maximum wind gust speeds (mph) at National Grid sub-transmission structures across the service territory



2.6.3.2 Transmission Structures

1-in-100-Year Wind Gusts

The Study analyzed potential exposure of transmission structures to 1-in-100-year extreme wind gusts. Projections show that broad segments of transmission corridors along Lake Erie could experience 1-in-100-year wind gusts exceeding 100 mph (Figure 27). In addition, transmission structures in the Mohawk Valley could also experience elevated and impactful wind gusts.

Figure 28 shows the number of transmission structures falling within ranges of 1-in-100-year maximum wind gusts. Notably, almost half of National Grid's transmission structures are projected to experience 1-in-100-year wind gusts below 80 mph. Meanwhile, approximately 33% of transmission structures are projected to experience 1-in-100-year wind gusts between 80 and 100 mph, while a smaller portion (11%) are projected to experience the most extreme gusts of over 100 mph.

Figure 27. 1-in-100-year near century (2025-2041) maximum wind gust speeds (mph) at National Grid transmission poles across the service territory

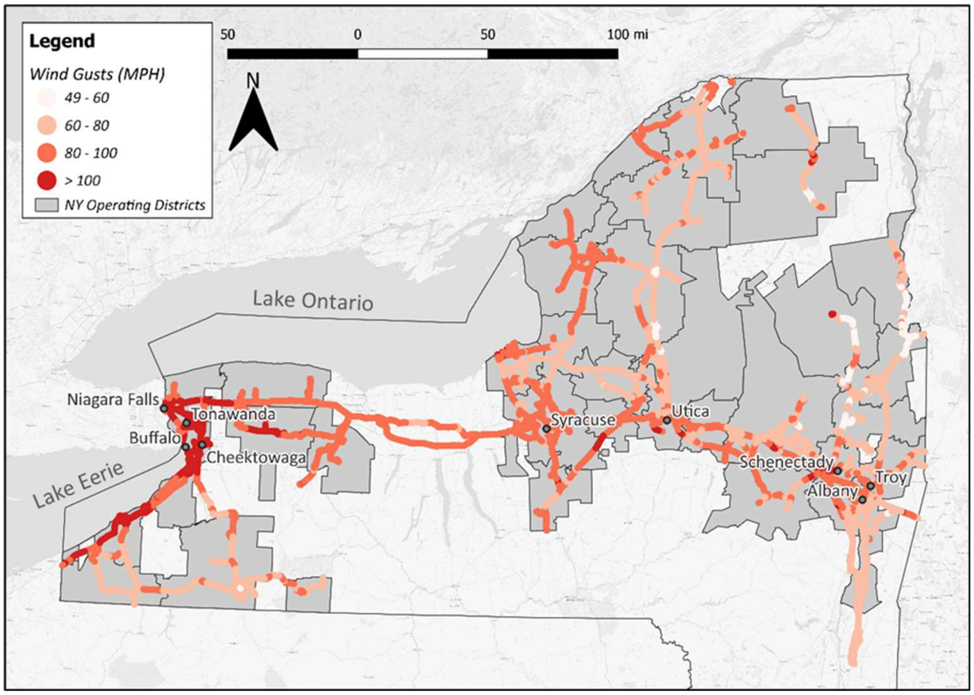
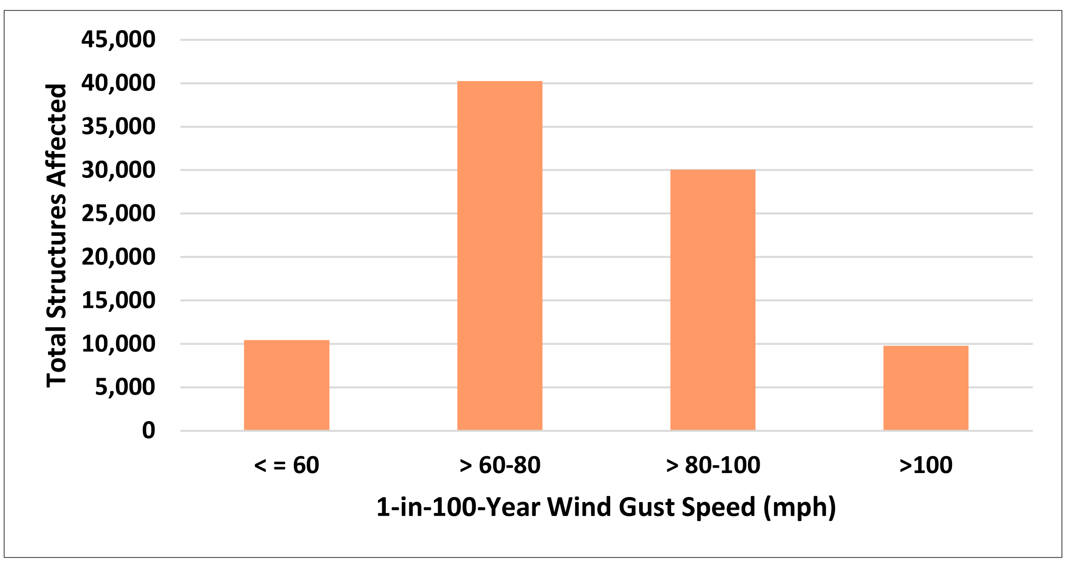


Figure 28. Number of transmission structures within ranges of projected near century (2025-2041) 1-in-100-year maximum wind gusts.



2.6.4 Ice

Radial icing events occur when moisture and precipitation freeze and build up on an exposed line, such as distribution or transmission conductors. Radial icing can have adverse effects on energy infrastructure as the added weight can cause line sag, mechanical and electrical line failure, or other consequences that result in electric infrastructure damage and outages. Projections show that assets across the service territory may face significant icing events in the near term. The Study used near-term (2025-2041) radial icing projections developed by MIT to derive projections of radial icing totals for 1-in-10-year and 1-in-100-year events, to evaluate potential exposure of distribution poles, and transmission and sub-transmission structures respectively. While 1-in-10-year represents a 10% annual likelihood of occurrence, 1-in-100-year represents a 1% annual likelihood of occurrence. The 1-in-100-year values represent more of a worst-case scenario and are used for systems with lower risk tolerances, such as transmission and sub-transmission lines. For distribution poles, higher frequency, lower impact, 1-in-10-year events were considered in the analysis. This approach is consistent with NESC standards traditionally used to inform line designs.

2.6.4.1 Distribution Poles and Sub-Transmission Structures

1-in-10-Year Radial Icing Events

Projections show that distribution poles along the shoreline of Lakes Erie and Ontario, as well as the northwest and northern portion of the Central region, and some interior areas along a historical band, are within ranges of 1-in-10-year radial icing events. This historical band begins in the northwest portion of the Central region and runs in a southeasterly direction to the Albany area. Areas west of the Capital region, near Cobleskill, are projected to see 1-in-10-year event with highest totals of radial icing reaching 0.6 to 0.9 inches (Figure 30). Assets in the Western region, including in the Buffalo area, are similarly projected to see 0.5 to 0.6 inches of total radial icing during the 1-in-10-year event, and projections show these high totals to be far more geographically extensive than those around Albany. Assets in the Central region, near Syracuse, are projected to see comparatively lower radial icing totals from 1-in-10-year event than other portions of the service territory.

UNDERSTANDING EXPOSURE OF DISTRIBUTION LINE ASSETS TO PROJECTED WIND AND ICE IMPACTS

Recent extreme events like ice storms provide insights on concurrent impacts from climate hazards, such as wind and ice. National Grid carried out a multi-variate analysis to better understand the ability of existing distribution and sub-transmission assets, including poles, conductors, transformers, and structures, to withstand combined impact from wind and icing. National Grid used various banded wind gust levels and radial icing accumulation data for its service territory. It then used in-house data analytics tools to geo-locate and join the wind and ice data to specific feeder and circuit data. It used an in-house mapping tool to subsequently enhance the data and provide additional granularity at the level of a single pole/structure (Figure 29). This user-friendly mapping tool is helping National Grid develop insight into the viability of existing structures under concurrent wind and ice conditions and identify assets that may likely be affected.

Figure 29. Visual from National Grid's in house mapping tool to identify distribution and sub-transmission assets likely affected by combined wind and ice

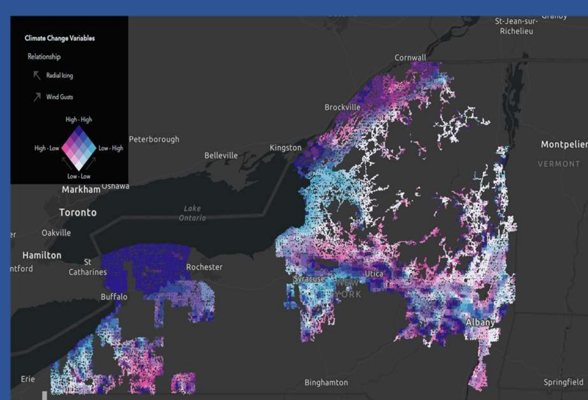


Figure 30. Ranges of total radial icing (inches) for near-century (2025-2041) 1-in-10-year icing event at National Grid distribution poles across the service territory.

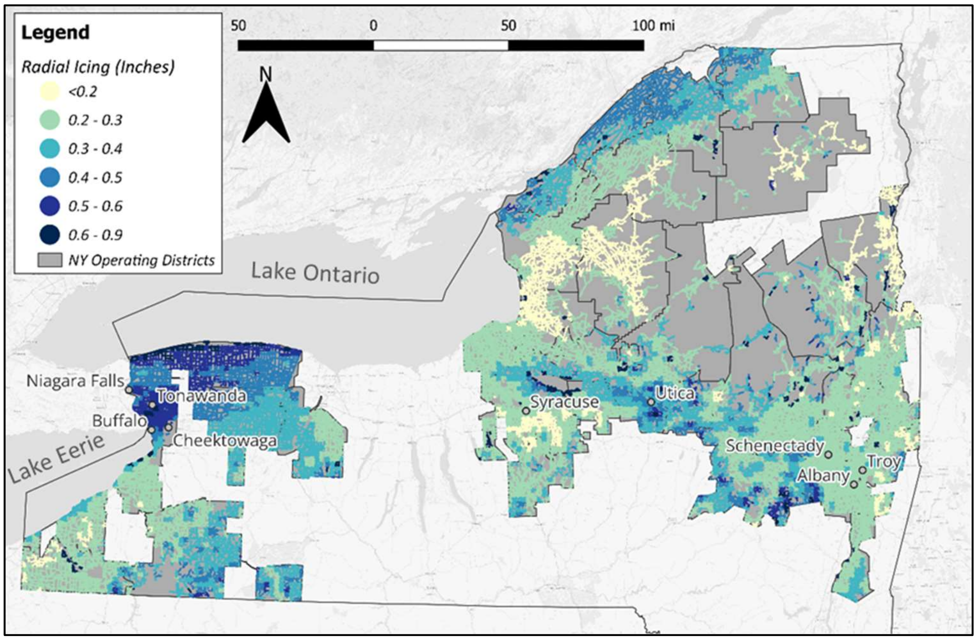
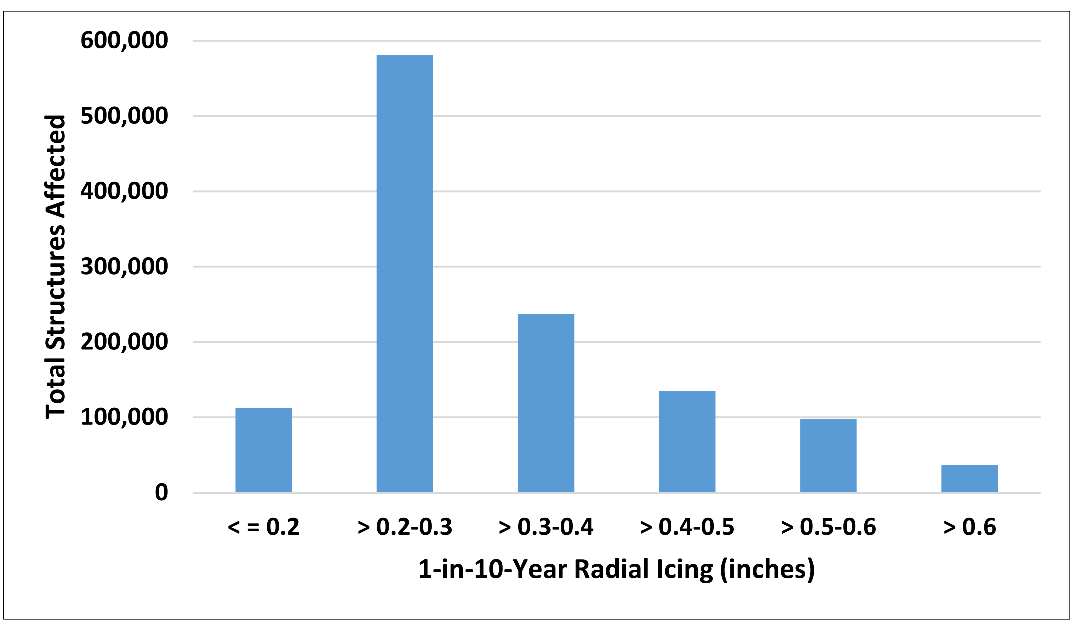


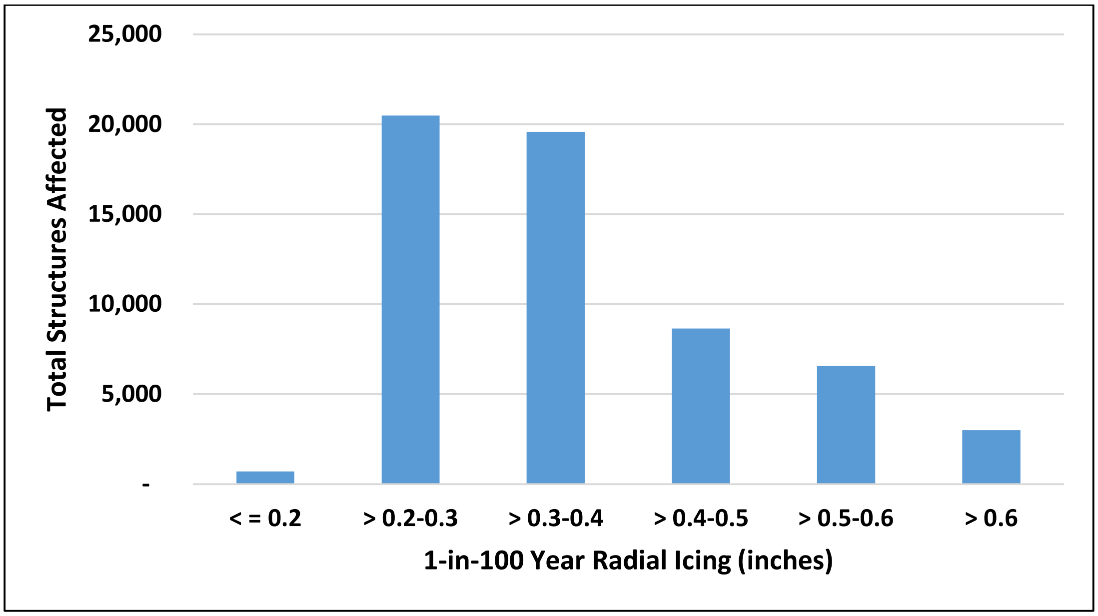
Figure 31 shows the number of distribution poles within ranges of total radial icing from 1-in-10-year event. The figure shows that the vast majority of distribution poles (as many as 78%) are projected to experience total radial icing of less than 0.4 inches. A smaller yet still significant portion (19%) of distribution poles is projected to experience 1-in-10-year radial icing totals between 0.4 and 0.6 inches, while 3% of distribution poles could see more than 0.6 inches of radial icing.

