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STRATEGIC PLANNING

Climate Change Vulnerability Study

New York State Electric & Gas Corporation and Rochester Gas and Electric Corporation

SEPTEMBER 22, 2023

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List of Acronyms

CCRP	Climate Change Resilience Plan
CCVS	Climate Change Vulnerability Study
CMIP6	Coupled Model Intercomparison Project Phase 6
CRWG	Climate Resilience Working Group
CTHI	Cumulative Temperature. Humidity Index
DAC	Disadvantaged Communities
EOP	Emergency Operations Procedures
ETR	Estimated Time of Restoration
FEMA	Federal Emergency Management Agency
FSF	First Street Foundation
GCM	Global Climate Models
GHG	Greenhouse gas emissions
GIS	geographic information system
HILL	high impact and low likelihood
IEEE	Institute of Electrical and Electronics Engineers
IPCC	United Nations Intergovernmental Panel on Climate Change
JU	New York State Joint Utilities group
MPH	Miles Per Hour
NASA	National Aeronautics and Space Administration
NEX-GDDP	NASA Earth Exchange Global Daily Downscaled Projections
NOAA	National Oceanic and Atmospheric Administration
NYSEG	New York State Electric & Gas Corporation
NYSERDA	New York State Energy Research and Development Authority
PSL	Public Service Law
RG&E	Rochester Gas and Electric Corporation
SME	Subject Matter Expert
SSPs	Shared Socioeconomic Pathways

1. Executive Summary

Today's climate is changing rapidly because of greenhouse gas emissions released from human activities. Sea level rise, heatwaves, floods, and more frequent storms are examples of damaging impacts from climate change that have already affected New York State (Department of Environmental Conservation, n.d.). These extreme weather events have and will continue to cause substantial damage to communities and utility assets.

The service areas of New York State Electric & Gas Corporation (NYSEG) and Rochester Gas and Electric Corporation (RG&E) (together, the Companies) are experiencing the damaging impacts from extreme weather events. The chronic and acute effects from climate change are projected to increase in severity and frequency throughout the century and will continue to impact New York State (Doblas-Reyes, et al., 2021). Without planning and investment, the impacts from climate change will make it increasingly difficult for utility companies to deliver safe and reliable power to its customers.

NYSEG and RG&E are taking action to address the risks from climate change through the development of this Climate Change Vulnerability Study (CCVS) in accordance with the New York State Public Service Law (PSL) §66[1] and the Order issued by the Public Service Commission in Case 22-E-0222.[2] NYSEG and RG&E will also be completing a Climate Change Resilience Plan (CCRP) to identify appropriate resilience measures for their most vulnerable assets and procedures.

The CCVS presents the vulnerability findings of the Companies' electrical transmission, distribution, and substation assets across five climate hazards: temperature, precipitation, flooding, wind, and wind-and-ice in combination. To understand these anticipated climate hazards, the CCVS uses climate projections prepared by Columbia University and the New York State Energy Research and Development Authority (NYSERDA). The projections are made to the year 2100 under two greenhouse gas emissions scenarios: SSP2-4.5 and SSP5-8.5,[3] as well as other supplementary sources of data. In its analysis, NYSEG and RG&E use SSP5-8.5 50th percentile[4] as the primary planning scenario for determining climate change vulnerabilities.

1.1 Key Study Takeaways

Temperature projections: Climate projections reveal the potential for significant temperature increases across the NYSEG and RG&E service areas. For example, the number of days with

[1] Section 66. https://www.nysenate.gov/legislation/laws/PBS/66

[2]Case 22-E-0222. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={CA027C18-8246-47E7-A1A1-B2C096AC42C0}

[3] Shared Socioeconomic Pathways (SSPs) are scenarios of projected socioeconomic global changes used to define greenhouse gas emissions scenarios under different climate policies. The first numeral in the SSP naming convention identifies a future society while the second number (e.g., 4.5 or 8.5) identifies the amount of radiative forcing (Watts/m^2) expected in 2100.

[4] In this context, 50th percentile means that half of the discrete simulation results were above and half below.

maximum daily temperatures exceeding 95°F in Rochester is projected to increase from the historical value of approximately 1 day per year to over 11 days per year by 2050.

Temperature Vulnerabilities: Transformers, a critical component in substations, are highly sensitive when exposed to maximum ambient temperatures above 104°F or prolonged exposure to average temperatures[5] above 86°F; these temperatures have rarely occurred throughout the Companies' service areas. The projected higher ambient temperatures could lead to accelerated transformer degradation, damage, or sudden failure.

Under the study planning scenario (SSP5-8.5 50th percentile 2050), NYSEG is projected to have 67 substations (14%), 489 miles of transmission lines (12%), and 5,541 miles of distribution lines (16%) experience between 5 and 15 days with average temperatures above 86°F. RG&E is projected to have all substations, transmission lines, and distribution circuits experience between 2 and 5 days with average temperatures above 86°F.

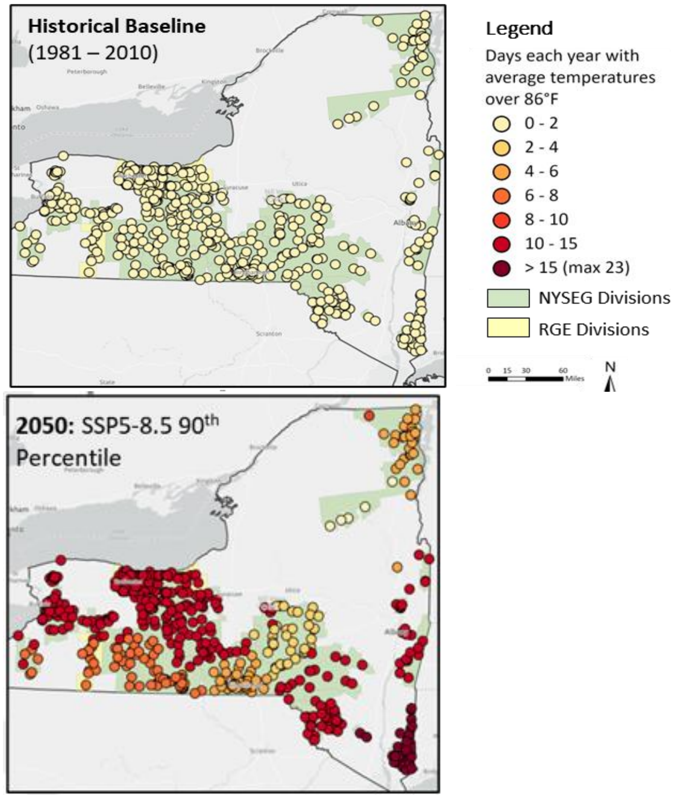

Figure 1. Historical and projected number of days with temperatures over 86°F in the service area

Precipitation Projections: Extreme precipitation is projected to increase across the NYSEG and RG&E service areas. The maximum 5-day total precipitation is projected to range from 3.5 to 6 inches in 2050 under the planning scenario.

Precipitation Vulnerabilities: Assets throughout NYSEG's and RG&E's service areas have low sensitivity to direct, non-frozen precipitation events. The impacts from pluvial or riverine flooding caused by extreme precipitation events are captured under the flooding projections.

Flooding Projections: NYSEG and RG&E's service areas are not coastal; therefore, the CCVS focuses on inland flooding. In general, floods throughout the NYSEG and RG&E service areas are expected to increase in depth and extent for both 100- and 500-year storm scenarios due to increased precipitation. By 2050, substations that already experience some levels of flooding are projected to see, on average, an approximate 2-inch increase in flood depth under the 100-year storm scenario, and a nearly 2.4-inch increase under the 500-year storm scenario.

Flooding Vulnerabilities: Components in substations are highly vulnerable to flooding due to their sensitivity to water exposure. If flood waters reach critical components (such as control cabinets,

[5] Average temperature across a 24-hour period including the nighttime low and daytime high

fans, pumps, external wiring connections, or other accessories), the damage can range from minor to complete and prolonged de-energization.

The takeaways from the exposure analysis are summarized below. An example of the change in the flooding extent between a 100- and a 500—year storm event is shown in Figure 2.

- Under the 100-year flood, 143 substations are projected to be exposed to more than 12 inches of water in the substation yard at present day and in 2050.
- Under the 500-year flood, 192 substations are projected to be exposed to more than 12 inches of water in the substation yard at present day. In 2050, five additional stations are projected to be exposed to more than 12 inches of water in the yard.

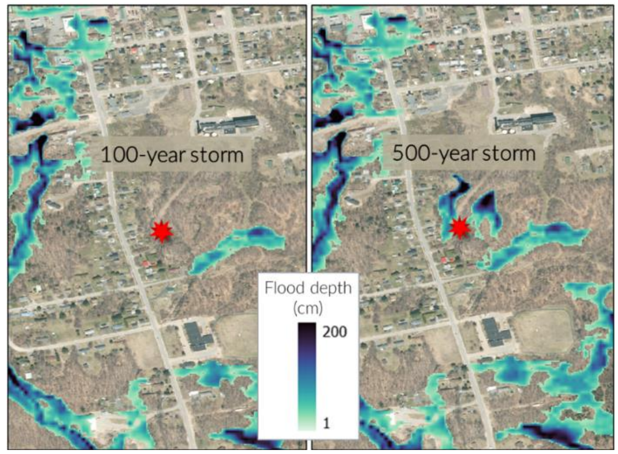

Figure 2. Flooding at a substation during 100- and 500-year storm events.

Wind Projections: Extreme wind speeds and gusts are projected to increase in both frequency and intensity by mid- through late century based on available peer-reviewed research on these infrequent but highly impactful events (Thrasher, 2022).

Wind Vulnerabilities: Extreme winds speeds that occur in low likelihood events, such as tornadoes and hurricanes, can directly affect utility assets and frequently cause fallen vegetation to impact the transmission or distribution system. While these assets are designed to be resilient, these additional and sudden impacts may cause assets to be damaged or to fail.

Wind & Ice Projections: Quantitative projections for the influence of climate change on ice and simultaneous windstorms remain uncertain due to the specific atmospheric conditions required for ice storms to occur (Intergovernmental Panel on Climate Change (IPCC), 2021). However, there has been qualitative analysis that shows that the overall frequency of ice storms is projected to decrease in the service areas as temperatures warm, but that the intensity of these events could increase (Zarzycki, 2018).

Wind & Ice Vulnerabilities: Concurrent wind-and-ice events can damage transmission and distribution structures and conductors. Significant accumulation of ice, followed by strong wind gusts, can exceed the design capabilities causing assets to be damaged or fail.

1.2 Summary of Priority Vulnerabilities

Identification of priority vulnerabilities is the focus of the CCVS. An asset's vulnerability is determined by sensitivity and exposure to a particular climate hazard, as well as the consequence of its malfunction or failure. The identified priority vulnerabilities listed in Table 1 are based on the study findings as well as input from stakeholders and subject matter experts. Asset/hazard combinations not included in the table (e.g., transmission + flooding) were not identified as priority vulnerabilities.

The focus of the CCRP will be to improve the resiliency of assets to the identified priority vulnerabilities.

Table 1. Summary of Priority Vulnerabilities by Asset Family Type

Hazard	Transmission	Distribution	Substation
High Temperature			✓
Flooding			✓
Wind	✓	✓	
Wind & Ice	✓	✓	✓

Introduction

2. Introduction

Today's climate is changing rapidly because of greenhouse gas emissions from human activities. Sea level rise, heatwaves, floods, and more frequent storms are examples of climate change impacts that New York is already experiencing (Department of Environmental Conservation, n.d.). NYSEG and RG&E performed this CCVS to 1) analyze the projections for climate change in their service areas, 2) understand the vulnerabilities of their assets and processes to climate change, and 3) identify high-level climate resilience options to address these identified vulnerabilities to climate change. Specifically, the assets considered in the CCVS are the Companies' electrical transmission, distribution, and substation assets. In addition to assessing the risk to assets, the CCVS considers the impact of climate change to the Companies' internal processes like facility rating calculations and load forecasting.

To complete this CCVS, NYSEG and RG&E engaged internal subject matter experts and ICF[6], a climate resilience consultant, to form the Study Team. In addition to the Study Team, external stakeholders were invited to participate in multiple Climate Resilience Working Group (CRWG) meetings. In these meetings the CRWG discussed key elements of the CCVS, including asset climate hazard vulnerability ratings, the selected planning scenario for climate projections, and the priority vulnerabilities that would be the focus of the CCVS. In addition, key CCVS results were shared with the CRWG on a periodic basis.

The historical climate data and future projections are described in Section 3. The climate vulnerability assessment is described in Section 4. The goals that climate resilience measures should achieve and a preliminary list of measures are presented in Section 5. Conclusions and next steps are included in Section 6. The remainder of the introduction provides a background on the motivation for this CCVS, the assumptions used for the analyses, a summary of priority climate hazards, the way in which equity is proposed to be included in the CCRP, and additional details on the CRWG engagement.

2.1 Background

In response to worsening climate hazards and in support of climate resilience planning, New York State signed into law on February 24, 2022, the addition of subdivision 29 to Public Service Law (PSL) 66. Under the law, combined gas and electric corporations in the state are required to conduct a Climate Change Vulnerability Study (CCVS) and develop a Climate Change Resilience Plan (CCRP) (New York State Public Service Commission, 2022). The CCVS is structured to evaluate the utility's assets, design specifications, and procedures to better understand the electric system's vulnerability to climate-driven risks[7]. Subsequently, the CCRP will detail how to increase system resilience to the vulnerabilities identified in the CCVS.

[6] https://www.icf.com/company/about

[7] NYS PSC Case 22-E-0222 Order Initiating Procedure

2.2 Overview of the NYSEG and RG&E Electrical Systems

NYSEG (Figure 3) was established in 1852 and operates approximately 35,000 miles of electric distribution lines and 4,000 miles of electric transmission lines. NYSEG serves more than 900,000 electricity customers across more than 40% of upstate New York (NYSEG, 2023).

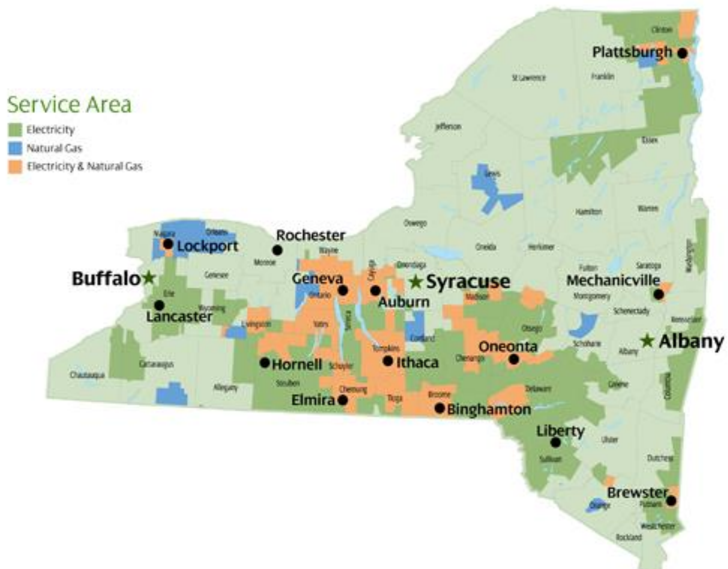

Figure 3. Map of New York State Electric and Gas Service Area

RG&E (Figure 4) was established in 1848 and operates more than 8,900 miles of electric distribution lines and nearly 1,100 miles of electric transmission lines. It serves more than 380,000 electricity customers in a nine-county region of New York State (Rochester Gas and Electric, 2023).

Figure 4. Map of Rochester Gas and Electric Service Area

2.3 Definitions of Assets and Operations

The NYSEG and RG&E electrical systems were grouped into three asset families for this study: transmission, distribution, and substation asset families.

Transmission assets carry electricity over long distances and at high voltage; for NYSEG and RG&E these voltages range from 34.5 to 345 kilovolts (kV). These assets allow for power to efficiently flow from interconnected generation facilities to substations where it is transformed to feed the distribution system. Transmission line structures, conductors, and other related components are included in the CCVS. Sub-transmission assets are included as part of the transmission assets.

Distribution assets originate at substations and deliver electricity to homes and businesses at voltages that typically range from 4.8 to 12 kV. The distribution conductors, structures, transformers, regulators, capacitors, surge arrestors, and other current-carrying components are the distribution components included in the CCVS.

Substations are facilities where one or more generation, transmission, or distribution systems interconnect to supply electricity to other parts of the grid. Substations often include complex pieces of interconnected electrical assets, like transformers and circuit breakers, that are crucial to the operation of the grid.

In addition to assessing the climate change vulnerabilities of NYSEG and RG&E's assets, potential climate risks to operations and processes were evaluated. Emergency Response, Workforce Safety, Vegetation Management, Asset Management, Facility Ratings, Reliability Planning, and Load Forecasting were included in the CCVS.

Table 2. NYSEG and RG&E Assets Included in the CCVS.

Asset Family	NYSEG	RG&E	Total
Substations	430 (73%)	156 (27%)	586
Transmission Lines (mi.)	4,124 (85%)	701 (15%)	4,825
Distribution Circuits (mi.)	35,350 (80%)	8,947 (20%)	44,297
Distribution Structures	914,984 (87%)	133,591 (13%)	1,048,575
Transmission Structures	140,732 (79%)	36,663 (21%)	177,395

Note: Percentages represent the percent of total.

2.4 Broad Baseline Assumptions

Climate Data

The CCVS presents a robust analysis using the best available climate science and datasets. The following are integrated into the analysis in this report:

Climate projections developed by Columbia University (Columbia) and the NYSERDA[8]. These data use a weather station-based exposure approach, which generalizes exposure across each of the New York State climate regions.

- Baseline and projected flooding depths in 2050 for 100-year and 500-year return period storms from First Street Foundation[9].
- Baseline historical average wind speeds and wind gusts from regional National Oceanic and Atmospheric Administration (NOAA) weather stations and daily average wind speeds projections from NASA's NEX-GDDP downscaled global climate models (GCMs).[10]
- The exact timing and magnitude of climate change is uncertain. Climate projections are expressed as a range, depending on emissions scenarios and model-projected futures. In the CCVS, the plausible lower and upper bounds of the range were identified by using 16 Coupled Model Intercomparison Project Phase 6 (CMIP6) GCMs and two future greenhouse gas emissions trajectories based on Shared Socioeconomic Pathways (SSPs).
- The SSP5-8.5 50th percentile of results was selected as the climate resilience planning level. This SSP and percentile of results was selected and discussed with the Study Team and external stakeholders with the aim of establishing a conservative planning level for analysis of future conditions. This selection aligns with work performed by industry peers.

Asset Data

- The CCVS uses asset and operations data that represent the current state of the system at the time the data were gathered.
- The CCRP will include the plan for future climate resilience measures designed to address identified vulnerabilities in the CCVS and increase the resiliency of NYSEG and RG&E's assets to the impacts from climate change.

Electrical assets from both NYSEG and RG&E were incorporated into the CCVS analysis; all of these assets are in New York State.

2.5 Summary of Priority Climate Hazards

Electrical assets are sensitive to a range of climate hazards, including extreme ambient temperatures, high relative humidity, extreme precipitation and flooding, extreme wind speeds, and ice accumulation. These climate hazards, and their related climate variables, specifically identify the constraints and sensitivities of NYSEG and RG&E's assets to climate change. To perform these analyses, climate variables were quantified to the extent possible in the baseline period[11] and future scenarios and then compared to design or operational parameters of the assets.

[8] Columbia University and NYSERDA are currently updating the 2014 ClimAID report using these same newly produced CMIP6 station data.
[9] https://firststreet.org/
[10] https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp-cmip6
[11] Columbia/NYSERDA selected the baseline period 1981–2010

For example, the design, efficiency, capacity, and health of electrical assets are affected by ambient temperature. Many transformers, including those owned by NYSEG and RG&E, are designed with the assumption that the daily average ambient temperature does not exceed 86°F[12]. In this example, the climate hazard is extreme temperature, the climate variable is the number of days per year where the daily average temperature exceeds 86°F, and the assets being reviewed are transformers.

Temperature

Utility assets, particularly those energized at medium or high voltage, are sensitive to ambient temperature. Due to the overall increase in ambient temperature expected to occur due to climate change, only increases in ambient temperature were identified as a hazard.

The following temperature-related climate variables were created to assess asset sensitivities to increased temperature in the CCVS were: annual average maximum and minimum temperature, days per year with average temperatures above 86°F, days per year with maximum temperatures over 95°F, and days per year with average maximum temperatures over 104°F.

Precipitation and Flooding

Inundation of electrical assets can cause damage, malfunction, or, in some cases, failure. The precipitation and flooding climate variables linked to asset sensitivity were average annual maximum 5-day precipitation and inundation depth from 100- and 500-year storm scenarios.

Wind

Electrical structures and related assets are designed to withstand strong wind gusts but can be damaged if wind gusts exceed design tolerances[13], like the gusts during extreme wind events. The quantified wind variable used in the CCVS was the highest daily peak wind gusts.

The science evaluating climate change and extreme events (e.g., tornadoes and severe storms) has improved in recent years, but uncertainty remains for the most intense extreme weather events because of 1) the rarity of the event relative to the length of the historical record, 2) the small spatial and time scales at which the events occur, and 3) the limited ability of current global-scale climate models to resolve events at these scales. To complement the quantified wind gust projections, a qualitative analysis of projected severe weather trends was performed as detailed in Section 3.

Wind & Ice

The transmission and distribution asset families are designed to withstand ice accumulation and a moderate-strength wind event. However, if these types of events occur and exceed design tolerances, assets can become damaged.

The dynamic weather conditions necessary for ice formation occur across small space and time scales making these types of events difficult to resolve across a wide range of scenarios, time

[12] IEEE C57.12.00-2021 Section 4.1.2.1

[13] NYSEG and RG&E utilize the applicable portions of the National Electric Safety Code (NESC) when designing its distribution and transmission assets. For example, NESC Heavy (Rule 250B), NESC High Wind (Rule 250C), NESC Concurrent Wind/Ice (Rule 250D) and Heavy Ice (1.5 inches of ice) loading conditions are used when designing transmission lines.

horizons, and climate models. Therefore, a qualitative approach was used for this combination hazard that is further explained in Section 3.

2.6 Importance of Equity

NYSEG and RG&E acknowledge their roles in contributing to equitable development of the communities they serve. The Companies' investments to aid the transition to clean energy, for example, will generate jobs and access to clean, renewable, and affordable energy. Additionally, NYSEG and RG&E's Supplier Diversity program has the goal of increasing spending on businesses owned by ethnic minorities, women, people with disabilities, veterans, and members of the LGBTQI+ community (Avangrid, 2022).

NYSEG and RG&E are looking to continue pursuing equity in the prioritization of climate resilience projects by leveraging the work done by the New York State Climate Justice Working Group and the New York State Department of Environmental Conservation who identified disadvantaged communities (DAC) across New York State. Pursuant to the Climate Leadership and Community Protection Act that was signed into law in July of 2019,[14] these groups identified 35% of census tracts in New York State as DACs (New York State Climate Justice Working Group, 2023). A map of the DACs is available to the public and is depicted in Figure 5.

In this context, DACs are communities that "have historically been overburdened by environmental pollution[15]" and are now also exposed to climate hazards, like flooding and extreme heat. The Climate Act mandates that no less than 35% (with a goal of 40%) of the State's climate action benefits (e.g., reducing emissions and investing in clean energy) must go toward DACs. (New York State, 2023). While this mandate is not specifically applicable to resilience projects, NYSEG and RG&E are evaluating use of the DACs as part of the project prioritization process for climate resilience measures. This prioritization process is currently being developed and will be discussed in further detail within the upcoming CCRP.

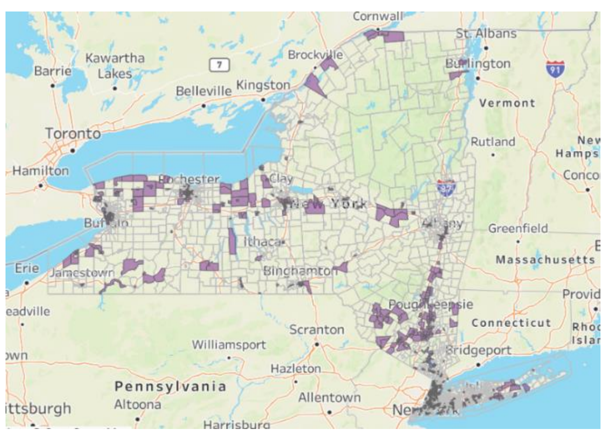

Figure 5. Map of Disadvantaged Communities in New York State (New York State Climate Justice Working Group, 2023)

[14] https://www.dec.ny.gov/press/127364.html

[15] https://climate.ny.gov/Our-Impact/Ensuring-Equity-Inclusion

2.7 Stakeholder Engagement

To gather information from community and public sources, stakeholders were engaged to form a Climate Resilience Working Group (CRWG); involvement in the CRWG was open to the public for anyone to participate. The CRWG met periodically to receives updates on the development progress of the CCVS. In these engagements stakeholders were given the opportunity to provide feedback via meeting participation, or e-mail. In addition, CRWG members were given an opportunity to review and comment on the CCVS before it was filed.

The Study Team would like to thank all CRWG members for their participation and contribution to the development of the CCVS.

Public Kickoff & Climate Resilience Working Group Meetings

Figure 6 provides an overview of the project timeline including the initial stakeholder meeting, and other Working Group sessions that established a process to provide regular updates to stakeholders.

There were five stakeholder meetings held throughout the development of the CCVS and CCRP that occurred regularly between September 2022 and September 2023. Again, participation in these meetings was open to the public such that anyone could participate and be considered a stakeholder. For each of these meetings the Study Team prepared presentation materials that were shared with all registered participants regardless of attendance at meetings. These materials were designed to communicate project progress and next steps, and to invite stakeholder participation and feedback.

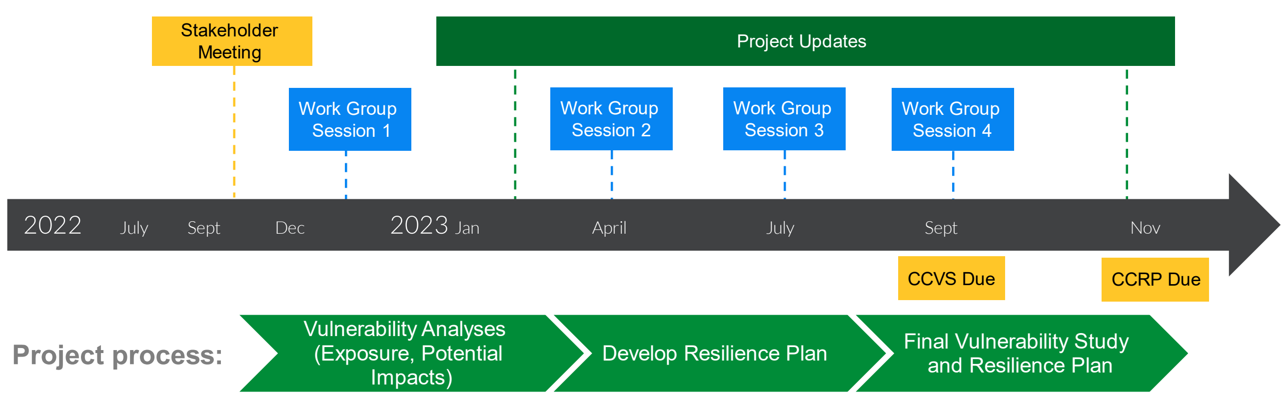

Figure 6. Project Timeline

Key inputs from Working Group participants included discussion of the most concerning climate hazards in their community and how these hazards may impact their communities. This stakeholder input was used to help tailor the CCVS and future CRWG meetings to focus on concerns raised by the CRWG.

Future CRWG Meetings

In 2024 and beyond, NYSEG and RG&E will continue to meet at least twice annually with the CRWG to discuss the CCRP and any updates from the Companies or stakeholders.

Climate Hazards

3. Historical Climate Data and Future Projections

The Study Team conducted an analysis on projected climate-related changes that may occur in the NYSEG and RG&E service areas. Climate projections model how climate and extreme weather may change over time and how different greenhouse gas emissions pathways could impact the future climate. These climate projections are not precise predictions for weather. Rather, they provide predictive data that can help entities assess and prepare for a range of potential future climate outcomes.

The climate hazards included in the analysis were temperature, humidity, precipitation, flooding, and wind/wind gusts. Extreme wind and wind-and-ice events were also included via a series of high-impact and low likelihood (HILL) extreme weather scenario studies or through review of literature published by climate science experts. The methods and results are summarized in this section.

3.1 Methods & Projection Result

Quantitative Climate Hazard Projection Data Sources

NYSEG and RG&E's CCVS utilizes quantitative climate hazard projections from three main sources: Columbia/NYSERDA, First Street Foundation, and NASA Center for Climate Simulation. The data used in this study align with the latest climate science developed for the United Nations Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report published in 2021.

Columbia University and NYSERDA

Columbia and NYSERDA developed climate projection datasets for New York State using an ensemble of 16 Coupled Model Intercomparison Project Phase 6 (CMIP6) GCMs, and two future greenhouse gas emissions trajectories based on Shared Socioeconomic Pathways (SSPs). The climate projection datasets were made available to each of the electric and gas utilities that make up the New York State Joint Utilities group.

First Street Foundation

First Street Foundation (FSF) is a non-profit organization that aims to provide present-day and future projections of risk from flooding, wildfires, extreme heat, and extreme wind. For its CCVS, NYSEG and RG&E utilized 100-year and 500-year flood depth projection datasets from FSF to quantify the risk to their assets. The FSF flooding data were used to supplement Federal Emergency Management Agency (FEMA) flood maps that may not have been recently updated, do not consider future conditions, do not exist, or were not available in a format compatible with geographic information system (GIS) software. Details on how FSF generates these datasets can be found on their website or in their detailed methodology document[16].