Figure 31. Number of distribution poles within ranges of projected total radial icing for near century (2025-2041) 1-in-10-year icing event



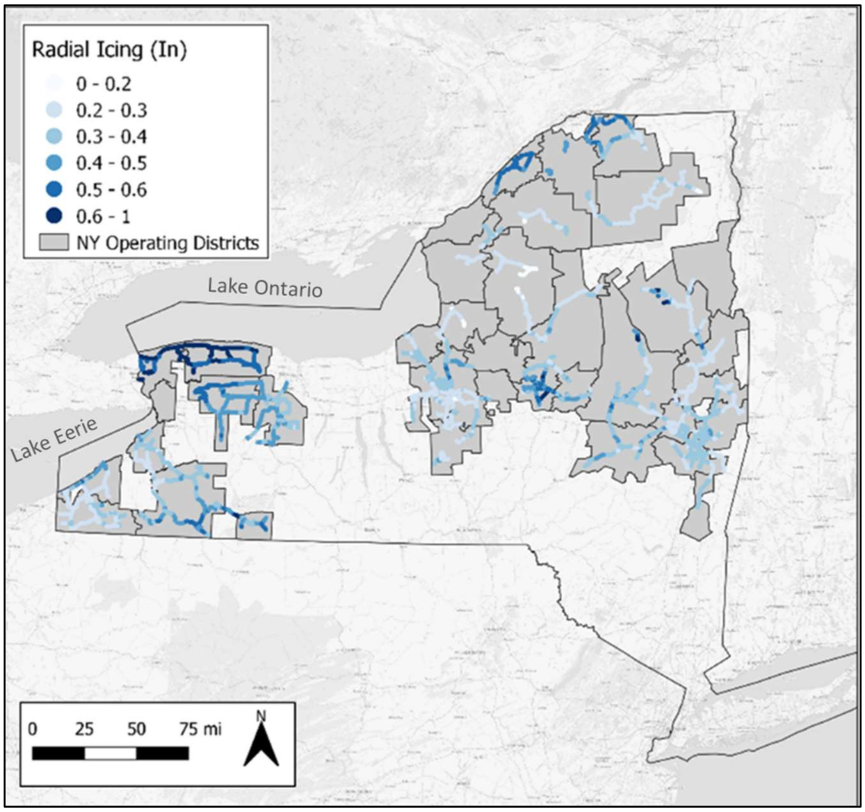
Additionally, projections show that the majority of sub-transmission structures could experience less than 0.4 inches of 1-in-100-year total radial icing, with more than half of structures seeing over 0.4 inches of icing. Only 5% of sub-transmission structures are projected to see more than 0.6 inches of total radial icing (Figure 32).

Figure 32. Number of sub-transmission structures within ranges of projected total radial icing for near century (2025-2041) 1-in-100-year icing event



Projections indicate similar spatial trends to those exhibited by distribution poles, with extensive high radial icing totals in the western portion of the service territory, near Buffalo and along the southwest coastline of Lake Ontario (Figure 33). Meanwhile, sub-transmission structures in the Central Division, near to and north of Syracuse, are projected to see lower totals of radial icing for 1-in-100-year event.

Figure 33. Ranges of total radial icing (inches) for near century (2025-2041) 1-in-100-year icing event at National Grid sub-transmission structures across the service territory

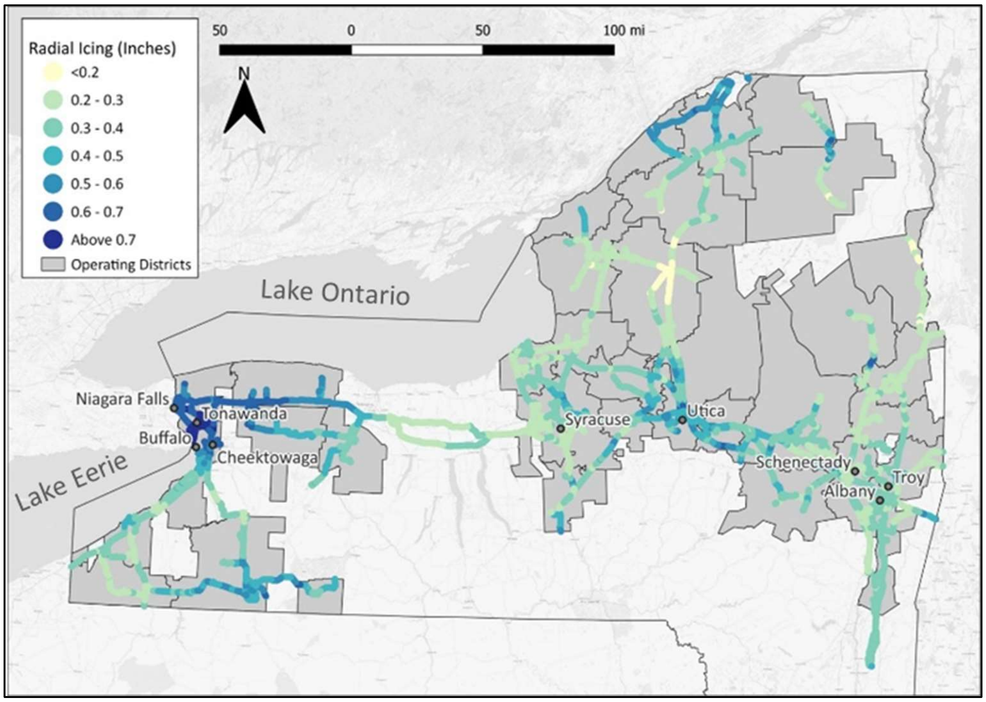


2.6.4.2 Transmission Structures

1-in-100-Year Radial Icing Events

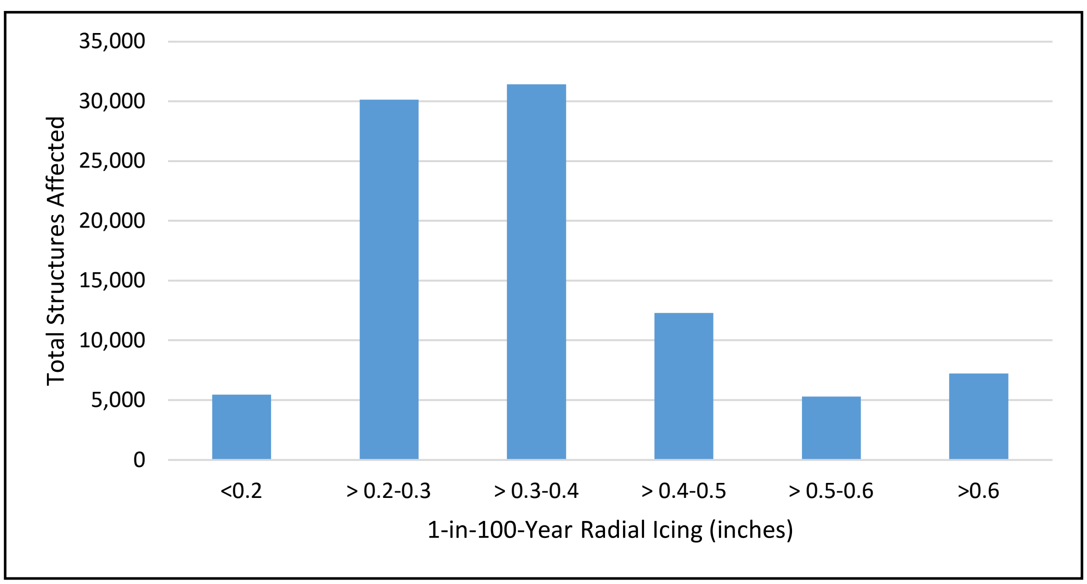
Transmission structures in the western division of the service territory, near Buffalo, are projected to see the 1-in-100-year event with highest totals of radial icing, at more than 0.7 inches (Figure 34). On the other hand, transmission structures in the Central region, north of Utica, are projected to see some of the lowest radial icing totals, at less than 0.2 inches.

Figure 34. Ranges of total radial icing (inches) for near century (2025-2041) 1-in-100-year icing event at National Grid transmission structures across the service territory



Approximately 73% of transmission structures in the National Grid service territory are projected to see 1-in-100-year events with radial icing totals of 0 to 0.4 inches (Figure 35). Meanwhile, 19% of transmission structures could see between 0.4 and 0.6 inches of total radial icing in the 1-in-100-year event, and 7% could see the most extreme totals of more than 0.6 inches.

Figure 35. Number of transmission structures within ranges of projected total radial icing for near century (2025-2041) 1-in-100-year icing event



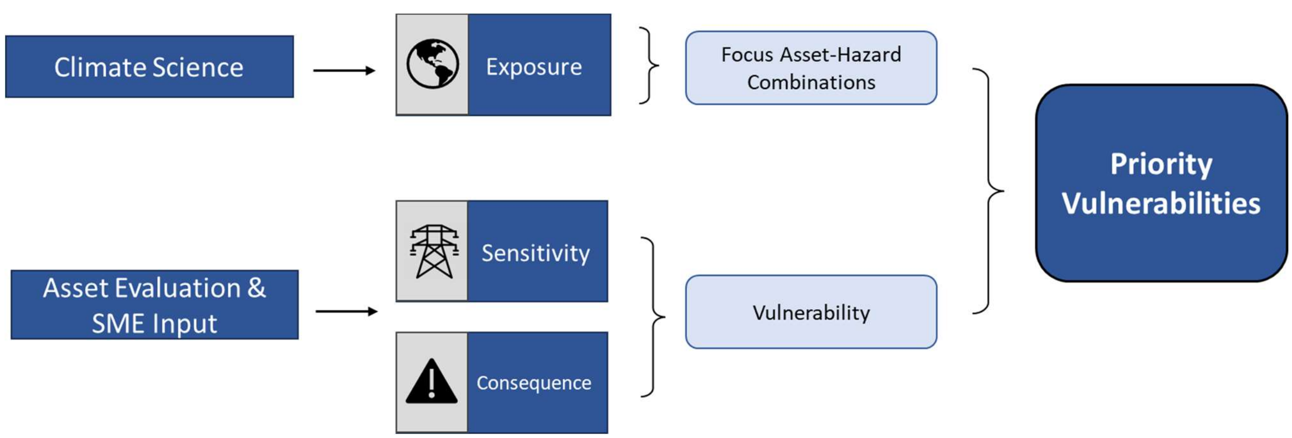
3. Vulnerability Assessment

Vulnerability represents the potential for National Grid's assets and operations to be adversely impacted by projected climate hazards and the significance of associated outcomes for National Grid's systems, services, and customers. National Grid assessed the vulnerability of its assets and operations to high temperature (extreme heat), inland flooding, high winds, and ice, all of which were identified as key climate hazards based on projections of climate data for the service territory and inputs from subject matter experts who reviewed a range of climate hazards that can potentially impact electric assets. Climate projections, asset evaluations, and inputs from National Grid's subject matter experts served as the cornerstones for these assessments.

3.1 Approach to Assess Asset Vulnerability

This section discusses National Grid's approach to assessing the vulnerability of its assets to climate hazards, based on the results of the exposure analysis and subsequent evaluation of their sensitivity and consequence ratings. Assets were grouped into three main asset families: substation, transmission line, and distribution line. Figure 36 graphically summarizes the approach.

Figure 36. Vulnerability assessment approach for National Grid assets



The first step in the vulnerability assessment process was to evaluate exposure. Exposure represents the degree to which assets could face changes in climate hazards within the Study timeframe (which extends out to the 2080s), based on their physical locations and the magnitude of future changes in climate. The latest climate science was used to determine exposure of National Grid assets to four key climate hazards across National Grid's service territory: extreme heat (high temperature), inland flooding, high winds, and ice (see Section 2.6 for a detailed discussion of exposure methods and results). Asset-hazard combinations were subsequently evaluated for sensitivity and consequence ratings.

3.1.1 Sensitivity Ratings

Sensitivity represents the degree to which National Grid's assets could be negatively affected by exposure to a climate hazard. For each climate hazard, the sensitivity of different assets was evaluated and rated by National Grid's subject matter experts based on their experience and understanding of the technical specifications of electric assets and applicable standards. The asset groups evaluated include substation, transmission line, and distribution line. Each asset group is composed of critical components and sub-components that contribute to the functionality and reliability of National Grid's electric system. Each asset type has a specific sensitivity to each climate hazard and these sensitivities were rated on a scale of low, medium, and high. Assets that are not expected to be exposed to a particular climate hazard were assigned a rating of "not applicable" or N/A. For example, because underground conductors are not exposed to high winds, their sensitivity is rated as N/A.

The criteria for sensitivity ratings are as follows:

- Assets were considered to have **low** sensitivity if they experienced no or minimal adverse impact, such as accelerated degradation or sudden failure, when exposed to a given climate hazard.
- Assets were considered to have **medium** sensitivity if:
  - Adverse impacts are only likely at high thresholds of exposure, such as very high temperatures or flooding levels.
  - Adverse impacts are more likely to be chronic/controlled rather than sudden/acute (e.g., accelerated degradation rather than sudden failure).
- Assets were considered to have **high** sensitivity if:
  - They may be subject to an increased risk of major or sudden failure in the event of exposure to a given climate hazard.
  - Existing protection or adaptation measures for the asset are typically limited or nonexistent (e.g., electrical substations without flood protection walls).