[16] First Street Foundation Flood Model (FSF-FM) Technical Documentation

NASA Center for Climate Simulation

Analysis of wind gust projections utilized daily average wind speed data from the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) (Thrasher, 2022). Like the data provided by Columbia/NYSERDA, this dataset (available from NASA) is simulated from multiple GCMs across a variety of SSPs.

3.2 Climate Change Projection Methodology

GCMs are computer-based simulations of Earth's climate and physical processes. They are used to understand how different levels of greenhouse gases, solar radiation, and other factors may affect future climates. Each research institution participating in CMIP6 creates a set of modeled climate data, and taken together as a group of GCMs, they can inform a range of potential future climates.

GCMs are initialized with differing parameters based on assumptions included in each SSP that were generated by IPCC for its Sixth Assessment Report. SSPs are narratives of the future that describe different socioeconomic development strategies and climate policies that may be adopted across the globe. These SSPs are based on a comprehensive assessment of the literature on future socioeconomic development as well as expert judgment. This CCVS utilized two SSPs to represent the range of possible climate futures:

- SSP2-4.5: A "middle of the road" scenario where CO_2 emissions are maintained at current-day levels until approximately 2050 and then decline to near zero by 2100. This scenario limits warming to 3°C. The CCVS refers to this as the low greenhouse gas emissions scenario.
- SSP5-8.5: An "unabated" emissions scenario where CO_2 emissions continue to increase until late into the 21st century when CO_2 emissions begin to level off. In this scenario, warming exceeds 4°C. The CCVS refers to this as the high greenhouse gas emissions scenario.

Global Climate Model Variability

Each GCM is designed with different assumptions or expectations on how Earth's climate processes react to increased levels of GHG emissions. To incorporate a variety of possible futures into this analysis, the results from multiple GCMs were combined and then a numerical distribution of the results was created. The contents of these distributions and how the values compare are described as percentiles. An example with temperature projections is shown in Figure 7. The CCVS focuses on the 50th percentile of projections for SSP5-8.5 as the planning level. The 50th percentile of results means that 50% of the GCM model simulations results for SSP5-8.5 are above the listed value and 50% are below.

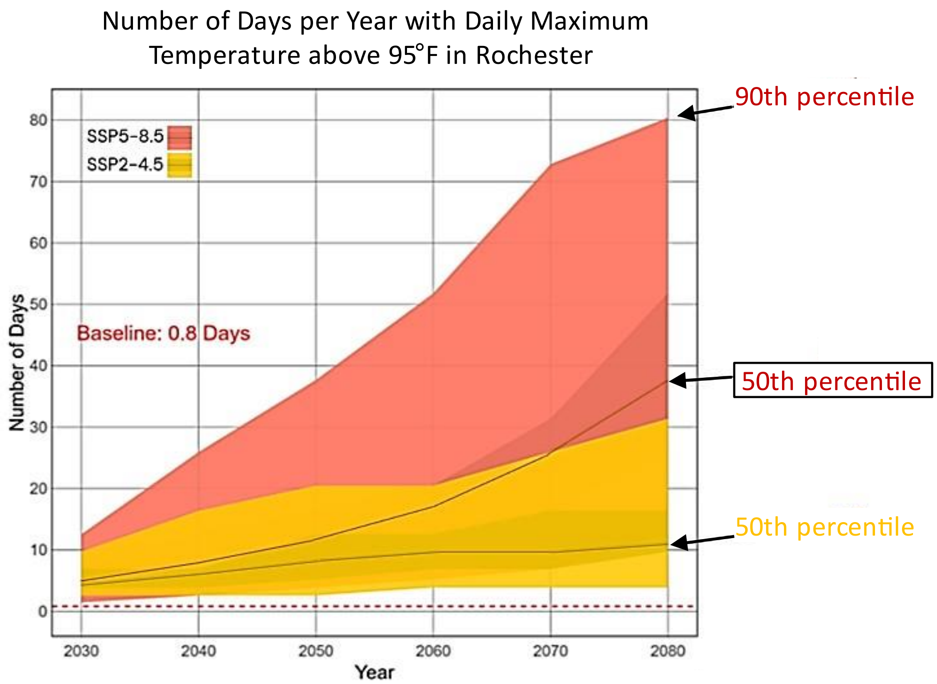

Figure 7. Projected days above 95°F in Rochester for lower and upper bounds of percentiles climate model projections across SSP2-4.5 and SSP5-8.5.

Global Climate Modeling Downscaling

A GCMs' raw output is a large grid-spaced dataset that offers limited insight into the difference in future climate within New York State without additional processing techniques. To obtain more detailed projections Columbia/NYSERDA statistically downscaled[17] GCMs by using 30 years of historical weather observations from 1981 to 2010 to form a baseline period for comparison. These data were obtained from over 20 weather stations across New York State (see Figure 8 below). This downscaling provides more meteorologically realistic projections while capturing regional differences in the projected climate across the service areas (e.g., among the Great Lakes, Adirondacks, and Finger Lakes).

[17] The term "downscale" means translating coarse spatial GCM results (e.g., 100km x 100km) to finer resolution results (e.g., 10km x 10 km).

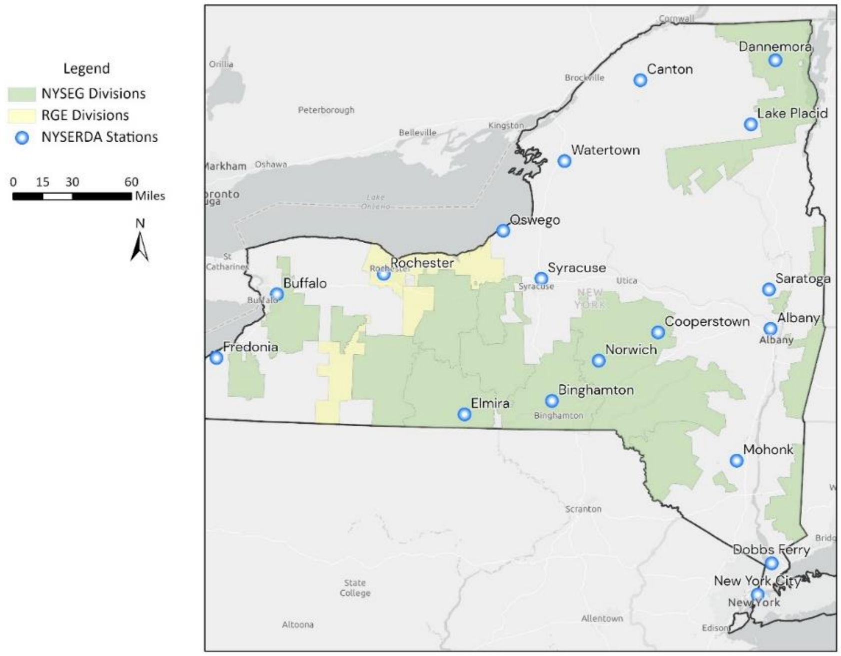

Figure 8. Map showing NYSEG (green) and RG&E (yellow) service areas and weather station locations (blue circles) for which climate projection datasets were developed by Columbia University.

Generating Climate Variables

The climate hazard datasets developed by Columbia/NYSERDA, FSF, and NASA were used in the CCVS to generate climate variable projections that could impact the NYSEG and RG&E systems. These variables were calculated as 30-year averages surrounding each time horizon of interest to account for climate trends and interannual variability in the daily temperature and precipitation datasets. For example, projections for 2050 used daily data from 2036 to 2065. Table 3 lists the variables that were created for this analysis.

Table 3. Quantifiable Climate Variables Assessed

Annual Hottest Maximum Temperature	Annual Coldest Minimum Temperature
Days Per Year with Daily Avg. Temperatures > 86°F (30°C)	Days Per Year with Max. Temperatures >95°F (35°C)
Days Per Year with Max. Temperatures > 104°F (40°C)	Avg. Annual Max. 5-day Precipitation
Days Per Year with Average Relative Humidity > 95%	Median (1-in-2 Year) Cumulative Temperature-Humidity Index (CTHI)
Highest Daily Peak Wind Gusts	First Street Flooding Data (100-year / 500-year)

3.3 Quantitative Climate Hazard Projection Results

Temperature

Climate projections reveal the potential for significant temperature increases across the NYSEG and RG&E service areas. For example, the number of days with maximum temperatures exceeding 95°F could increase from less than 1 day per year historically to between 6 and 30 days per year by 2050 and to more than 60 days per year by 2080 under a high greenhouse gas emissions scenario. This means that relatively rare historical temperatures could become a regular occurrence by late century. In addition, projections show the potential for warmer winters and less extreme winter cold snaps. Figure 9 shows an example of projections that were developed for the CCVS.

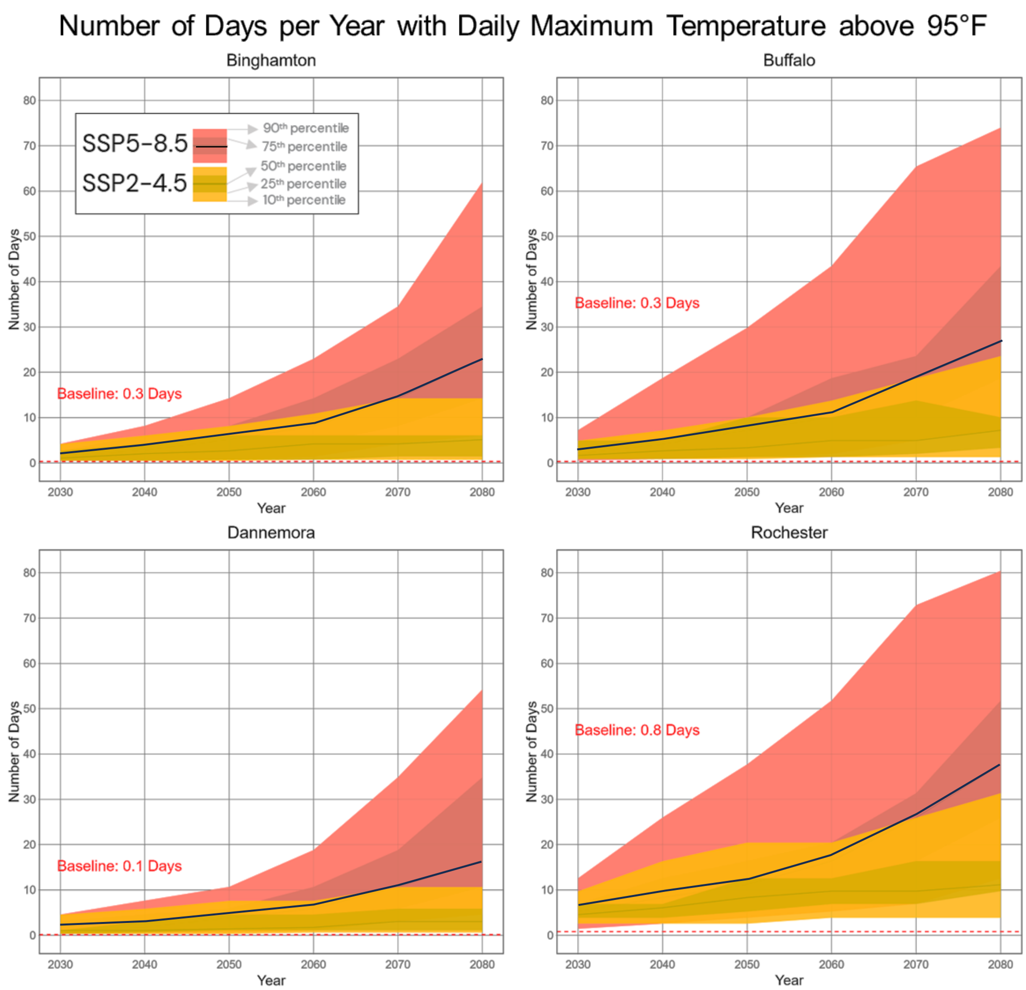

Figure 9. Average annual number of days that maximum temperature exceeds 95°F (35°C) for four representative weather stations for the 2030 to 2080 period.
Baseline values are shown on each panel in red text. Graph color gradations shown in legend on the top left panel show the 10th, 25th, 50th, 75th, and 90th model percentiles for both SSP5-8.5 (red) and SSP2-4.5 (yellow).

Humidity

Projections for days with average relative humidity over 95% show the potential for more frequent days with high relative humidity, particularly under a high greenhouse gas emissions scenario. Daily average relative humidity was calculated using hourly relative humidity projections provided by NYSERDA/Columbia.

Increasing temperatures combined with increasing relative humidity increases the apparent temperature to humans, also known as the heat index. NYSEG and RG&E load forecasting techniques use temperature and humidity to develop a Cumulative Temperature-Humidity Index (CTHI) that is used in load forecasting calculations to estimate how much customers may utilize air conditioning. A higher CTHI indicates greater air condition usage leading to a greater impact on load.

Projections show 1-in-2 (i.e., 50% chance of occurring per year) summer CTHI could increase from 78–86°F historically to 83–91°F or 88–94°F by 2050 under low (SSP2-4.5) and high (SSP5-8.5) greenhouse gas emissions scenarios, respectively. Humidity was not identified as impactful to NYSEG and RG&E assets and was not prioritized as a climate hazard for asset evaluation.

Table 4. 1-in-2 Summer Cumulative Temperature-Humidity Index (SSP2-4.5 50th – SSP5-8.5 90th)

Year	Dannemora	Binghamton	Rochester	Albany	Lake Placid
Observed	82.5°F	83.2°F	84.1°F	85.8°F	78.4°F
2030	85.8–88.6°F	86.6–89.2°F	87.4–89.4°F	89.1–91.6°F	81.9–84.6°F
2050	87.4–91.4°F	87.8–91.8°F	88.9–91.7°F	90.4–94.3°F	83.3–87.5°F
2080	88.5–97.4°F	89.0–98.0°F	90.1–98.5°F	91.5–100.4°F	84.3–93.9°F

Precipitation

Heavy precipitation events are projected to increase across the service areas. For example, projections show that the annual maximum 5-day precipitation amount could increase by approximately 7–17%through 2050 relative to historical conditions based on both low and high emissions scenarios, respectively. Projected changes are largest in the southeast areas of New York State, which are more frequently influenced by stronger storms drawing on moisture from the Atlantic Ocean.