3.1.2 Consequence Ratings

Consequence represents the magnitude of negative outcomes for National Grid's systems, customers, and/or operating personnel, when an asset is damaged. Consequence incorporates the criticality of assets, as well as any existing ability to cope with impacts (also known as adaptive capacity). Unlike sensitivity ratings, consequence ratings are *independent* of exposure to climate hazards. Consequence ratings focus strictly on the outcomes that may occur if the operational status and functionality of assets or asset groups were impeded. Similar to sensitivity, consequences were also rated on a scale of low, moderate, and high. The criteria for the consequence ratings are as follows:

- Assets were considered to have a **low** consequence rating if the impact to the asset is likely to result in minor or minimal adverse outcomes (e.g., several customers losing service for minutes to several hours with minor repair costs).
- Assets were considered to have a **medium** consequence rating if impact to the asset is likely to result in significant adverse outcomes, including sustained outages[37] in localized areas, safety risks to the public or utility personnel, and/or costly repairs.
- Assets were considered to have a **high** consequence rating if the potential for hazards to affect sensitive assets could result in widespread or long-duration outages[38], severe or numerous injuries, and/or major financial impacts.

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[37] Sustained outages are those that interrupt services for several hours and automatic restoration is unsuccessful.

[38] Widespread outages are those that affect a large region or several regions in the service territory; long duration outages are those lasting 24 hours or more.

3.1.3 Vulnerability Ratings

After sensitivity and consequence ratings were assigned to each asset or asset-hazard combination, the ratings were combined to derive asset vulnerability ratings, as shown in Table 5. Vulnerability can thus be understood as the magnitude of negative outcomes (i.e., consequence) when a climate hazard exceeds the asset's ability to withstand it (i.e., sensitivity). Therefore, the vulnerability rating is a valuable indicator that communicates not only if an asset could be impacted by a given climate hazard, but also the criticality of the impact to National Grid's systems and operations if that asset is damaged or fails. Vulnerability ratings range from low (pale blue cells) to medium (sky blue cells) to high (dark blue cells). Where sensitivity is rated as N/A, vulnerability rating is also rated as N/A; this is represented by gray cells.

Table 5. Rubric for asset vulnerability ratings based on sensitivity and consequence ratings

		Vulnerability Rating			
Consequence Rating	High	N/A	**Medium**	**High**	**High**
	Medium	N/A	**Low**	**Medium**	**High**
	Low	N/A	**Low**	**Low**	**Medium**
		N/A	Low	Medium	High
		Sensitivity Rating			

3.2 Identified Asset Vulnerabilities

Vulnerabilities are presented by climate hazard (high temperature, inland flooding, high winds, and ice) and asset group (transmission line, distribution line, and substation), with reference to specific sub-assets (such as conductors, transformers, capacitors, etc.) in each group.[39]

Vulnerability ratings together with the findings from the exposure analysis (discussed in Section 2.6), informed which asset-hazard combinations represent **priority vulnerabilities** for National Grid. Priority vulnerabilities represent the asset-hazard combinations with the highest potential for negative outcomes for National Grid, in the event of exposure to that climate hazard. These priority vulnerabilities will be considered for further evaluation and will be the focus of resilience recommendations in National Grid's CCRP. Table 6 shows the identified priority vulnerabilities for National Grid assets, denoted by a check mark.

[39] The sensitivity, consequence, and vulnerability ratings of all assets evaluated in the Study are presented in detail in Appendix C - Detailed Results from Asset Vulnerability Assessment showing Sensitivity, Consequence and Vulnerability Ratings for National Grid Assets.

Table 6. Identified priority climate vulnerabilities for National Grid assets

ASSET GROUP	High Temperature	Inland Flooding	High Winds	Ice
Transmission Line	✓		✓	✓
Distribution Line	✓		✓	✓
Substation	✓	✓		

The asset-hazard combinations representing priority vulnerabilities are discussed in detail in the following subsections and tables. The high vulnerability ratings shown in the tables are a helpful indicator to identify priorities where resilience efforts can be beneficial. However, the identification and prioritization of resilience projects and recommendations in the CCRP will be based on a number of criteria, including technical knowledge and experience of National Grid experts who will support the identification of specific vulnerable assets for resilience interventions.

3.2.1 High Temperature

As discussed in Section 2.6, both average and maximum temperatures are projected to increase across the National Grid service territory, throughout the later part of the 21st century (2080), posing potential risks to National Grid's electric assets. Considering future temperatures in today's designs is important because many assets have long service lives (50+ years) and will need to withstand changes in future conditions.

3.2.1.1 Transmission Line

Transmission overhead conductors and switches have medium vulnerability to high temperatures. Although overhead transmission lines are typically rated for high temperatures, ambient temperatures that are significantly higher than assumed when rating the line, coupled with higher demand associated with high temperatures, could result in excessive sag and flashover to vegetation (and other objects under the line) and subsequent line outages. National Grid rates its transmission lines for operation at a summer ambient temperature of 35°C (95°F).

National Grid conducted an analysis to quantify the impact of increasing ambient temperatures on overhead transmission conductors. The analysis used temperature projections from the Columbia/NYSERDA dataset. The analysis evaluated transmission line capacity for temperatures of 40°C (104°F) and 42°C (107.6°F). In 2080, the likelihood of experiencing an ambient temperature of 40°C (104°F) will be approximately equivalent to the likelihood of experiencing the current planning temperature of 35°C (95°F). For completeness, the highest temperature projected for the National Grid service territory in 2080, 42°C (107.6°F), was also evaluated. The analysis found 5% and 7% reductions in normal transmission line ratings would be necessary to account for the projected temperatures of 40°C (104°F) and 42°C (107.6°F) respectively.

Underground transmission lines are not considered to be vulnerable to high temperatures because ground temperatures are relatively stable, particularly at the burial depths of transmission lines. Underground transmission lines that incorporate cooling such as circulating oil systems also reduce their sensitivity to external heat. All vulnerability ratings for high temperature and transmission line assets are shown in Table 7.

Table 7. Vulnerability of transmission line assets to high temperature

TRANSMISSION LINE	Sensitivity	Consequence	Vulnerability
Line structures (Poles/towers)	N/A	High	N/A
Conductors (Overhead)	Med	Med	Med
Conductors (Underground)	N/A	High	N/A
Switches	Med	Med	Med

3.2.1.2 Distribution Line

Among the many critical sub-components within National Grid's distribution system, overhead and pad-mounted transformers are considered the most vulnerable to high temperatures. Notably, higher ambient temperatures reduce transformer thermal loading capacity. This reduction in capacity, coupled with higher demand associated with high temperatures, increases the rate of aging and marginally increases the risk of failure. The increasing frequency, severity, and duration of heat waves due to climate change has the potential to increase the replacement rate of transformers by accelerating aging and increasing failure rates. All vulnerability ratings for high temperature and distribution line assets are shown in Table 8.

Table 8. Vulnerability of distribution line assets to high temperature

DISTRIBUTION LINE	Sensitivity	Consequence	Vulnerability
Structures (Overhead)	N/A	Med	N/A
Conductors (Overhead)	Med	Low	Low
Conductors (Underground)	Low	Med	Low
Switches	Med	Low	Low
Transformers (Overhead)	High	Med	High
Transformers (Pad mount)	High	Med	High
Regulators (Pole mounted)	Med	Med	Med
Capacitors (Pole mounted)	Med	Low	Low

3.2.1.3 Substations

Substation transformers and circuit breakers are highly sensitive and considered vulnerable to the impacts of higher temperatures. National Grid rates its substation transformers based on a daily average ambient air temperature of 32°C (89.6°F). Temperatures that exceed this threshold lower the transformer's effective capacity by 1-1.5% per 1°C increase.[40] Higher ambient temperatures, coupled with higher demand associated with high temperatures, increase the rate of aging, reduce transformer life, and marginally increase the risk of failure. The result of the exposure assessment indicates that substations across the service territory could experience up to 1 day more per year with average

[40] IEEE Standard C57.91-2011, Guide for Loading Mineral Oil-Immersed Transformers and Step-Voltage Regulators, Table 3.

temperatures over 32°C (89.6°F) in 2050s and some up to 8 days per year with average daily temperatures over 32°C (89.6°F) by 2080s.

National Grid also conducted an analysis of the impact of future climate on substation transformer capacity and rate of aging. The analysis used climate projections for ambient temperature, the basis that National Grid currently uses for rating substation transformers and modeled the impact of ambient temperatures and loading on a set of representative transformers. The analysis also explored options to address the impacts that were identified. The results of the analysis will be included as part of the upcoming CCRP.

National Grid rates its circuit breakers based on a daily maximum ambient temperature of 40°C, according to IEEE C37.04. Higher ambient temperatures can reduce the effective capacity of a circuit breaker by around 1% for each 1°C increase and can increase the rate of aging.[41] All vulnerability ratings for high temperature and substation assets are shown in Table 9.

Table 9. Vulnerability of substation assets to high temperature

SUBSTATIONS	Sensitivity	Consequence	Vulnerability
Substation transformers	High	High	High
Circuit breakers	Med	High	High
Protection & control devices	Low	Med	Low
Instrument transformers (CTs and PTs)	Med	Med	Med
Control room/ Control house	Low	High	Med

3.2.2 Inland Flooding

Inland flooding, including pluvial (precipitation-driven) or riverine (river overflowing) flooding, presents a high risk to substations located in National Grid's service territory. High-risk substations are scattered throughout the National Grid service territory but are typically located near river systems.

Transmission and distribution line assets are generally not considered to have a high sensitivity to flooding unless floodwaters compromise the structural integrity of wood or steel structures or the foundation, causing washouts. For this reason, only the results from the substation analysis are discussed in detail.

3.2.2.1 Substations

Substations are vulnerable to the impacts of flooding and contain equipment that is highly sensitive to water. Severe flooding and heavy precipitation events can damage equipment, which can shorten its life expectancy and can lead to failures, which in turn can affect system reliability. Substation transformers, protection and control devices, circuit breakers, and instrument transformers, specifically, are unable to tolerate inundation without significant disruption or failure. Although transformer tanks are generally hermetically sealed, making precipitation and flooding unlikely to impact the internal components of a transformer, water from these events may enter and damage the transformer control cabinet, fans, pumps, external wiring connections, and other accessories.

Although new substation construction exceeds FEMA flood plain design standards (100-year flood elevation plus 2 feet), some existing substations are located in floodplains and are at an elevated risk of exposure and heightened vulnerability to the hazard. Besides considering the results from the exposure

[41] IEEE Standard C37.04-1999, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers. ICF analysis.

assessment, SMEs from National Grid also evaluated each substation based on topography, existing location above FEMA floodplain, criticality of that substations in terms of the number of customers it serves, and any existing or planned flood mitigation measures. These factors will be considered in identifying and prioritizing substations that will be recommended for flood mitigation projects in the CCRP. Vulnerability ratings for flooding and substation assets are shown in Table 10.

Table 10. Vulnerability of substation assets to inland flooding

SUBSTATIONS	Sensitivity	Consequence	Vulnerability
Substation transformers	High	High	High
Circuit breakers	High	High	High
Protection & control devices	High	Med	High
Instrument transformers (CTs and PTs)	High	Med	High

3.2.3 High Winds

Climate projections show potential increases in extreme wind gusts in the coming decades, which may result in greater vulnerability of wind-sensitive assets, such as transmission and distribution structures and overhead lines. As discussed in Section 2.6, the Study team leveraged MIT-generated projections to derive 1-in-10-year and 1-in-100-year maximum daily wind gust data to understand the exposure of National Grid's distribution line and transmission line assets, respectively.

Substation control enclosures are built to withstand wind loads conforming to the latest IBC/ASCE 7 codes/standards. These structures are typically constructed with steel and reinforced concrete masonry walls, which make critical damage from wind events unlikely. Due to the generally low sensitivity of substation components to wind loading, only the results from the analysis of transmission line and distribution line assets are discussed in detail.

3.2.3.1 Transmission Line

Transmission line structures, which are comprised of poles and towers, are considered vulnerable to conditions of extreme wind. Transmission pole structures and towers within National Grid's transmission system are designed to meet, at minimum, the wind speeds outlined in the NESC, which are gusts of 90 mph for the National Grid service territory. In most cases, existing poles and structures meet the new NESC 2023 95mph wind gust design guidance. Extreme wind speeds over 95mph may increase the risk of transmission structure failures, especially for single pole structures. Vulnerability ratings for high wind and transmission line assets are shown in Table 11.

Table 11. Vulnerability of transmission line assets to high wind

TRANSMISSION LINE	Sensitivity	Consequence	Vulnerability
Line structures (Poles/towers)	High	High	High
Conductors (Overhead)	Med	Med	Med
Conductors (Underground)	N/A	High	N/A
Switches	Low	Med	Low

3.2.3.2 Distribution Line

Similar to National Grid's transmission system, overhead distribution structures are also vulnerable to the impacts of extreme wind. High-to-extreme winds may cause pole failure, particularly during ice storms and in conjunction with vegetation impacts or aging infrastructure. National Grid accounts for wind in its distribution system by designing to withstand 40mph wind speeds, which is in accordance with the NESC's most stringent requirement. Vulnerability ratings for high winds and distribution line assets are shown in Table 12.

Table 12. Vulnerability of distribution line assets to high wind

DISTRIBUTION LINE	Sensitivity	Consequence	Vulnerability
Structures (Overhead)	High	Med	High
Conductors (Overhead)	High	Low	Med
Conductors (Underground)	N/A	Med	N/A
Switches	Low	Low	Low
Transformers (Overhead)	Low	Med	Low
Transformers (Pad mount)	Low	Med	Low
Regulators (Pole mounted)	Low	Med	Low
Capacitors (Pole mounted)	Low	Low	Low

3.2.4 Ice

Although rare, projections of more extreme and frequent ice storms in the New York State area are expected to lead to adverse impacts that may result in greater vulnerability of ice-sensitive assets, such as transmission and distribution structures and overhead conductors.

Substation control enclosures are generally built to withstand ice hazards and house their protection and control devices in cabinets to mitigate exposure and risk of icing, although this could vary based on the severity of the event. National Grid experienced some temporary impacts from ice accumulation on substation components during Winter Storm Elliot (in December 2022) that did not result in equipment damage. Due to general low sensitivity of substation components to ice events, only the results from the analysis of transmission line and distribution line assets are discussed in detail.

3.2.4.1 Transmission Line

Transmission line structures, including poles and towers, and overhead conductors are generally highly vulnerable to the impacts of ice. Transmission towers are built with a defined tolerance for ice loading; however, icing above this level can result in pole or tower failure, which can lead to structure failure. Depending on system configuration and operating conditions at the time, structure failures may result in circuit outages affecting a wide area of the service territory and significant numbers of customers.

Conductors and attachments are also designed with a defined tolerance for ice loading, but, like line structures, icing above this level can result in conductor or attachment failure. Ice accumulation on vegetation may also result in vegetation contact with conductors and contribute to failure. Icing may also lead to flashovers on transmission insulators. After the 1998 Ice Storm, which caused significant power outages, National Grid revised its transmission design standard to increase the assumed ice accumulation from 1 inch to 1.5 inches, as a customized heavy ice condition. As discussed in Section 2.6.4, around 7% of National Grid's transmission structure could see more than 0.6 inches of radial ice accumulation during 1-in-100-year events, while majority of the structure (around 73%) are projected to see radial icing totals between 0 to 0.4 inches, which is within range of National Grid's current design standard for ice – indicating potentially lower sensitivity and consequences related to such events. Vulnerability ratings for ice events and transmission line assets are shown in Table 13.