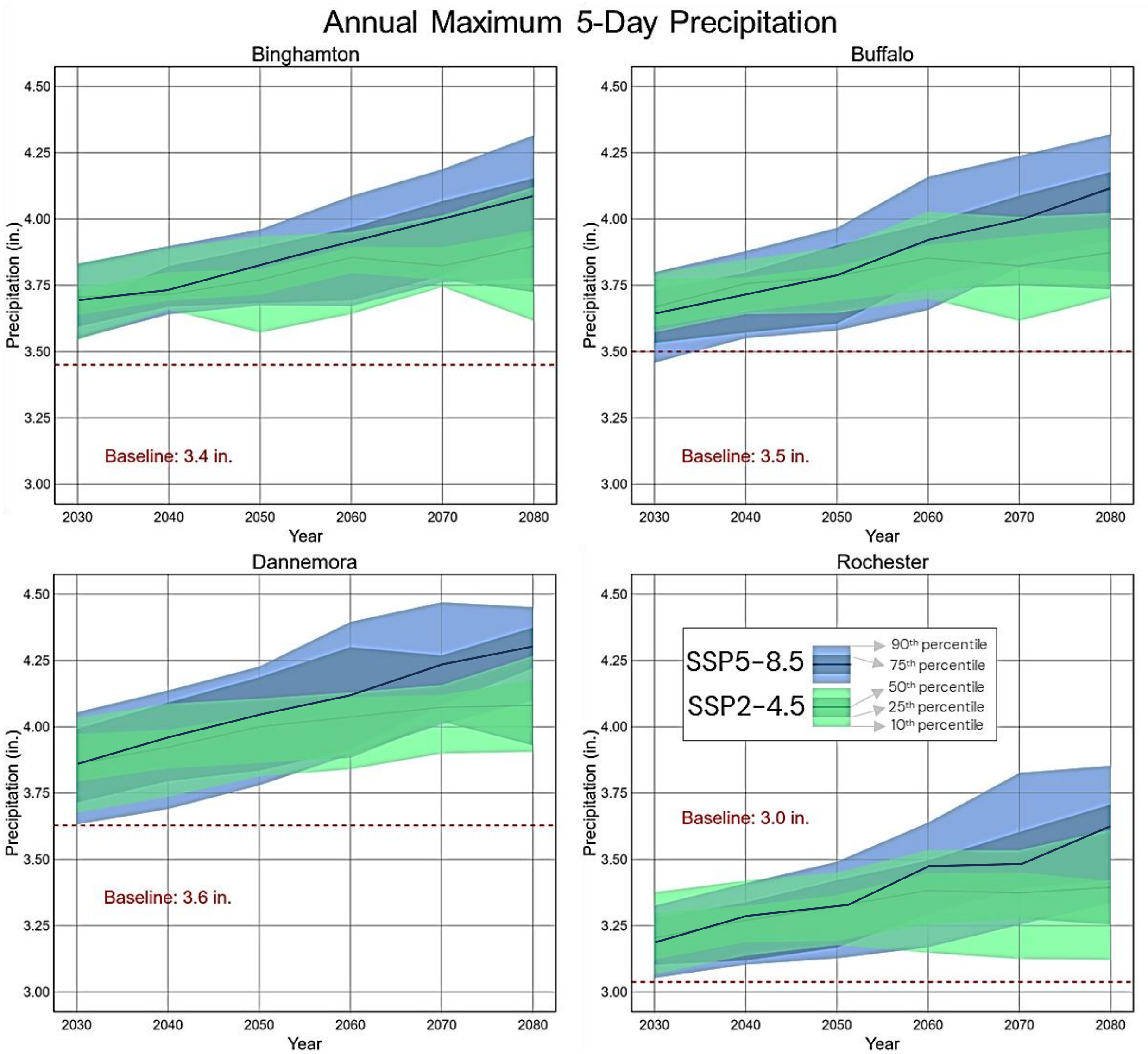

Figure 10. Average annual maximum 5-day precipitation for four select weather stations between the 2030 to 2080 period.

Baseline values are shown on each panel in red text. Graph color gradations shown in legend on the bottom right panel show the 10th, 25th, 50th, 75th, and 90th model percentiles for both SSP5-8.5 (blue) and SSP2-4.5 (green). Precipitation is reported in liquid water equivalent (e.g., frozen precipitation melted into liquid equivalent).

Flooding

Floodplains with 3-meter resolution were generated by the First Street Foundation[18] for present-day and 2050 projections in the SSP2-4.5 scenario. These floodplain datasets were used to obtain inundation depths for 100- and 500-year flooding events in NYSEG and RG&E's service areas. These

[18] https://firststreet.org/risk-factor/flood-factor/

events can occur throughout the NYSEG and RG&E system but tend to occur most often at locations near or adjacent to, existing waterways like the Susquehanna River.

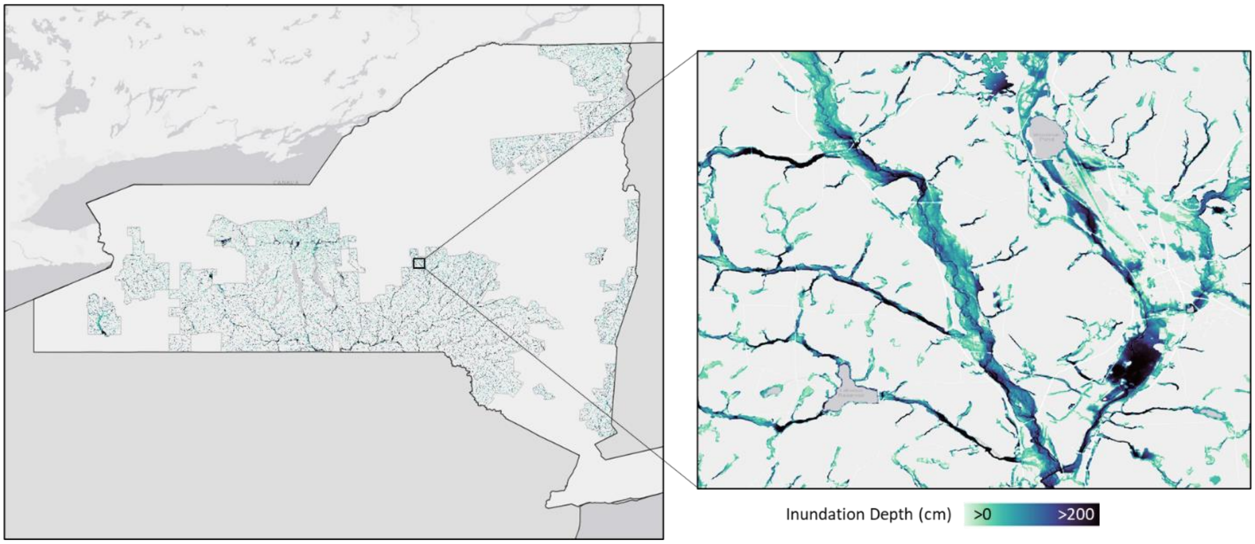

Figure 11. Extent of the 100-year floodplain in 2050 for the NYSEG service area. Inset image to demonstrate additional detail.

Wind Gusts

GCMs have made significant improvements in recent years but are still limited in their ability to resolve wind gusts given the small spatial and temporal scales at which extreme wind speeds occur and the limited availability of high-quality observational datasets. GCMs do have the ability to project daily average wind speeds, though that data alone are not illustrative of wind gust activity. In the projections developed for the CCVS, daily peak wind gusts are projected for six NOAA weather stations[19] spanning the service territory through an observed correlation between observed average wind speeds and wind gusts at these weather stations, i.e., a gust factor. While the projections do account for changes in wind gusts recorded at each station, future projections are not able to fully resolve changes in wind gusts due to the highest-intensity storms in the future, such as severe thunderstorms and tropical cyclones. In addition, projections are averaged over 30-year periods, which may dampen trends in the more extreme winds.

Overall, climate projections show marginal changes in both average daily wind speeds and daily peak wind gusts over the next century across the service areas. However, as noted previously, the climate projections used in this report cannot fully resolve all types of storms and extreme weather events driving wind gusts. The possibility of strong winds throughout New York State exists in all future scenarios. As such, the projected changes to wind speeds summarized in this report do not preclude the possibility of impactful or worsening winds in the future. Additional information on extreme wind events is covered in the Qualitative Climate Hazard section.

[19] Wind gust projections were developed for six NOAA weather stations: Burlington International Airport, Greater Binghamton Airport, Syracuse Hancock International Airport, Greater Rochester International Airport, Buffalo Niagara International Airport, and Albany International Airport.

Table 5. Change in Highest Daily Peak Wind Gusts for Each Scenario (SSP2-4.5 50th – SSP5-8.5 90th) at Weather Stations Proximal to the NYSEG and RG&E Service Areas

Year	Binghamton Airport	Albany Airport	Syracuse Airport	Rochester Airport	Buffalo Niagara Airport	Burlington Airport, VT
Observed Magnitude	73.6	77.0	75.8	67.8	73.6	62.2
2030	-1.1 to +0.5	-0.9 to +0.3	-1.1 to +0.3	-1.0 to +0.3	-0.7 to +0.3	-0.8 to +0.0
2050	-2.5 to +0.7	-1.6 to +0.5	-2.2 to +0.5	-1.7 to +0.2	-1.2 to +0.3	-1.3 to -0.1
2080	-4.0 to +0.5	-2.2 to -0.5	-3.1 to +0.4	-2.4 to +0.3	-2.3 to +0.2	-1.7 to -0.3

Wind & Ice

GCMs are not able to easily quantify climate projections for ice accumulation and concurrent wind gusts. To address this climate hazard, a qualitative approach was used and is detailed in the Qualitative Climate Hazard section.

3.4 Qualitative Climate Hazard Projection Methods & Results

GCMs are limited in their ability to resolve highly dynamic or extreme weather events. Two of the most common climatological phenomena that are assessed through other means are extreme wind events (tropical cyclones, extratropical cyclones, etc.) and frozen precipitation, including ice accumulation. These GCM projection limitations exist due to a combination of how these events occur over small spatial and time scales, the shortness of the historical record relative to the rarity of the events, and the complex and rare environmental and meteorological conditions that promote their occurrence. Due to these expected limitations, the climate projections developed by Columbia/NYSERDA used by Joint Utilities in their CCVS do not fully resolve extreme events in a quantitative fashion.

To assess these types of events, a qualitative assessment of peer-reviewed literature and historical events was performed to determine realistic future projections. A qualitative analysis may include statements about expected increases in frequency or intensity of extreme events but would not include a probabilistic or numerical projection of frequency or intensity. To fully explore these types of impactful events, the Study Team prepared two High-Impact Low Likelihood (HILL) extreme weather event scenarios: 1) a tropical cyclone with tropical storm force winds and inland flooding, and 2) an ice storm followed by a cold snap. These events were selected to supplement the quantitative climate hazard projections and allow for a broader understanding of potential future climate hazards for the NYSEG and RG&E service areas.

Tropical Cyclone with Tropical Storm Force Winds and Inland Flooding

Tropical cyclones are rapidly rotating low-pressure systems that produce extreme precipitation, high winds, and coastal storm surge. The strength and impact of a landfalling tropical cyclones in New York State is based on a range of factors including windspeeds, rainfall intensities, hurricane track speed and direction, and size as storms make landfall and progress inland. Tropical Storm Irene was the most recent significant tropical cyclone in the region, which led to widespread flood damage across the state. It was considered one of the most damaging and costly flood disasters in the Northeast, ranking among the top ten costliest disasters in U.S. history with $7 to 10 billion of damage[20]. The impacts were exacerbated by remnants of Tropical Storm Lee hitting central New York less than one month later.

Climate change is projected to impact many factors, such as atmospheric and ocean temperatures, that influence hurricane intensity, frequency, and trajectory. Projections show that warming atmospheric and ocean surface temperatures will likely make hurricanes in the North Atlantic more intense with higher rainfall amounts (Knutson, et al., 2013; IPCC, 2021). The latest IPCC Assessment Report shows a minor change in the overall frequency of hurricanes but an increase in the frequency of major hurricanes (Category 3 and above) (IPCC, 2021). Furthermore, both future projections and historical data show a persistent northward migration of the location of hurricane maximum intensity, increasing the chances that a hurricane exceeding Category 2 status could affect New York State in the future (Kossin, 2017).

Ice Storm & Extreme Cold

In New York State, a typical ice storm occurs when a warm air mass travels from the south and overrides cold air trapped near ground level (Robbins & Cortinas, 2002; DeGaetano, 2000). For example, the ice storm of 1991 completely covered Western New York in up to 2 inches of ice in addition to 4-6 inches of heavy snow. The ice-coated trees and power lines caused more than 300,000 customers to lose power; some lost power for weeks.[21] A similar event happened seven years later. The Ice Storm of 1998 lasted over 4 days and led to maximum radial ice accumulations exceeding 4 inches in parts of northern New York State. This storm led to a record 23 days of electrical power outages, snapped over 8,000 utility poles, and temperatures plunged to 10°F, leading to prolonged impacts in the region.[22]

Cold snaps generally occur in New York when anomalously cold, polar air from Canada protrudes into the northeastern United States due to an unstable polar vortex event (jet stream) or from strong northerly winds in the wake of a passing winter storm.

While the overall frequency of ice storms and cold snaps are projected to decrease in New York State as temperatures warm, future changes in the intensity of these events are less certain due to the specific atmospheric conditions required for ice storms to occur relative to other high-impact hazards (IPCC, 2021). Through the coming century, the number of hours of freezing rain is projected to decrease (McCray, Paquin, Thériault, & Bresson, 2022) as the likelihood of more extreme freezing rain events shifts farther north into Canada (Lambert & Hansen, 2011; Cheng, Li, & Auld, 2011). In addition, the total annual freezing precipitation under several warming scenarios is projected to increase in northern Canada and decrease south of the Canadian–U.S. border (Jeong et al., 2019, McCray et al., 2022). These projections are consistent with recent trends toward a gradual northward migration of the rain–snow transition zone across the United States (Easterling, et al., 2017).

[20] August 2011 Tropical Cyclones Report. National Centers for Environmental Information; Billion-Dollar Weather and Climate Disasters. National Centers for Environmental Information
[21] Looking back at the "Ice Storm of the Century" 31 years ago | RochesterFirst
[22] Throwback Thursday: Ice storm devastates North Country in 1998

3.5 Exposure

Exposure is the degree to which assets could face climate hazards. This is determined based on an asset's location and climate hazard projections in that area. To evaluate asset exposure to the identified climate hazards, the Study Team assigned the climate projections discussed in Section 3.1 to assets from the nearest weather station within each NYSERDA climate region using a nearest neighbor approach. This approach was selected because it allowed assets to be assigned projections from the closest weather station while adhering to climate region outlines, which were designed to capture regional gradients in temperature, precipitation, and other climatological factors. Figure 12 shows the region-specific nearest neighbor zones at each weather station in the exposure analysis. Regions with more than one weather station were split using the nearest neighbor approach.

The exposure results are summarized below by hazard; the potential results of equipment exposure to these hazards are discussed in the Section 4.