Table 13. Vulnerability of transmission line assets to ice

TRANSMISSION LINE	Sensitivity	Consequence	Vulnerability
Line structures (Poles/towers)	Med	Med	Med
Conductors (Overhead)	Med	Med	Med
Conductors (Underground)	N/A	High	N/A
Switches	Med	Med	Med

3.2.4.2 Distribution Line

Overhead distribution line structures are also highly vulnerable to icing events. Distribution structures, including poles and cross arms, are built with a defined tolerance for ice loading. However, icing above these levels may result in damage. Accumulation of ice on structures with long spans increases the likelihood of downed poles due to increased tension from the conductor on the poles and cross arms. National Grid accounts for ice in its distribution system by designing to withstand ½ inch of ice accumulation, which is in accordance with the NESC's most stringent requirement. Vulnerability ratings for icing events and distribution assets are shown in Tabl2 14.

Table 14. Vulnerability of distribution line assets to ice

DISTRIBUTION LINE	Sensitivity	Consequence	Vulnerability
Structures (Overhead)	High	Med	High
Conductors (Overhead)	High	Low	Med
Conductors (Underground)	N/A	Med	N/A
Switches	High	Low	Med
Transformers (Overhead)	Med	Med	Med
Transformers (Pad mount)	N/A	Med	N/A
Regulators (Pole mounted)	Med	Med	Med
Capacitors (Pole mounted)	Low	Low	Low

3.3 Planning and Operational Vulnerabilities

Resilience to climate change cannot be achieved through hardening of physical infrastructure alone; companies must also be internally and operationally prepared to adapt to changing climate and weather conditions. Where climate hazards severely impact assets, changes in operating procedures and practices may be necessary to maintain service reliability for customers. Thus, in addition to assessing the physical vulnerability of assets to climate change, as discussed in Section 3.2, the CCVS also evaluated potential impacts to National Grid's operations and planning processes.

This assessment was based primarily on input and feedback from National Grid's subject matter experts across functional areas. These areas included operations, emergency response, load forecasting, reliability, and capacity planning. The documents reviewed included public rate filings, company specifications, operating and emergency response procedures, and environmental health and safety standards. National Grid has taken a proactive approach to addressing how climate threats may impact its operational and planning processes. Although significant efforts have already been made in this direction, National Grid continues to build resilience of its operations and procedures to current and future impacts of climate change. The following analysis of planning and operational vulnerability is qualitative in nature and intended to help identify potential impacts from climate hazards that may affect the operations and performance of distinct functional groups. The operations and planning functions that were reviewed are shown in Figure 37.

Figure 37. Functions assessed to understand potential climate impacts on operations and planning

Table 15 summarizes the results from the planning and operational review, indicating climate hazards of most concern to each functional area (shown with check marks). The following sections discuss each of these operations and planning functions in more detail.

Table 15. Identified climate hazards with potential impacts on operations and planning functions

OPERATIONS AND PLANNING FUNCTIONS	High Temperature	High Winds	Inland Flooding	Ice
Emergency Response	✓	✓	✓	✓
Vegetation Management		✓	✓	✓
Workforce Safety and Methods	✓	✓	✓	✓
Reliability Planning	✓	✓	✓	✓
Load Forecasting	✓			
Capacity Planning	✓			

3.3.1 Emergency Response

National Grid's NY Electric Emergency Response Plan (ERP) guides the management of responses to electric outages caused by storms and other natural disasters, civil unrest, major equipment failure, cyber events, or other emergency events. The ERP provides the framework for the orderly response of the Company and Company-managed resources during emergency events. The ERP uses the National Incident Management System as a guide to a comprehensive approach to incident management that is applicable at all levels of National Grid's Emergency Response Organization (ERO) and across functional disciplines. The ERP is focused on public safety, workforce safety, and the safety of external resources obtained through mutual assistance agreements, outlines restoration priorities and procedures, and addresses the operation of the Emergency Operation Centers.

The ERP applies the principles of the Incident Command System and Group Crisis Management Framework to the structure of the ERO. The ERO establishes a chain of command that sets an orderly line of authority and relationships in place within the ranks of the organization, where lower levels are subordinate to and connected to higher levels. This chain of command is used to communicate direction and maintain management control of the Company's response to the event. Orders must flow through the chain of command while members of the organization may directly communicate with each other to ask for or share information.

3.3.1.1 Key Climate Hazards: High Temperature, High Wind, Inland Flooding, Ice

Climate change is projected to increase the frequency, severity, and duration of extreme weather events, which may affect emergency response operations in several ways. National Grid has identified the following areas as potential climate vulnerabilities in its emergency response process:

Safety challenges. Importantly, climate change may present safety challenges to the emergency response process. During storm restoration, there are more employees working under non-ideal and non-normal conditions to assess damage and restore customers, which can increase the likelihood of injuries. Extreme temperatures, high winds, flooding, and icing may hamper response efforts as responders may need to take more breaks or modify working hours to reduce risk of weather-related illnesses or injuries during response operations.

Increased Resource Requirements. A greater number of storm mobilizations may result in the need to maintain a higher level of readiness and a greater number of resources—including staffing, equipment, and materials—to support storm response, as well as higher capital, and operations & maintenance costs for repairs after storms.

Longer Restoration Times. Increasing frequency and severity of extreme events may lead to more extensive and widespread damage. More frequent and widespread impacts of extreme events would lead to a greater demand for finite materials and personnel resources to make repairs. These factors could in turn result in longer restoration times.

Disruption to Company Processes. More frequent storms may be disruptive to day-to-day Company processes and activities as employees will be deployed to restore services, while core functions may be delayed.

Materials Management. For materials that are in short supply, National Grid generates emergency purchase orders and works with suppliers to source the required materials. Climate change has already begun to impact supply chains and those impacts may accelerate in the future, affecting National Grid's ability to source non-stock materials during emergencies or depleting stock for non-emergency use.

Recharging Electric Fleet Vehicles. To meet CLCPA goals, companies, including National Grid, are transitioning more of their fleets to hybrid and electric vehicles. As the composition of the fleet changes, effectively responding to emergency events will require the Company to be proactive in supporting recharging of electric fleet vehicles.

Response Fatigue. The increasing frequency and intensity of storms may require more frequent mobilizations**,** which may improve efficiency but may also result in certain aspects of "response fatigue" which in turn may impact the effectiveness of storm response.

Obtaining Mutual Assistance. With more storms affecting not only the National Grid service territory, but also the service territories of neighboring utilities, National Grid may have difficulty in obtaining the mutual assistance resources needed to support the restoration of service.

3.3.2 Vegetation Management

Vegetation contacts with National Grid's overhead system assets are a leading cause of outages. National Grid's vegetation management program is responsible for developing long-term strategy, planning, budgeting, and delivering the annual work plan to reduce vegetation related interruptions on the National Grid system. National Grid continues to adapt its vegetation management program to address the latest research, meet regulatory and financial targets, and achieve high levels of customer reliability to achieve best in class status.

National Grid's vegetation management program is designed to minimize the impact of vegetation on the electric system to support safe and reliable service for customers. The Company's vegetation management specifications address cutting, clearing, pruning, tree removal, and herbicide treatment of vegetation along overhead electric transmission, sub-transmission, distribution lines, and within substations. The aim is to maintain minimum clearances between conductors and vegetation to reduce the risk of vegetation-caused outages while enabling access to National Grid's assets. The vegetation management program follows the American National Standards Institute (ANSI) A300 (Part 1) and International Society of Arboriculture (ISA) Integrated Vegetation Management (IVM), Best Management Practices for Tree Pruning. Different pruning clearances are specified for trees within maintained areas and outside of them, as well as for secondary and service lines. In addition, the transmission vegetation management program meets NERC FAC-003 transmission vegetation management standards.

The vegetation management programs are designed to reduce both interruption frequency and duration. When vegetation grows into power lines, it can cause interruptions in service and create hazards to public safety. Maintaining clearance between vegetation and the power lines allows National Grid to restore power more safely and efficiently during weather events.

The National Grid transmission vegetation management program has two main elements: a right-of-way (ROW) Floor Program and a Sideline Tree Program. The ROW Floor Program manages vegetation within the ROW corridor to ensure that the corridor is clear of vegetation that can present a risk to the transmission line. The Sideline Tree Program manages vegetation adjacent to the ROW that has the potential to fall into transmission lines and cause damage.

The National Grid sub-transmission and distribution vegetation management programs also have two main elements: a Cycle Pruning Program and an Enhanced Hazard Tree Mitigation (EHTM) program. The Cycle Pruning program is designed to maintain acceptable clearances between overhead vegetation and overhead conductors. The EHTM program addresses trees adjacent to the sub-transmission or distribution line with the potential to fall into the line or have branches break off and contact the line.

Climate change could provide a significant challenge in meeting all these goals in the years to come. With an estimated tree density of over 126 trees per mile, National Grid's electric system in New York is vulnerable to harsh conditions during major weather events. Severe weather events can cause substantial damage to older and poorly supported trees across the system and cause considerable damage to National Grid assets, causing long-duration interruptions of electric service to customers.

The Company's current pruning program is on an average 5.5 (five and one-half) year cycle. With higher average annual temperatures and longer growing seasons, vegetation growth rate is expected to increase. Tree limbs and understory vegetation are expected to grow into power lines much more quickly than in the past. This can make routine pruning and brush cutting more hazardous, more expensive, and increase restoration times during storm events. As a result, National Grid may need to consider shortening the pruning cycle.

National Grid's hazard tree mitigation program seeks to identify and cut hazard trees that could potentially impact the electric system on both blue-sky days and during weather events. The hazard tree mitigation program provides a significant reliability benefit to National Grid's customers. National Grid's hazard tree mitigation program continues to evolve to address constantly changing issues that affect vegetation throughout New York, such as extreme drought and invasive species. These issues, which may be exacerbated by climate change, are resulting in large numbers of dead or dying trees throughout the system that may impact the electric system during weather events.

In addition to these core programs, National Grid implemented an ash tree mitigation program across New York to address the infestation of the Emerald Ash Borer. Over the past few years there has been an escalation of other invasive pests and diseases that are impacting the health and structure of other tree species. The increase in average temperature may be allowing these pests and diseases to survive and infest the forest, which in turn is directly related to tree failures.

National Grid has a sound hazard tree mitigation process, but as forests across New York State become increasingly affected by invasive insects and diseases the mitigation program will need to be elevated to address the future decline of the New York forest.

3.3.2.1 Key Climate Hazards: High Wind, Inland Flooding, Ice

Climate change is projected to impact vegetation in several ways, including an increase in the rate of tree growth, a decrease in overall tree strength, increased proliferation of invasive species, and changes to the geographic distribution of forests.

Increased Growth. As a result of warming temperatures, Growing Degree Days (GDD)[42] increased by 9% nationwide from 1946 to 2020 and are expected to steadily increase as temperatures continue to rise.[43]

[42] Growing degree days (GDD) is a measure of heat accumulation used to predict the growth and development of plants and insects during the growing season.

[43] EPA 2023. Climate Change Indicators: Growing Degree Days. Available at:epa.gov/climate-indicators/climate-change-indicators-growing-degree-days.

The increase in GDD will lead to an increase in growth rates, requiring changes to pruning cycles. However, other factors such as reduced water availability may work to partially counteract increases in growth rates.

Reduction in Strength. Research on wood samples from forests has shown that climate change is resulting in decreasing wood density for certain dominant tree species. This has the potential to reduce tree strength and increase the risk of vegetation driven outages during storms.[44]

Invasive Species and Insects. Climate change may also create more favorable conditions for invasive species to thrive, posing threats to native trees and forests, which can also lead to weakening of trees. As noted above, rising temperatures have allowed invasive insects, such as the Emerald Ash Borer, to proliferate further north into New York State and increasing GDD has allowed them to thrive for longer periods of the year.[45]

Shifts in Forests. As a result of changes in temperature and the local environment, the geographic distribution of forests may shift with some tree species expanding their ranges to find suitable habitats, and others contracting their ranges due to changes in conditions.[46] This may result in changes to the species of trees that pose the greatest threats to National Grid infrastructure.

To the extent that climate change impacts vegetation growth rates, tree strength, and geographic distribution, along with the increasing risk of storms, the current vegetation management program may require updates in order to maintain customer reliability.

3.3.3 Workforce Safety

National Grid is committed to workforce safety and maintains critical policies and procedures designed to keep employees safe while performing their jobs. These range from corporate health and safety procedures to general environmental health instructions.

3.3.3.1 Key Climate Hazards: High Temperature, High Wind, Inland Flooding, Ice

Climate hazards such as extreme temperatures, high winds, heavy precipitation and flooding, and ice storms can pose safety risks to National Grid's workforce. National Grid's existing procedures prioritize proactive monitoring and reaction to climate hazards to mitigate risks posed to workers. Examples of hazard-specific workforce safety practices are described below.

Extreme heat-related vulnerabilities. Average and maximum temperatures are projected to increase across the National Grid service territory, with warmest temperatures projected to occur in the Southwest region and Eastern Divisions, especially around Fredonia, Albany, and Saratoga. Hotter days are often accompanied by high humidity. Increasing temperatures and humidity may impact worker productivity as more frequent rest periods are required, and higher humidity may impact workers' ability to perform live line work. National Grid operates a robust Heat Illness Prevention Program, which

[44] Hans Pretzsch, H. Pretzsch, Peter Biber, P. Biber, Gerhard Schütze, G. Schütze, Julia Kemmerer, J. Kemmerer, & Enno Uhl, E. Uhl. (0000). Wood density reduced while wood volume growth accelerated in Central European forests since 1870. Forest ecology and management, 429, 589-616.

[45] University of Waterloo. (2018, May 17). Climate change broadens threat of emerald ash borer. ScienceDaily. Available at:sciencedaily.com/releases/2018/05/180517113751.

[46] USGS 2023. Understanding Species' Range Shifts in Response to Climate Change: Results from a Systematic National Review. Available at:usgs.gov/programs/climate-adaptation-science-centers/science/understanding-species-range-shifts-response.

involves implementing practices of heat acclimatization, work/rest scheduling, and sufficient water intake based on increasing temperatures.

High winds-related vulnerabilities. National Grid's operations procedures incorporate thresholds for high winds. Although decisions are made at the discretion of a supervisor or crew chief, per National Grid's procedures, bucket truck work must be reassessed when wind speeds are between 25 mph and 45 mph. In addition, winds exceeding 40 mph, or 30 mph if material handling is involved, are considered high risk and all aerial work should be discontinued if winds are of such velocity that employees would be exposed to being blown from elevated locations and/or that an employee or material handling equipment could lose control of the material being handled. If winds could expose employees to other hazards, for example, to move energized conductors far enough to violate minimum approach distance, aerial work must be discontinued. Given the projected increases in extreme wind conditions, the number of days that bucket work may be performed by field staff may reduce, affecting restoration times.

Heavy precipitation-related vulnerabilities. To support worker safety, National Grid's contract with International Brotherhood of Electrical Workers (IBEW) Local 97 includes an inclement weather clause that indicates that non-emergency work must be stopped if rain or snow rate becomes greater than what is classified as "light".[47] Given the projected increases in heavy rain events, the number of days where work is impacted due to rain or snow is likely to increase in the future.

Icing-related vulnerabilities. Although National Grid has no standards or specifications that specifically address worker safety related to ice accumulation or ice storms, it can be expected that restoration times for these types of events would potentially increase due to the hazards of traveling to outage locations and the precautions needed to remove ice from electric assets during restoration.

3.3.4 Reliability Planning

The process of reliability planning involves establishing performance targets, capturing historical reliability performance, understanding the factors that influence reliability, and identifying necessary investments and operational improvements to achieve the desired level of reliability.

National Grid tracks the reliability performance of its systems and records detailed data for each customer outage that occurs. This data includes information such as date and time of the outage, location, outage cause, weather conditions, and operated protective device. The information recorded allows National Grid to identify trends in reliability performance and incorporate that information into the reliability planning process. In accordance with the requirements in New York State, National Grid tracks and reports on the System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI). The Company has reliability performance targets for both SAIFI and CAIDI. These reliability metrics are tracked and reported at the regional level across the eight operating regions.

National Grid classifies interruptions by one of nine cause codes,[48] two of which, Major Storms[49] and Lightning, are weather-related. National Grid tracks major storms and captures information about each

[47] "Light" rainfall is defined as taking less than 2 minutes to completely wet pavement or sidewalk or at least 4 consecutive hours where rainfall was at least .098 inches. "Light" snowfall is defined as a condition with visibility being greater than 1,100 yards.

[48] Cause codes include Major Storms, Tree Contacts, Overloads, Errors, Equipment Failure, Accidents, Prearranged, Customer Equipment, Lightning and Unknown.

[49] A Major Storm is a period of adverse weather that causes interruptions to at least 10 percent of the customers in an operating region or during which at least one customer is interrupted for 24 hours or more.

one, including categories of observed conditions such as high winds, thunderstorms, and heavy wet snow.

To identify action plans to maintain reliability, National Grid ranks each circuit on four reliability metrics and generates an overall ranking by summing the four rankings for each feeder. The four metrics include 1) the number of interruptions, 2) the number of customer-hours interrupted, 3) SAIFI, and 4) the System Average Interruption Duration Index (SAIDI). Action plans to address poorly performing circuits include four initiatives: Engineering Reliability Reviews; Sub-Transmission and Distribution Fault Location, Isolation and Service Restoration (FLISR); Vegetation Management Inspection and Maintenance Program (I&M); and the Trip Saver[50] Installation Program.

3.3.4.1 Key Climate Hazards: High Temperature, High Wind, Inland Flooding, Ice

Vulnerabilities in National Grid's reliability planning process include a need for a more granular understanding of the impact of climate hazards on reliability, an ability to model the future impact of climate change on reliability, and a need to understand the reliability benefit of capital investments.

Although National Grid tracks reliability performance at an individual circuit level and captures some weather characteristics as part of its reliability data, the information captured is still not granular enough to develop a clear understanding of the impact of specific climate variables, such as heat and wind, on customer reliability. For example, capturing weather conditions at the time of an outage, from a weather station reasonably close to the location of the outage, would support a better understanding of the impact of climate hazards on system performance.

National Grid uses CYME for steady-state analysis and ASPEN OneLiner for transient analysis to model the reliability of the distribution system[51]. These models allow the Company to project the impact of capital investments on customer reliability. These tools do not currently have the capability to model the impact of changes in weather on customer reliability.

Average and extreme temperatures are projected to increase across the National Grid service territory. Similarly, higher wind speeds can negatively impact trends in customer outages. Having tools that support reliability modeling would allow National Grid to model the impact of more events such as heat waves and storms on customer reliability.

The National Grid 2023 New York Capital Investment Plan includes investment programs for reliability and resilience. These programs contain a portfolio of investments, including equipment replacement and upgrades to address loading and voltage violations, reconfiguration of distribution circuits, FLISR (which includes upgrades and automation of existing components), and other investments. National Grid identifies, on a project-by-project basis, the reliability/resilience value of these investments based on expected improvements. For example, for distribution reliability projects, expected improvements in SAIFI and CAIDI are used.

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[50] Trip Savers are self-powered, electronically controlled reclosing devices that replace overhead fuses.
[51] CYME software models electrical system steady state conditions to determine and analyze system conditions against thermal and voltage limits to help minimize outages and other impacts to customers. ASPEN OneLiner software models abnormal electrical system conditions such as faults so that protection devices can be coordinated properly to minimize the area impacted by outages.

3.3.5 Load Forecasting

Electric demand is the amount of electrical power that is consumed by end users at a specific point in time. Demand varies throughout the day and year and is typically higher when it is very hot or very cold and heating/cooling needs are high. Weather variables, especially temperature, human activities, and the dynamic interactions of the two, drive the electric load. Additionally, New York State CLCPA includes electrification of heating and transportation, which would result in substantial increases in peak demand, particularly during the winter months. Thus, estimating peak demand, as well as the hour with the highest demand over the year is critical for planning electric network infrastructure because the network must be built to serve peak load. Forecasting future peak demand is important because it ensures the infrastructure gets built at the right place and at the right time to reliably provide customers with the power they need.

National Grid's electric infrastructure needs to be able to reliably provide power in extreme conditions, including the hottest days in the summer and the coldest days in the winter. The peak demand forecast is therefore calibrated to peaks that occur under extreme temperatures, at the 90th percentile, which is National Grid's planning weather condition. For summer, this means a temperature such that the hottest day of the year will exceed this temperature only once every 10 years. In addition, the peak demand forecast is also developed under a normal or 50/50 weather scenario and a more extreme 95th percentile for different use cases such as NYISO capacity market and supply procurement. The weather scenarios were developed from the 20 years of historical weather data at multiple weather stations within National Grid's service territory. In addition, National Grid includes a historical temperature trend-based climate scenario from the NYISO Climate Change Study.[52] This scenario assumes a 0.7°Fahrenheit increase in average temperature per decade in the summer season, based on analyzing the past 100 years' temperature history. More detail on the forecasting methodology and the weather and climate scenario can be found in the National Grid's peak load forecasting report.[53]

3.3.5.1 Key Climate Hazard: High Temperature

Climate change adds to uncertainties inherent in long-term load forecasting. National Grid has considered one climate scenario based on the NYISO Climate Study[54] in its long-term load forecasting and assessment process. The NYISO Climate Study concluded a 0.7°Fahrenheit increase in average temperature per decade in the summer season, based on analyzing past 100-year temperature records. One limitation of such a historical trend-based analysis is it may not account for projected increases in the rate of future climate change.

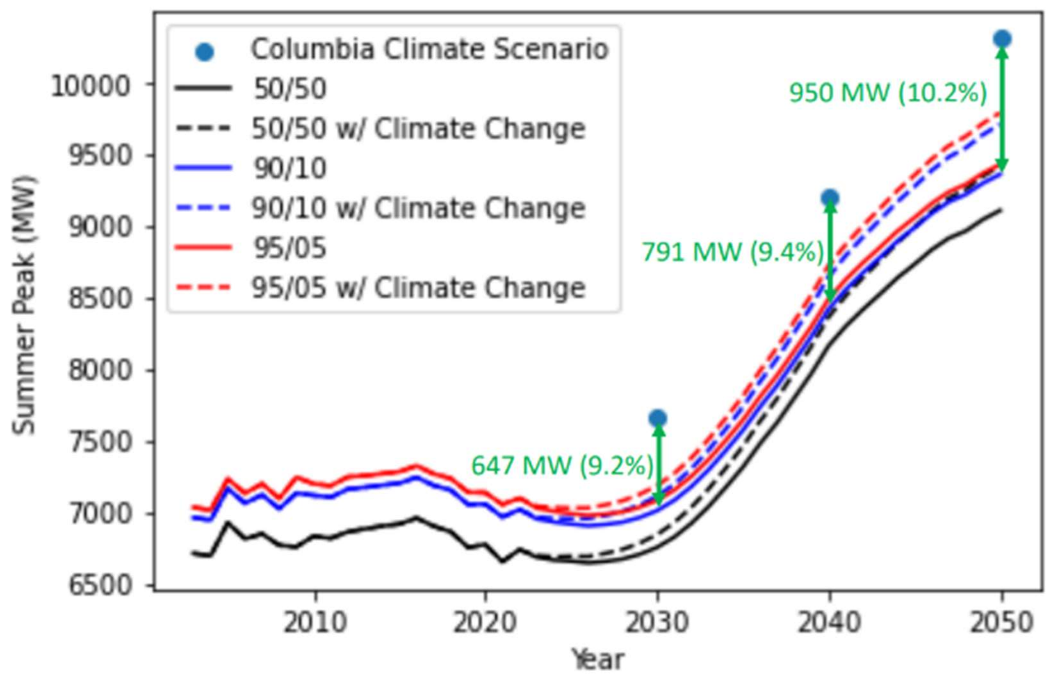
As part of the CCVS, National Grid has already begun exploring the climate scenarios developed by Columbia University for load forecasting. The study offers climate scenarios associated with socioeconomic global changes, but only for a subset of weather stations that National Grid considers in its load forecasting process. National Grid uses the same temperature variables as those used in its load forecasting process from the SSP 5-8.5 climate scenario generated by Columbia University to conduct a load assessment under this climate scenario. The assessment was performed at a decadal timescale for

[52] NYISO Climate Change Phase II Study, Presentation. Dated April 23,2020.
[53] Niagara Mohawk Power Corporation 2023 to 2050 Electric Peak (MW) Forecast, March 2023, Available at:systemdataportal.nationalgrid.com/NY/documents/Peak%20Load%20Forecast%20Report.pdf.
[54] NYISO Climate Change Phase II Study, Presentation. April 23, 2020.

2030, 2040, and 2050. The Columbia data set, referenced below, provided periods of 30 years of data, centered around each decade, to smooth variability.

Figure 38 captures the load assessments under the different weather and climate scenarios. The solid lines represent summer peak load under the normal, 90th, and 95th percentile weather scenarios. The increase in peak demand, beginning around 2030, is driven largely by electrification of heat and transportation. The dotted lines reflect summer peak load under the normal, 90th, and 95th percentile climate change scenarios with a 0.7-degree Celsius rise in average temperatures and a 5% percent increase in volatility, per each 10-year period, based on the NYISO Climate Change Phase II Study. The blue dots reflect summer peak load in 2030, 2040, and 2050, based on the climate scenario developed using climate data from Columbia University. These results are approximately 9.2% to 10.2% higher than National Grid's 90th percentile planning scenario. It is important to note that the infrastructure required to meet the increases in demand from electrification will also support meeting higher demand during the summer anticipated in the future with climate change.

Figure 38. Load projections under different climate scenarios, base distributed energy resources (DER) scenario



3.3.6 Capacity Planning

Capacity planning identifies portions of the electric system where demand growth could exceed asset ratings. This may necessitate the design and execution of investments to align system capacity with expected customer demand. Capacity planning incorporates current load, forecasted load, and asset ratings as inputs. The load forecasting process and the implications of climate change were discussed earlier in this report. Accurate asset ratings are critical for reliable electric system performance and correct projections of ambient temperature are necessary to develop accurate asset ratings.

National Grid develops annual 5-year Transmission & Distribution (T&D) investment plans that identify capital investments necessary to provide safe and adequate service at reasonable costs to customers.[55] The capital investment plans include the investment category of "System Capacity," which represents projects that are required to upgrade the capability of the T&D delivery system to provide adequate stability, thermal loading, and voltage performance under existing and anticipated system conditions.

National Grid's capacity planning process incorporates the impact of climate hazards on the system's ability to deliver energy based on assumptions about ambient temperature when developing ratings for assets. Table 16 outlines the ambient temperature assumptions that National Grid uses to rate selected assets. As discussed in Section 3.2, transformers were determined to have particularly high sensitivity to ambient temperatures in the asset sensitivity analysis.

Table 16. National Grid's ambient temperatures assumptions for rating selected assets

ASSET	Ambient Air Temperature	
Overhead conductors – transmission line	35°C (95°F)	Peak design temperature
Overhead conductors – distribution line	40°C (104°F)	Peak design temperature
T&D substation transformers	32°C (89.6°F)	24-hour average

3.3.6.1 Key Climate Hazard: High Temperature

Vulnerabilities for the capacity planning process include failure to capture local variations in ambient temperature across the National Grid service territory, incomplete real-time visibility into substation transformer temperatures, and the use of historical ambient temperatures to determine equipment ratings. The current use of a single ambient temperature for rating equipment, particularly transformers, may not capture potential localized variations in temperature across National Grid's service territory which in New York State covers approximately 25,000 square miles. Localized temperature variations may be attributed to factors such as topography, vegetation, shade etc., which may result in ambient temperatures exceeding design assumptions. This may result in accelerated aging along with a marginally higher risk of equipment failure.

Real-time monitoring of assets such as substations can provide insights into more localized weather conditions. National Grid already operates real-time transformer temperature monitoring for about 30% of its substations.

Asset ratings for National Grid are based on the past weather, which is consistent with industry norms, but this backward-looking approach does not consider the possibility that future weather will be different from that of the past. The capacity planning process anticipates long-term system needs and recognizes that assets that are installed today may be in service for many decades in the future, during which ambient temperatures are projected to increase, and thus the energy delivery capability of assets will decrease over time.

National Grid has begun to explore options to adapt its capacity planning process to climate change to identify potential revisions to ambient temperature assumptions for rating substation transformers over

[55] National Grid Case 20-E-0380, Capital Investment Plan. Presentation. February 1, 2023.

the next several decades. The Company currently assumes an average ambient temperature of 32°C for developing substation transformer ratings. As climate change increases ambient temperatures above this level, the risk of losing capacity due to de-rating or decreased lifespan will increase.

For transmission lines, National Grid will be moving to use ambient adjusted ratings as required by Federal Energy Regulatory Commission Order 881 and is also developing the capability to use dynamic line ratings. This will allow transmission operators to utilize more accurate line ratings based on current ambient temperatures. Although this will often result in higher line capacity when temperatures are lower, it will also mean that as peak seasonal temperatures increase over time there will be more instances when line capacity could become more limited. Ultimately, any decrease in line ratings due to increasing temperatures will need to be factored into changes to static ratings used for long term planning.