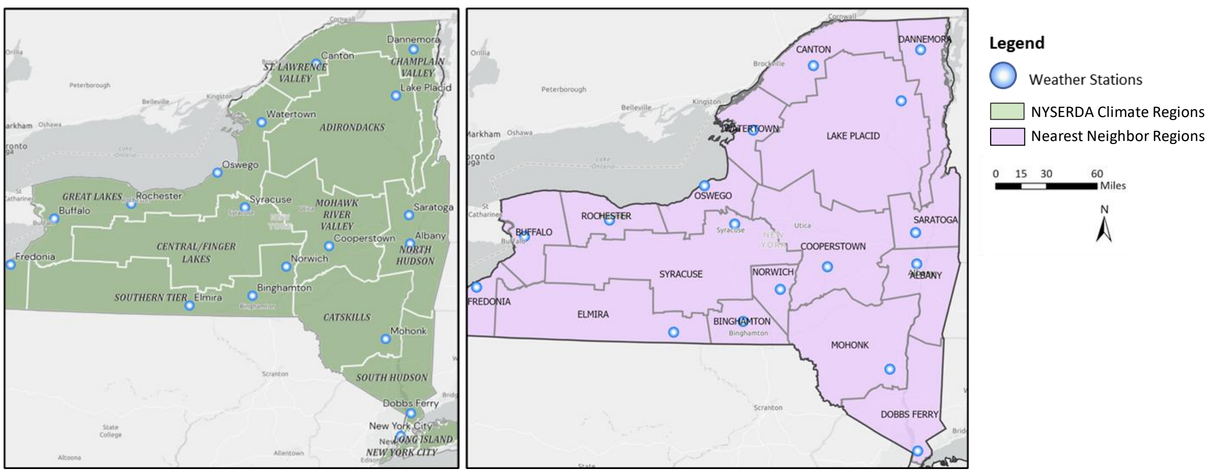

Figure 12. Weather stations and NYSERDA climate regions (left) and weather stations and polygons representing the area closest to each weather station within each NYSERDA climate region (right).

Temperature

- Assets in central and northern New York State are projected to experience smaller temperature increases than those in western and southern New York State.
- Based on SSP5-8.5 50th percentile projections by 2050
  - **NYSEG:** 83 substations, 746 miles of transmission lines, and 7,250 miles of distribution lines are projected to experience 5 to 15 days per year with 24-hour average temperatures over 86°F.[23] This represents a change from the historical baseline, at which all NYSEG assets experienced fewer than 2 days per year with 24-hour average temperatures over 86°F.
  - **RG&E**: All substations, transmission lines, and distribution circuits are projected to experience 2 to 5 days per year with 24-hour average temperatures over 86°F by 2050. Again,

[23] 86°F daily average temperature is one of the parameters used to determine ratings for transformers and overhead transmission conductors.

this represents a change from the historical baseline, at which all RG&E assets experienced fewer than 2 days per year with 24-hour average temperatures over 86°F.

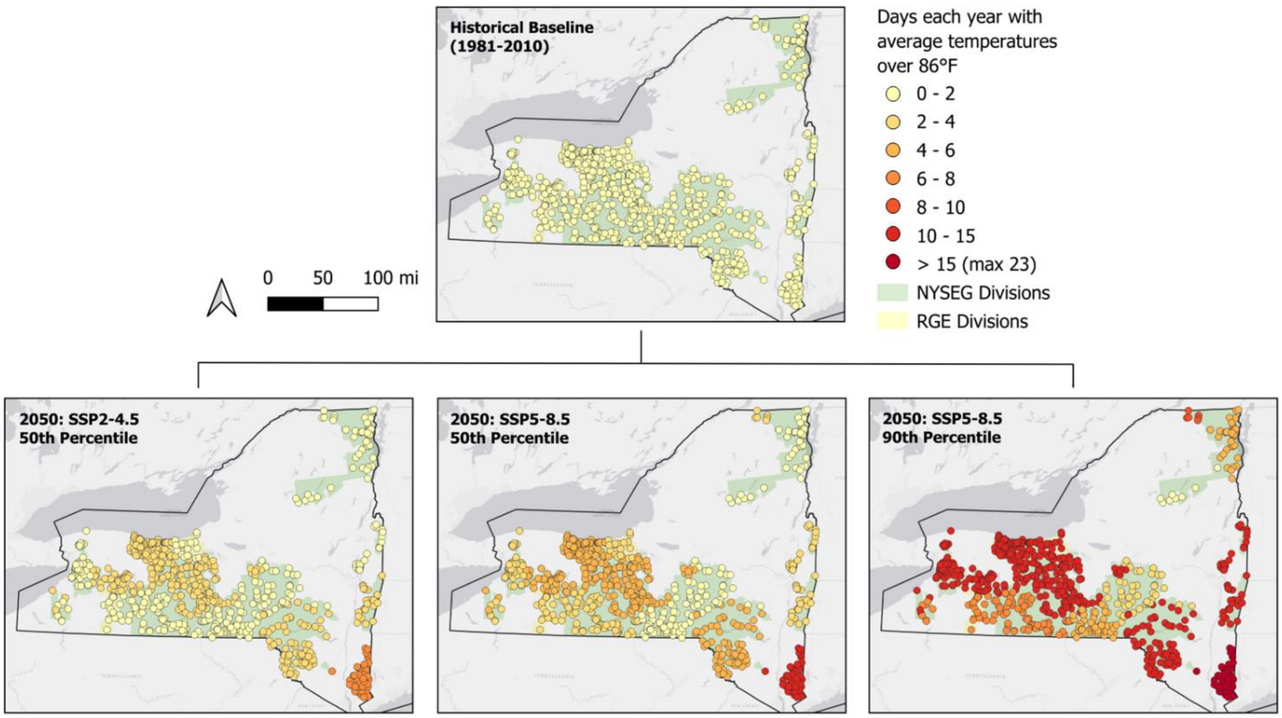

Figure 13. Days per year with 24-hour average temperature exceeding 86°F for NYSEG and RG&E and substations.
Historical (top), 2050 SSP2-4.5 50th percentile (bottom left), SSP5-8.5 50th percentile (bottom middle) and 2050 SSP5-8.5 90th percentile (bottom right).

- In the base period from 1981 to 2010 the annual maximum temperatures did not exceed 104°F[24]. However, the hottest temperature ever recorded in New York was 108°F in Troy on July 22, 1926, (NCEI, 2023). By 2050, areas of the state could experience 1 to 2 days each year with maximum temperatures over 104°F based on SSP5-8.5 50th percentile projections.
- Historically, less than one day each year has maximum temperatures above 95°F[25]. By 2050, assets could experience maximum temperatures above 95°F for 10 days each year for NYSEG assets and 9 days each year for RG&E assets based on SSP5-8.5 50th percentile projections.

Precipitation

- The historical average amount of precipitation (according to the baseline period of 1981-2010) falling during the 5-day maximum precipitation event at a given location in the NYSEG and RG&E service areas has been approximately 3.6 inches. Southeastern New York has historically seen the most precipitation during the 5-day maximum precipitation event relative to the rest of the state,

[24] 104°F maximum daily temperature is one of the parameters used to determine transformer ratings.
[25] 95°F maximum daily temperature is one of the parameters used to determine ratings for overhead transmission and distribution conductors.

with totals ranging from 3.6 to 5.2 inches. Average annual precipitation totals across the state have historically hovered around 40 inches (Kunkel, 2022); as such, these 5-day totals represent approximately 10%–12% of precipitation for a given year.

- The average amount of precipitation during the 5-day precipitation event is expected to increase by approximately 0.3 inches (9%) based on SSP2-4.5 50th percentile, 0.4 inches (10%) based on SSP5-8.5 50th percentile, and 0.6 inches (16%) based on SSP5-8.5 90th percentile projections by 2050.
- Based on SSP5-8.5 50th percentile projections, by 2050
  - **NYSEG:** 194 substations, 1,706 miles of transmission lines, and 14,249 miles of distribution lines are projected to experience over 4 inches of precipitation during the maximum 5-day precipitation event.
  - **RG&E:** A majority of RGE assets (92 of substations, 92 of transmission lines, and 90% of distribution lines) are projected to experience 3 to 3.5 inches of precipitation. Only 1% of distribution circuits are expected to experience more than four inches of precipitation.
- The direct effects of precipitation to NYSEG and RG&E's assets were not found to be a significant climate hazard.

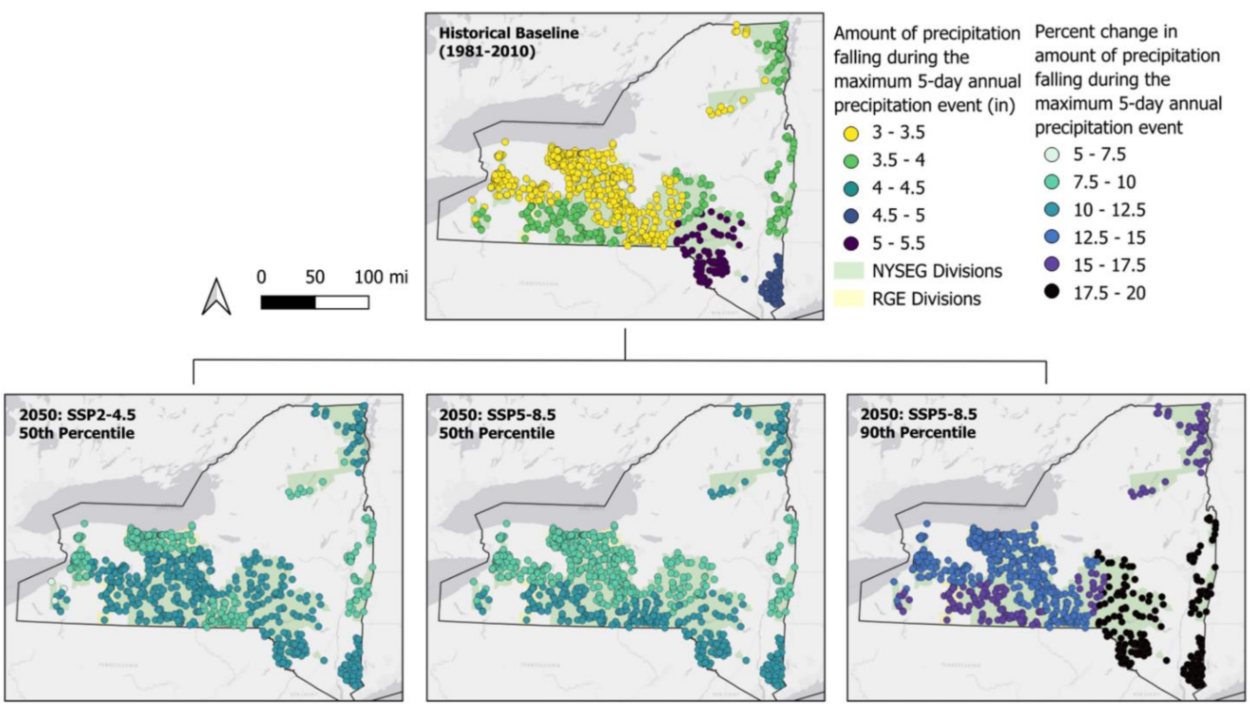

Figure 14. Average amount of precipitation at substations during the maximum 5-day precipitation event during a baseline period from 1981 to 2010 (top).
The figures on the bottom show the percent change from baseline in the amount of precipitation during the maximum 5-day annual precipitation event under three future scenarios.

Flooding

- Flood concerns exist for NYSEG and RG&E assets today, and increased precipitation will cause increasingly deep and extensive flooding in the future.
- Under the 100-year flood condition, 143 substation sites are exposed to more than 12 inches of flooding at present day and in 2050.
    - Inundation depths at substations are projected to increase, on average, by approximately 2 inches from present day to 2050, with the largest increase being 11.5 inches.
- Under the 500-year flood condition, 192 substations are exposed to more than 12 inches of flooding at present day, and 197 are projected to be exposed in 2050.
    - Inundation depths at substations are projected to increase, on average, by approximately 2.4 inches from present day to 2050, with the largest increases reaching nearly 24.5 inches.

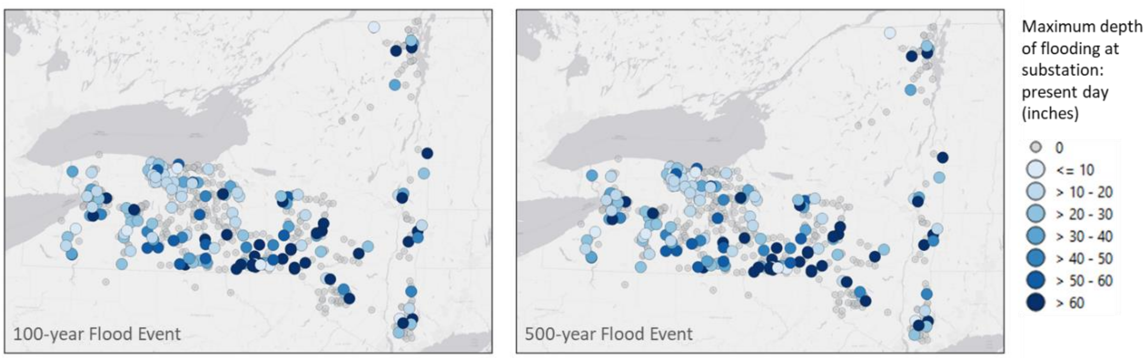

Figure 15. Maximum depth of flooding at substations: present day, both flood scenarios

Under the 100-year flood condition, 138,672 distribution structures and 24,684 transmission structures are exposed to flooding at present day. In 2050, 141,823 distribution structures (+2.2%) and 31,137 transmission structures (+26.1%) are projected to be exposed to a 100-year flood event.

Under the 500-year flood, 181,118 distribution structures and 25,234 transmission structures are exposed to flooding at present day. In 2050, 185,012 distribution structures (+2.1%) and 31,679 transmission structures (+25.5%) are projected to be exposed to a 500-year flood event.

Table 6. Total number of substations experiencing more than 12 inches of water for each flood scenario.

Timeframe	Utility	Substation Count: Present-day (Baseline)	Substation Count: 2050 Projected	Change through 2050
100-Year Flood	NYSEG	127	129	+2
	RG&E	32	36	+4
	Total	**163**	**167**	**+4**
500-Year Flood	NYSEG	169	171	+2
	RG&E	39	41	+2
	Total	**191**	**196**	**+5**

Wind

Future projections of wind speed were assessed qualitatively and quantitatively in the CCVS. The following bullets discuss the quantitative results; a subsequent section of the CCVS covers the qualitative results. The quantified projections for wind speed rely on the wind gusts in the observation dataset, i.e., those wind gusts that were experienced at the specific weather station. These values are not presented to quantify maximum wind speeds in New York.

- Wind gusts decrease in intensity based on SSP2-4.5 50th percentile projections and increase slightly based on SSP5-8.5 90th percentile projections, with the exception that in northeastern New York (area near Albany, NY and Burlington, VT airports), wind gusts are projected to decrease slightly.
- The magnitude of these changes in median wind gusts is minor, on the order of roughly 3% decrease to a 1% increase in wind gusts from the observed baseline.

Qualitative Exposure Results

To address exposure for tropical cyclones, ice storms and cold spells, the Study Team took a qualitative approach, as detailed in the Qualitative Climate Hazard section of Section 3.1 through a review of the referenced scientific literature. The key takeaways from this section are summarized below.

Tropical Cyclones

- Warming atmospheric and ocean surface temperatures will likely make hurricanes in the North Atlantic more intense, in terms of maximum sustained wind speed, rainfall leading to inland flooding, and coastal storm surge.
- The frequency and percentage of major hurricanes (i.e., Category 3 and above) are projected to increase during the 21st century in the Atlantic basin.
- The potential for higher-intensity tropical cyclones will likely increase during the 21st century, primarily in areas near the Atlantic coast.

Ice Storms and Cold Spells

- There is a high degree of uncertainty in future trends regarding ice storms. Models project decreasing frequency (or likelihood) of ice storms, but the ice accumulation of the highest-intensity ice storms could increase.
- Climate change is projected to lead to warmer winter temperatures and reduced cold snap frequency.
- The projected increase in winter temperature and projected decrease in the frequency of freezing rain suggest that by late century, cold spells following severe ice storms may not last as long as present day and have a warmer peak intensity.

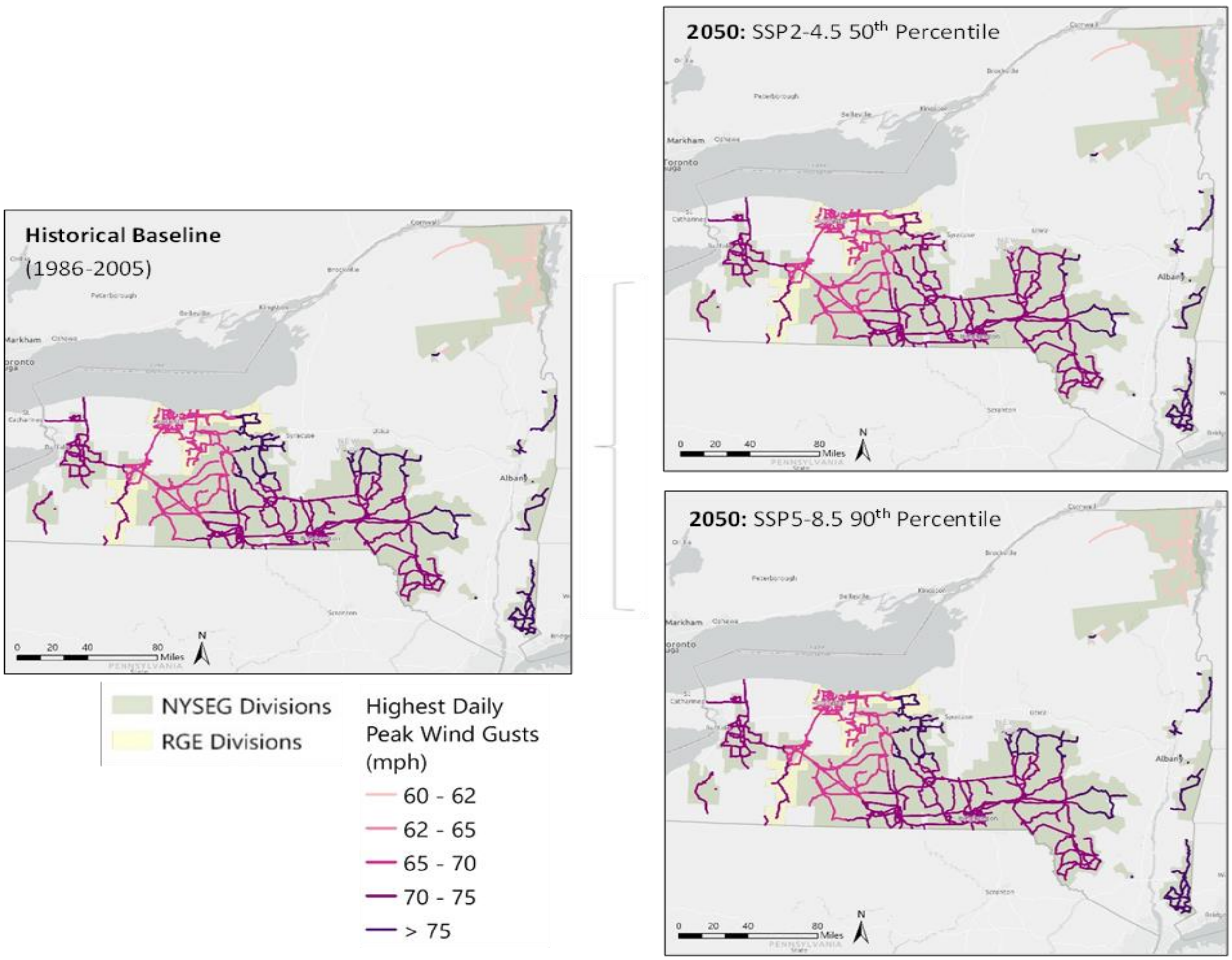

Figure 16. Wind exposure on transmission and distribution lines
Historical (left), 2050 SSP2-4.5 50th percentile (top right), and 2050 SSP5-8.5 90th percentile (bottom right) highest daily peak wind gusts (mph).

Vulnerability Assessment

4. Climate Change Vulnerability Assessment

A focus of the CCVS is to identify which asset–hazard combinations are considered priority vulnerabilities. “High” vulnerability ratings, along with specific subject matter expert (SME) feedback, identify which asset–hazard combinations are priority vulnerabilities and that will be the focus of the CCRP. The vulnerability assessment is composed of three main components: exposure (details discussed in Section 3), sensitivity, and consequence.

- **Exposure:** Exposure is the degree to which assets could face climate hazards. This is determined based on an asset’s location and climate hazard projections in that area.
- **Sensitivity:** Sensitivity is the degree to which assets could be affected by exposure to climate hazards.
- **Consequence**: Consequence is defined as the magnitude of negative outcomes for the NYSEG and RG&E systems, customers, or staff when an asset is damaged.

The assets and their respective asset family that were included in the vulnerability assessment are listed in Table 7.

Table 7. Assets and Asset Families

Transmission Asset Family	Distribution Asset Family	Substation Asset Family
Line Structures	Line Structures	Substation Transformers
Overhead Conductors	Overhead Conductors	Substation Regulators
Open-Air Current-Carrying Components	Open-Air Current-Carrying Components	Instrument Transformers (CT's and PT's)
Underground Conductors	Underground Conductors	Circuit Breakers
	Transformers (Overhead)	Control Room/Control House
	Transformers (Pad-Mounted)	Substation Reactors
	Regulators (Overhead)	Support Structures
	Capacitors (Overhead)	
	Surge Arrestors	

4.1 Vulnerability Assessment Overview

The first step in the vulnerability assessment process was to identify asset exposure to climate hazards. Climate science data generated by the CCVS were utilized to determine projected exposure for asset families across NYSEG and RG&E’s service areas. Exposure, alongside asset evaluations and SME input, was used to create a list of asset–hazard combinations that would be the focus of step two.

In the second step, the sensitivity and consequence ratings for the asset–hazard combinations identified in step one were assessed by SMEs. These ratings were then combined to produce a vulnerability rating for each asset–hazard combination. Finally, the vulnerability ratings for asset–

hazard combinations, along with SME feedback, were used to generate a list of priority vulnerabilities. An overview of the process is shown in Figure 17.

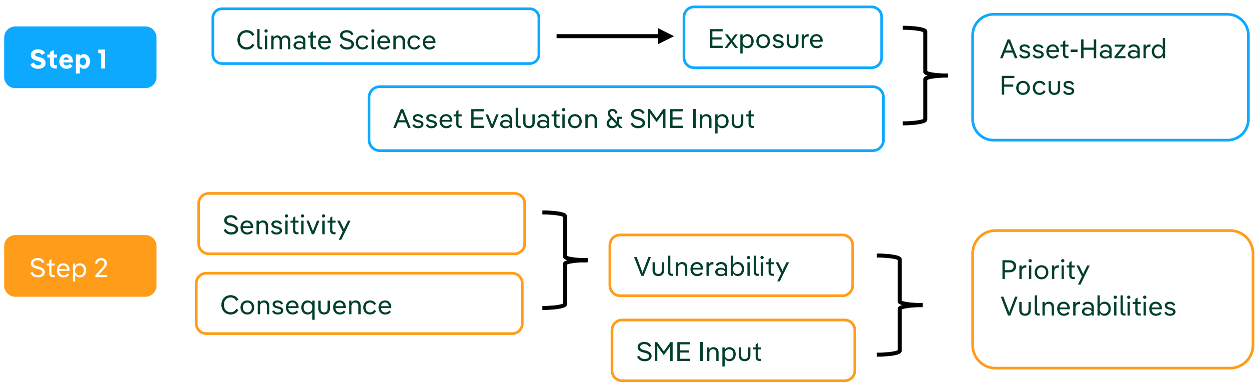

Figure 17. Vulnerability Assessment Methodology

Sensitivity Ratings

Sensitivity is the degree to which assets could be affected by exposure to climate hazards. For example, pole-mounted distribution transformers are not sensitive to flooding because of their elevated position, but the pole itself would be sensitive to flooding.

Each asset was given a sensitivity rating for each climate hazard ranging from not applicable to high. The sensitivity ratings for assets were determined through collaboration between SMEs and the Study Team and are defined as follows:

- **Not Applicable**: Assets that are not exposed to a climate hazard.
- **Low**: Assets that have low sensitivity or experience no or minimal adverse impact when exposed to a climate hazard. For example, overhead conductors have low sensitivity to rainfall.
- **Medium**: Assets that are considered to have medium/moderate sensitivity risk being adversely affected by high thresholds of exposure to a climate hazard. Sensitivity may also be considered moderate if potential impacts are more accurately characterized as chronic/controlled (e.g., the life expectancy of a capacitor is reduced by increasing ambient temperatures) rather than sudden/acute (e.g., a transformer fault due to water intrusion).
- **High**: Assets that may be subject to major or sudden failure in the event of exposure to a climate hazard (e.g., wind and ice loading above design tolerances can result in transmission tower failures). These assets typically do not have any existing protection or adaptation measures (e.g., electrical substations without flood protection walls), or if they do, they are limited in scope or level of protection against the projected climate events (e.g., an existing floodwall that is lower than the projected flood depths).

Table 8. Asset Sensitivity Ratings

Asset Family	Assets	Temp.	Precip.	Flooding	Wind	Wind & Ice
Transmission Asset Family	Line Structures	N/A	N/A	Medium	High	High
	Conductors (Overhead)	Medium	Low	N/A	Medium	High
	Conductors (Underground)	Low	N/A	Low	N/A	N/A
	Open-Air Current-Carrying Components	Medium	Low	N/A	Low	Medium
Distribution Asset Family	Line Structures	N/A	N/A	Medium	High	High
	Conductors (Overhead)	Medium	N/A	N/A	Medium	High
	Conductors (Underground)	Low	N/A	Low	N/A	N/A
	Open-Air Current-Carrying Components	Medium	N/A	N/A	Low	Medium
	Transformers (Overhead)	High	N/A	N/A	Low	Low
	Transformers (Pad Mount)	High	N/A	High	Low	N/A
	Regulators	Medium	N/A	N/A	Low	Medium
	Capacitors	Medium	N/A	N/A	Low	Low
	Surge Arrestors	Low	Low	N/A	Low	Low
Substation Asset Family	Substation Transformers	High	N/A	High	Low	Medium
	Substation Regulators	High	N/A	High	Low	Medium
	Circuit Breakers	Medium	N/A	High	Low	Medium
	Protection & Control Devices	Low	N/A	High	Low	N/A
	Instrument Transformers (CTs & PTs)	Medium	N/A	High	Low	Low
	Control Room/Control House	Low	N/A	High	Low	Low
	Substation Reactors	High	N/A	High	Low	Medium
	Structures	N/A	N/A	High	Medium	Medium

Consequence Ratings

Consequence is defined as the magnitude of negative outcomes for the NYSEG and RG&E systems, customers, or staff when an asset is damaged. Unlike sensitivity ratings, consequence ratings are independent of exposure to climate hazards; these ratings focus strictly on the outcomes that may occur if assets were to malfunction or be damaged. For example, the failure of a distribution transformer may cause multiple customers to lose power while the failure of a distribution capacitor may not result in any customer interruptions.

Each asset was given a consequence rating ranging from low to high. The consequence ratings for each asset were determined through collaboration between SMEs and the Study Team. The consequence ratings are defined as follows:

- **Low**: Assets are considered to have a low consequence rating if asset damage would result in minor or minimal adverse outcomes.
- **Medium**: Assets are considered to have a moderate consequence rating if asset damage could result in localized adverse outcomes, including outages restored in under 24 hours, limited safety risks to the public or utility personnel, and/or asset repairs.
- **High**: Assets are considered to have a high consequence rating if asset damage could result in widespread or outages lasting more than 24 hours, safety risks or potential injuries to the public or utility personnel, and/or asset damage beyond repair.

The consequence ratings for assets were rated as follows:

Table 9. Asset Consequence Ratings

Asset Family	Asset	Rating
Transmission Asset Family	Line Structures	High
	Conductors (Overhead)	Medium
	Conductors (Underground)	High
	Open-Air Current-Carrying Components	Medium
Distribution Asset Family	Line Structures	Medium
	Conductors (Overhead)	Low
	Conductors (Underground)	Medium
	Open-Air Current-Carrying Components	Low
	Transformers (Overhead)	Medium
	Transformers (Pad Mount)	Medium
	Regulators	Medium
	Capacitors	Low
	Surge Arrestors	Low
Substation Asset Family	Substation Transformers	High
	Substation Regulators	High
	Circuit Breakers	High
	Protection & Control Devices	Medium
	Instrument Transformers (CTs & PTs)	Medium
	Control Room/Control House	High
	Substation Reactors	High
	Structures	High

Vulnerability Rating

Determining an asset's vulnerability rating to a climate hazard was done by combining the asset's sensitivity to that climate hazard with its consequence rating. Vulnerability communicates not just if an asset could be impacted by a climate hazard but also the implications and criticality of the impact.

The vulnerability rating each asset–hazard combination ranged from "not applicable" to "high" depending upon its consequence and sensitivity ratings. The color-coded cells in Table 10 show the vulnerability rating for an asset–hazard combination that result when combining sensitivity and consequence ratings.

Table 10. Vulnerability Rating Rubric

Consequence \ Sensitivity	(Low)	(Medium)	(High)	(N/A)
(Low)	Low	Low	Medium	N/A
(Medium)	Low	Medium	High	N/A
(High)	Medium	High	High	N/A

4.2 Vulnerability Assessment Results

Summary of Identified Priority Vulnerabilities

Assets with a high vulnerability rating were used to determine which asset family–hazard combinations were considered as the initial priority vulnerabilities. Once this initial list was created, discussions with SMEs were used to determine if a high vulnerability rating found through this process represented a true vulnerability to climate change. If asset–hazard combinations were initially found to have a high vulnerability rating but de-prioritized based on SME feedback, it is indicated with an asterisk (*) in Tables 12, 13, or 14, along with an explanation in the appropriate section. The complete results for vulnerability assessment are discussed below.

Table 11 provides a summary of the final list of priority vulnerabilities.