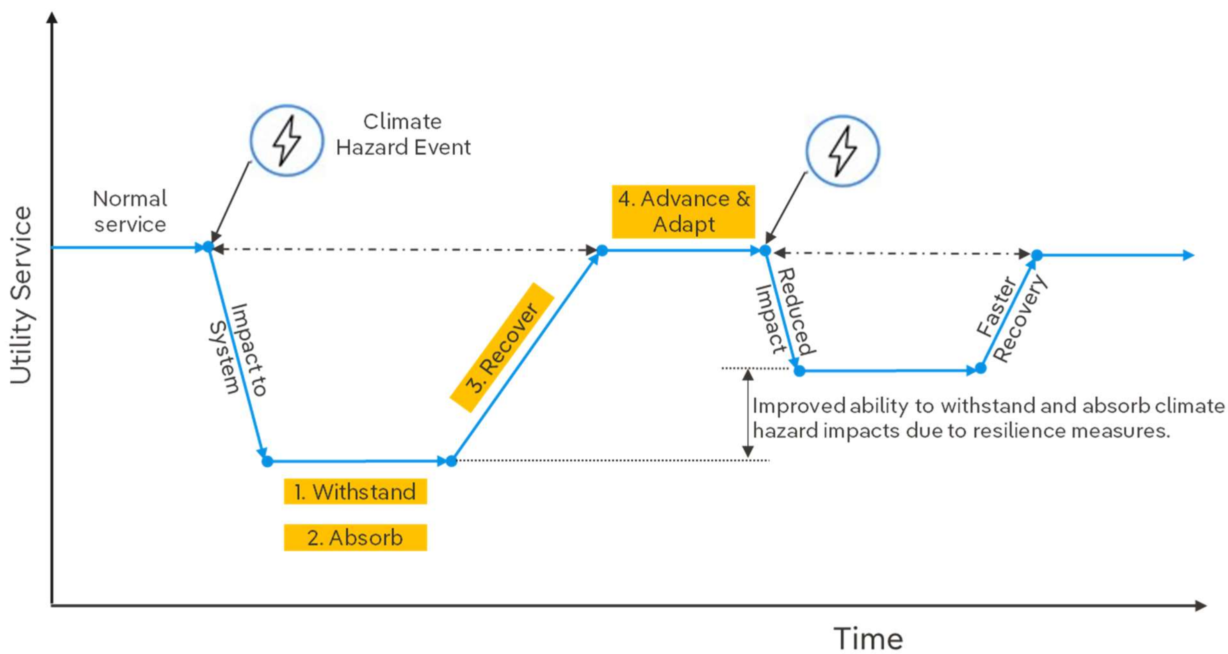
4. Potential Resilience Measures

The climate vulnerabilities identified in Section 3 for infrastructure assets and operations support the development of National Grid's CCRP which will incorporate resilience measures for addressing potential impacts. Public Service Law 66, subdivision 29, requires that the recommended resilience measures encompass a multipronged framework, considering a range of approaches to achieve resilience.[56]

National Grid is seeking to implement a resilience framework (Figure 39) that addresses four key objectives. This framework can be applied to physical assets and infrastructure, as well as operational procedures and design specifications. The four objectives of the multipronged resilience framework are:

1. **Strengthen** assets and operations to **withstand** the adverse impacts of a climate hazard event.
2. Increase the system's ability to **anticipate** when a climate hazard event may occur and **absorb** its effects.
3. Bolster the system's ability to quickly **respond** and **recover** in the aftermath of a climate hazard event.
4. **Advance** and **adapt** the system to address a continuously changing threat landscape and perpetually improve resilience.

Figure 39. Multipronged Resilience Framework



Developing resilience strategies that address risk to both operations and assets will improve system-wide ability to face the climate hazards analyzed in Study. The following are examples of measures that can contribute to the four objectives and enhance National Grid's resilience to identified priority climate

56 New York Public Service Commission. 2022. PSC Directs Utilities to Conduct Climate Vulnerability Studies (22057 / 22-E-0222). Available at: dps.ny.gov/system/files/documents/2022/10/psc-directs-utilities-to-conduct-climate-vulnerability-studies.pdf.

hazards and vulnerabilities. While some measures are effective in addressing specific climate hazards, others can promote resilience against multiple hazards simultaneously. The examples listed below will be evaluated further for potential inclusion in the CCRP.

4.1 Strengthen and Withstand

With the goal of maintaining service in the face of climate change, National Grid will identify opportunities to enhance existing infrastructure resilience during new installations, replacements and/or improvements to assets in poor health. Examples include:

- Flood hazard mitigation through storm hardening capital projects and programs including flood gates, deployable barriers, and impervious structures like concrete floodwalls.
- Extreme winds and ice mitigation through undergrounding transmission and distribution conductors, replacing distribution poles with stronger construction grades, and installing anti-cascading structures.
- Extreme heat mitigation through measures such as incrementally increasing the maximum ambient and maximum temperature specification in transformers, or through the installation of additional cooling systems to control the temperature of sensitive components.
- Building new infrastructure to higher strength standards, to withstand stronger wind gusts and ice accumulation.

4.2 Anticipate and Absorb

While implementing physical measures is an effective way to mitigate the risk to climate hazards, other strategies to be considered may include:

- Using the best available climate models to allow early decision making and evaluating system sensitivity to climate hazards.
- Keeping customers and critical facilities informed of activities during a severe weather forecast.

4.3 Respond and Recover

While risk can be mitigated, it cannot be entirely removed. Therefore, the CCRP will also evaluate measures that can help reduce outage times and customer impact, some of which are already established. For example:

- Implementing fault location, isolation, and service restoration (FLISR) systems.
- Continuing to perform trainings and function specific workshops to review role and responsibilities as part of the emergency planning, preparation, and response.

4.4 Advance and Adapt

The changing nature of projected climate hazards requires that National Grid take actions, ensuring resilience strategies will be continually updated and improved based on the best available climate science. For example:

- Integrating climate change risk into investment decision making and risk management tools.
- Periodically reevaluating climate risk scenarios as new climate data becomes available.

- Explicitly integrating climate considerations across operating procedures and discussing potential vulnerabilities to operations and planning procedures.
- Conducting performance reviews after a major event, to identify opportunities for improvements.
- Evaluating the potential impact of climate change on vegetation growth patterns and invasive species risk to operational procedures.
- Considering the integration of climate projections into current load forecasting process to plan for future forecasts.
- Considering updates on design standards as updated climate data or new information on climate hazards become available.

As part of developing the CCRP, National Grid will identify, evaluate, and prioritize resilience measures in the context of specific locations, assets, and/or programs.

5. Conclusions and Next Steps

The CCVS aimed to identify key climate hazards and priority climate vulnerabilities for National Grid's assets and operations. Subject matter experts contributed to every step of this process.

Based on available climate projections, the CCVS identified four key climate hazards with the potential to impact National Grid's assets and operations: 1) high temperature (extreme heat), 2) inland flooding associated with heavy precipitation events, 3) high winds, and 4) icing events. The Study evaluated substation, transmission line, and distribution line assets to assess their vulnerability to these climate hazards. Sub-transmission line assets were also examined as part of the distribution line asset group.

As discussed in Sections 2 and Section 3**,** the CCVS identified priority vulnerabilities from the combined understanding of exposure to climate hazards, sensitivity of assets, and potential consequences of asset failure for National Grid systems and customers. Priority vulnerabilities represent the asset-hazard combinations with the highest potential for negative outcomes for National Grid customers, in the event of exposure to that climate hazard. Overall, the Study identified transmission line and distribution line assets showing vulnerability to extreme heat, high winds, and icing events. It also determined that National Grid's substation assets are particularly vulnerable to projected exposure to extreme heat and precipitation-driven flooding.

In addition to assessing the vulnerability of physical infrastructure, National Grid reviewed potential impacts to internal operations and processes from climate hazards, based on extensive consultations with utility subject matter experts. The CCVS reviewed the key functional areas of emergency response, workforce safety, vegetation management, reliability planning, capacity planning, and load forecasting. Addressing these impacts is important, as resilience to climate change cannot be achieved through hardening of physical infrastructure alone; companies must also be operationally prepared to adapt to changing climate and weather conditions.

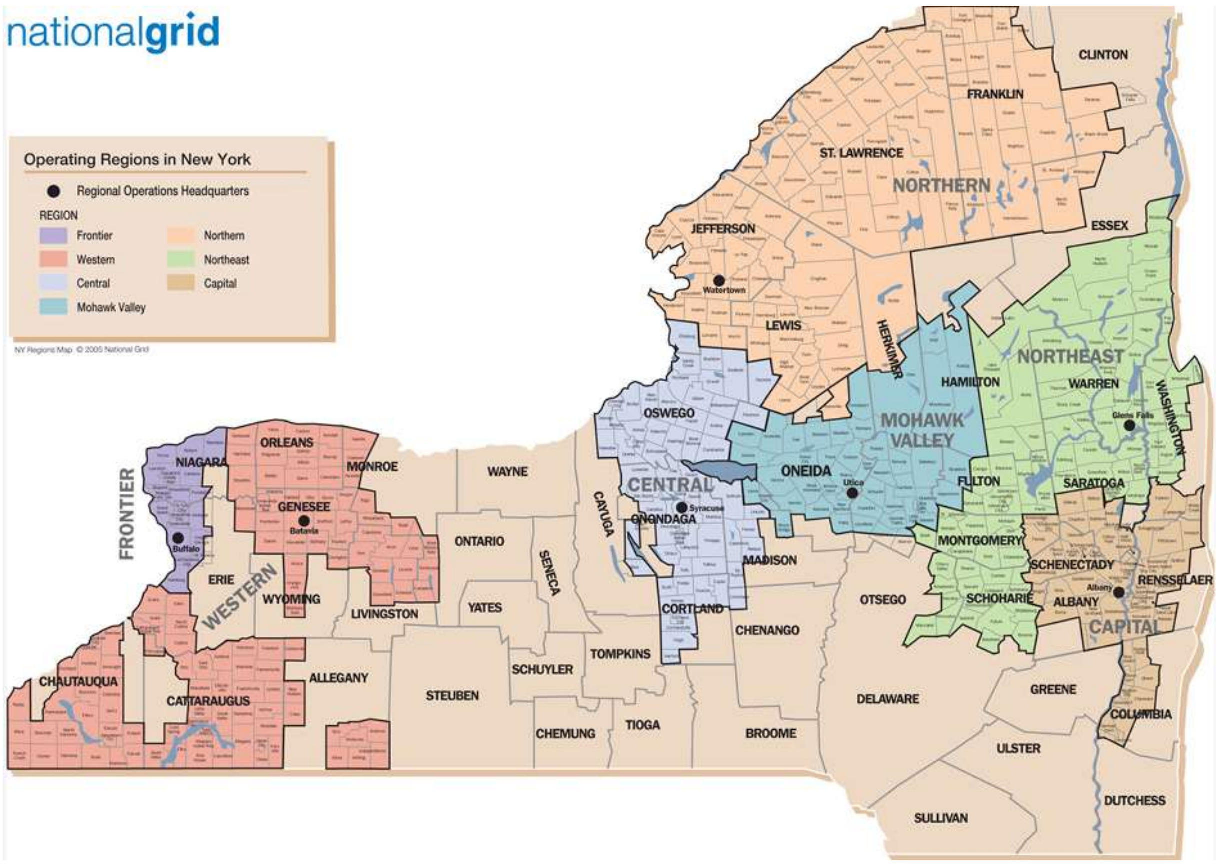
Climate vulnerabilities identified in the CCVS have potentially profound implications for National Grid's ability to deliver safe and reliable electric service to customers. Changes in climate and extreme weather events can aggravate rates of asset failure, cause more outages, and decrease system reliability. These impacts could also lead to higher costs due to increased repair and restoration expenses. Increasing operational costs may also result from the need to respond more frequently to severe extreme events, such as heat waves and storms. In addition, these impacts may cascade into concerns on workforce and public safety. National Grid is committed to timely and proactive actions to address these impacts to maintain its high standards of safety and reliability.

The next step for National Grid is to use the findings of the CCVS to develop the CCRP, which will follow a multipronged resilience framework, encompassing a range of approaches to maintain and strengthen resilience. The priority vulnerabilities identified in this Study will be the focus of resilience recommendations in the CCRP. As part of developing the CCRP, National Grid will identify, evaluate, and prioritize resilience measures in the context of specific locations and assets, including a business case rationale for the prioritized recommendations. The CCRP will also include recommendations for system-wide enhancements to address operational vulnerabilities.

National Grid acknowledges that while the findings from the CCVS are critical to its resilience planning and investment decisions for the next 5-20 years, the Company's understanding of the vulnerability of its assets to different climate hazards will continue to evolve, including from potential emergent risks such as wildfire. As infrastructure is upgraded or replaced, an asset's ability to withstand exposure to climate hazards will also change. Similarly, the understanding of the consequences of hazard exposure will increase as more advanced data and metrics related to system performance become available. Simultaneous improvements in climate science and climate modeling capabilities will also aid in identifying actionable resilience measures. This CCVS must therefore be seen as a part of an ongoing process through which National Grid will continue to update its resilience planning.