Table 11. Summary of Asset Family Priority Vulnerabilities

Transmission Asset Family	Distribution Asset Family	Substation Asset Family
Wind & Ice	Wind & Ice	Wind & Ice
Wind	Wind	High Temperature
		Flooding

Transmission Asset Vulnerability Results

Transmission assets are used to connect and transfer power between different portions of the grid, deliver power to load centers, and interconnect large generation resources. Transmission assets carry electricity over long distances and at high voltages, NYSEG and RG&E's transmission voltages generally range from 34.5 kilovolts (kV) to 345 kV (note that this CCVS includes all voltages). Some transmission assets are located underground and are less affected by climate hazards; though most transmission assets are above ground and are vulnerable to climate hazards. The priority vulnerabilities for transmission assets are the wind, and wind-and-ice. The vulnerability of each transmission asset is categorized in Table 12, followed by an explanation of how each climate hazard impacts transmission assets. The transmission assets of the vulnerability assessment are as follows:

- **Line Structures**: Provide physical support for the conductors or other system components.
- Overhead and Underground Conductors: Carry electric current overhead.
- **Underground Conductors**: Carry electric current underground.
- **Open-Air Current-Carrying Components**: Include switches, which allow sectioning of transmission lines, and jumpers, which connect sections of power conductors.

Table 12. Transmission Asset Vulnerability Ratings

Asset \ Hazard	Temperature	Precipitation	Flooding	Wind	Wind & Ice
Line Structures (Poles/towers)	N/A	N/A	High*	High	High
Conductors (Overhead)	Medium	Low	N/A	Medium	High
Conductors (Underground)	Medium	N/A	Medium	N/A	N/A
Open-Air Current-Carrying components	Medium	Low	N/A	Low	Medium
Priority Vulnerability	No	No	No	Yes	Yes

Transmission Asset Vulnerability to Temperature

Most transmission assets have a medium vulnerability to high temperature; no transmission assets were identified as having a priority vulnerability to temperature. The capacity of an overhead transmission asset is directly related to its operating temperature and its ability to transfer heat to the ambient air via convection. Due to the expected increase in ambient temperature throughout the century, the process to calculate overhead transmission asset ratings across New York State should be reviewed as discussed in the section of the CCVS focusing on process review. The thermal design of underground transmission lines and their ability to dissipate heat are an important part of its design. However, due to an underground conductor's burial depth and the temperature modulating effect of the earth, underground conductors were identified as having low sensitivity to temperature and a medium vulnerability rating.

Transmission Asset Vulnerability to Precipitation

Transmission structures and other overhead assets are designed to be located outdoors and are resistant to precipitation; accordingly, these assets were rated with a low vulnerability rating. Underground transmission assets are sheltered from the effects of precipitation and were rated with a not-applicable vulnerability rating. Overall, precipitation was not identified as a priority vulnerability for transmission assets.

Transmission Asset Vulnerability to Flooding

Transmission assets have varying degrees of vulnerability to flooding. Transmission structures are considered the most vulnerable to flooding due to their location in remote or water-permeable locations. The main risks to structures are erosion and scouring of the ground near structure bases, particularly near existing watercourses and flowing waters. This erosion or scouring can compromise the stability of structures which can lead to failure. However, given the periodic inspections of these assets, conditions affecting the integrity of the structure would likely be identified and addressed prior to failure. Underground transmission conductors can be exposed to flooding but are designed to be water resistant. For these reasons, flooding was not identified as a priority vulnerability for transmission assets.

Transmission Asset Vulnerability to Wind

Transmission towers and conductors are vulnerable to wind and can fail in extreme circumstances when winds exceed their design parameters. Underground transmission conductors are sheltered from wind impacts and were rated as not applicable. Overall, due to their sensitivity to wind and their high consequence of failure, transmission assets and wind were identified as a priority vulnerability, despite the projected marginal changes in wind gust.

Transmission Asset Vulnerability to Wind-and-Ice

Transmission assets have medium to high vulnerability to the combination of wind and ice. Transmission towers and overhead conductors are designed to withstand combinations of wind and ice; quantities above their design parameters can result in failure. Underground conductors are sheltered, so this climate hazard was not applicable to them. Transmission assets' high sensitivity to wind-and-ice and the high consequence of failure for transmission assets resulted in this combination being identified as a priority vulnerability.

Distribution Asset Vulnerability Results

Distribution assets originate at a substation and deliver electricity to the customers at voltages lower than transmission voltages. The priority vulnerabilities for distribution assets are wind and wind-and-ice climate hazards. The vulnerability of each distribution asset is categorized in Table 13, followed by a rationale for each climate hazard. The distribution assets of the vulnerability assessment are as follows:

- **Line Structures**: Provide physical support for the conductors or other system components.
- **Overhead Conductors:** Carry electric current from the substation along roadways to feed customer load.
- **Underground Conductors**: Carry electric current from the substation along roadways to feed customer load.
- **Open-Air Current-Carrying Components**: Includes switches, jumpers, reclosers, fuses, etc.

- **Overhead and Pad-Mount Transformers**: Step-down voltage to a level suitable for use by customers.
- **Regulators**: Maintain a proper level of voltage along a distribution circuit.
- **Capacitors**: Used to enhance the electrical supply quality and system efficiency. They compensate and correct power to maintain an even voltage level.
- **Surge Arrestors**: Protective devices that limit voltage on asset by discharging or bypassing during times of excessive voltage surges (e.g., lightning strike).

Table 13. Distribution Asset Vulnerability Ratings

Asset / Hazard	Temperature	Precipitation	Flooding	Wind	Wind & Ice
Line Structures (Overhead)	N/A	N/A	Medium	High	High
Conductors (Overhead)	Low	N/A	N/A	Low	Medium
Conductors (Underground)	Low	N/A	Low	N/A	N/A
Open-Air Current-Carrying components	Low	N/A	N/A	Low	Low
Transformers (Overhead)	High*	N/A	N/A	Low	Low
Transformers (Pad mount)	High*	N/A	High*	Low	N/A
Regulators (Pole-mounted)	Medium	N/A	N/A	Low	Medium
Capacitors (Pole-mounted)	Low	N/A	N/A	Low	Low
Surge Arrestors	Low	N/A	N/A	Low	Low
Priority Vulnerability	No	No	No	Yes	Yes

Distribution Asset Vulnerability to Temperature

Most distribution assets have a low vulnerability to projected temperature changes. However, higher ambient temperatures may reduce thermal loading capacity of current-carrying components. Increasing frequency, severity, and duration of heat waves has the potential to accelerate aging, particularly in transformers, leading to increased risk of malfunction or failure.

While overhead and pad-mounted transformers were characterized with high vulnerability, it is driven by the high sensitivity of the component when exposed to high temperatures; the consequence ratings were found to be low. Transformers are designed with the capability to overload and withstand elevated temperatures for intervals when high demand and high ambient temperature conditions occur. For this reason, and in coordination with NYSEG and RG&E's subject matter experts, the asset–hazard combination of distribution and temperature was deprioritized.

Distribution Asset Vulnerability to Precipitation

Most distribution assets are designed to be located outdoors and to be impervious to precipitation. Accordingly, these assets were found to have a not-applicable vulnerability to precipitation.

Distribution Asset Vulnerability to Flooding

Except for pad-mount transformers, NYSEG and RG&E's distribution assets tend to have low vulnerability to flooding. Pad-mounted transformers were characterized with high vulnerability to flooding, but this rating is driven by the sensitivity of the component when exposed to flooding rather than the consequence.

Flooding may result in damage to pad-mount transformers and lead to failure. Pad-mount transformers located in or near floodplains should utilize designs that are considered submersible to help mitigate against these risks. In the event a pad-mount transformer is damaged, it can be replaced quickly without affecting large numbers of customers. Accordingly, this asset–hazard combination was deprioritized.

Distribution Asset Vulnerability to Wind

Most distribution assets were rated with a low vulnerability to wind due to their limited cross-section and height from ground. However, wind also affects vegetation, which can then affect distribution assets, particularly distribution structures, which often affect all or part of a distribution circuit and its customers. The risk of failure for overhead structures is particularly acute for aging infrastructure, which may be less resilient to this hazard. The impacts from vegetation as well as the wind-loading on structures resulted in this receiving a high vulnerability rating. Accordingly, the combination of wind and distribution assets was determined to be a priority vulnerability.

Distribution Asset Vulnerability to Wind-and-Ice

Distribution assets have varying degrees of vulnerability to wind-and-ice. Overhead conductors and regulators both have medium vulnerability to wind-and-ice as the accumulated weight of ice and force from wind can exceed design tolerances and cause damage. In addition, wind and ice also affect vegetation which can then affect distribution assets, particularly distribution structures. The impacts from vegetation as well as wind-and-ice loading resulted in this receiving a high vulnerability rating. The combination of wind and ice and distribution assets was determined to be a priority vulnerability.

Substation Asset Vulnerability Results

Electrical substations are facilities where one or more generation, transmission, or distribution systems interconnect to distribute electricity to other parts of the power system. Substations often include complex pieces of interconnected electrical assets, like transformers and circuit breakers, that are crucial to the function of the grid.

The priority vulnerabilities for substation assets are temperature, flooding, and wind-and-ice climate hazards. The vulnerability of each component is categorized in Table 14, followed by a rationale for each climate hazard. The substation assets in the vulnerability assessment are as follows:

- **Substation Transformers**: Step-down voltage for use in other parts of the transmission or distribution system.
- **Substation Regulators**: Maintain a proper level of voltage at the distribution substation.
- **Circuit Breakers**: Provide isolation functions for maintenance activities or in case of faults on the power system.
- **Protection & Control Devices**: Collection of devices used to monitor and control devices inside of a substation during normal operation and fault conditions.
- **Instrument Transformers**: Provide accurate and reliable current and voltage measurements to meters, protective relaying, and other devices.
- **Control Rooms/Control Houses**: Area where most protection and control devices are located and interconnected. Includes assets allowing for assessing alarms, circuit breaker status, and measuring electrical quantities for other substation assets.
- **Substation Reactors**: Limit current or helps control voltage that could damage components of a substation.
- **Support Structures**: Provide physical support for the conductors or other system components.

Table 14. Substation Vulnerability Ratings

Asset / Hazard	Temperature	Precipitation	Flooding	Wind	Wind & Ice
Substation Transformers	High	N/A	High	Medium	High
Substation Regulators	High	N/A	High	Medium	High
Circuit Breakers	High	N/A	High	Medium	High
Protection & Control Devices	Low	N/A	High	Low	N/A
Instrument Transformers (CT's and PT's)	Medium	N/A	High	Low	Low
Control Rooms / Control Houses	Medium	N/A	High	Medium	Medium
Substation Reactors	High	N/A	High	Medium	High
Structures	N/A	N/A	Medium	High*	High
Priority Vulnerability	Yes	No	Yes	No	Yes

Substation Asset Vulnerability to Temperature

Increasing ambient temperatures reduce the ability of substation assets to effectively dissipate heat, which can adversely affect their operation. For example, high temperatures lower the effective capacity of transformers and voltage regulators by approximately 1% per 1°C (1.8°F) increase in daily average temperature above 30°C (86°F) (IEEE, 2011).

Substation transformers, regulators, circuit breakers, and reactors were the substation assets found to be highly vulnerable to increases in ambient temperature due to their high sensitivity and consequence ratings. Accordingly, substations and temperature were found to be a priority vulnerability.

Substation Asset Vulnerability to Precipitation

Substation assets are often located outdoors for the entirety of their multi-decade service lives. These assets are designed to be exposed to and are impervious to direct effects from exposure to non-frozen precipitation. Accordingly, these assets are not vulnerable to precipitation events due to not being sensitive to the hazard, and this was not considered a priority vulnerability.

Substation Asset Vulnerability to Flooding

A majority of substation assets are highly vulnerable to flooding based on their installation at or near ground level, along with their consequence of failure. Although substations are often designed to withstand some degree of flooding, increased intensity and extent of flooding can exceed design parameters, leading to significant disruption or asset failure. There is an elevated risk of exposure to flooding for substations that are located in or near floodplains or near bodies of water.

Outdoor equipment like transformers and circuit breakers are often hermetically sealed tanks, making flooding unlikely to impact internal components. However, higher inundation depths may reach equipment control cabinets or other accessories like fans, pumps, and external wiring connections, causing significant damage.

While control rooms and houses may have some flood protection measures, such as trench pumps/drains and flood-resistant doors, many are built at or near ground level and can be inundated by floodwater. If floodwaters breach the control house, protection and control assets that are highly sensitive to water are likely to be damaged.

Overall, substations and flooding were identified as a priority vulnerability.

Substation Asset Vulnerability to Wind

Overall, substations have low sensitivity to wind events. However, due to their consequence of failure, many of the vulnerability ratings ranked as medium. One outlier is substation support structures; these were rated as a high vulnerability due to their height and the expected force imparted on the structure by wind gusts. However, substation structures are robust, securely fastened in place, and are generally clear of vegetation and other objects that could negatively impact these assets. Therefore, this asset–hazard combination was deprioritized.

Substation Asset Vulnerability to Wind-and-Ice

Most substation assets have a moderate to high vulnerability to wind-and-ice, driven in part by their consequence of malfunction or failure. Transformers, regulators, circuit breakers, and reactors have high vulnerability because ice accumulation across bushings or insulators can lead to an increased risk of flashover[26]. Substation structures were found to have high vulnerability to wind and ice because of their consequence of failure and their large surface area, which has the potential for ice accumulation. Therefore, substations and wind-and-ice were found to be a priority vulnerability.

4.3 Operational Process Vulnerability Summary

In addition to assessing the climate change vulnerabilities of NYSEG and RG&E's assets, the risks from climate hazards to processes used by NYSEG and RG&E were also evaluated. Processes that could potentially be affected by climate change were analyzed to determine whether a climate hazard could pose a risk to its effectiveness. This analysis is summarized in Table 15 with checkmarks indicating which climate hazards may pose a risk to each process.

Table 15. Operational Climate Risk Overview

Function	Temperature	Wind	Flooding	Precipitation	Wind & Ice
Emergency Response	✓	✓	✓	✓	✓
Workforce Safety	✓	✓	✓	✓	✓
Vegetation Management	✓	✓		✓	✓
Asset Management	✓	✓		✓	✓
Facility Ratings	✓				
Reliability Planning	✓	✓			✓
Load Forecasting	✓				

Emergency Response

The Emergency Response plan include activities to prepare for and respond to adverse events, such as extreme weather events. The potential for increasing severity and frequency of extreme events (e.g., major storms and heat waves) could impact the effectiveness of NYSEG and RG&E's emergency response process.

While current emergency operations procedures provide a solid foundation for responding to many of the climate hazards included in this study, inclusion of climate projections and vulnerabilities identified in this CCVS may enhance current procedures and make the utility more resilient to adverse climate change impacts. Specifically, procedures for storm resource staging and allocation process, estimated time of restoration (ETR) development and calculation tool, and emergency substation de-energization are particularly important to evaluate with climate change considerations.

[26] Flashover is when there is a breakdown of electrical insulation and an electrical arc occurs between energized equipment and equipment at ground potential.

Workforce Safety

Workforce safety processes are designed to keep NYSEG and RG&E workers safe and healthy while performing their jobs; this is particularly important for employees in outdoor work environments. Climate change is projected to increase the number of storms, high heat days, and heat waves and could make adverse work conditions more frequent. NYSEG and RG&E's Environmental Health & Safety standard, *AVHS-STD-002, Hot and Cold Working Conditions,* provides guidance on establishing safe working conditions for various temperature, humidity, and wind-speed combinations. AVHS-STD-002 will continue to be followed and is not expected to require updates to account for climate change.