6. Appendix

Appendix A – Map of National Grid Operating Regions in New York



Appendix B – Stakeholder Engagement during CCVS Development

Table B.1. List of community and municipal organizations included in stakeholder engagement

Adirondack North Country Association	Essex County Emergency Management	Saratoga County
Albany County Emergency Management	Franklin County	Saratoga County Emergency Management
Albany County Executive Office	Fulton County Emergency Management	Schenectady County Emergency Management
City of Albany	Great Lakes Consortium	Shenendehowa CSD
City of Batavia	Hamilton County Emergency Management	St Lawrence County
City of Buffalo	Herkimer County (East)	Syracuse-Onondaga County Planning Agency
City of Dunkirk	Jefferson County	Town of Amherst
City of Glens Falls	Lewis County	Town of Bethlehem
City of Hudson	Madison County	Town of Clifton Park
City of Niagara Falls	Mohawk Valley Economic Development District	Town of Day
City of North Tonawanda	Montgomery County Emergency Management	Town of Dewitt/Onondaga Environmental Institute
City of Olean	Municipality	Town of East Greenbush
City of Rensselaer	National Weather Service-Burlington	Town of Guilderland
City of Saratoga Springs	NYS DOT Region 2	Town of Malta
City of Schenectady	NYS DOT Region 3	Town of Moreau
City of Troy	NYS DOT Region 7	Town of Northcumberland
City of Watervilet	NYS Homeland Security & Emer. Mgt.	Town of Stillwater
Clean Communities of Central NY	Oneida County	Town of Tonawanda
Clinton County	Onondaga County	Town of Waterford
CNY Regional Planning Development Board	Oswego County	Village of Greenwich
Columbia County Emergency Management	Otsego County Emergency Management	Warren County Emergency Management
Cortland County	Rensselaer County Emergency Management	Washington County Emergency Management

Table B.2. List of Climate Resilience Working Group (CRWG) member organizations

AARP	Mission: Data Coalition, Inc.	PULP
Alliance for a Green Economy (AGREE)	National Grid	Representing AARP New York
Bob Wyman	Natural Resources Defense Council	Representing Direct Energy Business Marketing, LLC, Direct Energy Business, LLC, Direct Energy Services LLC, Gateway Energy Services Corporation
Central NY Regional Planning & Development Board	New York Power Authority	Representing MARATHON POWER LLC
ChargePoint, Inc.	New York State Department of Public Service	Representing Multiple Intervenors
Citizen Action of New York, Inc.	New York State Office of General Services	Representing New York Geothermal Energy Organization
City of Albany	Niagara County	Representing Stop NY Fracked Gas Pipeline
City of Glens Falls	NYGEO	Representing Walmart
City of Niagara Falls	NYPA	Representing: New York State Office of General Services
City of Syracuse	NYSERDA	Schenectady County
Columbia County	NYSDOT	Schenectady Fire Department
Columbia Economic Development Corporation	Office of Environment, Onondaga County	Sierra Club
Direct Energy Services LLC	On behalf of Multiple Intervenors	St Lawrence County Emergency Services
Environmental Defense Fund	Onondaga County	Stop NY Fracked Gas Pipeline
Erie County DHSES	Onondaga County DOT	Town of Amherst
Family Energy, Inc.	Oswego County	Town of DeWitt
Franklin County Government	Pace Energy and Climate Center	Utility Intervention Unit, Division of Consumer Protection, Department of State
Genesee County NY	People United for Sustainable Housing (PUSH) Buffalo	Wyoming County Office of Emergency Services
Greenlots	PSC Staff	Wyoming County Planning Department
HOCCPP	Public Utility Law Project of New York, Inc.	

nationalgrid

Climate Resilience Working Group Kick-Off February 13, 2023

Meeting Summary

National Grid kicked off the Company's Climate Resiliency Working Group (CRWG) on February 13, 2023. More than Thirty community leaders and customer and environmental advocates along with representatives from the New York State Department of Public Service, NYPA, New York State Department of General Services and NYSERDA attended to hear about National Grid's on-going climate vulnerability study. The study is designed to help the Company to prepare for the increase in severe weather expected from climate change and will lead to the development of a comprehensive Resilience Plan. Provided below is the background on the initiative, the meeting objectives, and a summary of the questions from participants and Company's responses along with a list of Working Group participants. Separately, we have attached the Company's presentation along with the following link to the recording of the meeting. https://bcove.video/3LlqSJ9

Background

National Grid, together with the other electric utilities in New York and in consultation with NYSERDA and the New York State Department of Public Service Staff, has launched a climate vulnerability study to help prepare for the increase in severe weather expected from climate change. The study will provide additional perspective for us to evaluate the Company's electric infrastructure, design specifications, and procedures to better understand our electric system's vulnerability to climate-driven risks. Based on the study results, we will be creating a "Resilience Plan" detailing how climate change will be reflected in the Company's electric planning process and propose storm hardening measures for the next 5, 10 and 20 years.

An important part of our planning is to collaborate with stakeholders including state, regional and local planning and emergency response officials, customer and environmental advocates and other interested parties to understand and incorporate their concerns and priorities, ultimately informing our investment decisions. With that in mind, National Grid is standing up a working group to review our work and provide input into the creation of our resilience plans. The Working Group will be part of an on-going process designed to continually evaluate and adjust our resilience investment planning into the future.

In 2023, National Grid plans to conduct at least three Working Group meetings. Following this kick-off meeting, the Company will conduct a second meeting on June 5, 2023, to share the results of our Vulnerability Study and then hold a third meeting in the fall to share our draft Resilience Plan for comment prior to filing with the Public Service Commission. Working Group participants will receive a copy of our final Plan prior to filing and a fourth meeting may be scheduled at that time.

Meeting Objectives

Key objectives of the 1st CRWG were to:

- Provide context for the Vulnerability Study and Resilience Plan and introduce working group members to overall approach and key components of the study.
- Highlight how equity and justice considerations will inform the Vulnerability Study and Resilience Plan.
- Introduce working group members to ongoing work, such as key climate hazards being considered, and preliminary asset and operational vulnerabilities identified.
- Provide clear guidance on the role of the Working Group and gather initial feedback on issues presented.
- Provide opportunity to Working Group members to ask questions and establish a channel of communication for the period between Working Group meetings.

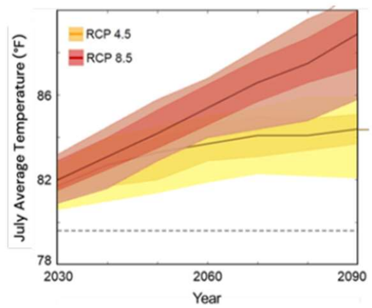
Next steps:

Our next CRWG meeting is slated for **June 5th, 2023**

Questions and Answers

Question	Response
Is the Columbia data set available to the public?	National Grid is taking the raw data from the Columbia data set and working with our SMEs to analyze. This will be presented and made available publicly in our study.
Additional Resources:	As new data becomes available, we will update this group. There are various sources where climate change data can be found. Some climate change data that is currently available include: NYSERDA ClimAID Report and the Intergovernmental Panel on Climate Change (https://www.ipcc.ch/). Other sources of information offered by participants at the first Working Group meeting include: The NY Climate Change Science Clearinghouse may be useful for identifying hazards: https://www.nyclimatescience.org/ A new report by Vote Solar shows that customer-sited solar PV and battery energy storage can provide significant resiliency benefits: https://votesolar.org/ders_as_a_roadmap_to_resiliency/
Can you provide link to MIT study?	Public information is available on this study: Toward resilient energy infrastructure: Understanding the effects of changes in the climate mean and extreme events in the Northeastern United States | MIT Global Change

Will the final plan present one or multiple scenarios or proposals for capital improvements? And will it include customer-sited DERs as well as utility-owned assets?	The Company expects the Resilience plan to reflect proposed investments to address the likely range of future conditions, taking into account risks, costs, and other relevant factors. The Company does not anticipate there will be multiple plans intended to address multiple scenarios. The plan will be looking at 5-, 10- and 20-year investment timeframes (short and long-term planning). DERs, whether customer-sited or located on the utility-side of the meter, have the potential to reduce emissions (climate change mitigation) and may have the potential to increase customer or local system resilience (climate change adaptation). Although the primary focus of the resilience planning effort to looking to address potential exposure on the transmission and distribution system to the effects of anticipated increase in severe weather conditions, the Company may also examine the potential for incorporating DERs to bolster resilience.
Customers who require refrigeration for their medicines and medical equipment - what is best way to help them?	Like other utilities in the State, National Grid's Emergency Response Plan includes procedures for alerting and assisting customers with life support equipment. The Company contacts such customers before and during a major storm to help them prepare for the event and checks on their status during such events. For outages over 48 hours, National Grid stands up dry ice and bottled water distribution sites available to all our customers for their needs. Customers that lose power for over 72 consecutive hours as the result of a widespread prolonged outage also can apply for compensation from National Grid for the loss of any spoiled food and medication in accordance with PSL 73 enacted last April.
Is the scope limited to electric only or are gas assets included? If gas is excluded, will there be a similar process to consider gas assets?	The legislation that requires the preparation of the Vulnerability Study and Resilience Plan is for electric only. Current study is only focused on Electric assets, particularly electric Transmission & Distribution. However, National Grid has for years considered and incorporated resiliency in its investment planning for all areas of the company (electric, gas, generation etc.).
In cases where electric assets are shared with non-electric providers (i.e., telephone, cable TV, street lighting, etc.) are the costs and risks associated with non-electric uses included within the scope of this work?	The current vulnerability assessment and resilience planning effort does not address the costs and risks associated with non-electric uses. It should be noted that joint use agreements typically require the phone company to pay for a portion of the cost for pole replacements. Any change in the standard size or class of distribution poles would likely impact the resilience of non-electric pole attachments and the associated cost borne by the phone company. Other third-party attachments pay annual rental agreements and would not be directly impacted pole replacement costs. If the need arises for pole replacement in this effort, then those costs would be shared.
It is anticipated that the electric T&D system must expand significantly before 2050. Is this process focused on those assets that exist now, or on the assets as that will exist in the future?	The focus of this effort is to identify climate change vulnerabilities and develop resilience plans to address those vulnerabilities. This will focus on existing assets, and future buildouts will reflect resilience planning considerations to some extent in design changes (e.g. making transmission structures more resilient to higher wind speeds). However, the plan is not focused on electric system buildout and other investments needed to meet increased electrical loading associated with electrification of heat, electrification of transportation, etc. Such investments will be impacted by the climate resilience plan (such as adding some incremental costs) but will not be the focus.
Will BCAs (Benefit Cost Analyses) be prepared for the various scenarios?	The Resilience Plan will focus on a selected climate change scenarios and for the most vulnerable assets, the Plan will identify and prioritize resilience measures focusing on 5-, 10- and 20-year investment timeframes. Aggregate costs and relative benefits for preferred mitigation measures will be analyzed and used to demonstrate that the cost to customers are justified through improvements in system reliability, resilience and safety. Cost-benefit analysis will be based on information from past investments and SME inputs.

Will the Climate Change Resilience Plan take into consideration other planned capital projects that may also address resilience needs to mitigate cost impacts on customers?	Yes. As always, National Grid will work to identify the most effective solution to address the multiple needs that may exist, with a goal to target and prioritize investments that will have value beyond just the climate resilience areas (reflecting multi-value investments). It is important to note that Climate Change Resilience Plan recommendations will focus specifically on addressing climate vulnerabilities and will include incremental costs above what is required for “business as usual” investments.
Additional Comments from Melanie:	I appreciate your answer to my question earlier, saying that the Company will work to combine decisions and investments to bring value beyond climate resilience. On behalf of Multiple Intervenors, I would just like to emphasize the importance of not only mitigating cost impacts, but also the need to be transparent about customer rate impacts throughout this process and in the resulting Study and Plan.
How will resilience be measured? Reliability standards have clear criteria, wondering how there is comparable metric?	At this time, there are no clear, nationally recognized resilience metrics to measure resilience; however, a substantial amount of work is going into establishing such metrics. For example, IEEE (Institute of Electrical and Electronic Engineers), ComEd (Commonwealth Edison) are spearheading efforts in that area, and National Grid is monitoring such activities as appropriate.
What do you consider the 'highest of the highest' temperatures?	There is no standard definition that applies. However, annual maximum daily temperature is often used to approximate annual heat extremes. We are planning to utilize the worst-case climate planning scenario (pathway) and using the 50th percentile of all the models *SSP5-8.5 50th percentile* (CMIP 6). The line in the middle of the red area in the figure below is representative of the SSP5-8.5 50th percentile in the following example: 

nationalgrid

Climate Resilience Working Group
Update

An important part of our planning is to collaborate with stakeholders including state, regional and local planning and emergency response officials, customer and environmental advocates and other interested parties to understand and incorporate their concerns and priorities, ultimately informing our investment decisions. With that in mind, National Grid utilizes our climate resilience working group [CRWG] to solicit feedback and collect information from stakeholders as well as update stakeholders and the public on developments and findings to review our work and provide input into the creation of our resilience plans.

June 5th meeting recap

If you didn't get a chance to attend our last working group meeting, here's a link to the video of our June 5th CRWG Meeting
Check out the presentation attached.

NationalGrid_CRWG Meeting 2.pdf

National Grid Vulnerability Matrix

We have provided our Vulnerability Matrix, please let us know if you have any questions or comments regarding the matrix. The matrix identifies climate hazards and associated system vulnerabilities, along with many other factors we are considering as we work through our process. Are your concerns showing up on the matrix?

NG_Vulnerability Matrix_03312023.xlsx

Next meeting:

Our next CRWG meeting is slated for **October, 2023**

Feedback and Responses

Your input encourages us to consider all perspectives and challenges us to create a better plan and study. Following up from our prior meeting, here are our responses to the feedback you had.

Question	Response
1. "Is there a summary of the resources that would be at risk at the different levels? Cost to upgrade at different risk exposures?"	Our vulnerability matrix identifies the vulnerabilities for each asset type for a given climate hazard. We are in the process of developing specific recommendations and associated costs to address high priority vulnerabilities. These recommendations are based on analysis where projected climate conditions are compared to equipment thresholds at our substation and line locations. Several of the visualizations included in the 6/5 working group presentation illustrate this analysis (see pages 22-29).
2. "How is risk determined at different temperature levels"	Equipment is evaluated based on temperature design thresholds. For example, substation transformers are presently specified to operate under a maximum average ambient temperature of 32 degrees C, (89.6 degrees F) and projected temperatures above this level will reduce the amount of load a transformer can handle. Therefore, risk increases as conditions rise above design thresholds. For the substation transformer example, for each degree C by which temperatures exceed the design threshold, the capacity of the transformer is reduced by about 1.5%.
3. "It would be interesting to understand some examples of actual risk and levels of potential mitigation with cost"	We are in the process of developing recommendations and associated costs, and we do not have the final results at this time. One example, where we have draft recommendations and costs is for substation flood mitigation. We anticipate recommending the addition of flood walls at 18 substations at a total cost of $28M where FEMA data along with climate projections indicate a high risk of flooding. Food walls will mitigate the risk of flood damage to these sites and avoid not only the cost for repairs, but also the associated equipment and customer outages.
4. "…we understand that it is supposed to get hotter, windier, and the potential for flooding is supposed to increase. I think what would be good is to understand the actual exposure of the actual assets along with the different levels of mitigation that could be implemented."	The visualizations on page 22-29 of the 6/5 working group presentation show the exposure of our lines and substations to each climate hazard (wind, icing, temperature, and flooding) and are compared to the relevant design thresholds. For example, transmission line structures were built to withstand wind gusts based on NESC guidelines which is currently 95 MPH. In areas where we project wind gusts in excess of this level, we are evaluating recommendations to specify upgraded designs that can withstand higher wind levels to be installed in those areas going forward. Although we have not finished developing recommendations at this time, this example illustrates the general approach we are taking to address other vulnerabilities as well.