Vegetation Management

Vegetation management processes consist of ongoing activities to maintain reliable service by monitoring, trimming, and/or removing vegetation that could pose risks to transmission and distribution assets. Throughout the coming decades, climate change is anticipated to impact the effectiveness and necessity of vegetation management processes due to increases in frequency and intensity of storms, changes in vegetation growth seasons, introduction of new and invasive species, and reduction in tree strength (Hans Pretzsch, 2018).

Like other effects from climate change, the impacts on vegetation are expected to occur gradually over time. As these changes occur, vegetation management processes and their effectiveness will likely become strained and should be monitored to determine if updates are necessary to maintain the program's effectiveness.

Asset Management

Asset management processes include engineering and design standards, inspections, monitoring, and asset replacement programs. Increased exposure to extreme storms, including events such as extreme winds, temperature, and precipitation can increase the failure rate of assets or shorten their lifespan. For example, temperatures, which are projected to increase across the NYSEG and RG&E service areas by 2050 and beyond, may increase the aging rate of transformers (Cui-fen Bai, 2013). Similarly, increases in temperature and humidity may decrease the expected lifespan of wooden poles (Salman, 2018).

Equipment specifications and other asset management processes should be consistently reviewed to determine if changes are necessary to account for future climate hazards. These changes will have an impact across multiple departments, including maintenance, asset management, and procurement, and it is critical that there is sufficient support to implement the climate-driven updates to management processes.

Facility Ratings

Facility ratings processes are used to calculate the power delivery capacity or "ratings" of transmission and distribution assets. These ratings are based on a set of assumptions which include climate factors, with ambient temperature being the most impactful. Projected increases in ambient temperature may cause existing facility rating calculation methods to not align with future conditions.

For example, the 2019 New York Transmission Owner's Tie-Line Ratings Report[27] specifies that the maximum and average temperatures for transmission facility rating calculations should be 35°C (95°F) and 30°C (86°F). As noted in the exposure sections of the CCVS, these are temperatures that are rarely experienced in current day but are expected to be exceeded more often in the future.

If ambient temperatures exceed the values used when calculating facility ratings, assets may exceed their design capabilities which can cause aging at an increased rate, clearance violations, and potentially equipment failure. However, FERC Order 881[28] "Managing Transmission Line Ratings" will somewhat mitigate these issues through requiring the use of Ambient Adjusted Ratings (AAR) on transmission lines. AARs are continuously updated in pseudo real-time based on the measured ambient temperature. This allows for asset limitations, particularly conductor maximum operating temperature, to be followed regardless of the ambient temperature.

Unfortunately, long-term planning cannot rely on AARs to help mitigate issues due to elevated temperatures and must instead rely on static ratings calculated using ambient temperature assumptions. NYSEG and RG&E SMEs are participating in the ongoing review of the New York Transmission Owner's Tie-Line Rating Report to share our CCVS findings related to increases in ambient temperature.

Reliability Planning

Reliability planning includes processes that determine reliability performance metrics, understand trends in historical reliability performance, project future reliability performance, and identify investments to meet reliability performance targets.

Climate projections indicate the potential for the increasing frequency, severity, and duration of heat waves as well as the potential for the increasing frequency and severity of major storms. Weather is a significant driver of customer interruptions and the increasing frequency, severity, and duration of heat waves and other severe weather events caused by climate change has the potential to negatively impact reliability. A strong understanding of the vulnerability of assets to failure from weather events is crucial to ensuring proper and informed reliability planning.

Load Forecasting

Load forecasting process at NYSEG and RG&E utilize CTHI as well as factors including demographic, macroeconomic concepts, renewable generation levels, and other inputs to develop a 10-year forecast for customer usage. These forecasts help identify areas of the system where customer usage may exceed the available delivery capacity, and where load relief projects may be needed. Climate change projections show that temperature, humidity, and consequentially CTHI, are expected to increase throughout the century which would tend to drive a higher peak summer demand.

However, there are other factors that are influencing future demand. For example, the expected increase in photovoltaic generation and the continued electrification of heating and transportation across New York State is expected to have profound effects on the summer and winter load forecasts. The New York Independent System Operator's 2023 Load & Capacity Data Gold Book[29]

[27] https://www.nyiso.com/documents/20142/1402024/NYTO-2019-Tie-Line-Report-V01-2020-January-9.pdf/7029e9e9-3f76-5355-5646-8b1f18699750

[28] https://www.federalregister.gov/documents/2022/05/25/2022-11233/managing-transmission-line-ratings

[29] https://www.nyiso.com/documents/20142/2226333/2023-Gold-Book-Public.pdf

forecasts that New York State will transition from a summer peaking to winter peaking region between 2033 and 2035, with sub-regions of New York State making this transition sooner.

NYSEG and RG&E load forecasting is performed over a 10-year horizon using observed weather as a basis for future forecasts. Due to the use of near-term observed weather in the forecasting process the gradual effects of climate change are implicitly included.

4.4 Continued Assessment of Climate Science & Related Vulnerabilities

This is the first CCVS that NYSEG and RG&E have completed in accordance with PSL §66. The refinement of climate science models is a continuous process that occurs as projections are validated with observed climate patterns, GCMs evolve, and computing power increases. These types of advancements may take the form of new or updated climate models that are more accurately able to simulate complex phenomena like freezing rain and ice development or research into future extreme weather frequency and intensity. PSL §66 requires that the required corporations must file an updated plan CCRP at least every 5 years after approval of the previous plan; in these efforts NYSEG and RG&E will incorporate the most appropriate and up-to-date climate science and data.

As explained in the previous sections, the approach to identifying vulnerabilities consisted of determining asset sensitivity, consequence of impact, and likelihood and magnitude of exposure to a climate hazard. Each of these could be advanced as climate science and the data on the impacts to assets and processes improve. For example, the understanding of sensitivity and consequence of the electrical system to different climate hazards will continue to evolve as asset management systems improve their ability to capture real-time data (e.g., asset health, status, and usage).

Addressing Climate Change Vulnerabilities

5. Potential Adaptation Measures

In accordance with the New York State PSL §66[30] and the Order issued by the Public Service Commission in Case 22-E-0222[31], NYSEG and RG&E, as well as other utilities in New York State, were required to develop a Climate Change Vulnerability Study (CCVS) that evaluates their Companies' infrastructure (i.e., assets) as well as design specifications and procedures (i.e., processes) to better understand the Companies' vulnerability to climate-driven risks and include adaptation measures to address vulnerabilities.

This CCVS has evaluated the Companies' assets and processes to understand the Companies' vulnerabilities to climate-driven risks. This section discusses climate resilience adaptation measures to address those vulnerabilities; these measures will be the basis for the more specific evaluations that will be included in the forthcoming CCRP.

NYSEG and RG&E's adaptation measures to address vulnerabilities consider four objectives:

1. Strengthen NYSEG and RG&E's assets and processes to **withstand** the adverse impacts of a climate hazard event.
2. Increase NYSEG and RG&E's ability to **anticipate** when a climate hazard event may occur and increase the electric system's ability to **absorb** the effects.
3. Bolster NYSEG and RG&E's ability to quickly **respond and recover** in the aftermath of a climate hazard event.
4. **Advance and adapt** the NYSEG and RG&E electric system to address continuous changes from climate change and to perpetually improve resilience.

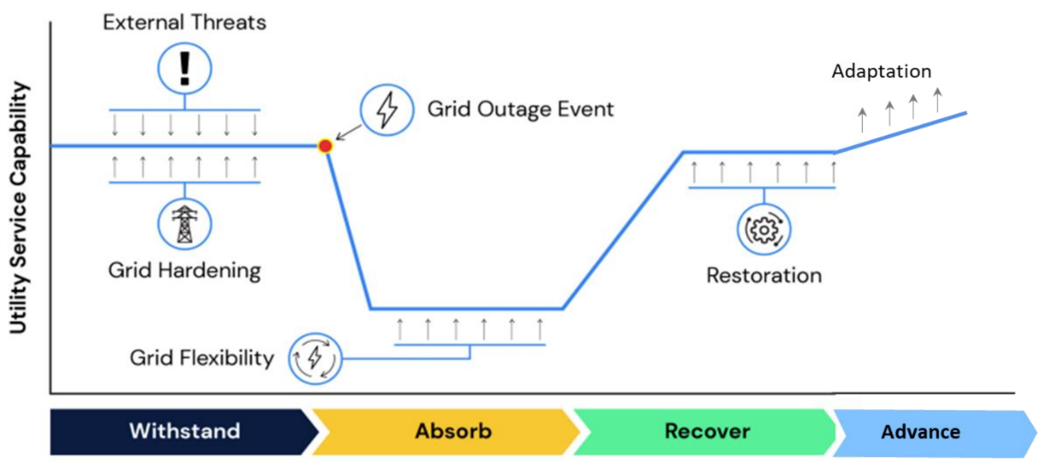

Figure 18. Resilience Plan Framework

These objectives can be applied to operational processes and physical assets. Developing adaptation strategies will improve system-wide resilience to the climate hazard vulnerabilities analyzed in this report.

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[30] Section 66. https://www.nysenate.gov/legislation/laws/PBS/66

[31] Case 22-E-0222. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={CA027C18-8246-47E7-A1A1-B2C096AC42C0}

Below are examples of resilience measures that could help NYSEG and RG&E assets and processes **withstand**, **anticipate and absorb, respond and recover**, and **advance and adapt** to climate change risks.

5.1 Withstand

1. Harden substations against flooding events through selective asset elevation, site relocation, or flood-resistant structures or barriers.
2. Replace/upgrade at-risk substation transformers that are heavily loaded and are expected to be exposed to extreme temperatures.
3. Replace older distribution poles with the updated standard Class 2 or 3 poles to withstand exposure to wind and wind-and-ice climate hazards.
4. Targeted undergrounding of distribution conductors to improve resilience to wind and wind-and-ice climate hazards in regions that are highly susceptible to extreme wind-induced damage and outages.
5. Update asset specifications (e.g., transformers ambient temperature standard) to prevent load shedding due to the projected extreme temperatures.

5.2 Anticipate and Absorb

1. Increase distribution circuit automation and circuit ties to limit the extent of outages due to exposure to wind and wind-and-ice climate hazards.
2. Procure temporary/deployable flood barriers and train personnel to deploy them in advance of extreme weather events that may cause flooding (e.g., hurricanes and tropical storms).
3. Facility ratings:
   a. Utilize temperature projections across the NYSEG and RG&E service areas to determine if and/or when changes to ambient temperature assumptions are appropriate.
   b. Evaluate if changes to asset specifications, particularly for ambient temperature, can establish risk thresholds due to climate change that is proportional to historical levels.
   c. Review temperature projections to determine the appropriate timeline to revise ambient temperature assumptions to maintain the selected risk threshold. This determination should explore a phased approach to updating facility ratings.
4. Reliability planning:
   a. Quantify the sensitivity of the NYSEG and RG&E electric systems' reliability when faced with adverse weather.
   b. Develop high-level projections of the potential impact on reliability performance in future years based on climate projections.

5.3 Respond and Recover

1. Increase stocks of portable assets that provide power supply redundancy (e.g., backup generators and mobile substations).
2. Increase stocks of spare assets and parts to avoid supply chain lead times in replacing damaged or destroyed assets.

3. Emergency response:

    a. Expand the operating capacity and training of emergency response teams, including to climate change-driven low probability but high-impact events like concurrent extreme storms, combined climate hazards, or newly identified substations exposed to flooding.
    b. Evaluate the resource allocation and storm resource staging process in the context of the climate change projections and extreme event scenarios included in this study.
    c. Review the factors and assumptions used to develop Estimated Time of Restorations (ETRs) in the context of climate projections and extreme event scenarios considered in this study.
    d. Evaluate the substations identified as being at risk in the upcoming CCRP against the listing of known areas at risk to identify any gaps. In addition, consideration could be given for projected changes to flood frequency and severity.

5.4 Advance and Adapt

1. Integrate climate change risk into business-as-usual investment decision-making and risk management tools.
2. Reevaluate climate risk vulnerability and related scenarios on a periodic basis.
3. Integrate climate considerations across operating processes as necessary, including load forecasting, asset management, vegetation management, capacity planning, reliability planning, and emergency response.
4. Workforce safety:

    a. Review expected increases to extreme temperature intensity and frequency to determine if, and when, changes to outdoor working conditions restrictions may be necessary.
    b. As other relevant hazards (e.g., wind, storm, flooding, and ice events) may occur more frequently, evaluate if it is necessary to develop additional working conditions guidance to address these or other relevant hazards.
    c. Evaluate the potential impact of climate change on vegetation growth patterns, strength of trees, and invasive species risk in the NYSEG and RG&E service areas.
    d. Evaluate integrating climate projections into the normal load forecasting process and compare to current forecasts.

Some of these adaptation measures will be further developed and applied to specific assets or processes, as applicable, in the CCRP. Other examples listed will require additional exploration of feasibility to understand if and how they could best be implemented in the future. The methodology for prioritization and the business case justification for each adaptation measure or program will be detailed in the upcoming CCRP.

Conclusions and Next Steps

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6. Conclusions and Next Steps

The goal of the CCVS was to determine priority climate vulnerabilities of NYSEG and RG&E's assets and operations. The CCVS determined that the main climate hazards that assets are projected to be exposed to in the NYSEG and RG&E service areas are **high temperatures**, **flooding, wind**, and **wind-and-ice**. Extreme temperatures and flooding are expected to increase across the service territory under the planning scenario climate projections (SSP5-8.5 50th percentile). Projections on extreme wind and wind-and-ice events are uncertain, however, average wind gusts are not expected to increase in frequency or intensity.

Asset vulnerabilities were determined based on their sensitivity and exposure to a particular climate hazard, as well as the consequence of its malfunction or failure. The identified priority vulnerabilities are based on the study findings as well as input from stakeholders and subject matter experts. Transmission and Distribution assets are primarily vulnerable to wind and wind-and-ice. Substations are primarily vulnerable to high temperatures and flooding.

The CCVS offers potential resilience measures under a framework that considers ways to strengthen the infrastructure, absorb the impacts of climate hazards, increase the ability to respond in the aftermath of an event, and continue to adapt to climate change risks. These potential resilience measures will be further explored in the CCRP.

The impacts from climate change are expected to be significant to NYSEG and RG&E's assets and the communities they serve. The goal of the upcoming Climate Change Resilience Plan (CCRP) is to provide resilience measures that will support the delivery of safe and reliable power to NYSEG and RG&E customers by increasing resilience to climate hazards. Using the findings contained in the CCVS, NYSEG and RG&E will develop their CCRP to adapt against the identified priority vulnerabilities. In the CCRP, the Study Team will perform a risk-based analysis for each priority vulnerability, tailoring the approach for each asset–hazard combination to provide the most actionable information. In general, the likelihood of a climate hazard, the sensitivity threshold of the asset, and its relative consequence will be the dimensions that define risk. Ultimately, the CCRP will yield resilience measures targeted at both specific locations and system-wide enhancements and how they should be prioritized. The adaptation measures, prioritization and the business case for each will be included as part of the upcoming CCRP.

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