5. "Understanding what could happen in terms of the climate is important but understanding the impact on the actual National Grid system is what we want to understand. Will the Vulnerability Study be looking at the actual system and specific assets? It would be good to know what is at risk and at what level of climate change the risk becomes real."	Yes, the vulnerability study is looking at specific assets such as transmission structures, distribution poles, transformers, and conductors and assessing their vulnerability based on when climate hazards will exceed the conditions they were designed for.
6. "If by 2080 the majority of substations are going to see more than 4 days per year with temps over 95 degrees what does that mean? [For the system] I do not believe I have heard of substations failing at 95 degrees (or even higher). With many areas of the country that already experience multiple days of 95+ what are they doing? Are they experiencing failure?"	Important substation equipment such as transformers will experience accelerated "loss of life" if they experience temperatures above what they were designed for, with the possibility of failure at higher levels. The ambient temperature is only one of several factors that impact the overall temperature of the transformer with the loading (MW/Amps) being a significant factor. We currently specify and develop ratings for substation transformers based on a maximum average ambient temperature of 32 degrees C (89.6 degrees F) with higher temperatures resulting in lower ratings (reduced capacity) or increased loss of life for transformers that are fully loaded. So, the consequence could range from having reduced capacity which we may need to serve customers on hot summer days, to decreasing the life of our assets, and in some cases even equipment failures and associated outages. One option that we are considering is to increase the average ambient temperature in our transformer design specifications to allow the transformers to operate at higher temperatures without experiencing these consequences. For example, increasing the average ambient temperature in our transformer spec from 32 to 40 deg C will result in our transformers being designed and built to withstand higher ambient temperatures without needing to be de-rated. The impact is similar to purchasing a transformer with a higher rating, but we believe this option will allow us to keep close to the existing transformer dimensions/size to minimize the need for more costly rebuilds that can be required when upgrading to a larger transformer. Simply increasing the nameplate rating of the transformers we specify would be more likely to increase the dimensions/size and could make asset condition replacements more costly.

7. [What is the vulnerability due to wind?]	Our transmission, sub-transmission, and distribution structures and poles are the most vulnerable to high winds. To use transmission as an example, we currently design structures to withstand wind gusts of 95 MPH per NESC standards. Areas with forecasted wind speeds greater than that level could result in a failure of one or more structures, which would result in a transmission line outage.
8. "The flooding issue would be very specific to flood zones or expected flood zones. A review of assets, and their preparedness for flooding, in those expected zones is what is needed for that. …there are assets in flood zones that are already at the highest point in that zone. Understanding what could really be at risk would be helpful."	To evaluate the substations at risk for flooding we identified their risk based on FEMA flood maps as well as using our climate change risk tool (CCRT) which incorporates future precipitation projections. A review was then conducted by subject matter experts (SMEs) with knowledge of the specific geography of the substation sites to further zero in on the substations at greatest risk of flooding.
9. When you look at priority, do you also consider what customers would be impacted (e.g., disadvantaged communities, emergency/medical services, etc.)?	Yes. Understanding the consequence and impact of a climate vulnerability includes factors such as whether critical customers would be impacted. When we evaluate recommendations to address climate vulnerabilities, we will also factor in considerations of equity so that disadvantaged communities are benefiting alongside other areas.
10. When rating the potential impacts and sensitivities, how many SMEs were involved and what was that process like?	We have about 40 SMEs directly working on our "Deep Dive Groups" evaluating vulnerabilities. These SMEs also reach out to other experts within their respective organizations as needed. We also have support from a consultant with extensive climate science expertise.

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Stay Updated

For your reference, please see attached presentation and link to recording. You can also access these and other information on our webpage. https://www.nationalgridus.com/Our-Company/New-York-Climate-Resiliency-Plan

Any questions you may have regarding climate change can also be sent to our dedicated email address. box.NYClimateresiliency@nationalgrid.com

Appendix C – Detailed results from Exposure Assessment for National Grid assets

Table C.1. Number and percentage of total substations experiencing total days per year with average ambient temperatures over 32°C (89.6°F)

Time Period	0 to 2 days	>2 to 4 days	>4 to 6 days	>6 days
Historical Baseline	702 (100%)	0 (0%)	0 (0%)	0 (0%)
2030	702 (100%)	0 (0%)	0 (0%)	0 (0%)
2040	702 (100%)	0 (0%)	0 (0%)	0 (0%)
2050	702 (100%)	0 (0%)	0 (0%)	0 (0%)
2060	700 (99.7%)	2 (0.3%)	0 (0%)	0 (0%)
2070	165 (23.5%)	535 (76.2%)	2 (0.3%)	0 (0%)
2080	108 (15.4%)	57 (8.1%)	119 (17.0%)	418 (59.5%)

Table C.2. Line mileage and percentage of total line mileage of distribution overhead conductors falling within ranges of summer maximum ambient temperatures

Time Period	< 32.2°C (90°F)	>= 32.2°C (90°F) - 35°C (95°F)	>35°C (95°F) – 37.8°C (100°F)	> 37.8°C (100°F) – 40.6°C (105°F)	> 40.6°C (105°F)
Historical Baseline	6790 (12%)	50259 (88%)	96 (0.2%)	0 (0%)	0 (0%)
2030	0 (0%)	10377 (18%)	46672 (82%)	96 (0.2%)	0 (0%)
2040	0 (0%)	6790 (12%)	47642 (83%)	2712 (5%)	0 (0%)
2050	0 (0%)	0 (0%)	32424 (57%)	24720 (43%)	0 (0%)
2060	0 (0%)	0 (0%)	24304 (43%)	32745 (57%)	96 (0.2%)
2070	0 (0%)	0 (0%)	5013 (9%)	37509 (66%)	14622 (26%)
2080	0 (0%)	0 (0%)	0 (0%)	32335 (57%)	24809 (43%)

Table C.3. Line mileage and percentage of total line mileage of distribution overhead conductors experiencing ranges of days with daily maximum ambient temperatures over 40°C (104°F)

Time Period	0 to 1 days	>=1 to 2 days	>=2 to 3 days	>=3 - 4 days	>= 4 days
Historical Baseline	57144 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
2030	57144 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
2040	57144 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
2050	57049 (100%)	96 (0.2%)	0 (0%)	0 (0%)	0 (0%)
2060	54363 (95%)	2686 (5%)	96 (0.2%)	0 (0%)	0 (0%)
2070	32266 (56%)	2819 (5%)	10054 (18%)	11910 (21%)	96 (0.2%)
2080	15010 (26%)	17255 (30%)	89 (0.2%)	2729 (5%)	22060 (39%)

Table C.4. Line mileage and percentage of total line mileage of transmission overhead conductors experiencing ranges of days with equivalent temperatures to baseline 35°C (95°F)

Time Period	36°C (96.8°F) - 37°C (98.6°F)	37°C (98.6°F) - 38°C (100.4°F)	38°C (100.4°F) - 39°C (102.2°F)	39°C (102.2°F) - 40°C (104°F)	40°C (104°F) - 41°C (105.8°F)	41°C (105.8°F) - 42°C (107.6°F)	42°C (107.6°F) - 43°C (109.4°F)
2030	9315.9 (9%)	95112.1 (91%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
2040	0 (0%)	24942.1 (24%)	79485.9 (76%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
2050	0 (0%)	0 (0%)	82685.1 (79%)	21742.9 (21%)	0 (0%)	0 (0%)	0 (0%)
2060	0 (0%)	0 (0%)	0 (0%)	79462.1 (76%)	24965.9 (24%)	0 (0%)	0 (0%)
2070	0 (0%)	0 (0%)	0 (0%)	0 (0%)	57261.9 (55%)	47166.1 (45%)	0 (0%)
2080	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	45032.8 (43%)	59395.2 (57%)

Table C.5. Number of distribution poles falling within ranges of projected near century (2025-2041), 1-in-10-year maximum wind gusts

1-in-10-Year Gust Speed (mph)	Total Poles Affected
>10-30	524
>30-40	26,801
>40-60	325,448
>60-80	612,910
>80-100	228,372
>100-120	4,843
>120-140	586

Table C.6. Number of sub-transmission structures falling within ranges of projected near century (2025-2041), 1-in-100-year maximum wind gusts

1-in-100-Year Wind Gust (mph)	Total Structures Affected
> 0 – 55	6,007
> 55 – 70	14,847
> 70 – 80	12,617
> 80 – 90	15,325
> 90 – 100	8,572
>100	1,585

Table C.7. Number of transmission structures within ranges of projected near century (2025-2041) 1-in-100-year maximum wind gusts.

1-in-100-Year Gust Speed (mph)	Total Structures Affected
< = 60	10,443
> 60-80	40,232
> 80-100	30,070
>100	9,791

Table C.8. Number of distribution poles within ranges of projected total radial icing for near century (2025-2041) 1-in-10-year icing event

1-in-10-Year Radial Icing Total (inches)	Total Poles Affected
< = 0.2	112,223
> 0.2-0.3	581,043
> 0.3-0.4	237,106
> 0.4-0.5	134,975
> 0.5-0.6	97,476
> 0.6	36,661

Table C.9. Number of sub-transmission structures within ranges of projected total radial icing for near century (2025-2041) 1-in-100-year icing event

1-in-100-Year Radial Icing Total (inches)	Total Structures Affected
< = 0.2	700
> 0.2-0.3	20,486
> 0.3-0.4	19,566
> 0.4-0.5	8,637
> 0.5-0.6	6,567
> 0.6	2,997

Table C.10. Number of transmission structures within ranges of projected total radial icing for near century (2025-2041) 1-in-100-year icing event

1-in-100-Year Radial Icing Total (inches)	Total Structures Affected
<0.2	5,453
>0.2-0.3	30,127
>0.3-0.4	31,418
>0.4-0.5	12,281
>0.5-0.6	5,298
>0.6	7,228

Appendix D – Detailed Results from Asset Vulnerability Assessment showing Sensitivity, Consequence and Vulnerability Ratings for National Grid Assets

Table D.1. Sensitivity Ratings for National Grid Assets

Sensitivity by Asset Group and Hazard	High Temperature	High Wind	Inland Flooding	Ice
Transmission Line				
Line structures	N/A	High	Med	Med
OH Conductors	Med	Med	Low	Med
UG Conductors	N/A	N/A	Low	N/A
Switches	Med	Low	Low	Med
Distribution Line				
OH Structures	N/A	High	Med	High
OH Conductors	Med	High	N/A	High
UG Conductors	Low	N/A	Med	N/A
Switches	Med	Low	N/A	High
OH Transformers	High	Low	N/A	Med
Transformers	High	Low	High	N/A
Regulators (Pole mounted)	Med	Low	N/A	Med
Capacitors (Pole mounted)	MEd	Low	N/A	Low
Substation				
Substation transformers	High	Low	High	Med
Circuit breakers	Med	Low	High	Med
Protection & control devices	Low	Low	High	N/A
Instrument transformers	Med	Low	High	Low
Control room/ Control house	Low	Low	High	Low

Table D.2. Consequence Ratings for National Grid Assets

Consequence by Asset Group	Consequence
Transmission Line	
Line structures	Med
OH Conductors	Med
UG Conductors	High
Switches	Med
Distribution Line	
OH Structures	Med
OH Conductors	Low
UG Conductors	Med
Switches	Low
OH Transformers	Med
Transformers (Pad mount)	Med
Regulators (Pole mounted)	Med
Capacitors (Pole mounted)	Low
Substation	
Substation transformers	High
Circuit breakers	High
Protection & control devices	Med
Instrument transformers	Med
Control room/ Control house	High

Table D.3. Vulnerability Ratings for High Temperature and National Grid Assets

High Temperature			
Asset Group	**Sensitivity**	**Consequence**	**Vulnerability**
Transmission Line			
Line structures	N/A	High	N/A
OH Conductors	Med	Med	Med
UG Conductors	N/A	High	N/A
Switches	Med	Med	Med
Distribution Line			
OH Structures	N/A	Med	N/A
OH Conductors	Med	Low	Low
UG Conductors	Low	Med	Low
Switches	Med	Low	Low
OH Transformers	High	Med	High
Transformers (Pad mount)	High	Med	High
Regulators (Pole mounted)	Med	Med	Med
Capacitors (Pole mounted)	Med	Low	Low
Substation			
Substation transformers	High	High	High
Circuit breakers	Med	High	High
Protection & control devices	Low	Med	Low
Instrument transformers	Med	Med	Med
Control room/ Control house	Low	High	Med

Table D.4. Vulnerability Ratings for High Winds and National Grid Assets

High Winds			
Asset Group	**Sensitivity**	**Consequence**	**Vulnerability**
Transmission Line			
Line structures	High	High	High
OH Conductors	Med	Med	Med
UG Conductors	N/A	High	N/A
Switches	Low	Med	Low
Distribution Line			
OH Structures	High	Med	High
OH Conductors	High	Low	Med
UG Conductors	N/A	Med	N/A
Switches	Low	Low	Low
OH Transformers	Low	Med	Low
Transformers (Pad mount)	Low	Med	Low
Regulators (Pole mounted)	Low	Med	Low
Capacitors (Pole mounted)	Low	Low	Low
Substation			
Substation transformers	Low	High	Med
Circuit breakers	Low	High	Med
Protection & control devices	Low	Med	Low
Instrument transformers	Low	Med	Low
Control room/ Control house	Low	High	Med

Table D.5. Vulnerability Ratings for Inland Flooding and National Grid Assets

Inland Flooding			
Asset Group	**Sensitivity**	**Consequence**	**Vulnerability**
Transmission Line			
Line structures	Med	High	High
OH Conductors	Low	Med	2
UG Conductors	Low	High	Med
Switches	Low	Med	2
Distribution Line			
OH Structures	Med	Med	Med
OH Conductors	N/A	Low	N/A
UG Conductors	Med	Med	Med
Switches	N/A	Low	N/A
OH Transformers	N/A	Med	N/A
Transformers (Pad mount)	High	Med	High
Regulators (Pole mounted)	N/A	Med	N/A
Capacitors (Pole mounted)	N/A	Low	N/A
Substation			
Substation transformers	High	High	High
Circuit breakers	High	High	High
Protection & control devices	High	Med	High
Instrument transformers	High	Med	High
Control room/ Control house	High	High	High

Table D.6. Vulnerability Ratings for Icing Events and National Grid Assets

Ice			
Asset Group	**Sensitivity**	**Consequence**	**Vulnerability**
Transmission Line			
Line structures	Med	Med	Med
OH Conductors	Med	Med	Med
UG Conductors	N/A	High	N/A
Switches	Med	Med	Med
Distribution Line			
OH Structures	High	Med	High
OH Conductors	High	Low	Med
UG Conductors	N/A	Med	N/A
Switches	High	Low	Med
OH Transformers	Med	Med	Med
Transformers (Pad mount)	N/A	Med	N/A
Regulators (Pole mounted)	Med	Med	Med
Capacitors (Pole mounted)	Low	Low	Low
Substation			
Substation transformers	Med	High	High
Circuit breakers	Med	High	High
Protection & control devices	N/A	Med	N/A
Instrument transformers	Low	Med	Low
Control room/ Control house	Low	High	Med